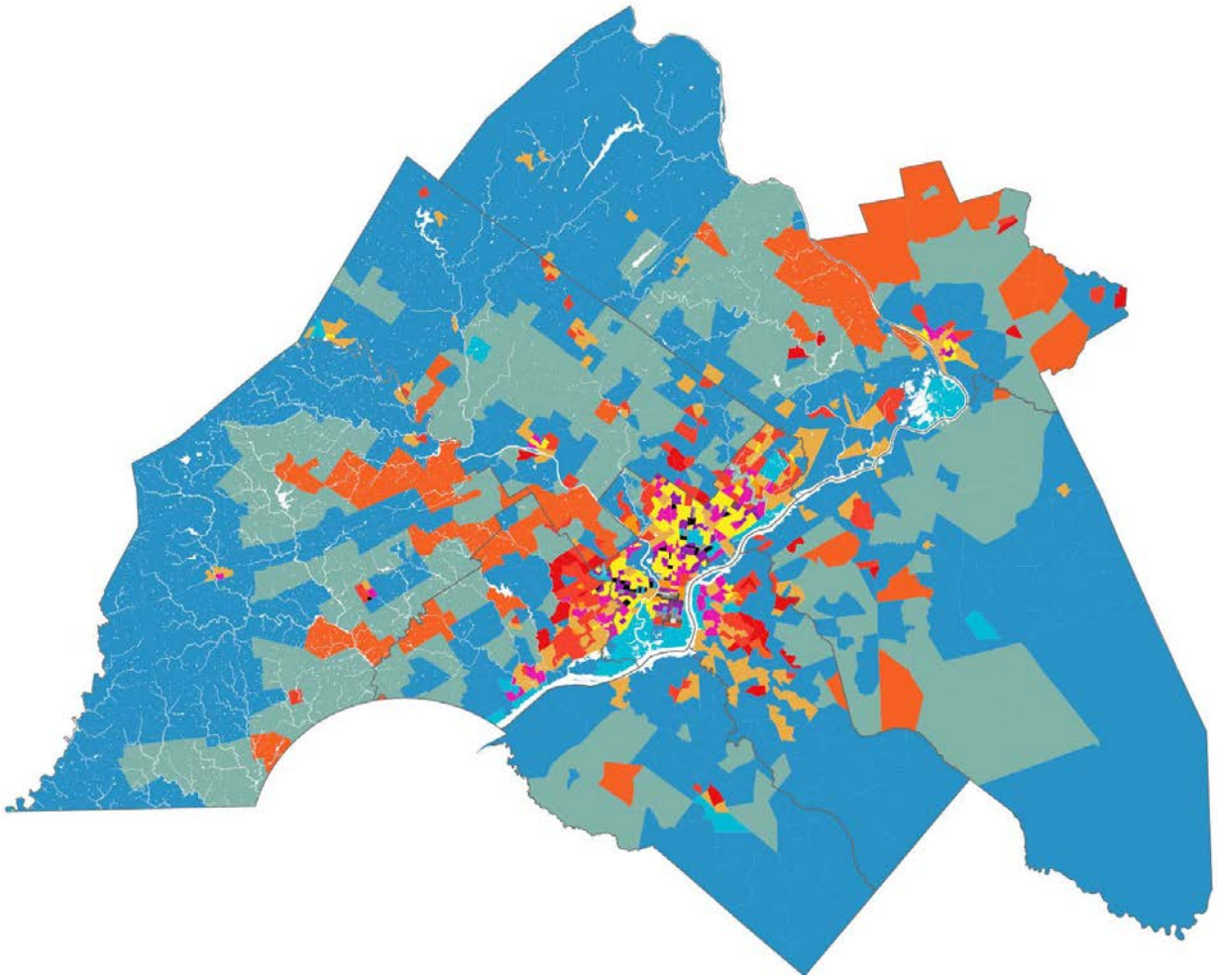
Kleinman Center for Energy Policy

Optimal Pathways to Greenhouse Gas Reduction for the Philadelphia Region based on Local Net-Benefits

Phase I Report & Phase II Proposal



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CENTER FOR ENVIRONMENTAL BUILDING AND DESIGN

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Project Description

When cities and regions have the responsibility for achieving national and international greenhouse gas (GHG) goals, they need to assure local citizens and decision makers that policy goals are not just possible, but physically, financially, and politically feasible. Policy options and potential solutions are not “one-size-fits-all” and need to be adapted to support regionally specific social, economic, and environmental systems. Policy makers need to understand if and how the Philadelphia region can achieve the “80% by 2050” national reduction target and what regional benefits and tradeoffs that target would involve. To provide regional decision-makers with usable guidance, researchers will investigate possible pathways within the parameters of a set of future scenarios and identify optimal pathways that maximize regional net benefits.

The first phase of the Philadelphia Region Energy Pathways has seven parts: 1) a literature review of national and international energy and GHG reduction domains; 2) regional scenario development; 3) identification of drivers and policy strategies; 4) a gap analysis of available regional data sets; 5) an investigation into how to construct a decision support system (DSS) through agent-based modeling; 6) a preliminary identification of cost-benefit analysis options; and 7) scoping Phase Two of the project.

The literature review allows the team to understand the state of research and reporting that currently exists in these domains within the U.S. and internationally. The research shaped the development of the scenarios and drivers and helped identify conditions that would make policy actions ineffectual, politically infeasible, uneconomical, or otherwise impact regional GHG pathway options.

Framed by the scenarios, the team created an accurate picture of the drivers of energy use and emissions in the region to establish the baseline regional conditions and identify strategic lever points for policy actions. The team also examined existing baseline data for the region’s energy production and consumption and its demographic, economic, and environmental conditions and noted critical gaps that will limit the resolution or accuracy of the analysis of future pathways.

Investigating alternative ways to construct a decision support system (DSS) through agent-based modeling was a critical component of phase one. Team members explored and built several pre-prototypes to help evaluate the value of the role for Agent Based Models (ABM) using alternative data sources (Census, energy reports, DVRPC, etc.), GIS modeling, and various social science theories of human behavior (land value theory, economic disparity theory, cognitive learning theory, etc.). The results are included in the Phase II proposal for an ABM-based DSS that models population decision-making about transportation and building energy choices and how these could impact the GHG projections.

Finally, the team synthesized all the research to develop a preliminary set of pathways (collections of policy actions) and a set of cost-benefit calculation methods, models, and indicators that will be used in the second phase of this project to understand the regional net benefits of those GHG reduction pathways on the region.

This report serves as both a summary of the outcomes of the first stage of this project, as well as a proposal for delivering an evaluation of the energy pathways for the Philadelphia Region in

a second phase.

Background

Global GHG reduction goals, translated into national commitments, are by necessity implemented by state, regional and city policies. The costs and benefits of reduction interventions, however, are not balanced across stakeholders. The issue of global and national distribution of costs and benefits is firmly established at the global scale (COP21 negotiations being a prime case study); however, the problem must also be addressed at city and regional scales, as policymakers and citizens debate how to distribute limited government and investment resources among multiple priorities. Cities, which have defined legal and physical boundaries, can be more easily analyzed than regions, which cross multiple boundaries. This project's goal is to expand the analysis beyond the Philadelphia city borders and work at a regional scale that can capture most of the opportunities for intervention, especially transportation and settlement patterns, which are primary drivers of GHG emissions.

The Region

As the regional study area the project team adopted the boundaries of the Delaware Valley Regional Planning Commission (DVRPC) authority, which consists of Philadelphia County and the eight counties that surround it. The team determined that the nine-county region is well established politically, provides a scale at which data is routinely available, and provides a meaningful and sufficiently large area to capture a large portion of the drivers for energy use and emissions. Further, while the region is part of a larger supply and generation grid, the nine-county area contains a significant energy generation capacity comprised of a representative mix of fuel sources.

Existing Analysis

The study area spans two states with differing policy landscapes and which are at different stages of climate planning. The State of New Jersey has an online 2050 GHG Emissions Scenarios Report. The report briefly describes a sector-level breakdown for three energy future scenarios along with a base case to determine if it is possible to achieve a 2050 GHG emissions level that is 80% lower than 2006. The report finds that the most aggressive emissions reduction scenario comes close, barely missing this target.[1] It should be noted that this study does not propose policy actions to yield these scenarios. The GHG Emissions Scenarios Report references the 2011 NJ Energy Master Plan, gives a more detailed plan for energy sector growth, including renewable portfolio standards and energy efficiency and peak load reduction.[2]

Pennsylvania released a Climate Action Plan (CAP) in 2015, which was then revised in 2016. The PA CAP examines thirteen "work plans" or strategies for reducing GHG emissions through 2030. Actions are ranked by both potential GHG reduction and cost-effectiveness. Pennsylvania passed an Alternative Energy Portfolio Standards Act that required modest levels of alternative energy sources as part of the electric energy mix by 2021 (8% Tier I (which includes solar PV), 10% Tier 2, and 0.5% Solar PV).[3] IN 2013 Pennsylvania also passed ACT 129: Energy

[1] 2050 GHG Emissions Scenarios Report. http://www.nj.gov/dep/aqes/sggi.html
[2] 2011 NJ Energy Master Plan. http://nj.gov/emp/docs/pdf/2011_Final_Energy_Master_Plan.pdf
[3] Pennsylvania Alternative Energy Credit Program. http://www.pennaeps.com/aboutaeps/

Efficiency and Conservation (EE&C) Program for electric utilities, which will affect carbon emissions.

The region is notable not just for state-level climate action planning, but also planning at the county and municipal level. As the State of New Jersey sets goals for its power sector, action is happening in the state, but that action is being driven at the municipal level with the support and leadership of Sustainable Jersey, a statewide nonprofit pushing for these actions. Sustainable Jersey works with municipalities to certify their local sustainability action plans, taking into account various categories of actions from arts and creative culture to energy efficiency and land use & transportation. A number of municipalities from the three study area counties - Burlington, Camden and Gloucester, and Mercer - are participating in the Sustainable Jersey program.

In Pennsylvania, the City of Philadelphia is providing strong leadership in climate action planning. The City's Greenworks sustainability plan set targets in areas of energy, environment, equity, economy, and engagement.

Philadelphia and other municipalities in the study region are leading in climate action through example by setting energy efficiency, renewable energy, and alternate fuel targets for municipal facilities and activities. These public-sector efforts are designed to showcase the opportunity and feasibility of such actions to drive private-sector participation.

As the regional planning body, DVRPC has also explored related scenarios, looking at future conditions ranging from severe climate change to a natural gas energy boom rewriting the region's economy, publishing a 2015 report titled Future Forces.[4] The Future Forces study provides an excellent background to the challenges and opportunities faced by the region although it does not specifically address the region's energy use, mix of energy sources or changes in GHG emissions.

Regional Data

There is tremendous value in working with DVRPC due to their valuable work collecting, cleaning and analyzing vast quantities of regional planning data.[5] As the official regional body responsible for strategic visioning and regional planning working with DVRPC means leveraging important data sources without additional project cost or time needed to generate or find new data sources. A key DVRPC data component for this project is the Regional GHG Emissions Inventory, which is updated at five-year increments. The inventory provides sector-level data for energy use by fuel type and each sector's GHG emissions based on regional emission factors.

DVRPC's large data store is the team's starting point for analyzing future energy pathways. However, some data will need to come from external sources. In the case of the building sector, the project team has already begun to synthesize county and municipal data to clarify the specific building types and their energy consumption in the region. This added level of analysis will allow considerations for policy actions that affect specific building segments to yield more accurate projections of potential energy and emissions reduction. The team will obtain air quality

[4] Delaware Valley Regional Planning Commission, "Greater Philadelphia Future Forces Technical Report," DVRPC, Philadelphia, 2015.

[5] Delaware Valley Regional Planning Commission, "Energy Use and Greenhouse Gas Emissions in Greater Philadelphia, 2010: Methods and Sources," DVRPC, Philadelphia, 2015.

data from the PA and NJ state environmental protection agencies; this data will form the basis for modeling health outcomes of policy actions. Further, demographic data will be drawn from the Census Bureau.

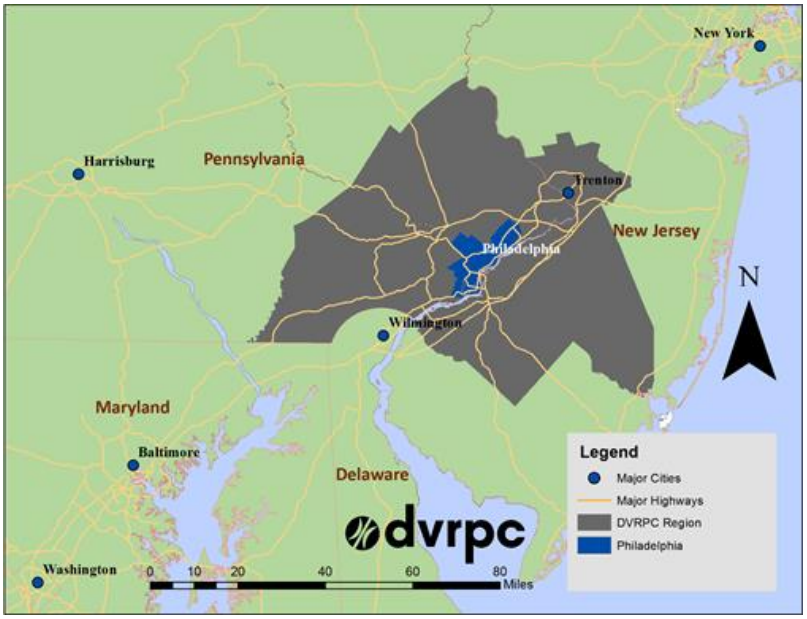


Figure 1 Nine county region (DVRPC)

Choosing the greater Philadelphia region as the subject of analysis has benefits and challenges. The nine-counties capture most of the working population and commuting patterns associated with the city, so the full economic activities associated with city can be addressed. Conversely, the region has 352 municipalities with no central governing authority, so actions to reduce emissions will necessarily involve cooperation among regional actors. As a key example, within its boundaries the region generates roughly 75% of the electricity it uses, but decisions about plant construction and fuel choices are determined by multiple companies within the PJM regional transmission organization and regulated by the Public Utility Commission. Municipalities can present themselves as supportive partners, and even take the lead to explain the type of systems they want to achieve.

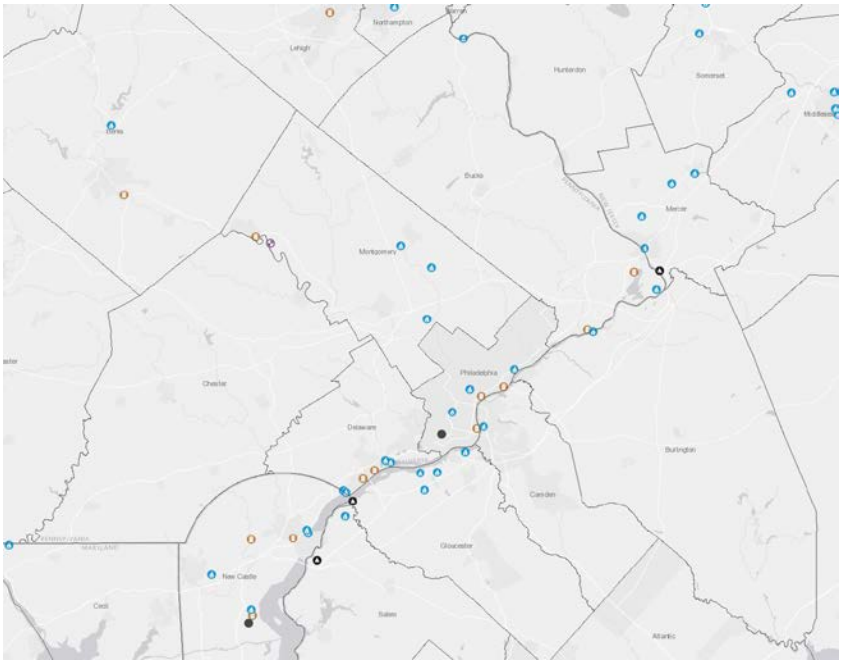


Figure 2 Electric generation plants in the nine county region, EIA

Phase 1: A Pathways Approach

Pathways—often called roadmaps—are flexible bundles of strategies, methods, and actions designed to reach a goal or hit a target. GHG reduction pathways are complex interconnected webs crossing ecological, technological, economic, and socio-cultural systems. Analysis of these pathways requires integrated frameworks across multiple domains of knowledge and a clear understanding of the scenarios and drivers under which they function. Pathway research within such complexity requires the inverse of the specialization, 'silo' approach in academia—rather, it requires a method to coordinate and synthesis multiple silos.

An illustration of the complexity of these pathways is the regional energy systems diagram below, which shows the flows of production and consumption in the energy system.

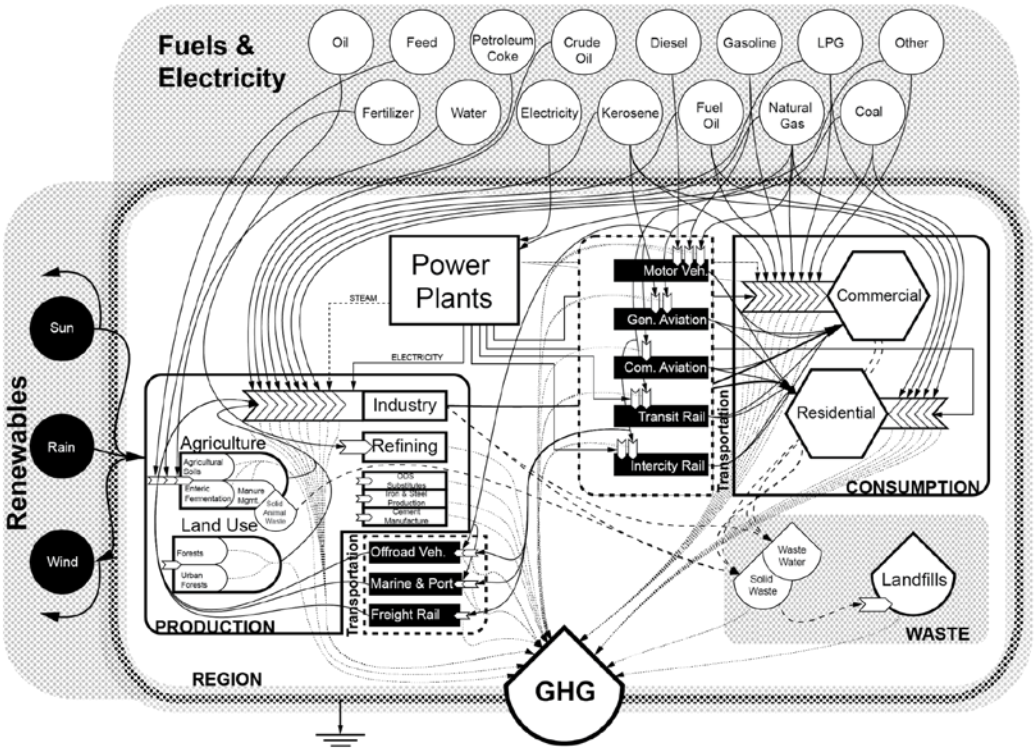


Figure 3 Regional energy systems diagram

One example of the complex dynamics of policy pathways within these flows is the implication of increasing reliance on automobiles that are fueled by electric batteries instead of gasoline. On its face, this fuel switch suggests a reduction in GHG emissions, however, the actual impact will depend on the GHG emissions of the power plants that are generating electricity used to power the electric vehicles. If the added demand in electricity generation to power these electric vehicles is met with high emitting generation sources, GHG emissions could remain unchanged or even worsen.

This project will model pathways by examining the four aspects that define a pathway: scenarios, drivers, strategies, and actions.

Scenario Framework

Scenarios in this project are a set of assumptions about possible future worlds and serve as a lens through which a decision maker is able to understand, at a *regional* scale, the risks and opportunities of pursuing various low-carbon pathways, including 1) context (ecological, technological, economic, and socio-cultural); 2) efficacy (does it reduce emissions?); 3) cost (can we afford it?; 4) cost-effectiveness (Is it efficient?), 5) acceptability (will citizens support it?)' and 6) value (what benefits does it provide?).

Driving Forces

To narrow down which lens would be most helpful for framing regional net-benefit research, the team looked at the driving forces that are moving the energy markets. Researchers at organizations like the World Energy Council (WEC), International Energy Agency (IEA), C40, and at universities around the world have published extensive research on the driving forces and uncertainties affecting the energy sector and GHG emissions. The WEC identifies 116 issues that impact the energy landscape and rank them each year according to level of uncertainty and potential impact.[6] Their top five uncertainties - commodity prices, global recession, climate frameworks, electric storage innovation, and market design[7] are all global issues that reflect possible future scenarios and influence regional carbon reduction planning.

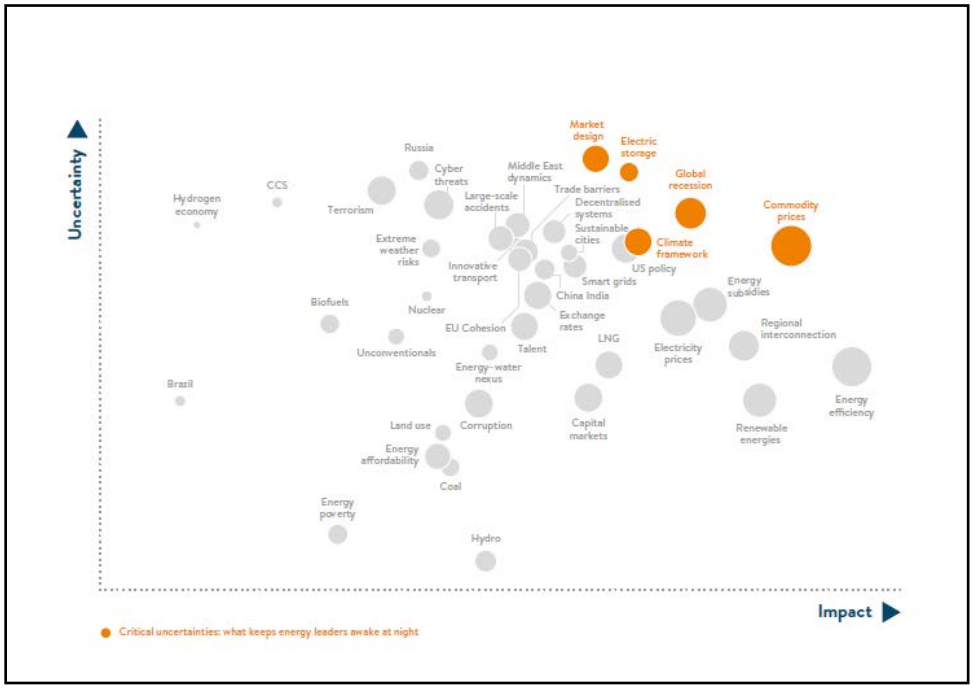


Figure 4 Uncertainties and Relative Impacts in the Global Energy Sector

Most of these driving forces will either impact the Philadelphia region through energy prices or by influencing political will and public policy and some may have more impact regionally than others to due local or national conditions such as weather risks or energy supply mix. Global

[6] World Energy Council citation; report on BOX.
[7] World Energy Council, World Energy Issue Monitor, 2016

recession, electric storage innovation and market design will all be reflected in energy market prices. Issues such as energy affordability, land use and climate frameworks illustrate issues that may be reflected in political will and public acceptance of GHG reduction goals and policies.

Scenario Framework

In addition to driving forces, the team reviewed over thirty reports from organizations and researchers who used scenarios to frame low-carbon strategy and policy analysis.

Multi-variable models confront many obstacles due to their complexity; a framework of future conditions under which to model variables, development of Business-as-usual assumptions, availability and quality of data, and coordination and agreement among experts are all challenges that must be met within the scope and budget of Phase 2. The first—a framework of future conditions—can be most effectively addressed by reducing the number of driving forces or uncertainties that will be addressed in the project.

The team proposes using two axis of uncertainty in Phase 2 to frame the analysis and three different models coordinated across three teams to investigate different aspects of the question of regional net benefits.

Axis 1: Low-Carbon Energy Markets

The price competitiveness of low-carbon energy can be seen as a surrogate indicator for market-driven adoption of low-carbon GHG-reduction strategies because it encourages energy efficiency, renewable energy, and alternative fuels in the power production, mobile, and stationary sectors. Whether prices change by market forces or regulation (carbon tax or trading), they serve as a powerful incentive for consumer decisions. Consumers, often short-sighted in their shopping choices, are more driven by first cost than long-term energy cost. This issue is exacerbated when energy costs are low, as consumers do not perceive a value in paying a premium for energy efficiency. A clear example of this phenomenon has been illustrated in the aftermath of plummeting oil prices following their historic high in 2008 and sustained period of high prices through 2014. The drop in oil prices has led to a market shift to larger, less fuel-efficient vehicles, just as the preceding rise in oil price had the opposite effect of increasing average fuel economy of purchased vehicles.[8] [9] Consumer choice has direct impact on the residential and commercial building sector, as well, since traditional investment decisions are predicated on simple payback calculations. Thus, when purchasing decisions are made in a low-price environment, a higher cost of energy efficiency is often ruled out due to longer payback times. Competitive low-carbon options would hedge against low oil prices in investment calculations.

Fuel price is a critical factor in the source energy sector, affecting investment decisions in the type of fuel used to produce electricity. This has played out prominently in the last decade during which coal burning generators have been replaced by natural gas plants, in large part because of the price disparity between the two commodities. The economics that drive this cost disparity are also strongly influenced by the increased cost of operating coal plants with ever

[8] Unemployment Rate and Price of Gasoline Predict the Fuel Economy of Purchased New Vehicles https://deepblue.lib.umich.edu/bitstream/handle/2027.42/83358/102735.pdf

[9] This example belies the fact that the average fuel economy of fleets have been rising under pressure from federal government CAFE standards.

stricter environmental regulations for plant emissions requiring expensive pollution controls that are not necessary for natural gas. Solar and wind generation have experienced similar cost declines that are making these technologies competitive with natural gas and coal burning plants. Continued price reductions will make solar generation cost effective on residential and commercial buildings in the region (though increased grid penetration of variable sources presents secondary costs for grid modernization and storage). In all cases, the economics favor low-carbon sources of electricity if the cost of fossil fuels are higher, whether through market mechanisms or as a result of government policies such as a carbon tax.

		Low-Carbon Energy Markets	
		Weak	**Strong**
Regional Climate Action Agreement	**High**	**High agreement | Weak Markets** • *Example: Regional support for efficiency investments with strong ROI but also supportive of local incentives and technology investment;* • *Carbon trading or carbon tax more attractive*	**High agreement | Strong Markets** • *Example: Low-carbon options for household energy increasingly affordable without regional subsidies or incentives, lowers barriers; Power supply sector incentives to resolve intermittency problems increase as renewables increase their market share, driving positive feedback towards more renewable policy support regionally*
	Low	**Low agreement | Weak Markets** • *Example: Reduced willingness to support government subsidies or incentives for renewables, reducing demand; Increased support for natural gas investments and hub expansion*	**Low agreement | Strong Markets** • *Example: Despite skepticism, prices and ROI for increasingly efficient technology means larger market share for both buildings and personal vehicles; reduced local costs for incentivizing low-emission behaviors and technologies*

It is important to note that low commodity fossil fuel price is also affecting the economics of operating existing nuclear plants. While questions remain about disposing of nuclear waste, which has to be stored safely for hundreds of years, these plants produce electricity with no GHG emissions. Competition from cheaper natural gas plants, along with increasing maintenance costs of aging plants, is making nuclear plants uncompetitive. The likely replacement of these plants with natural gas plants will result in a net increase in GHG emissions. Early decommissioning of these plants will also create a burden of having to store the spent nuclear fuel on site as no centralized federal storage has been developed.[10]

The time frames for this axis will be determined in Phase 2. Timeframes include short-term (5

[10] Nuclear Decommissioning: Paying More for Greater, Uncompensated Risks
http://kleinmanenergy.upenn.edu/paper/nuclear-decommissioning-paying-more-greater-uncompensated-risks

year), mid-range (through 2030) and long-range (through 2050).

Axis 2: Regional Climate Action Agreement

Throughout the climate change and carbon planning literature, public awareness, political will, and a coordinated leadership are consistently cited as critical factors for reaching national and international emission targets. This also holds true for local and regional decision-making

Public perceptions on the reality of climate change, its connection to human activity, and the risk it poses have a bearing on the appropriate policy responses to low-carbon strategies, as well as on the likelihood of commitment to personal actions that reduce energy use and emissions. The public's perception is critical to shaping and implementing regional actions that support GHG reduction goals.

In a scenario in which public perception is dominated by beliefs that climate change doesn't exist, isn't caused by humans, doesn't pose local risks, or is too costly to address, there may be insufficient political will to commit to low-carbon policy actions (e.g. carbon tax), especially if these policies were not strongly supported at the state and federal levels. In this scenario, individuals would also be less willing to make personal lifestyle changes to reduce their own energy use (e.g. changing HVAC set points, reducing VMT).[11] [12]

The Yale Project on Climate Change Communication's 2014 survey, which tracks public perception of climate change through a series of questions, helps to illustrate the diverse views throughout the Philadelphia region and the inconsistencies between awareness of problems verses proposed solutions, as illustrated in the figure below.

[11] Hagen, B., Middel, A., & Pijawka, D. (05/01/2016). Environmental policy and governance: European climate change perceptions: Public support for mitigation and adaptation policies ERP Environment. doi:10.1002/eet.1701

[12] Jan C. Semenza, David E. Hall, Daniel J. Wilson, Brian D. Bontempo, David J. Sailor, Linda A. George, Public Perception of Climate Change: Voluntary Mitigation and Barriers to Behavior Change, American Journal of Preventive Medicine, Volume 35, Issue 5, November 2008, Pages 479-487, ISSN 0749-3797, http://dx.doi.org/10.1016/j.amepre.2008.08.020.

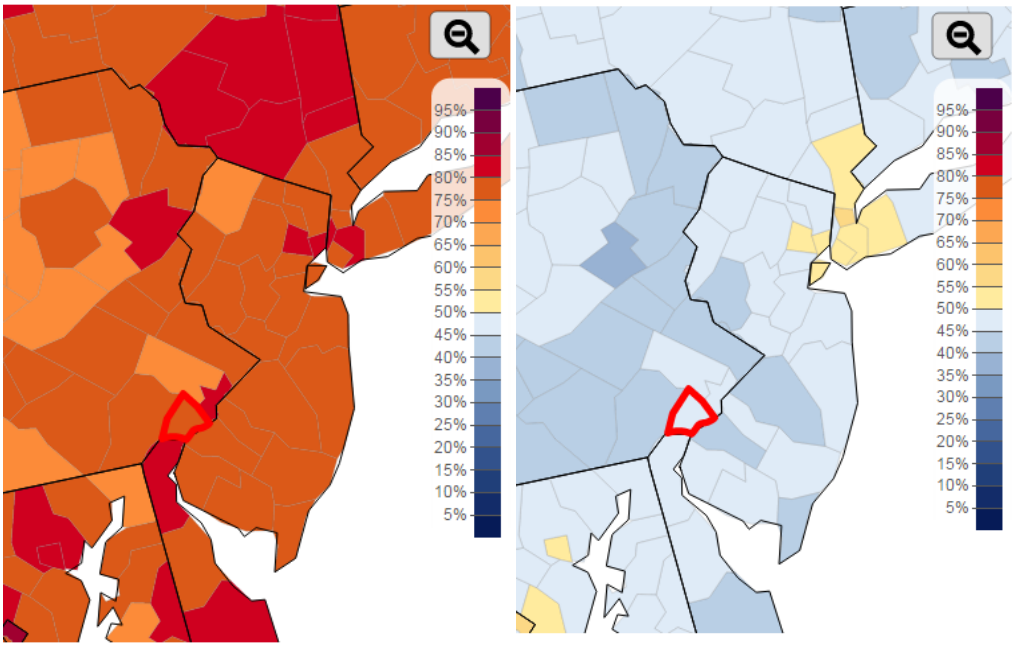


Figure 4 Perception of support for regulation of CO2 as a pollutant (left) vs support for a carbon tax with revenues refunded to American households (right)

Political will and support for climate action is particularly important at the regional scale due to the challenges of coordination across political boundaries and the scales of energy and climate systems. An example of this plays out in New York City's Pathways to Deep Carbon Reductions report, which describes the investments into the power grid that NYC would need to make if working alone rather than in a regional context. NYC would need to invest in 250% as much renewable generation capacity when pursuing its goals alone instead of collectively with the surrounding region.[13] The economic linkage across the region also mean that businesses and residents can relocate throughout the region if localized policies negatively affect cost or quality of life.

There are already examples of regional alliances in our study area such as coordination between DVRPC and the Southeastern Pennsylvania Transportation Authority (SEPTA) on transportation planning and GHG emissions. Examples like these demonstrate that alliances to set climate change goals or affect a regional policy such as a carbon tax may be feasible. Regional planning powers in the US, however, are primarily advisory because of strong constitutional rights and protections of local and state jurisdictions over issues that impact GHG emissions including land use and transportation. The Metropolitan Caucus, which was formed in response to Federal American Recovery and Reinvestment Act funding in 2009, provides some precedence for regionalism in the context of energy investments. The Caucus was comprised of leaders from five counties in Pennsylvania and its purpose was to use the ARRA funding for energy management and sustainability planning throughout the region. It is unclear whether a similar bureaucratic organization would be feasible across two states and without the incentive of federal funding.

Scenario Modeling

[13] PlaNYC, "New York City's Pathways to Deep Carbon Reductions," The City of New York, New York, 2013.

Scenario modeling can be grouped generally as:

1) Single-System Complexity – constrains the analysis around one system or key uncertainty
    a. New York City's PlanNYC limits its scenario to addressing policies the city has the legal power to pass without state or national support.
    b. Reports that investigate single sectors, such as buildings or transportation
2) Multi-Systems Complexity – expands the analysis to multiple systems, usually addressing inter-connecting uncertainties
    a. 'Worldview' models like Shell's "New Lenses on the Future" report which explores two axis of global energy uncertainty: shifting power of market forces and government policymaking.[14]
    b. Agent-based computer simulations that look at the combined behavior of hundreds of individual agents within a world defined by sets of complex rules. Agent-based simulation models are often used in environmental and climate decision making.
    c. Dynamic multi-variable economic models that build scenarios out of a set of economic assumptions and proposed policies, such as the REMI regional economic model, or strategies, like the UK Carbon Pathways 2050 Calculator[15],

To maximize the feasible number of variables within the time and budget of Phase 2 a coordinated effort with two Penn multi-system model teams coordinated with a third non-Penn consultant team are proposed:

1. The **Penn GHG Input/Output (I/O) team** will have the 2-prong responsibility of building expert consensus about pathways, and determining, to the extent possible, the most accurate picture of the GHG reduction potential for those pathways. These pathways will inform the framework for the other two teams:
2. The **Penn "Philly" Sim** team will take the buildings and transportation pathways and analyze them through an agent-based simulation model, with the intent to understand how decision choices vary and how those choices change the policy pathways' intended consequences.
3. The **ICF REMI team** will use those pathways to inform their selection of policy choices in the REMI economic model, as well as using any changes in GHG emissions estimates that the GHG I/O generate to more accurately estimate net benefits.[16]

More details about these the UPenn teams' models and their methodologies are in the Phase 2 proposal. The details of the REMI model are addressed in the ICF Scope of Work.

[14] http://www.shell.com/energy-and-innovation/the-energy-future/scenarios/new-lenses-on-the-future.html
[15] http://2050-calculator-tool.decc.gov.uk/#/home
[16] ICF REMI team is on a separate contract and will coordinating with the UPenn research teams.

Drivers of emissions

Project drivers are sources of GHG emissions in the region. The largest sources of emissions are commercial, industrial, and residential buildings and on-highway transportation, accounting for 85% of the total. These are followed by fuel refining, industrial processes (non-fuel based), waste management, and commercial aviation. This data is documented by the DVRPC in their 2005 and 2010 emission reports and reflected below in Figure 4. Most of the emissions come from direct combustion of fuels, though 33% are released through electric generation.

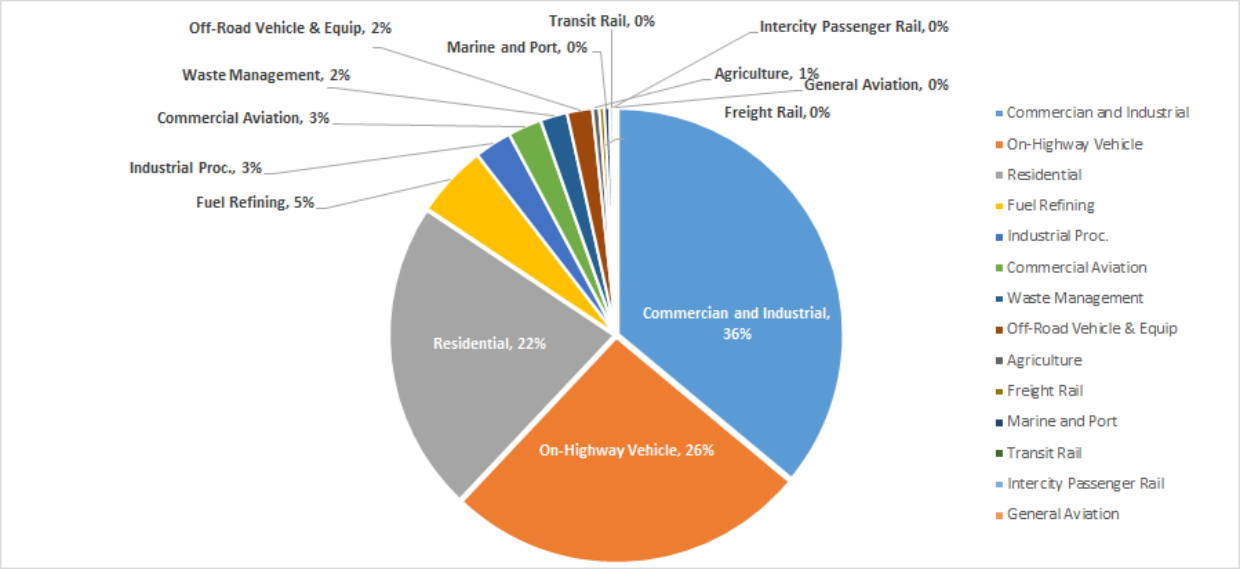


Figure 5 Carbon emissions in the nine county Philadelphia Region, DVRPC

Strategies for reducing emissions

Strategies are defined as high-level pathways to reduce emissions organized around the four sectors in which policy interventions can significantly lower regional emissions—Power Supply, Buildings, Mobility (Transportation), and Land Use/Smart Growth. Each sector can be divided in three general categories - technical, behavioral and political strategies.

Like most of the United States, the Philadelphia region's consumer related sectors—buildings and transportation—account for the vast majority of emissions. The third priority sector is electric power supplied to the other sectors. The International Energy Agency (IEA) states that "electricity production accounts for 32% of total global fossil fuel use and around 41% of total energy-related CO2 emissions. Transforming the electricity generation sector will therefore need to be at the heart of any efforts to make substantial reductions in global CO2 emissions". In the Philadelphia region, electricity accounts for about 33% of regional emissions, and about 75% of the power consumed is generated within the nine-counties. The region's electric emission intensity is relatively low due to a high percentage (~40%) of nuclear power in the PJM grid.

Regional land use patterns and smart growth policies can either support or undermine strategies in those three sectors.

Examples of strategies include:

Strategy / Sector	Power	Buildings	Mobility	Land Use
Technical	Retire polluting plants	New building-efficiency packages	Expand bike lane network	Higher density mixed use development
Behavioral	Reduce demand for and consumption of electricity	Expand owner and building manager education and training	Encourage walking and cycling	Education about air pollution and health impacts of land use patterns
Political	Attract renewable technology industry companies	Strengthen regulations building codes	Vehicle travel fees, dynamic parking pricing, “pay as you drive” insurance	Transit-oriented development zoning

Actions for reducing emissions

What current and potential powers do cities and regions have to translate strategies into action? Each strategy can be pursued through suites of actions taken by regional stakeholders in each sector. Determining the composition and variability of these action clusters based on strategic impact, future scenario uncertainties, and available regional data for analysis is the cornerstone of Phase 2. Actions can be characterized by:

- Governance[17]
    a. Type: Project/Program, Policy/Regulation, Incentive/Disincentive, Procurement
    b. Scale: City/Region/State/National
    c. Control: Own, Policy, Budget, Values/Vision
- Market Mechanisms[18]
    a. Risk Mitigation (regulation, climate impacts)
    b. Competitive Advantage (cost, demand, technology)
- Partnerships
    b. Civil Society, Private Sector, Academic Institutions, Transnational Networks

C40, in partnership with Arup, looked at the potential for climate action by C40 member cities around the world and concluded that cities have a major role to play in bridging the emissions gap. During that process, they gathered a staggering list of nearly 27,000 actions in 11 sectors and identified 2,332 of those actions as ‘First Priority’, or actions with the highest impact for reducing emissions and for which cities typically have a high degree of control.[19] Key findings

[17] C40 Analysis of Cities Control over Climate Change Policy http://www.c40.org/researches/executive-summary-powering-climate-action
[18] Kolk, A., Pinkse, J., (2004) Market Strategies for Climate Change. European Management Journal, Vol. 22, No. 3, pp. 304–314,
[19] Potential for Climate Action, December 2015

from the report include:

- When it comes to delivering action, the ability of cities to partner is more important than the type or degree of power they have.
- Over 75% of the challenges cities face cannot be managed unilaterally
- Limited Powers do not mean limited actions
    - cities can supplement their own power mix by partnering with other actors who hold complementary powers
- Elected leaders deliver more action, and those directly elected deliver the most transformative action
- Action is carried out in the majority of sectors suggest that cities are using both their conventional powers – to own or operate, for example – in combination with alternative forms of powers such as partnerships with other actors.

The analysis is less complete when taking in consideration a region that includes nine counties and 352 municipalities; however, the report's emphasis on collaboration and multilateral action points to the opportunities of a regional approach.

Climate action planning by similar cities such as Seattle and New York City also offer insights into potential combinations of actions. In Seattle the built environment accounts for 30% and transportation for over half of city emissions. In its "Getting to Zero: A Pathway to a Carbon Neutral Seattle," the City of Seattle Office of Sustainability and Environment stated that the largest challenge in the building sector will be existing building retrofits, estimating that 75 percent of the population in 2050 will be living in buildings constructed before 2011. As a result, the city of Seattle is developing retrofit programs for residential and non-residential programs such as a public-private partnership between property owners and city agencies. However, many of the changes identified by the report have fiscal and technological constraints that will be largely tackled by market conditions. In contrast, the city acknowledges that VMT and mobility policies are ones where it has more leverage; therefore, the report offers a more policy-oriented suite of actions. Recommendations include investment in transit infrastructure to increase passenger miles travelled via transit from 8% in 2011 to 25% by 2050, and incentives to reduce single occupancy vehicle travel with changes to roadway and parking pricing policies, pay-as-you-drive insurance, and trip reduction programs.

In 2012, NYC was already nearly two-thirds of way toward their "30 by 30" GHG abatement goal, most of which was due to the shift to natural gas in electric generation. In "Pathway to Deep Carbon Reductions" the Mayor's Office of Long-Term Planning and Sustainability determined that "if the City aggressively implements and strategically expands several existing initiatives it could achieve the 6.4 million ton reduction" and meet the 2030 target by 2020. The figure below shows which policies could be used to reach that more aggressive target, the most substantial of which are directed to increased efficiencies in existing buildings and their systems.

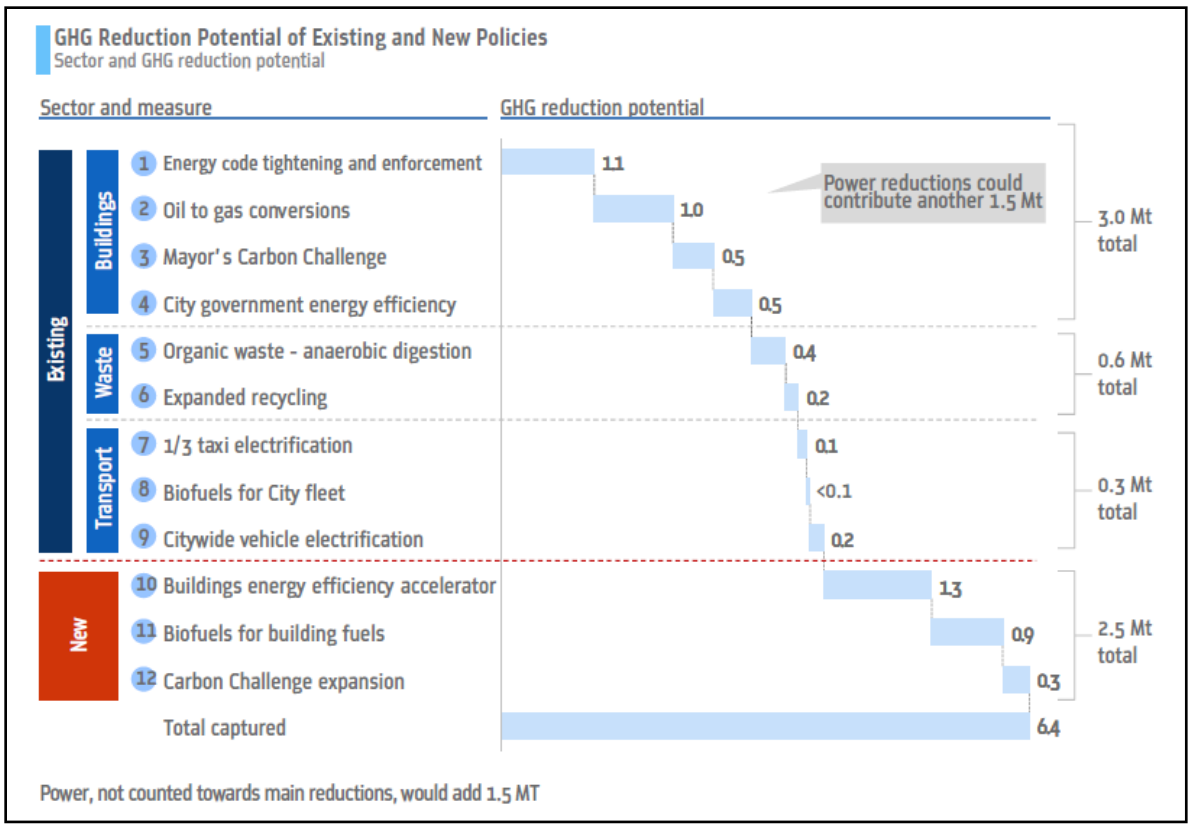


Figure 5 GHG Reduction Potential of Existing and New Policies, Pathway to Deep Carbon Reductions, New York City Office of Long-Term Planning and Sustainability

Capturing the potential of these twelve strategies requires a combination of government and market actions. Like Seattle, the transportation sector offers the city many opportunities for direct governance-related action, including:

- Zoning for Density and Transit Access
- Building and Maintaining Transit Infrastructure: bus rapid transit, bicycle share expansion, maintain and improve subways
- Supporting Cleaner Vehicles: State and local tax credits, EV charging infrastructure, Electric taxi pilot program, EVs at Hunts Point Market,
- Support Bio-fuels: Municipal fleet adoption, requirements for city contractors
- Make Driving more Economically Efficient: Use fees, congestion pricing, dynamic parking pricing, pay-as-you-drive insurance
- Improving Freight Operations: The movement of freight in NYC is mostly by truck. Trucking is more CO2 intensive (0.37 pounds CO2 per ton-mile) compared to rail, at 0.22 pounds, and sea, at 0.09 pounds.

A preliminary list of roughly 170 carbon reduction actions have been selected for evaluation in Phase 2, and are grouped in 4 sectors addressing the primary drivers of emissions: Buildings, Transportation, Source Energy, and Land Use/Smart Growth. These are listed in Appendix A. Additional actions in sectors with fewer carbon emissions may also be considered for their ability to contribute greater local benefits.

Phase 2: Pathway Evaluation

In the second phase of the project, we propose to evaluate the varieties of carbon reduction actions identified in Phase 1, determining the net regional benefits of different pathways and the powers of local actors to implement them. This will be a two-step, iterative process. The first step will be to evaluate the costs and greenhouse gas emission reductions for each action, providing a first set of criteria for prioritizing them. The second step will be to evaluate the net local benefits of each action, determining regional economic, employment, and health impacts. The Greenhouse Gas Emission Modeling team will coordinate the process, evaluating emission effects, convening expert roundtables to review the results, and developing the net benefit analysis

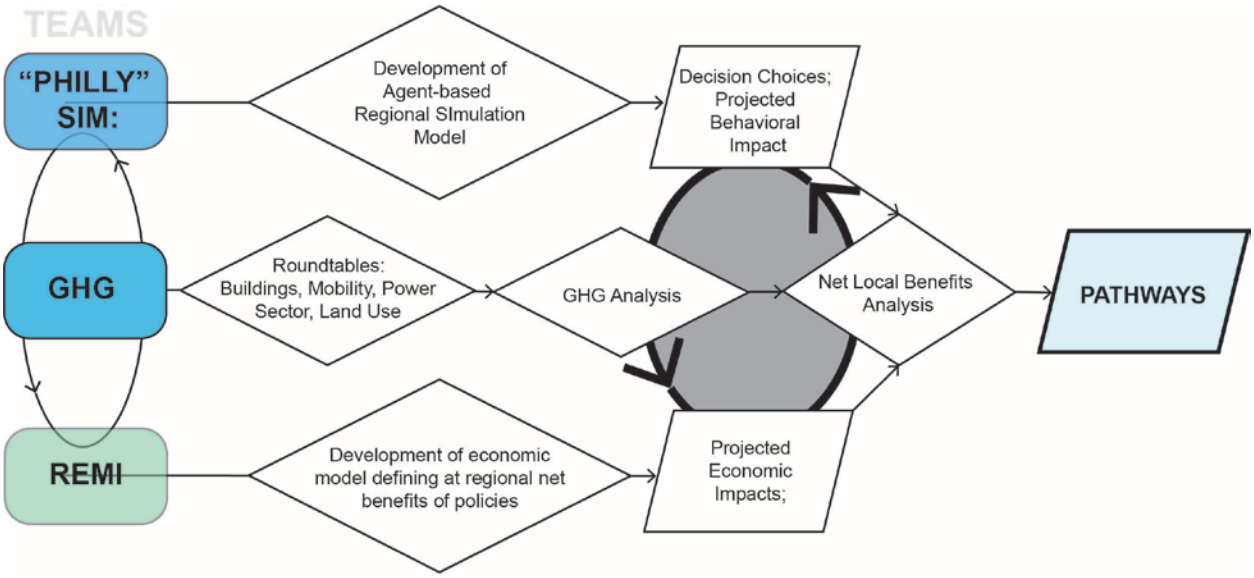


Figure 6 Team work flow

Step 1: Evaluate and Prioritize Actions for Reducing Emissions

The first task will be to evaluate and prioritize the larger set of regional-specific strategies and actions within the building, mobility, supply, and land use sectors. Leveraging expert roundtables the team will then narrow down the set and establish a suite of pathways consisting of strategies and actions, framed around each of the scenarios' parameters. These pathways will overlap and diverge, either in composition or by degree depending on the scenario. Important outputs of this analysis will be determining their comprehensiveness, emission measurability, and their role in defining the scope of the ABM and REMI modeling efforts.

The baseline emissions for the region are based on the DVRPC 2010 inventory, and a regional carbon emission calculator will be developed using the Global Protocol for Community-Scale Greenhouse Gas Emission Inventories, a collaboration of WRI, C40, and ICLE.[20] Actions will be evaluated for costs and savings, emission effects, ability of regional authorities to implement them, and the precision or uncertainty of the analysis. Many of the actions have direct, physical effects that can be evaluated—changing efficiencies of equipment or new code requirements—

[20] WRI, C40, ICLE. *Global Protocol for Community-Scale Greenhouse Gas Emission Inventories: An Accounting and Reporting Standard for Cities*. 2014

while others depend on consumer or resident response to incentives. The Philly Sim ABM will be used to explore the effects of these actions, considering both the economic and value judgements made by consumers.

	Sector		MTCDE	percent of total	MTCDE Reduction	Action	Implementing Agent	Impacted Agent	Regional Control	Mandate	Plans/Targets	Financing/Incentive	Direct Investment	Education	Partnerships	Service Delivery	Reduction Potential	Implementation Cost	Source
Buildings																			
	Commerical & Industrial Buildings		29.9	36.9%															
		Institutions & Government	7.0	8.6%															
		Commerical	13.7	16.9%															
		Industrial & Utilities	9.2	11.4%															
	Residential Buildings		18.5	22.8%															
		SFH & Attached	13.5	16.7%															
		Multi-Family	4.9	6.1%															
	Buildings Action 1			-2.7%	-2.2	Replace Residential Furnace w/ Heat Pump	State, Municipal Governments, PUCs	Utilities, Developers, Consumers	med	x	x				x				Mass2030, Greenovate Boston
Transportation																			
	On Highway Vehicle		21.6	26.6%															
		Private Vehicle																	
		Commerical Vehicle																	
	Land Use																		
Source Energy																			
	Electric Usage		26.91	33.2%															
Transportation																			
	Transit Rail		0.2	0.2%															
	Commercial Aviation		2	2.5%															
	Freight Rail		0.3	0.4%															
	Marine and Port		0.3	0.4%															
	Intercity Passenger Rail		0.1	0.1%															
	General Aviation		0.1	0.1%															
	Off-Road Vehicle & Equip		1.5	1.8%															
Industrial																			
	Fuel Refining		4.3	5.3%															
	Industrial Proc.		2.2	2.7%															
Other																			
	Waste Management		1.6	2.0%															
	Agriculture		0.4	0.5%															
Carbon Capture																			
Regional Total Emissions			81.1	100.0%															

Figure 7 Emission action evaluation, example for Buildings Action 1

Data Sources

As described above, projected emission futures will be evaluated against environmental, economic, health, and resilience metrics. The precision and quality of the pathway analysis is contingent on the quality of available data for the region. This analysis relies on energy production and consumption information, demographics, environmental quality, and economic details, among others.

The pathways analysis will utilize emissions and population growth data from DVRPC, the U.S. Census Bureau, the Energy Information Agency, the US, NJ, and PA Departments of Environmental Protection, and the City of Philadelphia. This data establishes baseline conditions and provides trends for changes in regional conditions into the future.

Because buildings accounts for nearly 60% of the region's GHG emissions, the study group will probe deeper into the available data on buildings. The distributed nature of the sector—each site is an individual user of energy with decentralized ownership—means that a successful analysis requires a more nuanced understanding of building characteristics.

Using data from tax records and national energy consumption databases, the team will develop a "bottom-up" description of building related energy consumption by sector and building type. It can be challenging to reconcile this precisely with the "top-down" data used in the regional

emissions inventory, which uses consumption records from energy suppliers, but the differences in energy use patterns among of different categories of building adds a corresponding degree of precision to the evaluation of the emission reduction effects of different actions. For example, the differences between buildings owned or operated by larger centralized entities—hospitals, universities, companies—and those smaller, individually owned houses or businesses, will involve very different kinds of policy actions.

A preliminary example of more finely described building consumption data for Philadelphia is shown in Appendix B. The rural counties tend to have less information about individual buildings in their tax records, but taken together, they should add a great deal of precision to the analysis.

The pathways analysis will also require technical data for each consumption sector. For example, the future consumption of the transportation sector will be impacted in large part by changes in driving behavior, as well as improvements in the energy performance of future vehicles. Such technological changes present one of the biggest uncertainties in future pathways analysis. As such, this analysis will rely on best available estimates of future efficiencies based on peer-reviewed research. These estimates will then be vetted through consultation with topic experts from the University of Pennsylvania and elsewhere.

Step 2: Evaluate Net Local Benefits

GHG Emission Modeling (GHG team)

In phase 2 pathways will be tested for their impacts on the region's energy use and GHG emissions for the time period 2017-2050. This analytical method will account for the four scenarios by assigning limiting coefficients to the rate of adoption and the action's level of impact. In some cases, the action may not be included at all if the experts and scenario parameters warrant exclusion.

The figures below illustrate the analysis of a hypothetical strategy in the Philadelphia buildings sector, showing how residential and commercial building retrofit strategies can be analyzed within the proposed scenario framework. The example strategy looks at the potential to retrofit a subsection of Philadelphia's residential and commercial buildings in Philadelphia. Data for building energy use was obtained from the Philadelphia Office of Sustainability for commercial buildings that have reported their use and from the Philadelphia Energy Authority (PEA) and U.S. Energy Information Agency for residential buildings.[21] [22] The PEA proposes a goal of retrofitting 25,000 units. To simplify the analysis, it was assumed that this example program would target all commercial buildings in Philadelphia over 50,000 square feet, approximately 2,100 units. Next, retrofit energy savings potential was taken from PEA for residential buildings (25-40%) and from Hendricken, et al for commercial buildings (30-50%).[23]

Each scenario would affect both the rate of adoption and relative intensity. In our example, this translates to how many of the target buildings are retrofitted in a given period (rate of adoption) and the intensity of those retrofits (i.e. how close they get to the target set in the pathway; level

[21] The Philadelphia Energy Campaign. Philadelphia Energy Authority. 2016

[22] http://www.eia.gov/consumption/residential/data/2009/#sqft

[23] L. Hendricken, "Pareto Efficient Retrofit Package Selection for Multi-Family Buildings in the Philadelphia Metropolitan Region," in Future Build, Bath, UK, 2013.

of intensity).

Example Strategy		Low-Carbon Energy Markets: Weak	Low-Carbon Energy Markets: Strong
Regional Climate Action Agreement	High	**Action Potential** *Rate of Adoption: **MEDIUM*** *Level of Intensity: **LOW***	**Action Potential** *Rate of Adoption: **HIGH*** *Level of Intensity: **HIGH***
	Low	**Action Potential** *Rate of Adoption: **LOW*** *Level of Intensity: **LOW***	**Action Potential** *Rate of Adoption: **MEDIUM*** *Level of Intensity: **HIGH***

Figure 8 Carbon reduction action potential effect under different scenarios

In this example, the rate of adoption was varied between low (5%), medium (15%), and high (25%) and the level of intensity between low (50%) and high (90%). These example rates of adoption and level of intensity are purely hypothetical. In practice, these values would be determined by subject matter experts. The cumulative energy use through 2045 was plotted for each scenario along with a Business as Usual (BAU) scenario in which no retrofits take place for reference.

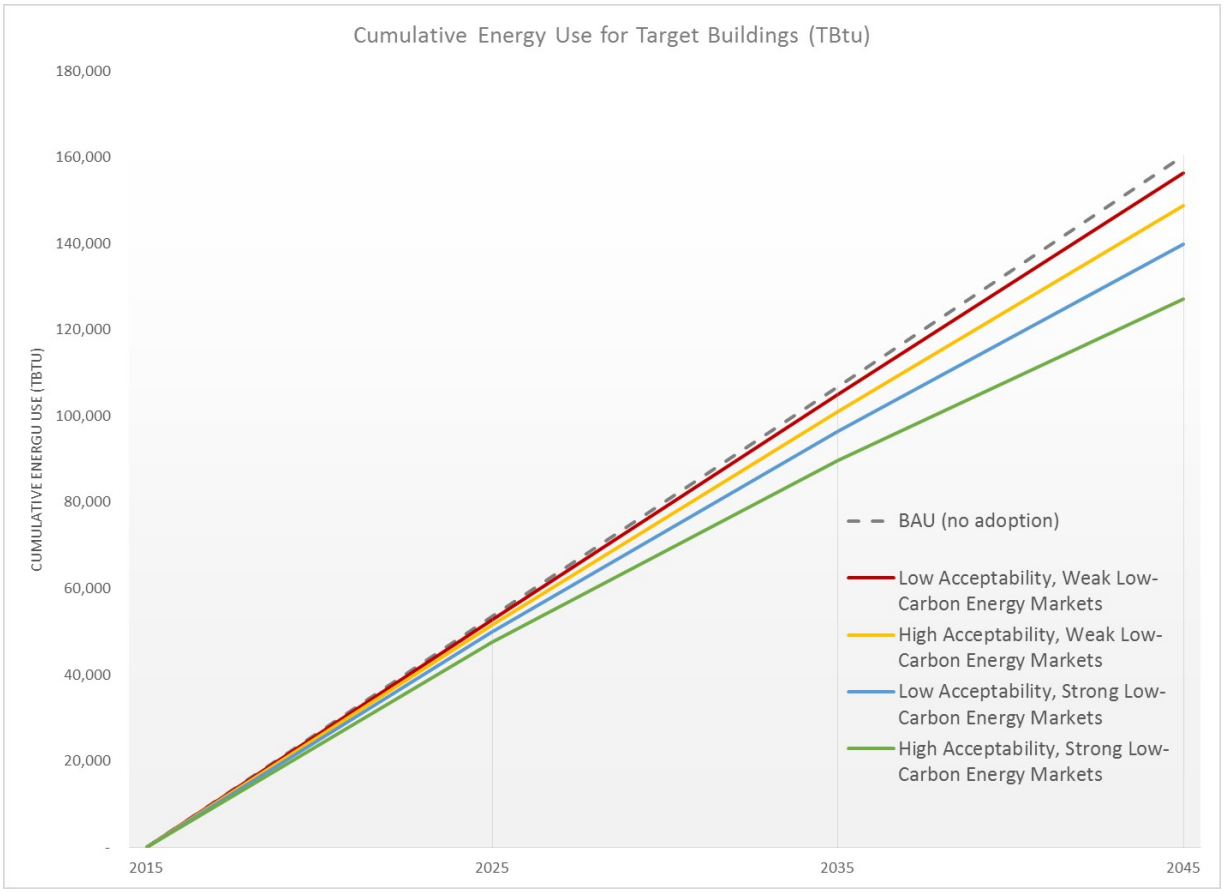


Figure 9 Cumulative energy use for buildings targeted by the hypothetical pathway

Philly Sim: Decision Support System

The project team will build on an Agent Based Model (ABM) decision support system (DSS) that will focus on population decision-making about transportation and building energy choices and how these would impact the GHG projections as different policy actions are applied. This modeling approach will itself take two approaches: top-down holistic DSS and bottom-up emergent outcome modeling.

The team will explore whether holistic modeling is useful as a central coordination function for municipalities and regions that straddle multiple planning zones, government agencies, and infrastructure systems. This will allow analysts to explore the effects of the array of policy instruments available to all-of-government. This method will, at a minimum, cover the policy responses of the transportation and buildings sector actors on the consumption side and of the energy sector alternatives on the production side. As a result, analysts should be able to explore a myriad of approaches and action choices to see how they will influence the GHG and energy usage outcomes of the region. The analysts will also be able to explore the impact of various urban development and smart city initiatives. This DSS will not be intended for predictive accuracy; its purpose is to allow analysts to explore the possibility space in order to glean insights on what effects might emerge.

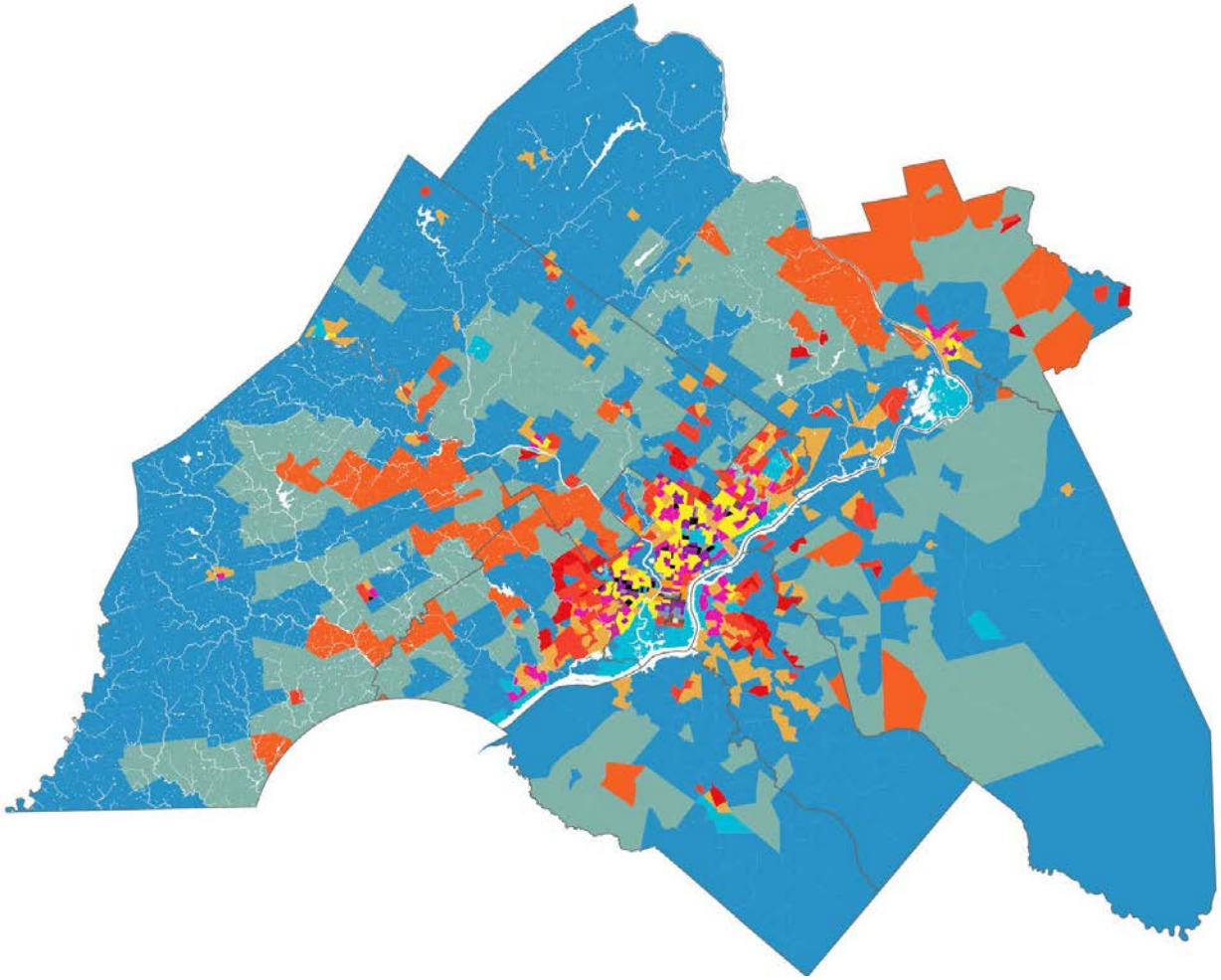


Figure 10 Map of simulation zones for the agent-based model for aggregating agents based on census data

The second part of this analysis will look at bottom-up effects by modeling the actions of individuals represented by agents capable of autonomous, self-motivated micro-decision making. These agents will be motivated by their internally derived utilities, personal objectives, and local payoff functions. Agent Based Modeling (ABM) has emerged as a powerful analytical and computational method for studying complex adaptive systems and understanding of micro processes and their emergent consequences at the macro level. Agents are "software entities that have mental states and can sense, think, and act with some degree of autonomy to carry out goals of their own choice." Agents represent discrete decision-makers as individual people or as aggregates of individuals. They have behaviors defined by simple rules and dynamic interactions with other agents that influence future behavior. The ABM method offers a flexible architecture that allows for a detailed representation of complex agent systems, including the behavior of agents, their social interactions and the physical and economic environments surrounding them. In terms of the latter, we are building into the ABM, an initial profile of the built-environment of the DVRPC landscape including things like land value, densities, building energy consumption, transit modes available, etc.

The goals of an ABM tool would be to help users analyze when and where to deploy various types of interventions. Since cities are made up of people, the issue is to alternately sway the populace into adopting these new measures of interest, and/or to study how they might interact with the new measures. The ultimate ABM we design needs to factor people's goals and micro-decision making into the process so that policy will be formed with that in mind. It is one thing to tell everyone to stop a behavior, it is another to get them to adopt a change.

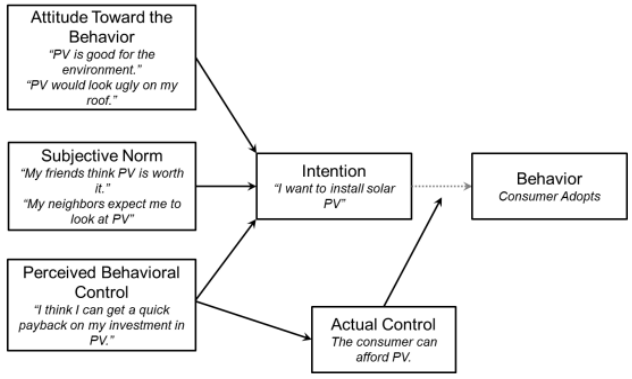


Figure 11 Example of Agent Thinking: Theory of Planned Behavior, Photovoltaics (PV) as Case Study

Our agent thinking will conform to Ajzen (1991)'s Theory of Planned Behavior which states that human action is governed by three things: attitude towards the behavior, social norms, and perceived control. Together these three factors (I want to do it, people agree with it, and I can afford it) combine to shape an individual's intentions to behave a certain way. In term of attitude we will explore two sets of factors to profile archetypes in the population – worldview and climate information awareness. We will utilize well-known taxonomies for each of these and combine them with census data to profile where these archetypes reside in the DVRPC counties. An archetype is a common profile of residents with frequently observed combinations

of attributes (e.g. working class family with ‘fortress world’ mentality and low info awareness). In terms of social norms, the ABM uses cellular automata neighborhoods so that agents are influenced by what those around them do. We will also explore the impact of varying the strength of connections across archetype networks. Finally, in terms of the economic factors, we plan to track and project socio-economic levels of the population and whether agents have savings and disposable income that they can invest in alternate energy devices or vehicles, altering homes, moving residences, changing transit modes, etc. Agents will use an economic choice model to assess dollar benefits, though the overall decision is guided by subjective expected utility since it combines attitude and social influence.

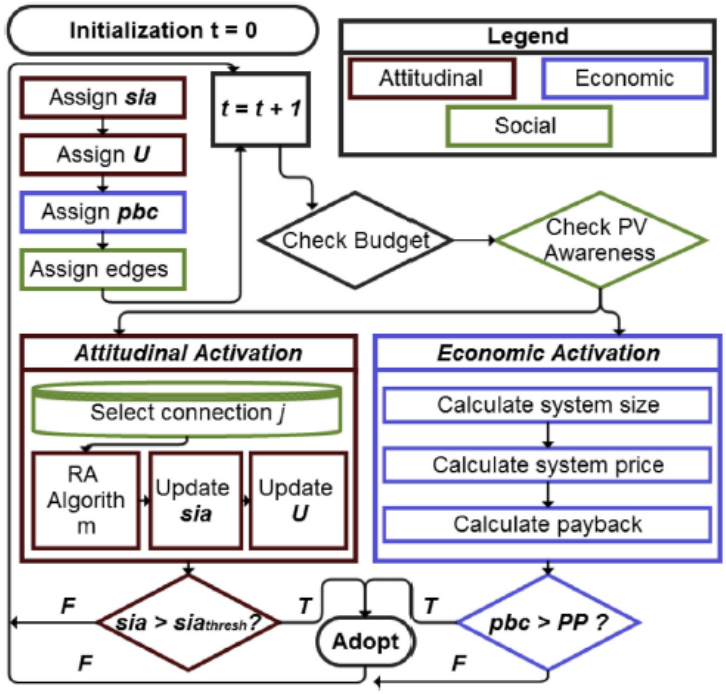


Figure 12 Initial sequence of agent decision making

The agent approach will allow the team to model social choices, sequences of mechanisms, and behavior theories of individual consumers and producers and how all these interact to produce emergent macro-effects in the community. One of the characteristics of this approach to the study of complex systems is that it accounts for both expected and unexpected outcomes including secondary and tertiary feedback as equilibria shift (e.g., as roads become less congested this might induce more people to use autos, as one infrastructure system collapses this might cascade to others, and so on). As part of this research on agents, the team will investigate different archetypes that populate the sectors: people holding varying views and values about how they personally, and also their community, should manage sustainability tradeoffs. The agents will also be classified along other factor sets, such as level of being informed (important for informational campaigns) and willingness to change and adopt new technology, products, and behaviors. The analysts will use these and/or similar frameworks to profile the producing and consuming sector agents in the model to assess if this improves the realism of the modeling outcomes.

Regional Economic Modeling (REMI)

In consultation with the Penn teams, an ICF team with expertise on economic modeling of public sector policy will use REMI, a dynamic cost-benefit modeling tool, to evaluate the local economic impacts of the pathways' policy actions. Each pathway is analyzed to determine if it is a cost-effective policy that can lead to a net positive economic gain for the region. The primary economic indicators will be regional employment, gross regional product (GRP), and disposable household income for the region.

The model is flexible and highly customizable; the team will also evaluate the net social benefits and co-benefits for the region, seeking to identify as well the distribution of benefits within the population.

Regional Health Assessment

'Co-benefits' is a political analysis used to ensure that externalities are included in climate policy discussions. However, these dos not have a methodology or the conceptual rigor of an economic concept like NSB.[24].The IPCC[25] distinguishes co-benefits as the positive effects that a policy or measure aimed at one objective might have on other objectives, irrespective of the net effect on overall social welfare.[26] In addition to economic analysis by the REMI team, the GHG and Sim team will be working with Penn experts in health and quality of life issues to expand the discussion to address regional concerns and issues.

Along with the direct benefits of a more stable climate that would result from the GHG mitigation of the regional energy pathways, there are also a host of health co-benefits. These benefits occur as a result of reduced exposure to air pollutants, increased physical activity, and other secondary impacts such as reduction of noise pollution, auto-related accidents associated with travel mode shifts, or asthma related to household moisture.[27] Including health co-benefits not only improves overall social benefits calculation of GHG mitigation actions, these effects "occur earlier than climate ones, making the social benefits calculation less sensitive to the choice of discount rate, thereby diminishing the significance of using low or high discount rate." Further, "inclusion of [air quality] co-benefits increases appeal of transforming energy production and use relative to other means of addressing climate change, which have less pronounced effects on air quality."[28]

The health impacts of air quality change can be quantified either through the application of dynamic air modeling methods (e.g. community multi-scale air quality modeling system[29]) or static models. Dynamic models account for pollutant transport and transformation processes (e.g. ozone precursors) and therefore provide more accurate estimates of pollution exposure in

[24] Mayrhofer, J., Gupta, J., The Science and Politics of Co-benefits in Climate Policy. Environmental Science & Policy Volume 57, March 2016, Pages 22–30.
[25] http://www.ipcc.ch/
[26] Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge (2014)
[27] Jack W.D. and Kinney P.L. Health co-benefits of climate mitigation in urban areas. Current Opinions in Environmental Sustainability. June 2010.
[28] G F Nemet et al. Implications of incorporating air-quality co-benefits into climate change policymaking. 2010 Environmental Research Letters
[29] Community Multi-scale Air Quality (CMAQ) Modeling System for Air Quality Management. US EPA. https://www.epa.gov/air-research/community-multi-scale-air-quality-cmaq-modeling-system-air-quality-management

local populations. Static models relate changes in emissions to changes in atmospheric concentrations of pollutants. These models will not account for geographic changes in the sources of emissions.

While some research has found significant value of air quality co-benefits (e.g. mean of $44/tCO2[30]), others have concluded that impacts in developed cities may be fairly insignificant. "At city level, GHG reduction policy impact on health impacting exposures was generally small at least in part as a result of previous adoption of policies. Policies with the potential to reduce air pollution significantly are generally at a national or international scale."[31]

Another health impact is related to increases in physical activity that come from transitioning more people from personal automobile use to active transportation methods, such as walking, bicycling and even public transit which necessitates a certain amount of walking. The methodology for quantifying the resultant health benefits of mode change are thus determined by first calculating the change in active transport and modeling that change to the disease burden of the population.[32]

The inclusion of a reduction in automotive collisions and reduction in noise is generally perceived to have a relatively limited impact on social welfare value from reviewed literature.[33]

[30] G F Nemet et al

[31] C E Sabel et al. Public health impacts of city policies to reduce climate change: findings from the URGENCHE EU-China project. 2016 Environmental Health

[32] Woodcock, J. et al. Public health benefits of strategies to reduce greenhouse-gas emissions: urban land transport. Health and Climate Change. 2009

[33] Felix Creutzig, Dongquan He, Climate change mitigation and co-benefits of feasible transport demand policies in Beijing, Transportation Research Part D: Transport and Environment, Volume 14, Issue 2, March 2009, Pages 120-131, ISSN 1361-9209, http://dx.doi.org/10.1016/j.trd.2008.11.007.

Outcomes: Optimal Pathways

Combining greenhouse gas reduction, economic analysis, and health benefits will be the basis for identifying optimal pathways for the region. After quantifying the benefits of the various actions to reduce emissions—both individually and in combination—the results with be evaluated in different combinations to characterize the range of pathways among which regional leaders can choose.

Starting with actions that yield the greatest benefit per Metric Ton Of Carbon Dioxide Equivalent (MTCDE) that is eliminated, captured, or offset, the cumulative effect of actions in combination will be evaluated to identify optimal pathways for the region. See Fig. 12. These will be considered for the four different scenarios described previously. It is anticipated that for scenarios with stronger Low-Carbon Energy Markets or greater Regional Climate Action Agreement, that pathways with greater local net benefits will be evident.

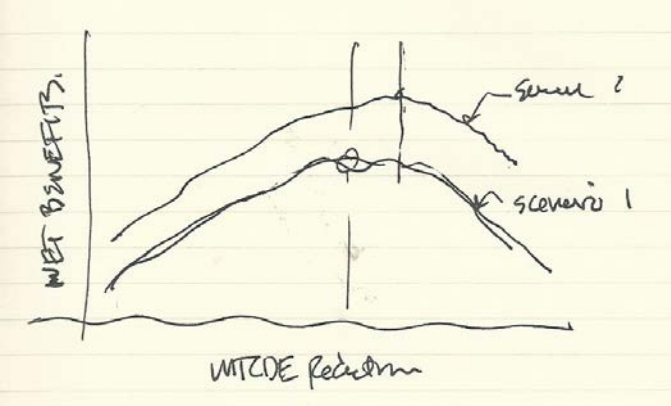
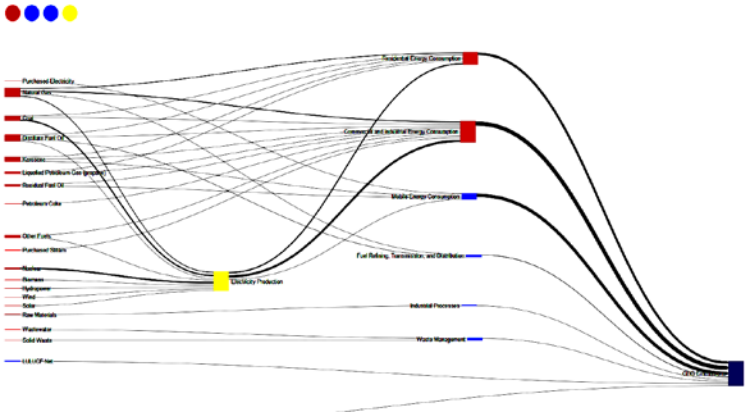


Figure 13 Illustration of cumulative net benefit curves for selections of actions under different scenarios

Visualization

It is not sufficient to simply identify optimal pathways, the information and its logic have to be presented in forms useful to regional leaders and policy makers. Two aspects of the process and its data will be developed in this phase of the work.



One is representations of the regional drivers of carbon emissions to help citizens and leaders understand the data and establish priorities. Conventional charts and graphs will be accompanied by map-based representations and interactive tools that can be used to explore the interaction of the different drivers.

Figure 14 Dynamic sankey diagram of regional carbon emissions

The second will be a tool to assemble, represent, and explore the optimal pathways for carbon reduction.

Phase 3: Developing A Carbon Action Plan

The development of a carbon action plan for the region can only occur with the active engagement of regional leaders, policy makers, and citizens. At the completion of the study, the tools for exploring optimal pathways can be used in discussions and meetings to shape a public plan.

In phase 1 the team identified six possible themes with which collections of actions can be described. These are not analytical categories, but characterizations meant to appeal to broader arguments about the future of the region.

Faith in Technology

Leap to Renewable Electricity

More with Less

Climate-Smart Growth

Building a Natural Gas Bridge

A Gas Industry is Born

They are described in more detail in Appendix C.

Appendix A: List of Actions to reduce emissions

	Sector	Action	Strategy	Implementing Agent	Impacted Agent	Regional Control	Mandate	Plans/ Targets	Financing/ Incentive	Direct Investment	Education	Partnerships	Service Delivery	Reduction Potential	Implementation Cost	Policy Pathway	Source
1	Buildings	Switching from fossil fuel use (largely natural gas for heat and hot water) to electric heat pumps and district energy for heat and hot water needs	Decarbonize Source Energy	State, Municipal Governments, PUCs	Utilities, Developers, Consumers	med	x	x				x					Mass2030, Greenovate Boston
2	Buildings	Tree Retention and Planting to Reduce Heating and Cooling Loads	Demand Reduction	Municipal Governments	Developers	high	x	x									Seattle
3	Buildings	Require all new residential and commercial buildings to be zero net emission by specified date	Demand Reduction	State, Municipal Governments	Developers	med	x	x									Center for Climate Strategies
4	Buildings	Require solar-ready building infrastructure and require solar ot water systems in new buildings	Demand Reduction	State, Municipal Governments	Developers, Consumers	med	x										
5	Buildings	Create market for demand side management (white tags)	Demand Reduction	State, Municipal Governments, Utilities, PUCs	Developers, Consumers	med		x	x			x					Center for Climate Strategies
6	Buildings	demand response and other curtailment,	Demand Reduction	PUCs, Utilities, Municipal Governments	Industry Players, Developers, Consumers	med		x				x	x			Coalitions	Greenovate Boston
7	Buildings	Occupant behavior change (smart thermostats)	Demand Reduction	State, Municipal Governments, Utilities	Consumers	med					x	x					Mass2030
8	Buildings	leading by example (government agencies reduce energy and emissions from their assets)	Improved Efficiency	State, Municipal Governments	State, Municipal Governments	high	x	x		x						Local/Regional Program	Mass2030, Greenovate Boston
9	Buildings	program to install Smart Building Energy Management and Monitoring Systems in commercial buildings	Improved Efficiency	Municipal Governments, Industry Players, Developers	Industry Players, Developers	high	x	x			x	x	x				NYC One City
10	Buildings	expand enforcement of energy code	Improved Efficiency	Municipal Governments	Developers	high	x	x					x				Greenovate Boston
11	Buildings	Require buildings meet a design standard such as LEED	Improved Efficiency	Municipal Governments	Developers, Consumers	high	x	x			x						Greenovate Boston
12	Buildings	require "green" capital needs assessment for projecs receiving municipal financing to capture energy improvement opportunities within scope of work	Improved Efficiency	Municipal Governments	Developers	high	x										Greenovate Boston
13	Buildings	expand scope and reach of building energy rating and labeling	Improved Efficiency	Municipal Governments, Utilities	Developers, Industry Players, Consumers	high	x				x	x	x			Local/Regional Program	Mass2030, Greenovate Boston, PlaNYC
14	Buildings	local-option stretch energy code for municipalities	Improved Efficiency	Municipalities	Developers, Consumers	high	x									State Program	Mass2030
15	Buildings	Energy auditing (point-of-sale, building permit triggered)	Improved Efficiency	Municipal Governments	Developers, Industry Players, Consumers	high	x										Greenovate Boston
16	Buildings	require multi-family building owners to sub-meter buildings, comply with energy code	Improved Efficiency	Municipal Governments	Developers, Consumers	high	x									Coalitions	NYC One City
17	Buildings	Neighborhood accelerator (focus on areas with overlapping issues of affordability and grid resiliency)	Improved Efficiency	Municipal Governments	Developers, Industry Players, Consumers	high		x	x	x	x	x	x			Direct Financing	NYC
18	Buildings	modify zoning regulations to remove barriers to energy efficiency	Improved Efficiency	Municipal Governments	Developers	high		x	x	x	x		x				Greenovate Boston, PlaNYC
19	Buildings	affordable housing loan program	Improved Efficiency	Municipal Governments	Developers	high			x	x							
20	Buildings	partner with community-based orgs to push out education, outreach, and assistance for residential retrofits	Improved Efficiency	Municipal Governments	Industry Players, Developers	high					x	x	x			Coalitions	Greenovate Boston
21	Buildings	program for installing high efficiency systems when existing systems are retired	Improved Efficiency	State, Municipal Governments	Developers, Consumers	med	x	x			x	x				Local/Regional Program	Mass2030, Greenovate Boston
22	Buildings	enact performance targets for building types	Improved Efficiency	State, Municipal Governments	Developers, Consumers	med	x	x			x					Direct Financing	Greenovate Boston
23	Buildings	Feebate Program to encourage energy efficiency	Improved Efficiency	State, Municipal Governments	Developers, Consumers	med	x		x								Center for Climate Strategies
24	Buildings	coordinated workforce training programs	Improved Efficiency	State, Municipal Governments, Industry Players, Developers	Developers	med		x		x	x	x					PlaNYC Pathways
25	Buildings	weatherization programs	Improved Efficiency	State, Municipal Governments	Developers, Consumers	med			x	x		x	x				NYC One City
26	Buildings	sector-specfic targeted efficiency programs - Commercial (small business, tenant fit-out, large buildings)	Improved Efficiency	State, Municipal Governments	Developers, Consumers	med			x	x							NYC One City
27	Buildings	sector-specfic targeted efficiency programs - Residential (low income, multi-family, renter)	Improved Efficiency	State, Municipal Governments	Developers, Consumers	med			x	x							NYC One City
28	Buildings	whole-building retrofit incentive	Improved Efficiency	State, Municipal Governments	Developers, Consumers	med			x	x		x					NYC One City
29	Buildings	energy and water retrofit accelerator (data-driven priortization, direct outreach, training, etc)	Improved Efficiency	State, Municipal Governments	Developers, Consumers	med			x	x	x	x	x				San Diego CAC
30	Buildings	establish or leverage existing 3rd party financing agency (eg NYCEEC)	Improved Efficiency	State, Municipal Goverments	Developers	med			x	x		x	x				San Diego CAC
31	Buildings	Modify tax incentives to encourage investments in efficiency	Improved Efficiency	State, Municipal Goverments	Developers	med			x	x							McKinsey
32	Buildings	Federal qualified energy conservation bonds (QECBS)	Improved Efficiency	Federal, Municipal Governments	Municipal Governments, Developers	med			x							Local/Regional Program	NYC One City
33	Buildings	Property Assessed Clean Energy (PACE) financing	Improved Efficiency	State, Municipal Governments, Industry Players	Developers	med			x				x			Local/Regional Program	NYC One City
34	Buildings	coordinated utility incentives	Improved Efficiency	State, Municipal Governments, Utilities, PUCs	Utilities, Developers, Consumers	med			x			x				Direct Financing	NYC One City
35	Buildings	Green/Energy Efficient Mortgages	Improved Efficiency	State, Municipal Governments, Industry Players	Developers, Consumers	med			x								Center for Climate Strategies
36	Buildings	Investment tax credits for energy efficiency improvements in Industrial/Commercial buildings	Improved Efficiency	State Governments	Industry Players, Developers	med			x								Center for Climate Strategies
37	Buildings	appliance and product efficiency standards (beyond products covered by Federal govt)	Improved Efficiency	State Governments	Industry Players, Consumers	low	x									Local/Regional Program	Greenovate Boston, PlaNYC
38	Buildings	Inverted Block Rates (tiered enegy price based on usage) to fund energy efficiency	Improved Efficiency	State Governments, PUCs	Industry Players, Developers, Consumers	low			x								Center for Climate Strategies
39	Buildings	PEA - Low Income Residential plan	Improved Efficiency	State Governments, PUCs	Industry Players, Developers, Consumers	low			*							Local/Regional Program	PEA, Philadelphia Energy Plan
1	Land Use	Promote housing affordability around transit	Coordination	Municipal Governments, Developers	Consumers	high		x				x					
2	Land Use	Land Use Priority Plans	Coordination	Municipal Government	Developers	high		x								Smart Growth	Mass2030
3	Land Use	Balance Economic Development with Agriculture, Protection of Natural Resources and Preservation of Rural Character	Coordination	Municipal Governments	Developers	high		x				x					
4	Land Use	State Sustainable Development Principles to guide state agency programs, land and investment	Coordination	State Government	Developers, Municipal Governments	med		x								Smart Growth	Mass2030
5	Land Use	Transit Oriented Development	Decarbonize	Municipal Government	Developers	high										Smart Growth	
6	Land Use	Reforming planning, subdivision, and zoning codes (reducing building setback requirements; shifting parking minimum requirement to maximum standards; reducing restrictions on density, floor area ratios, and mixed-use development; reforming on-street parking availability and pricing)	Demand Reduction	Municipal Government	Developers	high	x									Smart Growth	Mass2030
7	Land Use	Infill, Brownfield Re-development	Demand Reduction	Municipal Governments	Developers	high		x									
8	Land Use	Targeted Open Space Protection	Demand Reduction	Municipal Governments	Developers	high		x				x					
9	Land Use	Downtown Revitalization	Demand Reduction	Municipal Governments	Developers	high		x				x					
10	Land Use	Promote development of housing near employment centers (e.g. Illinois Efficient Business Incentive Statute)	Demand Reduction	Municipal Governments	Developers, Industry Players	high		x				x					
11	Land Use	Smart Growth Housing Trust Fund (eligibility by using smart growth overlay zoning)	Demand Reduction	Municipal Government	Developers	high			x							Smart Growth	Mass2030

	Sector	Action	Strategy	Implementing Agent	Impacted Agent	Regional Control	Mandate	Plans/ Targets	Financing/ Incentive	Direct Investment	Education	Partnerships	Service Delivery	Reduction Potential	Implementation Cost	Policy Pathway	Source
1	Source Energy	Integrated Resource Planning	Coordination	PUCs, Utilities	Utilities, Developers, Consumers	med		x				x					Center for Climate Strategies
2	Source Energy	contract with alternative electricity generators to supply a portion of the City's power	Decarbonize Source Energy	Municipal Governments	Utilities	high		x									Chicago
3	Source Energy	ordinances to govern the siting of small-scale renewable energy systems	Decarbonize Source Energy	Municipal Governments	Developers, Industry Players, Consumers	high		x								Smart Growth	DVRPC
4	Source Energy	Eliminate fossil-fuel heating sources	Decarbonize Source Energy	State, Municipal Governments, PUCs	Utilities, Developers, Consumers	med	x	x				x					Carbon Neutral Cities Alliance
5	Source Energy	promote a market for renewable biomass thermal fuels	Decarbonize Source Energy	State, Municipal Governments, PUCs	Utilities	med		x	x							Coalitions	NYC One City
6	Source Energy	promote community-based and shared solar programs	Decarbonize Source Energy	State, Municipal Governments, PUCs	Utilities, Developers, Industry Players, Consumers	med		x	x			x					NYC One City
7	Source Energy	Implement District heating/cooling systems	Decarbonize Source Energy	Municipal Governments, Utilities	Developers, Consumers	med		x	x			x	x				Greenovate Boston
8	Source Energy	Community Choice Aggregation	Decarbonize Source Energy	State, Municipal Governments	Municipal Governments, Utilities, Consumers	med		x				x	x				San Diego CAC
9	Source Energy	Establish policies, programs and ordinances that facilitate and promote siting of new onsite photovoltaic energy generation and energy storage systems.	Decarbonize Source Energy	State, Municipal Governments	Industry Players, Developers, Consumers	med		x									San Diego CAC
10	Source Energy	Grid-based renewable energy incentives and/or barrier removal	Decarbonize Source Energy	Federal, State Governments, PUCs	Utilities, Developers, Consumers	med			x		x	x					Center for Climate Strategies
11	Source Energy	Distributed renewable energy incentives and/or barrier removal	Decarbonize Source Energy	Federal, State Governments, PUCs	Utilities, Developers, Consumers	med			x		x	x					Center for Climate Strategies
12	Source Energy	carbon capture and storage or reuse: enabling policies, incentives & infrastructure, research and development	Decarbonize Source Energy	PUCs, Utilities, State Governments, Industry Players	Utilities, Industry Players	low	x	x	x	x		x					Center for Climate Strategies
13	Source Energy	GHG cap and trade	Decarbonize Source Energy	Federal, State Governments, PUCs	Industry Players, Utilities	low	x	x									Center for Climate Strategies
14	Source Energy	Carbon tax	Decarbonize Source Energy	Federal, State Governments, PUCs	Industry Players, Utilities	low	x	x									Center for Climate Strategies
15	Source Energy	Build renewable electricity generation - Encourage the replacement of fossil fuel fired plants with renewable plants	Decarbonize Source Energy	State Governments, PUCs, Utilities	Utilities	low	x	x									Chicago
16	Source Energy	Nuclear power review, support, and incentives	Decarbonize Source Energy	PUCs, Utilities, State Governments	Utilities	low		x	x								Center for Climate Strategies
17	Source Energy	Promote energy storage deployment	Decarbonize Source Energy	PUCs, Utilities, Industry Players	Utilities, Industry Players, Consumers	low		x		x		x					Center for Climate Strategies
18	Source Energy	Develop new nuclear energy capacity	Decarbonize Source Energy	PUCs, Utilities, State Governments	Utilities	low		x		x							Center for Climate Strategies
19	Source Energy	support the Renewable Portfolio legislation in Congress	Decarbonize Source Energy	Municipalities	Utilities	low		x									Chicago
20	Source Energy	Sequester carbon in new fossil fuel plants	Decarbonize Source Energy	PUCs, Utilities	Utilities	low		x									Chicago
21	Source Energy	Repower existing power plants	Decarbonize Source Energy	PUCs, Utilities	Utilities	low		x									Chicago
22	Source Energy	Relicensing/up-rating existing nuclear facilities	Decarbonize Source Energy	PUCs, Utilities, State Governments	Utilities	low		x									Center for Climate Strategies
23	Source Energy	create tax credits for purchasing energy from low-emitting alternative sources	Decarbonize Source Energy	State Governments, PUCs, Utilities	Utilities, Consumers	low			x								Chicago
24	Source Energy	Pricing Strategies to Promote Renewable Energy (e.g. Net Metering)	Decarbonize Source Energy	PUCs, Utilities	Utilities, Consumers	low			x								Center for Climate Strategies
25	Source Energy	Feed-in Tariffs for small-scale RE (i.e. utilities requireed to purchase RE from producers under long-term contracts at rates established by the regulatory agency)	Decarbonize Source Energy	PUCs, Utilities, State Governments	Utilities, Industry Players	low			x								Center for Climate Strategies
26	Source Energy	Reverse Auction mechanism for larger scale distributed RE (i.e. developers bid into an auction qualifying renewables projects and the projects with the lowest offers are accepted)	Decarbonize Source Energy	PUCs, Utilities, State Governments	Utilities, Industry Players	low			x								Center for Climate Strategies
27	Source Energy	Integrate citywide energy management - This will be a new municipal function, with energy goals and targets; sophisticated analysis of energy systems serving the city; strategies and plans, including capital investment, to achieve goals for the system; and a capacity to manage implementation of new design and monitor progress.	Demand Reduction	Municipal Governments	Municipal Governments	high		x		x			x				Carbon Neutral Cities Alliance
28	Source Energy	Reduce demand for and consumption of electricity - Reduced consumption will be mostly in the building sector	Demand Reduction	State, Municipal Governments, Developers	Utilities, Consumers	med		x									Carbon Neutral Cities Alliance
29	Source Energy	expand the use of Combined Heat and Power projects	Improved Efficiency	Municipal Governments, Utilities	Developers, Consumers	med		x									Chicago
30	Source Energy	Reduce emissions from natural gas production: inentives, support, or requirements	Improved Efficiency	PUCs, Utilities, State Governments	Utilities	low	x	x	x								Center for Climate Strategies
31	Source Energy	Reduce emissions from oil refining: inentives, support, or requirements	Improved Efficiency	PUCs, Utilities, State Governments	Utilities	low	x	x	x								Center for Climate Strategies
32	Source Energy	Reduce emissions in natural gas transmission and distribution	Improved Efficiency	PUCs, Utilities, State Governments	Utilities	low	x	x		x							Center for Climate Strategies
33	Source Energy	Enforce efficency standards for new generation	Improved Efficiency	State Governments, PUCs, Utilities	Utilities	low	x	x									Chicago
34	Source Energy	Investments in generation technology R&D	Improved Efficiency	Federal, State Governments	Industry Players, Utilities	low				x							Center for Climate Strategies
35	Source Energy	setting policies, standards, and protocols to guide development of smart grid systems (integrate new technology such as distributed generation, storage, demand-side technologies, and electric vehicles)	System Management	PUCs, Utilities, State Governments	Utilities	low		x		x							Center for Climate Strategies
36	Source Energy	regulations, incentives, and support programs to improve efficiency of transmission and distribution system comonents	System Management	PUCs, Utilities, State Governments	Utilities	low		x		x							Center for Climate Strategies
37	Source Energy	Natural Gas Pipeline - chamber of commerce plan															
38	Source Energy	Purchased Carbon Offsets outside of region															

	Sector	Action	Strategy	Implementing Agent	Impacted Agent	Regional Control	Mandate	Plans/ Targets	Financing/ Incentive	Direct Investment	Education	Partnerships	Service Delivery	Reduction Potential	Implementation Cost	Policy Pathway	Source
1	Transportation	Atlanta Regional Commission's Livable Communities Initiative (LCI) - awards planning grants to local governments & nonprofits to preppare and implement plans consistent w regional development policies	Coordination	DVRPC	Municipal Governments	high		x	x	x		x	x			Coalitions	Chicago
2	Transportation	San Francisco Bay Area Metropolitan Transportation Commission's Transportation for Livable Communities (TLC) program	Coordination	DVRPC	Municipal Governments	high		x	x	x		x	x			Coalitions	Chicago
3	Transportation	Align funding for planning and ordinance updates	Coordination	State, Municipal Governments, DVRPC	Municipal Governments	high		x								Smart Growth	Chicago
4	Transportation	CREATE (Chicago Region Environmental and Transportation Efficiency Program)	Coordination	Municipal Governments	Developers	high		x				x				Coalitions	Chicago
5	Transportation	Complete Streets Programs	Coordination	Municipal Governments	Municipal Governments, Developers	high		x								Mobility Mode Shift	Mass2030
6	Transportation	Eastern Pennsylvania Alliance for Clean Transportation	Coordination	Municipal Government	Transit Agencies	high						x				Coalitions	Research
7	Transportation	Healthy Transportation Programs - Promote inter-agency cooperation to implement healthy transportation options	Coordination	Municipal Governments	Transit Agencies	high						x	x			Mobility Mode Shift	
8	Transportation	Tie state funding criteria for transportation projects to sustainability goals	Coordination	State Governments	Municipal Governments	med	x		x							Smart Growth	Mass2030
9	Transportation	Multi-State zero emission vehicles Action Plan	Coordination	State Government	Developers, Municipal Governments	med		x				x				Alternative Fuel	Mass2030
10	Transportation	U.S. Department of Energy (DOE) and Department of Transportation Programs	Coordination	Federal Government	State, Municipal Governments, Developers, Consumers	low		x			x	x				Coalitions	Mass2030
11	Transportation	Require MPOs/ RPOs to evaluate and track GHG emmissions and impacts of Regional Transportation Programs	Coordination	Federal, State Government	DVRPC	low							x			Coalitions	Mass2030
12	Transportation	procurement of low-GHG fleet vehicles (light duty)	Decarbonize Source Energy	Municipal Governments, Industry Players	Municipal Governments, Industry Players	high		x		x							Center for Climate Strategies
13	Transportation	Low-GHG Fuel Standard ((renewables such as ethanol and/or biodiesel)	Decarbonize Source Energy	State Governments, Utilities	Consumers	low	x										Center for Climate Strategies
14	Transportation	Alternative Fuel Infrastructure Development	Decarbonize Source Energy	State Governments, Utilities	Consumers	low		x		x							Center for Climate Strategies
15	Transportation	support R&D into low-GHG vehicle technology	Decarbonize Source Energy	Federal Government, Industry Players	Consumers	low			x								Center for Climate Strategies
16	Transportation	Improve user Perception of public transit - safe, attractive, clean, etc. to increase use	Demand Reduction	Transit Agencies	Consumers	high	x	x		x	x		x			Mobility Mode Shift	Chicago
17	Transportation	Parking Management and Parking Pricing	Demand Reduction	Municipal Governments	Consumers	high	x		x							System Management	DOT Reference Sourcebook
18	Transportation	Reduce parking requirements for new construction	Demand Reduction	Municipal Governments	Developers	high	x		x							Smart Growth	Chicago
19	Transportation	Invest in Bike-share	Demand Reduction	Municipal Governments	Consumers	high		x		x		x				Mobility Mode Shift	NYC
20	Transportation	Invest in transit maintenance	Demand Reduction	Transit Agencies	Transit Agencies, Consumers	high		x		x			x			System Management	Chicago
21	Transportation	Set Mode Shift % Goals	Demand Reduction	Municipal Governments	Municipal Governments, Developers, Transit Agencies	high		x								Smart Growth	Mass2030
22	Transportation	Car Sharing	Demand Reduction	Municipal Governments, Developers, Industry Players	Consumers	high		x				x				Mobility Mode Shift	DOT Reference Sourcebook
23	Transportation	Green Communities Technical Support for Communities; regional offices, a division of energy/environmental departments	Demand Reduction	Municipal Governments	Municipal Governments, Developers	high			x				x			Smart Growth	Mass2030
24	Transportation	Improve Transit Service (frequency, convenience, quality)	Demand Reduction	Transit Agencies	Consumers	high				x			x				Center for Climate Strategies
25	Transportation	Create Regional Multimodal Transportation Centers	Demand Reduction	Transit Agencies	Consumers	high				x		x					Center for Climate Strategies
26	Transportation	Promotional Campaigns	Demand Reduction	Municipal Governments	Consumers	high					x					Smart Growth	
27	Transportation	Pay-As-You Drive Insurance	Demand Reduction	State, Municipal Governments, Industry Players	Consumers	med	x		x		x					Mobility Mode Shift	DOT Reference Sourcebook
28	Transportation	Road Pricing (including distance-based fees and cordoning)	Demand Reduction	Federal, State Governments	Municipal Governments, DVRPC, Consumers	med	x									System Management	DOT Reference Sourcebook
29	Transportation	Require Government Agencies to Use Telecommuting	Demand Reduction	State, Municipal Governments	Consumers	med	x										Center for Climate Strategies
30	Transportation	Ride-sharing and HOV	Demand Reduction	State, Municipal Governments	Consumers	med		x		x			x			System Management	DOT Reference Sourcebook
31	Transportation	Implement Transit in all Highway projects (BRT)	Demand Reduction	State, Municipal Governments, Transit Agencies	Transit Agencies, Consumers	med		x		x		x	x				Chicago
32	Transportation	Tax incentive for adult bicycling	Demand Reduction	State, Municipal Governments	Consumers	med			x								Center for Climate Strategies
33	Transportation	Intercity Bus Incentives and Subsidies	Demand Reduction	State, Municipal Governments, Transit Agencies	Transit Agencies	med			x								Center for Climate Strategies
34	Transportation	Funding Consolidation (one-stop-shop) for infrastructure project grants (MassWorks Infrastructure Program)	Demand Reduction	State, Municipal Governments	Municipal Governments, Transit Agencies	med							x			Smart Growth	Mass2030
35	Transportation	Vehicle-Miles-Traveled Charges	Demand Reduction	State Governments	Consumers	low	x		x								Center for Climate Strategies
36	Transportation	State gas tax increases to pay for transit and infrastructure	Demand Reduction	State Governments	Consumers	low	x			x						Fiscal	Chicago
37	Transportation	new Transit operating funding: increases in the sales tax, Chicago's Real Estate Transfer Tax.	Demand Reduction	State Governments	Municipal Governments, Consumers	low	x			x						Fiscal	Chicago
38	Transportation	Increased Fuel Tax (with Targeted Use of Revenue)	Demand Reduction	State Governments	Consumers	low	x			x							Center for Climate Strategies
39	Transportation	Congestion Pricing (with Targeted Use of Revenue)	Demand Reduction	State Governments	Consumers	low	x			x							Center for Climate Strategies
40	Transportation	Emission-Based Tolls (with Targeted Use of Revenue)	Demand Reduction	State Governments	Consumers	low	x			x							Center for Climate Strategies
41	Transportation	Telecommute and Live-Near-Your-Work, Compressed Work Week	Demand Reduction	Industry Players	Consumers	low		x				x					Center for Climate Strategies
42	Transportation	revise Federal "New Starts" transit program (provides funds for construction of new fixed guideway systems or extensions to existing fixed guideway systems)	Demand Reduction	Federal Government	State, Municipal Governments, Transit Agencies	low			x							Federal Standards	Chicago
43	Transportation	Traffic Calming	Improved Efficiency	Municipal Governments	Consumers	high				x	x						Center for Climate Strategies
44	Transportation	Feebates (combine a tax on inefficient vehicles with subsidy for efficient vehicles)	Improved Efficiency	State, Municipal Governments	Consumers	med	x		x								Center for Climate Strategies
45	Transportation	Zero Emission Vehicle Commission	Improved Efficiency	State, Municipal Governments	Municipal Governments	med	x						x			Alternative Fuel	Mass2030

	Sector	Action	Strategy	Implementing Agent	Impacted Agent	Regional Control	Mandate	Plans/ Targets	Financing/ Incentive	Direct Investment	Education	Partnerships	Service Delivery	Reduction Potential	Implementation Cost	Policy Pathway	Source
46	Transportation	lower and/or enforce speed limits	Improved Efficiency	State, Municipal Governments	Consumers	med	x				x						Center for Climate Strategies
47	Transportation	GHG-linked registration fees	Improved Efficiency	State, Municipal Governments	Consumers	med	x										Center for Climate Strategies
48	Transportation	Development of electric vehicle charging infrastructure	Improved Efficiency	Municipal Governments, Industry Players, Developers	Municipal Governments, Industry Players, Developers	med		x		x		x				Alternative Fuel	Mass2030
49	Transportation	funding programs to purchase plug-in EV, charging stations	Improved Efficiency	Federal, State, Municipal Governments	Municipal Governments, Industry Players, Developers	med			x							Alternative Fuel	Mass2030
50	Transportation	Tax Credits for Low-GHG Vehicles (tax rebates for fuel efficiency, alternative fuel vehicles)	Improved Efficiency	State, Municipal Governments	Consumers	med			x								Center for Climate Strategies
51	Transportation	Incentives for Low-GHG Vehicles (preferential parking, use of HOV lanes, lower tolls)	Improved Efficiency	State, Municipal Governments	Consumers	med			x								Center for Climate Strategies
52	Transportation	Tax Credits or Incentives to Retire or Improve Older High-GHG Vehicles	Improved Efficiency	State, Municipal Governments	Consumers	med			x								Center for Climate Strategies
53	Transportation	Vehicle scrapping program	Improved Efficiency	State, Municipal Governments	Consumers	med			x								Center for Climate Strategies
54	Transportation	Establish a fleet replacement grant program	Improved Efficiency	State, Municipal Governments	Consumers	med			x								Center for Climate Strategies
55	Transportation	vehicle maintenance/driver education programs	Improved Efficiency	State, Municipal Governments	Consumers	med				x	x						Center for Climate Strategies
56	Transportation	ZEV test drive events - Clean Car Campaign	Improved Efficiency	Municipal Governments, Industry Players	Consumers	med					x	x				Alternative Fuel	Mass2030
57	Transportation	Federal Emissions and Fuel Efficiency Standards for Medium and Heavy Duty Vehicles	Improved Efficiency	Federal Government	Industry Players	low	x									Federal Standards	Mass2030
58	Transportation	Renewable Fuel Standard (RFS) and Regional Clean Fuel Standard (CFS)	Improved Efficiency	State Governments	Utilities	low	x									Federal Standards	Mass2030
59	Transportation	Establish more rigorous Vehicle Efficiency and emissions Standards	Improved Efficiency	State Governments	Industry Players	low	x									Federal Standards	Mass2030
60	Transportation	Aircraft Emissions Reductions	Improved Efficiency	Federal Government, Industry Players	Industry Players	low	x										Center for Climate Strategies
61	Transportation	Clean Vehicle Grant program for medium and heavy-duty alternative fuel vehicles	Improved Efficiency	Federal, State Governments	Consumers	low			x							Alternative Fuel	Mass2030
62	Transportation	EV vehicle rebate program (MORE-EV)	Improved Efficiency	Federal, State Governments	Consumers	low			x		x					Alternative Fuel	Mass2030
63	Transportation	Advanced Signal Timing	System Management	Municipal Governments	Consumers	high		x		x			x			System Management	DOT Reference Sourcebook
64	Transportation	Congestion Management	System Management	Municipal Governments	Consumers	high		x		x			x			System Management	DVRPC
65	Transportation	Traveler Information Systems	System Management	Transit Agencies	Consumers	high		x		x			x			System Management	Chicago
66	Transportation	Universal Fare Payment Systems	System Management	Transit Agencies	Consumers	high		x		x			x			System Management	Chicago
67	Transportation	Travel demand management (TDM) information and services	System Management	Municipal Governments, Industry Players	Municipal Governments, Transit Agencies, Industry Players	high				x			x			Mobility Mode Shift	Mass2030
68	Transportation	Expanding Bus Rapid Transit Routes	Demand Reduction	Municipal Governments, Transit Agencies	Consumers	high		x		x		x				Smart Growth	NYC
69	Transportation (Freight)	Support a National plan for Freight Movement/Investements	Coordination	Federal, State Governments	Industry Players	low		x								Coalitions	Chicago
70	Transportation (Freight)	Truck Stop Electrification and Auxiliary Power Units	Decarbonize Source Energy	State, Municipal Governments	Industry Players, Consumers	med		x		x						Alternative Fuel	DOT Reference Sourcebook
71	Transportation (Freight)	Increased Emission-Based Truck Tolls or Highway User Fees	Demand Reduction	State, Municipal Governmens	Industry Players	med	x										Center for Climate Strategies
72	Transportation (Freight)	Improve marine/freight connectivity (state or federal)	Demand Reduction	Federal, State, Municipal Governments	Industry Players	med		x		x		x	x			Mobility Mode Shift	NYC
73	Transportation (Freight)	Adopt and/or Enforce Anti-Idling Regulations for Buses/Trucks	Improved Efficiency	State, Municipal Governments	Industry Players	med	x										Center for Climate Strategies
74	Transportation (Freight)	Create a regional freight authority	Improved Efficiency	State, Municipal Governments	Industry Players	med		x		x		x	x			Coalitions	Chicago
75	Transportation (Freight)	Procurement of Efficient Heavy-Duty Fleet Vehicles	Improved Efficiency	State, Municipal Governments, Industry Players	State, Municipal Governments, Industry Players	med		x		x							Center for Climate Strategies
76	Transportation (Freight)	Maintenance and Driver Training (freight)	Improved Efficiency	State, Municipal Governmens	Industry Players	med					x						Center for Climate Strategies
77	Transportation (Freight)	R&D on Low GHG Vehicle Technology	Improved Efficiency	Federal Government	Industry Players	low		x		x							Center for Climate Strategies
78	Transportation (Freight)	Increase Rail Capacity and Address Rail Freight System Bottlenecks	Improved Efficiency	State Governments, Industry Players	Industry Players	low		x		x		x					Center for Climate Strategies
79	Transportation (Freight)	Freight Vehicle Technology Improvements	Improved Efficiency	Industry Players	Industry Players	low		x									Center for Climate Strategies
80	Transportation (Freight)	Facilitate Adoption of New Clean Technologies – Rail and Marine Engines	Improved Efficiency	Federal, State Governments, Industry players	Industry Players	low		x				x					Center for Climate Strategies
81	Transportation (Freight)	Shift Freight Movements from Truck to Rail	Improved Efficiency	State Governments, Industry Players	Industry Players	low		x				x					Center for Climate Strategies
82	Transportation (Freight)	Tax Credits and Incentives for New Equipment or to Retire or Improve Older, Less Efficient Vehicles (freight)	Improved Efficiency	Federal, State Governments	Industry Players	low			x								Center for Climate Strategies
83	Transportation (Air)	Next Generation Air Transportation System (NextGen).	Improved Efficiency	Federal, State, Municipal Governments	State, Municipal Governments, Industry	low											FAA. NEXTGen

Appendix B: Building energy consumption data for Philadelphia

Table - Building Energy Consumption Estimate from Aggregated Parcel (Property Tax Data)

Categories	Energy Consumption (BPD)			Land Area		Building Area		FAR	Estimated Energy Consumption			
Sub-categories	Mean	Natural Gas	Electricity						Total Consumption		Natural Gas	Electricity
Description	(kBtu/sqft/yr)	(kBtu/sqft/yr)	(kBtu/sqft/yr)	(acre)	(%)	(million sqft)	(%)	(net)	(Billion Btu/yr	(%)	(Billion Btu/yr	Billion Btu/yr
		0.6	0.5	43,560.0		1,000,000.0					0.6	0.5
Institutions & Government												
Education										***3.5%***		
Education - Preschool or daycare	107.4	59.1	48.3	2.7	0.1%	1.8	0.1%	0.7	195.2	0.1%	107.3	87.8
Education - Laboratory	693.8	381.6	312.2	44.8	0.1%	12.8	0.0%	0.3	386.9	0.2%	212.8	174.1
Education - Elementary or middle sc	119.0	65.5	53.6	2,072.4	3.9%	1,251.2	4.1%	0.6	6,486.9	3.2%	3,567.8	2,919.1
Health Care										***7.6%***		
Health Care - Outpatient Diagnostic	302.6	166.4	136.2	3.6	0.2%	3.7	0.3%	1	1,107.6	0.5%	609.2	498.4
Health Care - Uncategorized	551.9	303.6	248.4	46.0	2.0%	26.0	1.9%	0.6	14,326.5	7.1%	7,879.6	6,446.9
Public Office										***0.3%***		
Office-Government	185.2	101.9	83.3	0.7	0.0%	0.5	0.0%	0.7	90.1	0.0%	49.5	40.5
Public Safety - Fire or police station	207.6	114.2	93.4	7.3	0.3%	1.1	0.1%	0.2	228.7	0.1%	125.8	102.9
Service - Post office or postal center	190.6	104.8	85.8	3.6	0.2%	1.1	0.1%	0.3	201.6	0.1%	110.9	90.7
Recreational										***2.5%***		
Public Assembly - Entertainment/cul	298.2	164.0	134.2	0.8	0.0%	0.5	0.0%	0.6	141.7	0.1%	77.9	63.8
General Recreation	-	-	-	55.8	2.4%	5.6	0.4%	0.1	-	0.0%	-	-
Golf Course	-	-	-	3.9	0.2%	-	0.0%	0	-	0.0%	-	-
Public Assembly - Library	238.2	131.0	107.2	1.1	0.0%	0.7	0.1%	0.7	176.7	0.1%	97.2	79.5
Public Facilities - Museum	267.9	147.3	120.6	3.0	0.1%	1.3	0.1%	0.5	359.9	0.2%	197.9	161.9
Public Assembly - Rec Center	254.5	140.0	114.5	34.5	1.5%	7.6	0.6%	0.2	1,937.4	1.0%	1,065.6	871.8
Public Assembly - Pool	179.8	98.9	80.9	1.1	0.0%	0.2	0.0%	0.2	36.3	0.0%	20.0	16.3
Religious worship	124.6	68.5	56.1	43.1	1.9%	18.6	1.4%	0.4	2,318.4	1.1%	1,275.1	1,043.3
subtotal				***299.2***	***12.9%***	***123.8***	***9.3%***	***0.4***	***27,993.9***	***13.8%***	***15,396.6***	***12,597.2***
Commercial												
Office										***10.3%***		
Office - Bank or other financial	266.0	146.3	119.7	3.2	0.1%	2.4	0.2%	0.8	637.8	0.3%	350.8	287.0
Office - High Rise	211.4	116.3	95.1	2.5	0.1%	41.6	3.1%	16.4	8,796.5	4.3%	4,838.1	3,958.4
Office - Low Rise	213.1	117.2	95.9	54.9	2.4%	53.4	4.0%	1	11,386.0	5.6%	6,262.3	5,123.7
Office - Misc	-	-	-	2.8	0.1%	0.1	0.0%	0	-	0.0%	-	-
Retail										***10.5%***		
Retail - Vehicle dealership/showroo	291.8	160.5	131.3	27.3	1.2%	8.4	0.6%	0.3	2,462.2	1.2%	1,354.2	1,108.0
Convenience store with gas station	989.1	544.0	445.1	6.4	0.3%	0.6	0.0%	0.1	565.5	0.3%	311.0	254.5
Commercial - Retail Store	369.7	203.4	166.4	36.9	1.6%	18.1	1.4%	0.5	6,676.4	3.3%	3,672.0	3,004.4
Food Service - Restaurant or cafeter	1,229.7	676.3	553.4	6.5	0.3%	2.3	0.2%	0.4	2,828.1	1.4%	1,555.5	1,272.6
Retail - Enclosed mall	389.9	214.4	175.4	64.9	2.8%	18.9	1.4%	0.3	7,351.3	3.6%	4,043.2	3,308.1
Grocery store or food market	519.9	285.9	234.0	6.1	0.3%	2.2	0.2%	0.4	1,130.0	0.6%	621.5	508.5
Food Service - Uncategorized	836.3	460.0	376.3	0.2	0.0%	0.3	0.0%	1.3	254.0	0.1%	139.7	114.3
Mixed Use Commercial										***3.3%***		
Mixed Use - Predominantly Commer	142.5	78.4	64.1	6.3	0.3%	6.7	0.5%	1.1	955.8	0.5%	525.7	430.1
Mixed Use - Commercial and Reside	147.2	81.0	66.3	26.7	1.2%	38.4	2.9%	1.4	5,650.9	2.8%	3,108.0	2,542.9
Lodging										***1.7%***		
Lodging - Hotel	231.2	127.2	104.0	0.5	0.0%	6.8	0.5%	13.8	1,581.1	0.8%	869.6	711.5
Lodging - Hotel	231.2	127.2	104.0	3.3	0.1%	7.7	0.6%	2.3	1,776.5	0.9%	977.1	799.4
Lodging - Motel or inn	140.6	77.3	63.3	0.5	0.0%	0.2	0.0%	0.4	28.1	0.0%	15.5	12.7
Parking										***1.5%***		
Parking Garage	194.3	106.8	87.4	9.3	0.4%	15.2	1.1%	1.6	2,945.9	1.5%	1,620.2	1,325.6
Surface Parking Lot	-	-	-	27.1	1.2%	0.6	0.0%	0	-	0.0%	-	-
subtotal				***285.3***	***12.3%***	***223.7***	***16.7%***	***0.8***	***55,026.0***	***27.1%***	***30,264.3***	***24,761.7***
Residential												
SFH & Attached										***29.8%***		
Single Family - Attached	89.9	49.4	40.4	70.8	3.1%	45.4	3.4%	0.6	4,080.3	2.0%	2,244.2	1,836.2
Single Family - Detached	109.9	60.4	49.4	0.1	0.0%	0.1	0.0%	0.9	14.5	0.0%	8.0	6.5
Single Family - Attached	89.9	49.4	40.4	455.5	19.7%	466.9	34.9%	1	41,958.9	20.7%	23,077.4	18,881.5
Single Family - Detached	109.9	60.4	49.4	430.0	18.6%	131.0	9.8%	0.3	14,391.4	7.1%	7,915.3	6,476.1
Multi-Family										***10.9%***		
Apartment Unit	104.7	57.6	47.1	117.2	5.1%	125.0	9.3%	1.1	13,092.6	6.5%	7,200.9	5,891.6
Multifamily - Uncategorized	135.0	74.2	60.7	40.4	1.7%	67.5	5.0%	1.7	9,107.8	4.5%	5,009.3	4,098.5
subtotal				***1,113.9***	***48.2%***	***835.9***	***62.5%***	***0.8***	***82,645.5***	***40.8%***	***45,455.0***	***37,190.5***
Industrial & Utilities												
Industrial										***18.3%***		
Industrial	258.4	142.1	116.3	355.8	15.4%	142.5	10.7%	0.4	36,837.3	18.2%	20,260.5	16,576.8
Transportation Terminal	417.7	229.8	188.0	18.3	0.8%	0.7	0.1%	0	288.7	0.1%	158.8	129.9
Warehouse - Non-refrigerated	95.9	52.7	43.1	-	0.0%	-	0.0%	#DIV/0!	0.2	0.0%	0.1	0.1
Utilities										***0.0%***		
Powerhouse / Substation	-	-	-	6.3	0.3%	2.9	0.2%	0.5	-	0.0%	-	-
SEPTA Depot	-	-	-	4.3	0.2%	0.9	0.1%	0.2	-	0.0%	-	-
subtotal				***384.8***	***16.6%***	***147.0***	***11.0%***	***0.4***	***37,126.2***	***18.3%***	***20,419.4***	***16,706.8***
Other												
Other Facilities										***0.0%***		
Funeral Home	-	-	-	1.8	0.1%	0.9	0.1%	0.5	-	0.0%	-	-
Greenhouse	-	-	-	0.1	0.0%	-	0.0%	0.1	-	0.0%	-	-
Correctional Facilities	-	-	-	1.5	0.1%	0.6	0.0%	0.4	-	0.0%	-	-
Military Facilities	-	-	-	2.4	0.1%	0.7	0.1%	0.3	-	0.0%	-	-
Misc	-	-	-	0.2	0.0%	0.4	0.0%	1.6	-	0.0%	-	-
Other Vacant										***0.0%***		
Air Right	-	-	-	0.9	0.0%	1.8	0.1%	2	-	0.0%	-	-
Cemetery	-	-	-	11.8	0.5%	0.1	0.0%	0	-	0.0%	-	-
Vacant	-	-	-	211.4	9.1%	2.2	0.2%	0	-	0.0%	-	-
subtotal				***230.2***	***9.9%***	***6.8***	***0.5%***	***0***	***-***	***0.0%***	***-***	***-***
TOTAL				**2,313.4**	**100.0%**	**1,337.2**	**100.0%**	**0.6**	**202,791.6**	**100.0%**	**111,535.4**	**91,256.2**

Appendix C. Pathway Themes

Among the diverse driving forces and uncertainties, the team identified 6 potential themes to help describe how individuals and communities in the region might prioritize strategies and policies.

1. **Faith in Technology:** Changing behavior quickly is hard, swapping devices can be easier. Many people expect that countries can rely on existing technologies to bridge the gap between BAU and GHG goals, while others look to technology innovation to achieve radical structural and cultural changes required for a fully decarbonized 2°C global economy. Maximizing technology potential, existing or innovative, requires unprecedented investment and political will. How does climate change acceptance and energy prices impact policies that push technology-driven pathways?
2. **Leap to Renewable Electricity:** Today's regional electric fuel mix is only supplied with marginal levels of low-carbon energy, aside from nuclear generated electricity. Fossil fuels heat our buildings and fuel our automobiles and planes. If national and global hurdles such as market design transformation and energy storage (batteries) are overcome and electricity was supplied by renewables, what will the region's emissions profile look like? Which types of local and regional policy actions can leverage or support a leap to renewable electricity market transformation?
3. **More with Less**: Efficiency within existing systems is often considered the low-hanging fruit for improving GHG emission rates because it can do so without requiring structural changes to energy markets or significant behavioral shifts. Energy Conservation Measures (ECMs)* can improve operational efficiencies in buildings, transportation, and industry but are still not widely adopted. What do aggressive regional investments in energy efficiency mean for the region? Which pathways support efficiency and conservation measures, and how will scenarios affect the adoption of those pathways?
   **EPA GHG Inventory Report 1990-2001*
4. **Climate-Smart Growth:** Integrating resilience, sustainability and climate action planning into land use and transportation planning acknowledges the interdependencies and linkages between urban and regional systems and GHG emissions. Compact transit-rich development has been proven by studies to permanently lower GHG emissions per capita compared to suburban sprawl. Cities have significant power and authority over land-use and transportation planning, ideally integrating the environmental, social, health and economic needs of citizens. How do climate-smart growth policies support GHG reduction pathways in the region? Which pathways support regional climate-smart growth within the four scenarios and how can their benefits be measured?
5. **Building a Natural Gas Bridge:** Many have proposed that natural gas can act as a bridge fuel in the short- to medium-term to move the electricity supply mix away from coal- and oil-burning plants. Cleaner natural gas has begun to replace older and dirtier power plants (188MW in NJ and 70MW in PA to date with a 1,124MW plant in the works) in the region. Maximum de-carbonization, however, requires this shift to lead to a long-term transition to renewable or low-carbon electric generation, while moving all demand-side consumption to electricity from fossil fuels. Which regional pathways support a

natural gas bridge? Can regional gas bridge policy pathways lead to ever cleaner generation through renewables and other sources or will these plants dominate the future energy mix?

6. **A Gas Industry is Born**: Philadelphia Energy Solutions and others have expressed plans to build out a regional natural gas hub for processing and exporting natural gas, as well as utilizing its byproducts for industrial uses. This industrial development could occur with or without a concurrent reliance on natural gas for electricity generation in the region. What are the economic impacts of the Philadelphia region becoming a natural gas industrial hub? How would a hub support GHG reduction pathways?

Appendix D. Budget and Schedule of Work

Phase II Budget: January-September, 2017				
		Wage	Benefits	Total
Compensation				
Carbon Accounting				
Braham	FT	**$5,472**	$1,877	$10,000
PostDoc - Alex Waegel	FT	**$5,472**	$1,877	$27,196
PostGrad - Evan Oskierko-Jeznacki	FT	**$4,500**	$1,544	$18,824
Graduate Student	PT	**$7,200**	$698	$8,886
Scenario Development				
PostGrad - Alon Abramson	FT	**$6,768**	$2,321	$29,009
PostGrad - Amanda Lloyd	PT	**$7,296**	$708	$23,695
Graduate Student	PT	**$7,200**	$698	$8,886
Modelling				
Silverman		**$5,472**	$1,877	$10,000
PostDoc - Nasrin Khansari	PT	**$7,200**	$698	$29,619
Grad student	PT	**$7,200**	$698	$8,886
Consultant Honoraria				
Consultants, 5 @ 1500				$12,000
Total Compensation		**$63,780**	**$12,997**	**$187,000**
Expense				
Workshop Expenses				$10,000
Databases, Supplies, and Services				$3,000
Total Expense		**$48,336**	**$7,700**	**$13,000**
Total Project Budget				**$200,000**