

MOVING TOWARDS A LOW CARBON ECONOMY: AN ANALYSIS OF THE METHODOLOGY FOR
CREATING A U.S. LOW-CARBON DEVELOPMENT STRATEGY

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I. EXECUTIVE SUMMARY

At the 2009 United Nations Framework Convention on Climate Change (UNFCCC) in Copenhagen, the United States (U.S.) committed to reducing national emissions 17% by 2020, and 83% by 2050. In 2010 the U.S. made further international commitments to create a low-carbon development strategy (LCDS)—a national plan to achieve emission reduction targets. However, despite these pledges, a comprehensive strategy to achieve those emissions reductions has yet to be developed. In this report, we set out to characterize the content and methodologies for twenty-two domestic and international low-carbon strategies in order to inform the creation of a LCDS for the U.S. In analyzing various components of these plans including the scope, targets, modeling and key assumptions, policy options, and stakeholder involvement, we have identified common features and methodologies that are typically used to create low-carbon plans. This analysis has enabled us to highlight potential advantages and disadvantages of each kind of approach in order to better inform the development of a low-carbon strategy for the U.S.

Gaining an understanding of generic LCDS methodologies is important, but must be considered in the context of the current U.S. political climate. We have characterized this context as one defined by limited political will for addressing climate change in addition to other economic and resource constraints. Accordingly, rather than focus on what would be *ideal* given perfect circumstances, this analysis instead focuses on what is *practical* given the numerous political and economic constraints to low-carbon development in the U.S. Through this approach, we have developed a set of robust recommendations for the following key areas which correspond to the LCDS development process:

- Setting the Scope of Emissions Source Coverage for a U.S. LCDS
- Setting Targets for a U.S. LCDS
- Selecting Policy Options to be Considered in a U.S. LCDS
- Selecting Inputs, Outputs and Focus of a U.S. LCDS
 - Using Cost-Benefit Metrics and Other Economic Outputs
 - Evaluating Basic Approaches for Emission Reductions
 - Selecting Model(s) to Perform the Analysis
- Determining Stakeholder Involvement in a U.S. LCDS

Table ES 1 below outlines our general recommendations for each of these selected key areas.

Table ES 1: Recommendations for Creation of a U.S. LCDS

Recommendations for Setting the Scope of Emissions Coverage for a U.S. LCDS

- A U.S. LCDS should cover emissions across all major source sectors of the economy to identify lowest-cost abatement possibilities and synergies among sectors regardless of whether policymakers intend to develop regulations for only a select few sectors in the near future.
- The LCDS should provide a clear breakdown of emissions reductions sources and clear definitions of the relevant sectors.
- Identifying sectors that require long-term capital investments will be essential for achieving 2050 goals.
- Economic “sectors” should be defined at a level that truly results in grouping similar entities may help to streamline coordination and ease administration of policy recommendations.

Recommendations for Setting Targets for a U.S. LCDS

- Targets should achieve at least 83% emissions reductions below 2005 levels by 2050; however, target parameters should be framed in a manner that is sensitive to the political and economic climate in the U.S.
- Both interim and long-term emissions targets should be set to incentivize early action and encourage the implementation of policies with longer time horizons.
- Targets should consider minimum requirements for renewable energy and energy efficiency standards for the buildings, transportation and the power sector.
- Targets should be framed in a manner that emphasizes economic benefits such as reducing oil dependence in the transportation sector, capturing business opportunities, eliminating waste (energy efficiency), and improving energy security.

Recommendations for Selecting Policy Options to be Considered in a U.S. LCDS

- A U.S. LCDS should consider:
 - a variety of non-carbon price, sector-specific policy options as well as an economy-wide carbon price so that policymakers have information about the relative cost-effectiveness of pursuing different low-carbon strategies;
 - the impact of establishing a national Renewable Portfolio Standard (RPS); and
 - mandating a broad upgrade to next-generation building and appliance efficiency policies that encourage the wide adoption of energy-efficient technologies throughout the building sector.
- If considering a national feed-in tariff (FIT), a U.S. LCDS should analyze all potential interactions with existing state RPSs, a potential national RPS, or a potential economy-wide carbon price.
- The LCDS should confirm the U.S. commitment to a long-term low-carbon framework and ensure an adequate planning process, a reasonable presentation of alternatives, and the availability of necessary financing.

Table ES 1: Recommendations for Creation of a U.S. LCDS (Continued)

Recommendations for Using Cost-Benefit Metrics and Other Economic Outputs

- A U.S. LCDS should implement a system to identify the most important costs and benefit metrics to be considered in the analysis and should provide guidance for decision-making based on the results of the CBA.
- The LCDS should attempt to quantify costs and benefits for the most important impact categories.

Recommendations for Evaluating Basic Approaches for Emission Reductions

- A U.S. LCDS should explore both policy and technology options rather than focusing on one or the other.
- Disfavored or controversial policy or technology options may be addressed by running modeling scenarios with and without those options.
- The LCDS should present a robust analysis of potential alternatives including alternative means of achieving program objectives by examining different methods of provision and different degrees of government involvement.

Recommendations for Selecting Model(s) to Perform the Analysis

- The LCDS should rely on quantitative models that are capable of a dynamic simulation of the economy so that the transition pathway to a low-carbon future can be described.
- All sectors the LCDS seeks to address should be covered and modeled in as much detail as is useful. All reasonable technological options should be considered by the LCDS in as much detail as possible.
- Comprehensiveness must be balanced with available resources. The LCDS model should be based on an existing model.
- Assumptions should be stated clearly and model sensitivity to these assumptions should be tested to avoid criticism.
- GDP or other indicators of economic growth should be calculated endogenously by the model rather than assumed.

Recommendations for Determining Stakeholder Involvement in a U.S. LCDS

- A U.S. LCDS should:
 - identify leading industries, experts, and relevant agencies that can provide valuable data and enhance the credibility and buy-in of the report's findings.
 - utilize the stakeholder process to enhance awareness about low carbon development opportunities, align interest, and reduce information gaps.
 - ensure benefits are clear and conveyed by credible actors.
 - solicit feedback and engagement from industries targeted for regulation.
 - begin cultivating political buy-in among both parties early in the stakeholder process.

II. INTRODUCTION

A. BACKGROUND

Earth's climate is warming as a result of human activities that have altered the composition of the atmosphere. Increasing temperatures will likely shift precipitation patterns, increase the number and severity of storms, increase the frequency of droughts, raise sea levels, damage habitats, and increase risk of extinction of many plant and animal species.¹ The worst predicted effects of climate change may be avoided or mitigated by limiting greenhouse gas (GHG) emissions in the near future.

The United States (U.S.) ranks second only to China in annual GHG emissions.² Although some effort has been made by the federal government to encourage voluntary GHG reductions, little has been done on a large scale to push the country toward lower emissions.

In 2009, based on legislation that later failed to pass the Senate, President Obama proposed to reduce emissions to 17% below 2005 levels by 2020, and to cut emissions by 83% by 2050.³ At the 2010 Conference of the Parties of the United Nations Framework Convention on Climate Change in Cancun (COP-16), the U.S. reaffirmed those GHG targets and agreed to create a low-carbon development strategy (LCDS) that would describe a plan to reduce the nation's emissions to safe levels.⁴ However, limited action has been taken on climate change, and there is currently no comprehensive strategy to achieve those emissions reductions.

As one of the world's largest and most respected conservation organizations, World Wildlife Fund (WWF) seeks to influence U.S. policy to ensure that the country plays a positive role in reducing global emissions. Importantly, that role includes demonstrating a strong commitment to reducing domestic GHG emissions. The creation of an LCDS for the U.S. is not simply a requirement for the country to meet its obligations under the Cancun Agreements; a comprehensive plan is critical to set the country on a course to making meaningful reductions in GHG emissions. Ideally, an LCDS will capture the technological and policy changes needed to lower emissions. WWF also views the process of creating an LCDS as a chance to improve coordination among different agencies, enhance communication with stakeholder groups such as businesses and civil society, and raise public awareness about low-carbon development.

¹ Environmental Protection Agency. (2012, April 16). U.S. Environmental Protection Agency. Retrieved from Climate Change: <http://www.epa.gov/climatechange/>.

² Environmental Protection Agency. (2012, April 16). U.S. Environmental Protection Agency. Retrieved from Global Greenhouse Gas Data: <http://www.epa.gov/climatechange/emissions/globalghg.html>.

³ The White House, Office of the Press Secretary. (2009). President to Attend Copenhagen Climate Talks.[Press Release]. Retrieved from <http://www.whitehouse.gov/the-press-office/president-attend-copenhagen-climate-talks>.

⁴ UNFCCC. (2010). The Cancun Agreements: Outcome of the work of the Ad Hoc Working Group on Long-term Cooperative Action under the Convention, Decision 1/CP.16 Retrieved from: unfccc.int/resource/docs/2010/cop16/eng/07a01.pdf.

B. PURPOSE AND OBJECTIVES

WWF plans to help the U.S. meet its international obligations by ensuring that an accurate, authoritative, and effective LCDS is created as soon as possible. WWF also sees the process of developing an LCDS as an opportunity to involve many stakeholders in setting U.S. climate change policy. This involvement may also allow policies that emerge from the LCDS to be more politically viable than previous efforts at combating climate change in the U.S. While the organization could play any number of roles, from leading development of an independent LCDS to advising those government agencies involved in creating an official U.S. plan, WWF needs a clear understanding of the appropriate methodology to do so effectively.

The purpose of this project is to enable WWF to participate meaningfully in the creation of a U.S. LCDS that can guide federally-supported action on climate change. To that end, this report aims to provide an overview of the typical content and methodologies of existing foreign and domestic LCDSs that have been created by governments and non-governmental organizations. This analysis will provide WWF with an understanding of the resources required to produce an LCDS, as well as the steps within the LCDS creation process where the organization can leverage its expertise or facilitate dialogue with relevant industries. This study also identifies best practices and considers how to appropriately apply lessons learned and methodologies in a U.S. context, with severe political and financial constraints.

C. OUR ROLE

Our task was to read, evaluate, and analyze existing carbon-reduction strategies to characterize both their content and the methods used to produce the content. WWF requested information regarding several aspects of the studies including: (1) the scope; (2) any targets set, such as specific emissions reductions or fraction of energy produced from renewable sources; (3) the chosen approach to carbon emissions reductions, such as a policy or technological focus; (4) the use of modeling; (5) key assumptions; (6) treatment of costs and benefits; (7) discussion of policy options; and (8) discussion or involvement of different stakeholders in the process. Based on our analysis of these features, we have developed a set of recommendations and best practices that may be applied to future efforts to create an LCDS for the U.S.

D. METHODOLOGY

The team at WWF provided us with a collection of twenty-two studies that analyze different approaches to reducing carbon emissions; a brief description of these studies can be found in Appendix A. These studies range from international reports that describe how GHG emissions reductions can be achieved on a global level to country- and even sector-specific investigations of GHG reduction potential. Some studies have been commissioned by foreign governments while others were led by non-profit groups. They may focus on policy solutions,

technological innovation, or some combination of both. Most use some form of quantitative modeling, either to identify or to demonstrate the effectiveness of proposed solutions.

We set out to characterize the content and methodologies of each of these studies, emphasizing the features of most interest to WWF. The main questions of interest include:

- What is the scope of the study? For instance, does the study cover the entire economy or only one sector?
- What are the study targets—e.g., emissions reductions or renewables penetration—and how are they set?
- Does the study approach GHG emissions reductions from a technological or policy viewpoint?
- How does the study make use of quantitative modeling? What are common or key assumptions?
- How does the study treat cost and benefit metrics and other economic outputs?
- How does the study present and discuss policy options or recommendations?
- How are relevant stakeholders involved in creating the study?

Following these questions and subsequent refinements, we created a matrix summarizing the results of this review for each of the low-carbon strategies we analyzed. After summarizing the individual reports, we synthesized the information and compared methods across all of the studies. This allowed us to identify common features and methodologies among the studies as well as the range of possible approaches. We also used this process to identify potential advantages and disadvantages of each kind of approach.

We then applied our understanding of the generic possibilities for LCDS methodologies to the U.S. context. Informed by input from WWF, we have characterized this context as one defined by: (1) limited political will for addressing climate change, (2) a political system that can be controlled by minority interests even when political will exists, (3) a political system and public that is somewhat distrustful of climate science and international efforts to address climate change, (4) the expectation of strong industry opposition to caps or prices on emissions, (5) a larger and more diverse economy and geography than other nations, and (6) a different mix of embedded technologies than other countries.

Based on our understanding of LCDS methodologies, and in consideration of existing political and economic constraints in the U.S., we developed recommendations for best practices for creating a U.S. LCDS. We then supplemented the conclusions we drew from the various studies with an expanded literature review to better inform our recommended methods.

III. ANALYSIS, FINDINGS AND RECOMMENDATIONS

The following sections describe our findings regarding the methodologies in existing low-carbon strategies for establishing scopes, setting targets, considering policy options, selecting an approach, and involving stakeholders. Findings for each of these sections are paired with our recommendations for applying these methodologies to the U.S. context.

A. SETTING THE SCOPE OF EMISSIONS COVERAGE FOR A U.S. LCDS

A critical first step for creating a U.S. LCDS is to determine the appropriate scope of analysis. By this we mean identifying and defining which sectors of the economy should be analyzed for possible emissions reductions. Two broad categories of coverage emerge from the studies reviewed: those that analyze opportunities for carbon abatement across the entire economy (“economy-wide” studies), and those that focus on one specific sector (“single-sector” studies). The choice between a single-sector approach and an economy-wide approach has important implications for stakeholder engagement, policy development, cost minimization, and target attainment.

The extent to which various economic sectors should be covered by an LCDS depends on several factors. For example, abatement goals should be considered; is the LCDS being developed to achieve relatively small, short-term reductions, or large, long-term emissions reductions? Both goals require an assessment of each economic sector’s current and projected GHG emissions to determine priority areas including which sector the majority of emissions are coming from and how many sectors need to be covered in order to achieve the desired emissions targets. Other issues, such as available technologies and interactions among policies covering different sectors, must also be considered.

In the U.S., political constraints may be the key component driving scope selection. While an economy-wide cap-and-trade program may be the most cost-effective strategy for achieving very large reductions in GHG emissions, it remains politically contentious. A U.S. LCDS should therefore attempt to propose politically-viable solutions, which may require limiting short-term action to only part of the economy. In light of these considerations, this section examines the key factors that influence the choice between a single-sector and an economy-wide LCDS and the resulting implications of that choice. Beginning with the low-carbon studies under review, this section first identifies distinctions and tradeoffs between the two approaches. Next, it examines how the studies selected and defined sectors, and how that choice impacted the reported conclusions and recommendations. Finally, it proposes a scope that may be appropriate for the U.S. given political and economic constraints.

A.1. SINGLE-SECTOR VS. ECONOMY-WIDE ANALYSES: FACTORS TO CONSIDER

Several factors affect the relative merits of sectoral and economy-wide coverage. The most commonly considered points are as follows:

- **Political viability** – Determining where sufficient political will exists is critical for setting the scope of coverage. Some politicians and the public have demonstrated an aversion to comprehensive climate legislation, making an economy-wide approach to GHG emissions reduction politically tenuous. Many parts of the economy comprise a relatively small fraction of total emissions and may be diffuse, difficult to regulate, and opposed to potentially costly regulations. However, when combined, the U.S. electric power generation and transportation sectors emit the majority of domestic GHG emissions (33% and 28%, respectively⁵), thereby presenting an opportunity to reduce emissions effectively using a less-divisive, single-sector approach.
- **Ease of administration** – Targeting emissions in a single sector generally requires less administrative oversight when compared to an economy-wide target. Working with a smaller, defined set of actors may present a more manageable first step for regulation and may enable more immediate action.
- **Fiscal constraints** – Due to the current economic downturn, fiscal considerations may limit the funding available to carry out an LCDS. The scope should be set with consideration of the greater costs of an in-depth, economy-wide LCDS when compared to a single-sector LCDS.
- **Cost-effectiveness** – Some economists contend that a comprehensive approach encompassing sources and sinks of GHG emissions from all sectors enables greater flexibility and minimizes cost. Focusing on a few selected sectors will ignore emissions from sectors that may present a significant contribution to national emissions, or sectors for which emissions reductions could be achieved with little investment. Additionally, sector-specific coverage may fail to capitalize on synergies between policies that economy-wide coverage achieves. In WWF's *Blueprint Germany*, for example, emission reductions from the electrification of passenger cars depend on the successful development of decarbonized electrical generation and smart power distribution.
- **Environmental effectiveness** – Achieving large GHG reduction targets may require regulation across all sectors. For example, covering the power or transportation sector will be insufficient to achieve 80-95% emissions reductions by 2050 in the U.S. Furthermore, policy initiatives and investments may need to be implemented in the near term if long-term emissions reductions are to be viable. For example, emissions sources or sectors that are highly energy-intensive, or those that have slow turnover of invested capital may need to be specifically targeted if the resulting reductions are to occur within the target timeframe.

⁵ United States Environmental Protection Agency. (2012, February). *ES-2 DRAFT Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2010*. February 2012. Retrieved from US EPA website: <http://www.epa.gov/climatechange/emissions/downloads12/Executive%20Summary.pdf>

A.1.1. Single-Sector Approaches

Studies covering only one sector selected that sector based on its contributions to GHG emissions. In most of the low-carbon plans, the electric power sector constitutes the largest share of emissions, and the analysis typically focuses on how to transition power generation away from the use of fossil fuels. Almost all of the reports identify coverage of the power sector as a critical ingredient for encouraging low-carbon development and achieving emissions reduction targets.

In Germany, 40% of GHG emissions come from the electricity sector. The German UBA's *Energy Target 2050* therefore examines the measures required to achieve 100% renewable electricity generation. The study identifies this transition as essential for reaching 80-95% reductions in GHG emissions by 2050. As previously mentioned, focusing on a single sector minimizes the number of stakeholders involved and can facilitate early and decisive action. Additionally, an in-depth analysis of only the power sector enables the study to provide precise recommendations for spurring targeted action.

GPI's *Powering the Plains* examines emissions reductions from the electric power sector in the upper Midwest (Iowa, Minnesota, North Dakota, South Dakota, Wisconsin and the province of Manitoba). Narrowing the analysis to a specific geographic region enabled extensive stakeholder collaboration and allowed the report's recommendations to reflect local considerations. The states (and province) included in the study share a common electric transmission system, regularly exchange power, and face similar challenges and opportunities in a carbon-constrained environment. Modeled scenarios for carbon reductions based on stakeholder input identified prominent roles for coal with carbon capture and storage (CCS), integration of wind energy, and biorefinery industries that produce liquid fuels, biogas, electricity and bio-products from cellulosic biomass. The central roles these technologies play in shaping the report's recommendations illustrate how stakeholders that are consulted in selecting the scope of the LCDS can influence its end results.

HBC's *Transportation Study* evaluates GHG emissions in the transportation sector, specifically assessing whether proposed strategies could achieve President Obama's stated goal of reducing total U.S. GHG emissions 17% below 2005 levels by 2020. Five scenarios were analyzed: (1) an economy-wide cap and trade program, (2) economy-wide carbon dioxide (CO₂) prices paired with a strong gasoline and diesel tax, (3) economy-wide CO₂ prices paired with increases to the passenger car fuel efficiency standards between 2020 and 2030, (4) economy-wide CO₂ prices paired with aggressive performance-based tax credits for alternative motor vehicles, and (5) implementation of all aforementioned policies. This analysis shows that the economy-wide CO₂ pricing policies will have a minimal impact on reducing GHG emissions from the transportation sector, will only have a marginal effect on oil imports, and will likely fail to stimulate innovation in advanced vehicle and fuel technologies. The study concludes that Corporate Average Fuel Economy (CAFE) standards and CO₂ pricing are not sufficient to reduce

emissions from the transportation sector through reduced oil consumption. Rather, the study identified increasing the cost of driving with fuel taxes as the most effective mechanism through which to achieve reductions in GHG emissions from transportation.

A.1.2. Economy-Wide Approaches

The majority of studies we reviewed could be classified as “economy-wide.” Although no report can capture all conceivable economic activity, most make an effort to account for all major sources of GHG emissions by covering major emitting sectors. Covered sectors typically include electricity generation, transportation, building efficiency, and industry.

Sectoral Breakdown

WWF's *Blueprint Germany* includes an expansive breakdown of all sectors of the German economy. The report distinguishes between the following sectors: residential; commerce, retail, and service; industrial; transport; power plant fleet; waste management; agriculture; and land use, land use change, and forestry. For each sector, the report presents a detailed itemization of energy use. For example, the commerce sector is first separated into broad categories (e.g., agriculture, government, banking, healthcare, construction, and retail). These categories are then further refined according to different types of energy use (e.g., space heating, lighting, cooling, process heat, ventilation, and office equipment). Transportation is analyzed by type of transport (e.g., passenger or freight), and vehicle-type information is highly detailed (e.g., diesel, hybrid, pure electric, and plug-in hybrid), each with defined and distinct characteristics. This level of specificity is extended to all covered sectors of the economy.

Contrasting the detailed sectoral classification utilized in WWF's *Blueprint Germany*, RMI's *Reinventing Fire* identifies four energy intensive sectors: transportation, industry, buildings, and electricity. In this report, transportation encompasses passenger cars, trucks, trains, airplanes, biofuels; industry is defined by both manufacturing and non-manufacturing activities; and the building sector covers both commercial and residential buildings.

The EC's *Low-Carbon Roadmap 2050* strikes a balance between the simplified sectoral breakdowns in RMI's *Reinventing Fire* and the comprehensive approach utilized in WWF's *Blueprint Germany*. It differentiates between six categorical sectors within the EU: power generation, industry, transport, residential and services, agriculture, and other non- CO₂ emitting sectors.

Implications of Sectoral Breakdown for a U.S. LCDS

The manner in which sectors are distinguished in an LCDS is important for determining the appropriate policy instruments. It also influences monitoring and implementation and can have a significant impact on the political viability of the proposed regulations. Of the reports that use an economy-wide analysis, sector definitions and the level of detail provided varied substantially. In WWF's *Blueprint Germany*, the detailed description of each sector enables the

report to provide a very specific set of recommendations for policymakers. This specificity also provides a high level of transparency regarding emissions sources and sheds light on potential stakeholders by identifying those who may be impacted by alterations in energy use, behavior, or regulations. By providing a very comprehensive menu of policy options, WWF's *Blueprint Germany* attempts to identify all opportunities where emissions reductions can be achieved. The rationale is two-fold: such an approach can capitalize on low-cost opportunities for efficiency improvements while also recognizing the importance of emissions reductions from capital stock with long lifespans such as buildings, power plants, and other infrastructure. While WWF's *Blueprint Germany* is one of the few reports that outline an exhaustive list of potential energy saving and low-carbon initiatives, most of the LCDSs, at a minimum, address the need to cover sectors that require long-term capital intensive investments. If new options for generating electricity and more-efficient transport are going to be realized, policymakers need to account for long-term planning.

RMI's *Reinventing Fire* also emphasizes the importance of selecting the appropriate long-term investment pathway, yet it conducted its sector analysis in four broad categories. This consolidation enabled the reporting of drastic benefits, a factor that could be appealing to public audiences. For example, by addressing residential and commercial buildings under one sector, RMI's *Reinventing Fire* estimates that investing an additional \$0.5 trillion (in 2010 present value) over the next forty years could result in \$1.9 trillion in savings from reduced energy costs. The study's "buildings sector," if analyzed as two or more separate sectors, would not comprise the same magnitude of energy savings or economic benefits.

Cost-Effectiveness

When deciding what type of sectoral coverage should be pursued, cost effectiveness should be considered. In particular, cost effectiveness can vary significantly depending on which sectors are covered and how policies are paired with one another to achieve intended targets. Covering only a subset of the economy can incur substantial costs that economy-wide approaches avoid by achieving synergies across sectors.

Furthermore, low-cost opportunities for carbon abatement and improvement efficiency may exist outside the covered sector. An advantage to pursuing an economy-wide approach to low-carbon development is the ability to identify sectors in which low-cost emissions reductions can be achieved. For instance, EC's *Low-Carbon Roadmap 2050* identifies the built environment as providing low-cost and short-term opportunities to reduce emissions by improving the energy performance of buildings.

A.2. RECOMMENDATIONS FOR SETTING THE SCOPE OF EMISSIONS COVERAGE FOR A U.S. LCDS

- **A U.S. LCDS should cover emissions across all major sectors of the economy to identify lowest-cost abatement possibilities and synergies among sectors regardless of whether policymakers intend to develop regulations for only a select few sectors in the near future.**
- **A U.S. LCDS should provide a clear breakdown of emissions reductions sources and clear definitions of the relevant sectors.**
- **Identifying sectors that require long-term capital investments will be essential for achieving 2050 goals.**
- **Economic “sectors” should be defined at a level that truly results in grouping similar entities to streamline coordination and ease administration of policy recommendations.**

A U.S. LCDS should cover emissions across all major sectors of the economy to identify lowest-cost abatement possibilities and synergies among sectors regardless of whether policymakers intend to develop regulations for only a select few sectors in the near future. Focusing on one sector may not enable the U.S. to meet short-term targets. Even if it does, it may disrupt the nation's ability to achieve long-term goals; to achieve 80-95% reductions obviously requires contributions from all sectors. Regulation of one sector should be guided by an LCDS that shows the impacts of that regulation in the context of the broader effort to lower emissions by 2050. Regulation of other sectors could then be phased in at a later time when there is sufficient political will. Additionally, an analysis that covered every single conceivable economic activity would be prohibitively costly, thus the LCDS should capture as many of the most carbon-intensive sectors as possible. Currently, the electric power sector constitutes 33% of national GHG emissions, transportation 28%, industry 20%, residential and commercial 12%, and agriculture 7%. With this breakdown of GHG emissions in mind, it is clear that electric power emissions must be addressed. Moreover, power sector coverage was identified by all reports as a critical component for low-carbon development and is most often targeted due to its high contribution to GHG emissions and the large capital investments needed to alter electric generation. In the U.S., this sector has been expecting some form of regulation, and so its stakeholders may be more willing to engage in the LCDS process.

A U.S. LCDS should provide a clear breakdown of emissions reductions sources and clear definitions of the relevant sectors. The manner in which some of the reports defined emissions from economic sectors differed from the way they were inventoried by the national

registry. For example, in Germany's national inventory, emissions from power plants in industry are attributed entirely to the industry sector, while in the WWF's *Blueprint Germany* they are taken into account in the overall consideration of the electric power sector. Ensuring this disparity is clearly addressed is important for demonstrating where emissions reductions are to come from.

Identifying sectors that require long-term capital investments will be essential for achieving 2050 goals. According to the analysis in WWF's *Blueprint Germany*, for these sectors in particular it will be especially critical to introduce the appropriate climate protection measures early on as achieving drastic emissions reductions will depend on whether significant innovation occurs in the coming years (technology, investment, system integration).

Economic "sectors" should be defined at a level that truly results in grouping similar entities to streamline coordination and ease administration of policy recommendations. In the US, the EPA typically inventories GHG emissions by five major fuel consuming sectors: electricity generation, transportation, industrial, residential, and commercial, and by end-use with the transportation, industrial, residential, and commercial GHG emissions broken down by combustion and electricity.⁶ Breaking sectors down by end-use enables a better assessment of efficiency gains, thus if targets are set in terms of increasing efficiency, end-use may be a more appropriate breakdown.

⁶ Environmental Protection Agency (2012). *2012 Greenhouse Gas Inventory Report*. Retrieved from: <http://epa.gov/climatechange/emissions/usinventoryreport.html>.

B. SETTING TARGETS FOR A U.S. LCDS

The following section describes our findings regarding the types of targets included in existing low-carbon strategies. First, this section presents an overview of the types of targets included in the studies reviewed. It then provides recommendations for setting targets in an LCDS, including a discussion of important factors which should underpin the basis for setting an appropriate target in a U.S. LCDS.

B.1. TYPES OF TARGETS

B.1.1. Primary Targets

Developing targets for an LCDS is important in that it establishes the framework and timeline for action, shapes public perception, and determines the desired emissions reductions. Most of the studies analyzed set GHG emissions reduction targets in accordance with the recommendations from the Intergovernmental Panel on Climate Change (IPCC). Although 2050 targets were fairly consistent among these reports, interim targets tended to vary slightly between studies both in timeframes and GHG reduction levels (refer to Table 1 below).

Reports that did not follow the IPCC's recommendation of 80–95% GHG emissions reductions by 2050 instead often employed a single sector approach in which the target more narrowly focused on achieving deep cuts in emissions or 100% renewable energy in the power sector. For the reports that set renewable energy and energy efficiency targets, measures often resulted in similar emissions reduction levels to the IPCC recommendations despite being framed as increases in renewable energy generation and efficiency measures. For example, in ASES's *Tackling Climate Change* leading energy experts assess the amount of carbon reductions needed by 2030 to ensure a 60-80% reduction from 2006 levels in 2050. However, GHG emission reductions were not the primary focus, but rather the authors of the report developed carbon-reduction potentials from the different technologies based on an aggressive carbon reduction scenario. As opposed to dividing the gap between desired emissions and business-as-usual, the authors of the report determined the potential size of the wedge for energy efficiency and for each renewable energy area with the intent to fill unmet demand using non-renewable low carbon technologies. Finally, in addition to setting a GHG emission reduction target, a number of reports include strategic guidelines or outline policies that would achieve a specified target for increased renewable energy. For example, the German UBA's *Energy Target 2050* sets renewable energy targets for the electric power sector, specifying different percentages for each technology type considered.

If the goal of a U.S. LCDS is to meet both President Obama's international commitment of 17% emissions reductions by 2020 and long-term targets of at least 83% reductions by 2050, then the choice becomes less about what the target should be and more about how the target should be expressed (e.g. GHG emissions reductions, renewable energy and energy efficiency

targets, percent reduction in fossil-fuel use). Table 1 below provides an overview of how targets were stated in reviewed reports.

Table 1. Overview of Targets Considered in Selected Studies

ECONOMY-WIDE GHG EMISSION REDUCTION TARGETS	
Report Title	Targets
WWF's <i>Blueprint Germany</i>	Interim Target: (2020) GHG reductions of 40%; (2030) 60% reductions; (2040) 80% reductions Long-term Target: (2050) GHG reductions of 95%
EC's <i>Low-Carbon Roadmap 2050</i>	Interim Target: (2030) GHG reductions of 40 to 44%. GHG reduction targets specified for each sector Long-term Target: (2050) GHG reductions of 80% (Compared to BAU baseline)
SEI's <i>40% Study</i>	Interim Target: (2020) Reduce emissions by 40% in the EU Long-term Target: (2050) GHG reductions of 90%
DECC's <i>Low Carbon Transition Plan</i>	Interim Target: (2020) GHG emission cuts of 18% by (2008 levels) Long-term Target: (2050) GHG emission cuts of 80% (1990 levels)
POWER SECTOR GHG EMISSION REDUCTION TARGETS	
GPI's <i>Powering the Plains</i>	Interim Target: None specified Long-term Target: (2055) Reduce CO2 emissions by 80% from 1990 levels in the Midwest power sector
EPRI's <i>Roadmap for a Low-Carbon Power Sector by 2050</i>	Interim Target: None specified Long-term Target: Reduce power sector emissions by 90% (deep emission cuts are anticipated to take place between 2025-2040). EU energy mix (2050): RES: 38% of total mix, Wind: 56% of RES; Nuclear: 27% of total mix, CCS: 30% of total mix (1414TWh); Other fossils: 5% of total mix (231TWh)
ENERGY EFFICIENCY (EE) AND RENEWABLE ENGERY (RE) TARGETS	
The Danish Government's <i>Energy Strategy 2050</i>	Interim Target: (2020) increase RE to 30% of final energy consumption, increase share of RE in the transport sector to 10%, reduce primary energy consumption (4% below 2006 levels) Long-term Target: (2050) fossil-fuel free economy
The German UBA's <i>Energy Target 2050</i>	Interim Target: None specified Long-term Target: (2050) 100% RE in German power sector (potential for reductions is 100% of the power sector emissions, with the potential reduction depending on projected energy use and fuel sources)
RMI's <i>Reinventing Fire:</i>	Interim Target: None specified Long-term Target: (2050) Shrink U.S. energy usage to 71 quads (BAU 117 quads); eliminate need for oil, coal, nuclear energy, and one-third of the natural gas. (GHG emission reductions of 82–86% (2000 levels) by 2050 will result from implemented measures)
EC's <i>Low-Carbon Roadmap 2050</i>	Interim Target: (2020) increase RE in the energy mix to 60%; (2030)75 to 80% Long-term Target: (2050) increase RE in the energy mix to nearly 100%
WWF's <i>Blueprint Germany</i>	Interim Target: (2020) increase RE in the energy mix to 20% ; (2030) 35%; (2040) 55% Long-term Target: (2050) increase Rein the energy mix to over 70%

B.1.2. Interim Targets

Interim targets are included in most of the reviewed reports and often serve as benchmarks for assessing progress. These targets also enable opportunities for reevaluation of

appropriate pathways. Several of the reviewed studies, including ECF's *Power Perspectives 2030*, build on existing analyses to assess next steps. These supplemental analyses provide important insight for the required short term actions needed to remain on track for 2050 targets. In particular, ECF's *Power Perspectives 2030* utilizes the same models and assumptions presented in ECF's *Roadmap 2050* to assess potential barriers to implementation and to identify key progress indicators. For example, *Power Perspectives 2030* reveals that current power generation and grid plans are adequate to support the planned power mix in 2020; yet significant new grid capacity would be required beyond 2020. Such analysis is vital for long-term planning and for directing necessary investments. The review also identified sectors in which attracting new investment would be a significant challenge.

Additionally, interim targets can serve as litmus tests for whether longer term targets are in fact feasible as uncertainties increase with longer time horizons. Many of the reports set interim targets for 2020 and those that had more than one interim target tended to include them in 10 year increments. For example, WWF's *Blueprint Germany* outlined linear GHG reduction targets for every decade leading up to 2050 as well as increasing renewable energy (RE) targets. Reports also tended to include these short term targets in response to regional and international commitments. For example, the Danish Government's *Energy Strategy 2050* indicated that its share of renewable energy will be increased to 30% of final energy consumption by 2020 as part of the EU's 2020 renewable energy target. Given that the U.S. has made commitments to achieve reductions by 2020, targets should also be set in accordance with these international commitments.

B.2. RECOMMENDATIONS FOR SETTING TARGETS FOR A U.S. LCDS

- **Targets should achieve at least 83% emissions reductions below 2005 levels by 2050; however, target parameters should be framed in a manner that is sensitive to the political and economic climate in the U.S.**
- **Both interim and long-term emissions targets should be set to incentivize early action and encourage the implementation of policies with longer time horizons.**
- **Targets should consider minimum requirements for renewable energy and energy efficiency standards for the buildings, transportation and the power sector.**
- **Targets should be framed in a manner that emphasizes economic benefits such as reducing oil dependence in the transportation sector, capturing business opportunities, eliminating waste (energy efficiency), and improving energy security.**

The targets in a U.S. LCDS should achieve at least 83% emissions reductions below 2005 levels by 2050; however, target parameters should be framed in a manner that is sensitive to the political and economic climate in the U.S. Several factors underpin the basis for setting an appropriate LCDS target. At the most fundamental level, targets should be determined by what climate science indicates is necessary to limit emissions from breaching dangerous thresholds. However, equally important to being underpinned by robust science is developing the appropriate types of targets. For example, *RMI's Reinventing Fire* frames its targets in terms of reducing energy intensity, increasing renewables, and cutting the US dependence on foreign oil. Accordingly, by addressing these three factors, it is projected that the U.S. can reduce fossil-fuel carbon emissions by more than 80% from 2000 levels by 2050.

A U.S. LCDS should set both interim and long-term targets to incentivize early action and encourage the implementation of policies with longer time horizons. Long term targets are critical for ensuring necessary capital investments are made to shift existing energy infrastructure while interim targets are important for monitoring progress and meeting impending commitments. In particular, a short-term target will help the U.S. develop a plan for meeting President Obama's international commitment for achieving 17% reductions by 2020.

A U.S. LCDS should consider minimum requirements for renewable energy targets and energy efficiency targets for the industry, buildings, and power sectors. While public sentiment in the U.S. remains divided on the need for climate change action, Americans tend to view renewable energy and energy efficiency more favorably. In his 2011 State of the Union speech, President Obama set forth a challenge for 80% of America's electricity to come from clean energy sources by 2035. An analysis carried out by the Energy Information Administration (EIA) revealed that under the "basic case" in the American Clean Energy and Security Act of 2009 (H.R. 2454, also known as Waxman-Markey), the share of "clean fuels" (natural gas, nuclear, renewable) would increase to 70% by 2030 and coal with CCS would raise total generation from clean sources to 81%.⁷ While policy and technological feasibility will ultimately determine the path to achieving those increases, framing targets in terms of increasing electric generation from renewables may prove less politically divisive than emissions targets. Increases in renewable generation under Waxman-Markey would result in a reduction of power sector CO₂ emissions from 29 to 85%, depending on the inclusion of offsets. Power sector emissions reductions will thus likely be an important component for achieving President Obama's 2020 target.

A U.S. LCDS should set targets in terms of reducing oil dependence for the transportation sector. With rising gas prices and instability in the Middle East, reducing the United States' dependence on foreign oil has continued to gain public traction. As concerns over

⁷ Energy Information Administration. (2009). Energy Market and Economic Impacts of H.R. 2454. Retrieved from the EIA website: [http://www.eia.gov/oiaf/servicerpt/hr2454/pdf/sroiaf\(2009\)05.pdf](http://www.eia.gov/oiaf/servicerpt/hr2454/pdf/sroiaf(2009)05.pdf)

energy security and volatile prices dominate the political landscape it's important to work needed solutions into that framework. RMI's *Reinventing Fire* capitalizes on this sentiment with a specified target of eliminating the United States' reliance on coal and oil. The LCDS proposes strategies that focus on the transportation sector, which accounts for 73% of all oil used in the United States, and transitioning the power sector off fossil fuels. While the report did not specify the corresponding emissions reductions associated with cutting the fossil fuels by 73%, according to the report, deploying superefficient autos, trucks, and planes can result in 2.1 gigatons of CO₂ emissions reductions by 2050.

C. SELECTING POLICY OPTIONS TO BE CONSIDERED IN A U.S. LCDS

Providing relevant and achievable policy options is critical to the success of an LCDS for the U.S. At a minimum, a useful LCDS should describe the range of policy options available to policymakers, and highlight those policies which are necessary to achieve sufficient reductions in carbon emissions. However, the provision of a wide range of policy options is not, in itself, sufficient to ensure decision-makers will act in a timely manner. In addition, an effective LCDS should be accompanied by a detailed and achievable plan for moving forward, including a specific timeframe for implementing each policy recommendation and identification of specific action items for government, industry, and other stakeholders. The policy options provided by the LCDS must be prioritized in a coherent manner so that policymakers can easily identify which policies are necessary to achieve the desired target, and which policies are optional. The level of detail of policy recommendations is also important; they should be specific enough to provide clear guidance on how to move forward, yet not so specific as to alienate important stakeholders in the strategy development process.

This section aims to determine the extent to which policy options are defined and assessed in the reviewed studies. First, it presents an overview of the level of detail and sector approaches contained within the reports analyzed. Next, it discusses policy options commonly addressed or considered in other studies including carbon pricing, carbon-offsets, clean energy standards, building energy efficiency standards, appliance efficiency standards, and feed-in tariffs. Finally, it presents recommendations for selecting policy options for a U.S. LCDS including potential policy options that should be considered, and general recommendations for the policy development process.

C.1. SECTOR COVERAGE & LEVEL OF DETAIL FOR POLICY OPTIONS

C.1.1. Level of Detail

The majority of the reviewed studies tended to provide at least some policy recommendations for the four most energy-intensive sectors of the economy: transportation, buildings, industry, and electricity. Within these sectors, the reports primarily focused policy recommendations around energy efficiency in buildings and industry, clean energy standards for the electric power sector, and more efficient vehicle fuel standards and transportation systems. The discussion of policy and implementation varied widely among the reviewed reports, with some providing almost no discussion of policy and others providing more specific policy recommendations and implementation strategies on a sector-by-sector basis. WWF's *Blueprint Germany*, CSIS/WRI's *Roadmap*, and EPRI's *Full Portfolio* demonstrate this range in policy detail.

As mentioned in Section A.1.2 above, *WWF's Blueprint Germany* has highly-detailed sectors which enabled an inclusion of very specific policy recommendations. As an example, the report specifies energy efficiency targets (in kWh/appliance/year) for commonly-used household appliances for all scenario pathways through 2050. CSIS/WRI's *Roadmap*, in contrast, broadly concludes that a U.S. transition to a low-carbon economy will require significant action on the

CSIS/WRI's Roadmap Policy Recommendations

CSIS/WRI's *Roadmap* calls on the U.S. government to promote energy efficiency and other similar measures that contribute to both energy security and climate goals, including regularly tightening vehicle efficiency standards, setting more aggressive building energy codes, and creating incentives for consumers to buy efficient vehicles and drive less. As with many other roadmaps, these recommendations would benefit from further development. It would be beneficial to analyze, for instance, the required target for vehicle efficiency standards or the types of building codes that would be necessary to meet stated energy efficiency targets.

part of policymakers in three important areas: establishing a long-term vision for the future; putting the U.S. on the right path by updating energy policies and incentives; and continuing to meet U.S. energy demand while addressing the tradeoffs. For each of these overall action items, the report presents general policy recommendations. Finally, EPRI's *Full Portfolio* report provides no policy options at all. Rather, the report provides an energy-economic analysis of contrasting technology development strategies that can inform future policy.

C.1.2. Sector Approaches

The extent to which policy recommendations were provided for different sectors of the economy also varied significantly among the reviewed reports. Of the U.S. LCDSs, few explored policy options outside of the four primary sectors of the economy. However, more detailed reports such as *WWF's Blueprint Germany* provide recommendations on a variety of less-common topics such as technology development, information technology (IT), and reduced emissions in the agricultural sector.

C.2. COMMONLY ADDRESSED POLICY AREAS IN OTHER REPORTS

U.S. and E.U. official governmental responses to climate change have differed significantly since the Kyoto Protocol entered into force.⁸ Perhaps the largest difference is that most European governments remain focused on creating a legally binding climate treaty, while most Americans (and even some advocates of serious action on climate change) are relatively

⁸ Lorenzoni, I and Pidgeod, N.F. (2006). *Public Views On Climate Change: European and USA Perspectives*. *Climatic Change* (2006) 77: 73–95 DOI: 10.1007/s10584-006-9072-z. Retrieved From: <http://www.atmosp.physics.utoronto.ca/people/lev/ESSgc/lorenzoniPclimchn06.pdf>.

unconcerned about treaty prospects.⁹ Moreover, E.U. officials are currently operating under a regionally functioning cap-and-trade program (i.e., the E.U. Emissions Trading Scheme (ETS)), while the U.S. lacks such a national policy scheme. The noted differences between the U.S. and the E.U. on climate diplomacy highlights the need to distinguish between domestic U.S. and international E.U. studies when providing a relevant and realistic discussion of the policy options considered by each faction. Accordingly, the following analysis of commonly-addressed policy areas is separated between the two types of reports reviewed: International Low-Carbon Strategies and Domestic Low-Carbon Strategies.

C.2.1. Carbon Pricing

All of the international strategies consider assigning a price on carbon to be a necessary basis for ambitious and successful climate policy. Additionally, most international strategies consider the establishment of a carbon price, such as the E.U. ETS, to be a prerequisite to a low-

Pricing Carbon

A recent study, which has been published in the book *Pricing Carbon*, was undertaken by a group of European and U.S. economists in order to assess the first phase of the E.U. ETS, which ran from 2005 to 2007. The researchers estimated that despite the price of carbon falling to almost zero, the scheme still led to a reduction in GHG emissions of between two and five per cent against BAU scenarios, resulting in carbon savings of 120 million to 300 million tons during the three-year period.

carbon roadmap rather than a policy option. Of the seven domestic reports analyzed, all but one stated that development of a sufficient carbon price should strongly be considered as a policy option for successful implementation of their strategy. RMI's *Reinventing Fire* avoids calling for a nation-wide cap-and-trade program or other similar mechanism. Instead, this report concludes that the U.S. has the potential to decarbonize its economy through a

variety of energy efficiency and renewable energy standards. However, it remains unclear as to whether RMI's strategy provides enough incentives to support the necessary energy efficiency and renewable energy standards required to meet their goals, especially in the absence of sufficient policy mechanisms. RMI maintains that, in the absence of a carbon price, adopting energy efficiency and renewable energy standards are generally in the interest of business.

Considering a Carbon Price in a U.S. LCDS

According to some economists, the E.U. ETS has proved extremely successful in setting a price for carbon as well as providing a basis for greater international collaboration on reducing

⁹ Levi, M. A. (2011). *U.S. v. Europe on Climate Diplomacy*. CNN World. 5/20/2011. Retrieved from: <http://globalpublicsquare.blogs.cnn.com/2011/05/20/u-s-vs-europe-on-climate-diplomacy/>.

carbon emissions.¹⁰ However, as reiterated throughout this analysis, significant barriers to the successful adoption of a cap-and-trade program in the U.S. are significant.

As discussed in Section A.2. above, a U.S. LCDS should have economy-wide coverage in order to identify the lowest-cost emissions reductions available and to allow for synergies across various sectors. This necessitates the use of an economy-wide model, which is discussed in detail in Sections D.2. and D.3. of this analysis. An economy-wide model can simulate scenarios with and without certain technologies or policies (such as a carbon price) in order to demonstrate the costs of implementing or avoiding them and the effect this has on emissions reductions. This information would be critical for policymakers to consider even if they will not ultimately implement a carbon price. Accordingly, regardless of a carbon price's political viability, the U.S. LCDS should consider a carbon price or cap-and-trade mechanism among the suite of policies considered in the analysis (refer to Section D.2. and D.3. for additional information).

C.2.2. International Carbon Offsets

Almost all of the international low-carbon studies appear skeptical of international carbon offsets or other similar policy mechanisms, with some specifically excluding the use of offsetting in their strategies. For example, while ECF's *Roadmap 2050* recognizes that well-designed offsets markets can play a role in engaging developing countries and encouraging sound investment in low-cost emission reduction strategies in the near to medium term, the report also states that the availability of international carbon credits (or equivalent) to developed economies

Disadvantages of Using Carbon Offsets

In theory, well-designed offset markets can play a role in engaging developing countries and encouraging sound investment in low-cost strategies for controlling emissions. However, many experts point out that offset schemes are unable to determine reliably whether credits are issued for activities that would have happened anyway, and that administration of these schemes makes it a very poor cost control mechanism, primarily because credits are issued only after long delays and in unpredictable quantities. Moreover, because of the need for stringent and complex regulatory oversight, offset markets cannot respond quickly to any price shocks in the cap-and-trade markets they are designed to serve.

by mid-century is highly uncertain and likely to be very limited. Therefore, the study maintains that offset allowances should be limited in order to ensure the E.U. ETS remains effective in driving innovation and fostering a competitive advantage. Of the U.S. reports, only two mention the use of carbon offsets. However, both of these reports simply model the projected amount of offsets likely required given a firm cap on emissions, and do not provide additional guidance on whether offsets should be used.

¹⁰ Ellermen, D.A., et al. (2010). *Pricing Carbon: The European Union Emissions Trading Scheme*. Cambridge University Press. ISBN 987-0-521-19647-5. Retrieved from: <http://books.google.com/books?hl=en&lr=&id=pigVprvX56QC&oi=fnd&pg=PR10&dq=pricing+carbon+book&ots=Cr0B0gIdVF&sig=xnN3yG-dWlgPvf-mHC1irP3ooy0#v=onepage&q=pricing%20carbon%20book&f=false>.

Considering Carbon Offsets in a U.S. LCDS

Carbon trading runs parallel to a system of carbon offsets, and therefore it is not surprising that most of the domestic low-carbon strategies did not include a discussion of offsets in their analyses unless they were specifically modeling an economy-wide cap-and-trade program. Even assuming a firm cap on emissions in the U.S., there are still many significant problems with the use of carbon offsets, as is reiterated throughout many of the international low-carbon strategies discussed above.

In light of well-documented disadvantages associated with international carbon offsets, we recommend that a U.S. LCDS not rely on the use of offsets if considering an economy-wide cap-and-trade program.

C.2.3. Clean Energy Standards

Almost all of the international studies either adopted or reaffirmed some kind of clean energy standard for their power and transportation sectors. For E.U. countries the targets either met or exceeded the overall E.U. goal for all Member States to achieve 20% renewable energy in their energy mix by 2020. Refer to Table 1 in Section B.1. above for specific renewable energy and energy efficiency standards.

Among the domestic low-carbon strategies, only one recommended a specific binding clean energy standard for any sector of the economy. This report, UCS's *Climate 2030*, specifically recommends a policy requiring electricity providers to obtain 40% of remaining electricity demand from renewable energy (wind, solar, geothermal, bioenergy, and incremental hydropower) by 2030.

Other domestic studies provide a general policy discussion of the important role of renewable energy, followed by a list of broad policy recommendations to further support their integration into the U.S. energy mix. For example CSIS/WRI's *Roadmap* recommends that states and other regulatory agencies pursue energy efficiency programs and renewable energy as a "first resource" option over the next five to seven years, but does not recommend specific clean energy targets or standards.

Considering Clean Energy Standards in a U.S. LCDS

A federal RPS can achieve a variety of benefits such as harmonizing the current patchwork of state standards, coordinating and tracking renewable energy certificates (RECs), improving market efficiency, increasing the diversity and security of energy supply, reducing the volatility of power prices (given stable or non-existent fuel costs for renewable), and driving renewable energy generation at scale.^{11,12} Accordingly, in the absence of a price on carbon, an

¹¹ Environmental Protection Agency. (2009, April). U.S. Environmental Protection Agency. Retrieved from Renewable Portfolio Standards Fact Sheet.: http://www.epa.gov/chp/state-policy/renewable_fs.html.

effective U.S. LCDS should consider and assess a binding federal RPS or similar policy mechanism.

In deciding upon a specific RPS, policymakers should consider and be informed by state experiences. For example, the majority of existing state RPSs and proposed federal RPSs have certain common design features including: a renewable production target and schedule; a range of qualifying technologies; tradable credits; credit price caps; and exemptions for certain classes of retail electricity suppliers. Additionally, state experiences reveal that if an RPS is to successfully increase the use of renewable resources, there should be available transmission or strategies to build in the needed transmission.¹³

C.2.4. Building Energy Efficiency Standards

The Danish Government's *Energy Strategy 2050* provides some of the most detailed policy recommendations related to building energy efficiency among all the reports analyzed. As an example, the strategy calls for the market promotion of initiatives for energy-efficient heat pumps and solar heating, including labeling schemes, certification schemes, package solutions and consistency with Europe's Energy Service Company models. In addition, the report calls for the enhancement of saving efforts by energy companies aimed at private homes and businesses and the establishment of future-proof efficiency standards for building components to ensure houses are more energy efficient. Finally, the report includes additional recommendations, such as tightening the E.U.'s Energy Performance of Buildings Directive. Most studies lack this level of detail, instead providing more general policy recommendations that promote energy efficiency in buildings without further guidance.

Similarly, WWF's *Blueprint Germany* provides a high level of detail in policies related to building efficiency standards. *Blueprint Germany* finds that existing buildings are crucial to an efficiency strategy for the residential and industry sectors, and thus calls for a substantial increase in energy rehabilitation levels to more than 2% per year. In light of this overall goal, the report then sets a medium, interim, and long-term standards for the rehabilitation of buildings.

Among the U.S. studies, RMI's *Reinventing Fire* provides highly detailed policy recommendations for strategies to increase building energy efficiency in the buildings and industry sectors. In the building sector, the report recommends a broad upgrade to next-generation building efficiency policies that encourage the wide adoption of energy-efficient technologies including: easy-to-use IT based controls, integrative design, next-generation codes and equipment standards, low-cost financing, and the valuation of non-energy benefits. For industry, the report similarly recommends the wide adoption of building efficiency policies that

¹² American Coal Council (ACC). (2012). Renewable Portfolio Standards.. Retrieved from: <http://www.americancoalcouncil.org/displaycommon.cfm?an=1&subarticlenbr=159>

¹³ National Renewable Energy Laboratory (NREL). (2008, July). State Clean Energy Practices: Renewable Portfolio Standards. Retrieved from: <http://www.nrel.gov/docs/fy08osti/43512.pdf>

encourage energy-efficient technologies as well as integrative design through the use of cogeneration, fuel switching, dematerialization and closed material cycles, revolution in biomimicry and additive manufacturing.

Considering Building Efficiency Standards in a U.S. LCDS

According to the U.S. EIA, in 2009 the residential and commercial buildings sectors account for 21% of total U.S. energy consumption.¹⁴ The implementation of federal policies that increase building efficiency standards could serve to not only reduce the absolute amount of energy used for buildings, but also reduce associated CO₂ emissions from this sector. With more than one fifth of total U.S. energy consumption at stake, it would be unwise for a U.S. LCDS to ignore this potential.

If building efficiency standards are to be included in a U.S. LCDS, they should be accompanied by detailed policy recommendations that outline timelines for building energy efficiency targets. An example of this was provided in *Blueprint Germany's* medium-, interim-, and long-term standards for the rehabilitation of buildings. Moreover, it is important to ensure that the policy recommendations for building efficiency standards in an U.S. LCDS maintain consistency with the various federal programs currently in place to enhance building efficiency. In addition to EPA and DOE's Energy Star Program and the Federal Energy management Program (FEMP), the Building Energy Codes Program also mandates that the DOE participate in the national codes development process, and help states adopt and implement progressive building energy codes.¹⁵

C.2.5. Appliance Efficiency Standards

Of the international reports analyzed, only WWF's *Blueprint Germany* and the Danish Government's *Energy Strategy 2050* provide specific policy guidance related to appliance efficiency standards. As previously discussed, *Blueprint Germany* provides a detailed breakdown of energy use by application, including specific requirements for appliance standards and a timeline for achieving these targets. The Danish Government's *Energy Strategy 2050* also provides specific guidance including a proposed ban on installing oil furnaces in existing buildings from 2017, and a proposed ban on installing oil and natural gas furnaces in new buildings from 2012. The report calls for a tightening of the requirements for efficiency and labeling of appliances and products.¹⁶

¹⁴ U.S. Energy Information Administration (EIA). (2011, April). Annual Energy Outlook with Projections to 2035. Retrieved from: <http://www.eia.gov/forecasts/aeo/pdf/0383%282011%29.pdf>.

¹⁵ U.S. Department of Energy. (2012, January 25). U.S. Department of Energy. Retrieved from Building Energy Codes Program.: <http://www.energycodes.gov/>.

¹⁶ European Commission. (2012, January 22). European Commission. Retrieved from Energy Efficiency: Eco-Design of Energy Saving Products: http://ec.europa.eu/energy/efficiency/ecodesign/eco_design_en.htm.

The domestic strategies tended to provide less-detailed policy recommendations regarding appliance and equipment standards when compared to the international strategies. For example, ASES's *Tackling Climate Change* calls for setting strict appliance and equipment efficiency standards, but gives no further details on how the standards should be set or implemented. Similarly, Google's *Clean Energy 2030* and RMI's *Reinventing Fire* both call for long-term commitments to energy efficiency, but do not recommend any specific appliance standards.

Considering Appliance Efficiency Standards in a U.S. LCDS

The implementation of appliance efficiency standards can foster significant reductions in a nation's carbon-emissions profile, at a low or even negative net cost. By providing such standards, a U.S. LCDS can ensure greater investment in the development of domestic and regional research networks, increased collaboration with the private sector for transfer of best practices, and the commercialization of technologies likely to be a source of competitive advantage.

C.2.6. Feed-In Tariffs

Most of the international strategies reinforced the role of feed-in tariffs (FITs) and other financing mechanisms in achieving a low-carbon economy. However, few international strategies provide specific recommendations other than to continue their development, and ensure they remain a key focus of policymakers. For example, in order to realize the significant increase in electricity production from renewable sources outlined in the report, WWF's *Blueprint Germany* requires a number of additional flanking measures that are generally implemented within the German Renewable Energy Sources Act (RESA)¹⁷ including: the priority feed-in of electricity production based on renewable energies, ensuring high investment security through guarantee processes, and the creation of innovation incentives by means of a corresponding digression of FITs. *Blueprint Germany* states that the German RESA should be further developed to incentivize the continued integration of renewables into the power sector, although specific guidance beyond this is not provided.

ASES's *Tackling Climate Change* was the only low carbon strategy that considered the role of FITs or similar mechanisms, although it only recognizes the ability of tariffs to speed development of renewable energy without providing any policy recommendations.

¹⁷ RESA is intended to contribute to the increase in the percentage of renewable energy sources in Germany's power supply to at least 12.5% by 2010 and to at least 20% by 2020. RESA promotes renewable energy mainly by stipulating feed-in tariffs that grid operators must pay for renewable energy fed into the power grid.

Considering Feed-in Tariffs in a U.S. LCDS

Although experience from Europe may demonstrate that properly designed FITs could be more cost-effective than a federal RPS, this notion is not evident in most of the domestic low-carbon strategies we analyzed. In general, fixed price FITs are not a common or politically viable approach to renewable energy development in the U.S., primarily because federal policymakers increasingly prefer support mechanisms that stimulate competition and minimize cost.¹⁸ The lack of a national FIT scheme has prompted a number of U.S. states and cities to consider their own equivalents, even in combination with other existing renewable energy standards.¹⁹ For example, Arizona's 2010 proposed feed-in tariff scheme²⁰ is specifically designed to maintain compatibility with the state RPS system currently in place. Regardless of these state experiences, significant opposition to a national feed-in tariff scheme still exists in the U.S.²¹

NREL's "A Policymaker's Guide to Feed-in Tariff Policy Design"

A 2010 report prepared by NREL outlines many of the arguments against the use of FIT's in the U.S:

- *Electricity Prices*: FITs can lead to near-term upward pressure on electricity prices, particularly if they lead to rapid growth in emerging renewable energy technologies.
- *Up-Front Costs*: FITs do not directly address the high up-front costs of renewable energy technologies, and instead generally offer stable revenue streams over a period of 15-25 years
- *Market Orientation*: FITs are not "market-oriented" because FITs often involve must-take provisions for the electricity generated and thus the payment levels are independent from market price signals.
- *Social Inequality*: FITs may exclude lower-income individuals from participating because the renewable energy investments are generally limited to those with disposable income, as well as with property on which to install renewable energy systems,
- *Cost of Policy*: It may be difficult to control overall policy costs under FIT policies, because it is difficult to predict the rate of market uptake without intermediate caps;
- *Price Competition*: FITs do not encourage direct price competition between project developers.

¹⁸ Wisner, Ryan. (2002, June). Renewable Energy Policy Options for China: A Comparison of Renewable Portfolio Standards, Feed-in Tariffs, and Tendering Policies. Center for Resource Solutions. Retrieved from: http://www.resource-solutions.org/pub_pdfs/IntPolicy-Feed-in_LawsandRPS.pdf.

¹⁹ Alliance For Renewable Energy. (2012, March). Status of FIT Legislation in Each State. Retrieved from: <http://www.allianceforrenewableenergy.org/us-reps.html>.

²⁰ Memorandum from Kris Mayes to Gary Pierce. (2010, July). Draft Proposed Feed-In Policy Statement. Docket No. E-00000J-09-0505. Retrieved from: <http://images.edocket.azcc.gov/docketpdf/0000113828.pdf>.

²¹ National Renewable Energy Laboratory (NREL). (2010). A Policymaker's Guide to Feed-in Tariff Policy Design. Retrieved from: <http://www.nrel.gov/docs/fy10osti/44849.pdf>.

C.3. RECOMMENDATIONS FOR SELECTING POLICY OPTIONS TO BE CONSIDERED IN U.S. LCDS

- **A U.S. LCDS should consider:**
 - **a variety of non-carbon price, sector-specific policy options as well as an economy-wide carbon price so that policymakers have information about the relative cost-effectiveness of pursuing different low-carbon strategies;**
 - **the impact of establishing a national Renewable Portfolio Standard (RPS); and**
 - **mandating a broad upgrade to next-generation building and appliance efficiency policies that encourage the wide adoption of energy-efficient technologies throughout the building sector.**
- **If considering a national feed-in tariff (FIT), a U.S. LCDS should analyze all potential interactions with existing state RPSs, a potential national RPS, or a potential economy-wide carbon price.**
- **The LCDS should confirm the U.S. commitment to a long-term low-carbon framework and ensure an adequate planning process, a reasonable presentation of alternatives, and the availability of necessary financing.**

A U.S. LCDS should consider and model a variety of non-carbon price, sector-specific policy options, as well as an economy-wide carbon price so policymakers have information about the relative cost-effectiveness of pursuing different low-carbon strategies. Although a U.S. economy wide cap-and-trade program is considered to be politically infeasible at this time, the potential cost-effectiveness of such a policy mechanisms should not be ignored. By choosing an economy-wide approach and model (refer to Sections D.2. and D.3.), it is possible to simulate scenarios with and without policies to demonstrate potential costs of implementing or avoiding them and the effect this has on emissions reductions.

A U.S. LCDS should consider and model the impact of establishing a National Renewable Portfolio Standard. In the absence of a price on carbon, policies that foster a long-term national commitment to renewable electricity will likely be necessary components of an effective LCDS for the U.S. The implementation of a federal RPS or other similar mechanism can help to transition the U.S. away from its dependence on coal and oil, toward the use of more sustainable energy sources, such as wind and solar. Accordingly, a U.S. LCDS should consider and model the potential impacts of enacting a national RPS, while ensuring compatibility with the current state RPS framework. Moreover, the majority of existing state RPSs and proposed federal RPSs have a number of common design features including a renewable production target and schedule; a range of qualifying technologies; tradable credits; credit price caps; and

exemptions for certain classes of retail electricity suppliers. These and other best practices should be accounted for if considering a federal RPS or other similar mechanism in a U.S. LCDS.

A U.S. LCDS should consider mandating a broad upgrade to next-generation building and appliance efficiency policies that encourage the wide adoption of energy-efficient technologies throughout the building sector. Increasing resource efficiency can bring major economic opportunities, improve productivity, drive down costs and boost competitiveness, and may be critical for securing growth and jobs for the U.S. Accordingly, a U.S. LCDS should consider and model the potential impacts associated with an upgrade to next generation building efficiency standards in all relevant sectors of the economy. The analysis should also consider ways to lift market and regulatory barriers (e.g., altering building codes to accommodate green building methods), and consider the impact of other policies such as increased appliance efficiency standards and weatherization programs. When assessing the impact of increased efficiency standards, the LCDS should include a detailed discussion of potential costs over the selected time period as well as policy recommendations that outline timelines for building energy efficiency targets. If the LCDS does include policies which mandate a broad upgrade to next-generation efficiency policies, the LCDS development process should engage in consultation with DOE, EPA, and other federal agencies to ensure that any recommended policy options do not conflict with established federal programs for building efficiency.

If considering a national feed-in tariff (FIT), a U.S. LCDS should analyze all potential interactions with existing state RPSs, a potential national RPS, or a potential economy-wide carbon price. Although evidence exists to suggest that FITs and RPS's can be structured to work together, harmonizing these legal instruments is very difficult politically. Ultimately, the design details of each specific policy mechanism will determine whether FIT will be successful in combination with other establishing renewable energy policy mechanisms in the U.S. Given current wide-spread opposition to the use of FITs in the U.S., serious consideration should be given to the political viability of including and/or analyzing the impacts of a FIT scheme in a U.S. LCDS. The decision to consider FITs in a U.S. LCDS should remain cognizant of these limitations as well as resource constraints.

The LCDS should confirm the U.S. commitment to a long-term low-carbon framework and ensure an adequate planning process, a reasonable presentation of alternatives, and the availability of necessary financing. An effective LCDS for the U.S. will develop a long-term policy vision and framework that reaffirms the U.S.'s commitment to creating a sustainable, low-carbon economy, and must ensure a transparent and flexible planning approach to the policy development process. Developing an appropriate timeline will also enable the U.S. to assess whether it's on track to develop and implement the recommended strategies. In addition, an effective U.S. LCDS must ensure that policies and their alternatives are clearly

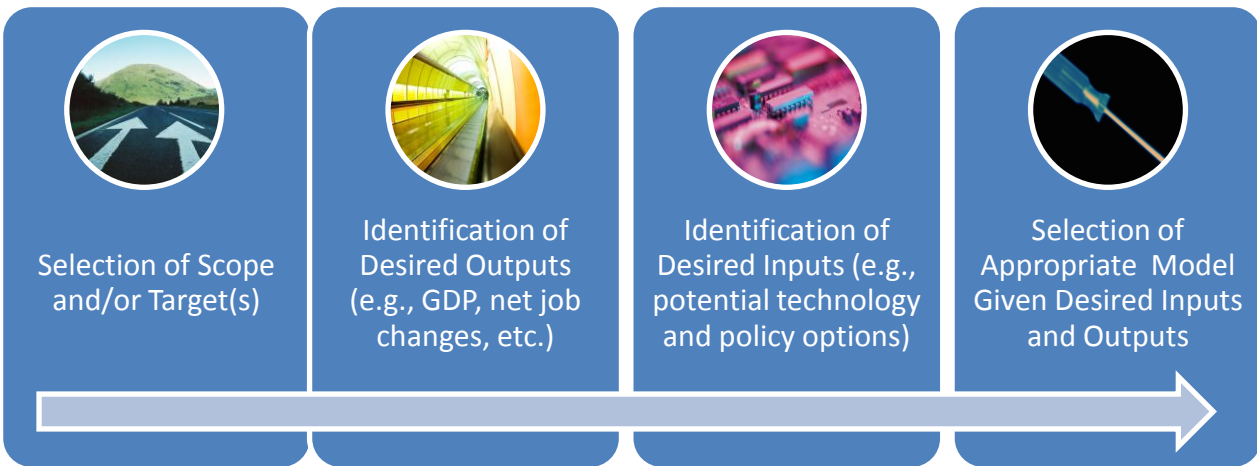
outlined, in order to provide policymakers with the best options for moving towards a low-carbon economy. Lastly, an effective U.S. LCDS must ensure that funding is available to demonstrate critical low-carbon technologies across all relevant regions along with appropriate instruments to allocate these funds. In an era where it is nearly impossible to create a line-item in a budget without specifying how the action will be paid for, it is especially important for a U.S. LCDS to specifically lay out how the proposed policies will generate revenue and how they will pay for any specific programs recommended in the LCDS.

D. SELECTING INPUTS, OUTPUTS, AND FOCUS OF A U.S. LCDS

There is no single appropriate approach for creating a successful U.S. LCDS. Many of the choices must be made in light of the desired scope, targets, and intended audience. As illustrated in Figure 1 below, a useful framework for thinking about the process of developing an LCDS is a general input-output model. After selecting the scope and target(s) for the low-carbon strategy, a clear idea of the desired outputs of the LCDS can be determined. The desired outputs will include information regarding the targets set (e.g., GHG emissions reductions or renewable energy penetration), and may also include information regarding the effects of the strategy on economic growth, future energy usage and supply mix, employment, and energy and national security. Identification of crucial policies or technologies that are required to reach the given targets may also be a desired output of the LCDS.

Once the desired outputs are determined, a path for reaching them can be created. The next step is to identify which tools—technologies or policies—will be used to lower emissions. Because providing policymakers with information on which they can act is essential, a policy-based approach seems useful. However, focusing on technological options and development may also have merit. The tradeoffs between the two approaches, and the possibility of combining them, are discussed in Section D.2. below. These technologies or policies can be considered the inputs of the LCDS.

Figure 1. Framework for Selecting the Approach for a U.S. LCDS



After identifying the suite of technology and policy options to be considered, some tool must relate these inputs to their impacts on the desired output features. For most studies, that tool is a quantitative model or models. These models range from the very simple to incredibly comprehensive and complex economic models. The choice of model can be determined by balancing the resources available for the study against the need for credible, useful, and

persuasive results. A discussion of potential modeling options for a U.S. LCDS is presented in Section D.3. below.

Section D.1. of this analysis begins with a discussion of the most important outputs or conclusions typically included in other LCDSs, with an emphasis on economic impacts. Next, the section examines the relative advantages and disadvantages of focusing on technologies versus policies as the tools for low-carbon development. It then reviews the models used by the studies. Finally, in Section D.4., a set of recommendations for the outputs of a U.S. LCDS, the approach that can best generate them and criteria for developing or selecting a model to bridge the gap between them is presented.

D.1. USING COST-BENEFIT METRICS AND OTHER ECONOMIC OUTPUTS

An LCDS can present the evidence base for potential costs and benefits to society resulting from its adoption, and can also aid in building consensus for implementation of a national low-carbon strategy.

Accordingly, this subsection examines whether the low-carbon plans our team reviewed included a Cost-Benefit Analysis (CBA), and if so, which cost and benefit metrics were utilized. This subsection then presents an overview of the most important costs-benefits metrics considered by other studies in an attempt to inform the possible direction for a CBA in a U.S. LCDS. Additional discussion of the modeling approaches used to calculate some of these economic outputs is provided below in Section D.3.2.

D.1.1. Overview of Cost Benefit Analyses

Some of the most frequent and persuasive arguments made in opposition to climate change policy are negative economic predictions: that climate change legislation will destroy jobs, reduce the nation's gross domestic product (GDP), damage U.S. businesses such as the coal and petroleum industries, and increase the cost of fuel. U.S. climate policy advocates often counter opposition to climate regulation with their own economic and scientific claims. For instance, in response to economic arguments opposing climate change legislation, proponents of climate action usually argue that climate change policies will create jobs or are necessary to develop new energy technologies that are vital to the health of the U.S. economy in the future. It is currently unclear which side has the better argument because of the complex effects climate policies may have on the U.S. economy; it's not as simple as counting jobs gained and lost. Additionally, few major policies are likely to be implemented in the U.S. without a showing of net benefits. Accordingly, quantifying the benefits of climate action through a robust CBA can be one of the most effective ways to counter opposition to GHG regulation based on economic grounds. The policy recommendations in a U.S. LCDS will undoubtedly be more credible if they are based on a robust CBA of their potential benefits and impacts. However, it should also be noted that the persuasiveness of a CBA relies not only on the robustness of the quantitative

arguments presented, but also on the broader credibility of its authors. In other words, who conducts the economic analysis can be just as important as its technical results.

The economic modeling associated with a U.S. LCDS may, in fact, reveal that the cost of implementing the strategy (or achieving a particular emission reduction target) may outweigh the resulting benefits to society. In such a case, decision-makers will be faced with two options: (1) either move forward with the strategy regardless of the fact that costs could potentially outweigh the benefits, or (2) scale back the ambition of the proposed strategy or emissions reduction target to ensure that benefits outweigh the costs of implementation. In light of the current economic and political climate in the U.S., it is unlikely that decision-makers will advocate for the first option in the near future. Therefore, it is possible that the ambition of U.S. LCDS will have to be scaled back, especially if the strategy is to receive bi-partisan support. We do not advocate for either option in this paper. Rather, we maintain that this choice should be made on a case-by-case basis and in consideration of all important factors, including short- and long-term goals.

D.1.2 Important Cost-Benefit Metrics and Economic Outputs Considered in Other Reports

None of the analyzed reports conducted a thorough CBA for the policy options explored. In lieu of a complete CBA, many studies instead provided a “relative” cost comparison analysis, in which the cost of a particular mitigation scenario is compared to the cost of a reference scenario (i.e., business as usual). For example WWF’s *Blueprint Germany* provides relative comparisons of prime and overall annual cost for all three of the pathways analyzed: an innovation pathway with carbon capture and storage (CCS), the innovation pathway without CCS, and the reference scenario.

In addition, most reports also relied on a variety of different “benefit-cost metrics,” sometimes referred to as economic outputs, when calculating the costs and benefits associated with their strategies. Commonly used metrics are discussed below, and include calculations of

Blueprint Germany’s Cost Comparison

In *Blueprint Germany*, the average annual prime costs and the overall annual costs of electrical generation are calculated from investments (capital costs), fuel costs, fixed and variable operating costs (maintenance, etc.), carbon costs and storage costs. In doing so, the report concludes that the prime costs of both of the innovation scenarios will be higher than the reference scenario for the years 2020 to 2040, primarily due to the increased cost of new gas powered plants when compared to new coal powered plants. However, once coal plants have reached the end of their lifecycle and become more expensive, the report concludes that the prime costs of both innovation scenarios will be significantly less than the prime cost of the reference scenario for the years 2040 to 2050. The overall annual production cost of the innovation scenarios are always lower than the reference scenario due to lower demand and the resulting decline in increases of total capacity; by 2050, the different between prime costs and overall annual production costs is estimated to be approximately 23%.

employment and green growth, economic growth and GDP, and the cost of saved energy. Other metrics, such as improvements to energy and national security, and health and air quality impacts are rarely quantified. Finally, some studies, such as CSIS/WRI's *Low Carbon Energy Roadmap*, did not perform economic modeling at all when determining the costs and benefits arising from their plan, and instead presented costs and benefits by highlighting the results provided in other studies.

D.1.2.1. Employment and Green Growth

The following discussion provides examples of low-carbon studies that project net employment changes from implementation of their strategies including Google's *Clean Energy 2030*, ASES's *Tackling Climate Change*, ECF's *Roadmap 2050* and Greenpeace's *Energy [R]evolution*. This section also provides examples of other analyses conducted by private companies and organizations including which estimate net employment changes from proposed climate legislation in the U.S.

Although none of the low-carbon reports analyzed set primary targets for job creation, a number of the reports did assess how investments in low-carbon development can create societal benefits such as jobs or enhanced energy security. Google's *Clean Energy 2030* clearly illustrates the potential employment opportunities that could result from their recommendations. In particular, the report estimates that approximately nine million net new jobs will be created in the electrical efficiency and renewable energy sectors alone. The report breaks down these employment opportunities by energy sector (i.e., efficiency, solar, wind, etc.) and also provides estimates of job losses in the coal and natural gas sector by 2030, which are estimated to be 9,020,000 and 5,440,000 respectively. The analysis further details cumulative job growth over the 20 year period, yearly averages of job creation, construction and operation jobs anticipated per TWh and the job scaling factor in 2030. The estimates include both direct and indirect job creation.

ECF's *Roadmap 2050* also estimates potential employment gains and losses. The total number of new jobs created by 2020 as a result of the strategy could range from 300,000 to 500,000, mainly within the construction and mechanical engineering sectors. At the same time, the report concludes that employment in some primary energy supply chains may erode as the demand for oil, coal and gas is anticipated to decrease 60-75% between 2010 and 2050 compared to the baseline. The report concludes that over 250,000 jobs could be affected, both in the baseline and the decarbonized pathways.

Greenpeace's *Energy [R]evolution* also provides calculations of job gains resulting from implementation of each of the three pathways analyzed: a basic scenario, an advanced scenario, and a reference scenario. According to the study, by 2015 a shift to either the basic or advanced scenarios would generate an additional 11.1 million employment opportunities, 3.1 million more than in the reference scenario. By 2030, a shift to either the basic or advanced scenarios would

result in cumulative increases in employment opportunities of 10.6 million and 11.9 million, respectively. Of the almost 12 million jobs created under the advanced scenario by 2030, approximately 8.5 million are estimated to originate from the renewables sector alone.

Following the release of ASES's *Tackling Climate Change*, the association conducted an analysis of the initiative's potential impact on job creation.²² The report detailed net cost of deployment for energy efficiency, wind, biofuels, biomass, photovoltaics, concentrating solar and geothermal as well as the net job creations that would result from investments in 2020 and 2030. The report was careful to account for lost jobs and displacement of business, a critical shortfall of the previous analyses.

Charles River Associates International (CRA) performed a modeling analysis of the job losses that could have resulted from adoption of the cap-and-trade proposals found within two recent pieces of climate legislation: the Climate Security Act of 2007 (S.2191, also known as Lieberman-Warner), which failed to pass the Senate in June 2008; and the American Clean Energy and Security Act of 2009 (H.R. 2454, also known as Waxman-Markey), which failed to pass the Senate in 2010. The first study estimated that adoption of Lieberman-Warner could result in 1.2-2.3 million net job losses by 2015, and 1.5-3.4 million net job losses by 2020, over a set of scenarios.²³ Regarding Waxman-Markey, the second study estimated that adoption of the bill could reduce employment by 2.3 million jobs in 2015, by 2.7 million jobs in 2020, by 2.5 million jobs in 2030, and by 3 million jobs in 2050.²⁴ Although both studies recognized that there would be a "substantial implied increase in jobs associated with 'green' businesses" (e.g., to produce renewable generation technologies), the studies still projected net losses in jobs due to the generalized macroeconomic impacts of the bills themselves.²⁵

The National Association of Manufacturers (NAM) and the American Council for Capital Formation (ACCF) also analyzed the potential employment impacts that could have resulted from adoption of the Waxman-Markey and Lieberman-Warner bills under "low" and "high" cost cases.^{26,27} Regarding Waxman-Markey, the first study estimates that by 2030, as emission

²² Management Information Services, Inc. (2009, October). Estimating the Jobs Impact of Tackling Climate Change.. Retrieved from: http://www.ases.org/pdf/ASES_TCCJobs_FullReport.pdf

²³ Testimony of Anne E. Smith, Ph.D. (2007, November). Retrieved from: http://epw.senate.gov/public/index.cfm?FuseAction=Files.View&FileStore_id=80bc79be-c338-4a76-b438-205eb79da3d5.

²⁴ Lewis, M. (2009). NBCC/CRA study estimates Waxman-Markey would reduce employment by 2.3 million jobs in 2015. *Openmarket.org*. Retrieved from: <http://www.openmarket.org/2009/05/21/nbccra-study-estimates-waxman-markey-would-reduce-employment-by-23-million-jobs-in-2015/>

²⁵ Testimony of Anne E. Smith, Ph.D. (2007, November 8). Retrieved from: http://epw.senate.gov/public/index.cfm?FuseAction=Files.View&FileStore_id=80bc79be-c338-4a76-b438-205eb79da3d5.

²⁶ National Manufacturers Association (NMA) and American Council for Capitol Formation (ACCF). (2009). United States Economic Impact of the Waxman-Markey Bill, H.R. 2454 Proposed Legislation to Reduce Greenhouse Gas Emissions. Retrieved from: <http://www.accf.org/media/docs/nam/2009/National.pdf>

reduction targets tighten and other provisions phase out, U.S. jobs would decline by 1.8 million under the low cost case and by 2.4 million under the high cost case.²⁸ Regarding Lieberman-Warner, the study estimates that U.S. would lose between 1.2 and 1.8 million jobs in 2020 and between 3 and 4 million jobs in 2030.²⁹ The primary causes of job losses from both climate bills would include lower industrial output due to higher energy prices, the high cost of complying with required emissions cuts, and greater competition from overseas manufacturers with lower energy costs.³⁰

Discussion of Employment and Green Growth as Economic Outputs

Most studies that estimate potential job gains and losses from a proposed climate strategy or bill are based on a variety of questionable assumptions, resulting in a sometimes deeply-flawed analysis. Accordingly, a clear and robust methodology for quantifying jobs is a requirement for any effective U.S. LCDS. It is also imperative that calculations provide a realistic assessment of both job gains and losses in order for policymakers to adequately assess the impacts of a proposed strategy. The estimates of job losses and gains should be accompanied by a clear timeline of when job transitions will occur, as well as the training requirements needed to foster this transition. In this timeline, it is also important to highlight the fact that job increases will likely not be immediate, but will rather occur gradually over a period of years or even decades.

D.1.2.2. Economic Growth and GDP

ECF's *Roadmap 2050* discusses the costs of its strategy in terms of increases in both the unit cost of electricity and the overall costs of energy. These values are then presented in terms of their impact on GDP growth rate. Similarly, DECC's *Low Carbon Transition Plan* also estimates that in 2020 the impact of the recommended policies will cause a 15% increase in current energy bills for businesses consuming a medium amount of energy. These reports caution that this type of macroeconomic modeling should be understood with its usual limitations; the calculations are not meant as a forecast but only as a tool to better understand the potential impact of implementing their mitigation measures.

²⁷ National Manufacturers Association (NMA) and American Council for Capitol Formation (ACCF). (2008) United States Economic Impact from the Lieberman-Warner Proposed Legislation to Reduce Greenhouse Gas Emissions. Retrieved from: <http://www.accf.org/media/docs/nam/2008/National.pdf>.

²⁸ National Manufacturers Association (NMA) and American Council for Capitol Formation (ACCF). (2009). Retrieved from United States Economic Impact of the Waxman-Markey Bill, H.R. 2454 Proposed Legislation to Reduce Greenhouse Gas Emissions: <http://www.accf.org/media/docs/nam/2009/National.pdf>

²⁹ National Manufacturers Association (NMA) and American Council for Capitol Formation (ACCF). (2008). Retrieved from United States Economic Impact from the Lieberman-Warner Proposed Legislation to Reduce Greenhouse Gas Emissions: <http://www.accf.org/media/docs/nam/2008/National.pdf>.

³⁰ National Manufacturers Association (NMA) and American Council for Capitol Formation (ACCF). (2009). Retrieved from United States Economic Impact of the Waxman-Markey Bill, H.R. 2454 Proposed Legislation to Reduce Greenhouse Gas Emissions: <http://www.accf.org/media/docs/nam/2009/National.pdf>

Discussion of Economic Growth and GDP as Economic Outputs

Proponents of an LCDS for the U.S. will have to make a strong case that the plan will not result in unduly large adverse impacts to U.S. economic development. Therefore, an effective LCDS should include a robust analysis of the potential impacts to economic growth and GDP that may arise from any technology or policy options that are considered. Evaluating the economic consequences of the climate change, as well as assessing the associated environmental and economic policies, generally requires the use of models capable of examining many types of economic, energy, environmental, climate change mitigation, and trade policies at the national, regional, and state levels. To investigate proposed policy effects, these models must combine a consistent theoretical structure with economic data covering all interactions among government, industry, businesses and households. As discussed in Section D.3 below, a variety of well-established models currently exist for such a task, including many regularly employed by the EPA. Regardless of the model chosen, the economic analysis contained in a LCDS should be conducted by leading experts in the field and based on the most accepted methodologies, in order to increase the credibility of recommendations outlined in the report.

ECF's Roadmap 2050: Cost Calculations

Over the 2010 to 2050 period, ECF's *Roadmap 2050* concludes that the unit cost of *electricity* could be 10-15% higher than in the baseline (excluding carbon pricing); however, during this period the overall cost of *energy* per unit of economic output in the decarbonized pathways declines by 20-30% relative to the baseline, primarily due to greater energy efficiency and a shift from oil and gas to decarbonized electricity in the transport and building sectors. In the 2010 to 2020 period, the slightly higher unit cost of electricity would reduce the growth rate in GDP by an estimated 0.02% compared to the baseline, meaning that the same 2020 GDP levels would be reached about one month later in the decarbonized pathways than in the baseline.

D.1.2.3. Cost of Saved Energy

ASES's *Tackling Climate Change* models the costs and benefits of its strategy in terms of the cost of saved energy (CSE), which is defined as the net cost of realizing the efficiency improvement divided by the annual savings in energy consumed. Typically, the cost of energy efficiency is all or mostly an initial expense for the high efficiency technology and the associated design, program, or administrative cost. ASES's *Tackling Climate Change* estimates CSE using the following formula:³¹

$$\text{Cost of Saved Energy} = \text{Capital Cost} * \text{Capital Recovery Factor} / \text{Annual Energy Savings}$$

³¹ The Capital Recovery Factor is defined as the ratio of a uniform annual (annuity) value and the present value of the annual stream, and depends heavily on the discount rate and the time horizon considered

Discussion of Cost of Saved Energy as an Economic Output

CSE is one of the most common and useful metrics for comparing the costs of efficiency measures and programs against supply-side resources. Because energy savings from efficiency programs often cost less than the supply resource they replace, the net cost of some of the resulting emission reductions can be negative. By allowing for an effective comparison of efficiency measures against supply side resources, CSE can help to inform policymakers regarding the benefits of energy efficiency, thereby generating more effective program and policy design. However, it is important that the CSE is clearly connected to other cost measures considered in an economic analysis, which should imbed energy cost effects from both higher prices and more efficient use.

D.1.2.4. Energy and National Security

Energy security and national security are difficult concepts to quantify, and therefore few reports attempt to calculate or monetize these as benefits. Even so, from a framing standpoint, almost all of the reports at least mentioned that that a robust low-carbon strategy ultimately increases both energy and national security. For example, RMI's *Reinventing Fire* identifies policies that could enable the U.S. to shrink 2050 energy usage to 71 quads (BAU projected at 117 quads), eliminate the need for oil, coal, nuclear energy, and one-third of the natural gas, and save \$5 trillion (all values 2010 net-present value). *Reinventing Fire* also quantifies the oil savings that may be expected from the implementation of several transportation-focused policy enablers including "feebates," (i.e., rebates for buying highly efficient autos, funded by fees on inefficient autos), smart fleet procurement policies, faster-turnover programs like Cash for Clunkers, prize competitions and superefficient trucks and planes. These transportation policies would require approximately \$2 trillion in investments through 2050 and would result in a total savings of \$5.8 trillion, for a net savings of \$3.8 trillion by 2050. The study specifically states that counting the important hidden benefits and costs (to health, productivity, security, etc.) not included in their analysis would make the economic case even stronger, and that a failure to shift to efficiency and renewables would significantly impact national security by: (1) spreading rather than limiting nuclear weapons, (2) creating rather than removing attractive terrorist targets, (3) exacerbating rather than relieving global poverty and inequity, (4) fueling rather than soothing global tensions and instabilities, and (5) sending military forces on more and riskier missions rather than fewer and safer.

As previously mentioned, instead of setting a quantifiable emissions reduction target, CSIS/WRI's *Roadmap* aims to identify a set of policies which address energy security and climate change simultaneously. This study identifies the following primary risks to U.S. energy security: (1) the current concentration of conventional supplies in volatile regions of the world, (2) heightened geopolitical risks for investors which undermine efforts to ensure the uninterrupted production and delivery of energy supplies and to build and maintain

infrastructure, and (3) erosion of the U.S. political influence in global energy markets due to the emergence of important new players like China, India, and Russia. Based in part on these identified threats, the report provides a policy framework as well as specific recommendations for achieving the energy security and climate change goals (for more information on the policy recommendations provided by this report, please refer to Section C of this analysis).

EC's *Low-Carbon Roadmap 2050* states that implementation of its strategy will ensure energy and national security by increasing the reliability of the power network and by increasing competitiveness in key growth sectors. The Danish Government's *Energy Strategy 2050* and the German Advisory Council on the Environment's *100% Renewable Electricity Supply by 2050* both involved analyses of scenarios wherein these countries provided all of their own energy needs internally or with limited interaction with other countries in the region. Because these were feasibility studies that attempted to analyze whether the goal of a 100% decarbonized power sector can be achieved, energy security is generally not treated as a benefit but rather as a prerequisite or modeling assumption.

Discussion of Energy and National Security as Economic Outputs

Similar to employment and green growth, the benefits of increasing energy and national security are persuasive arguments, and therefore quantification of these benefits (to the extent practicable) should be a goal of an LCDS for the U.S. As discussed above, RMI's *Reinventing Fire* attempts to quantify energy security in terms of absolute fossil fuel reductions, which are then quantified into both long-term and short-term savings. This may also represent a useful method for attempting to quantify energy and national security for a U.S. LCDS.

The general lack of clarity in defining and quantifying energy security has prompted some institutions to create indices aimed at clarifying this vague, but important term. For example, the Institute for 21st Century Energy, a U.S. Chamber of Commerce affiliate, released the Index of U.S. Energy Security Risk, with the primary goal of influencing policy decisions to mitigate current risks and meet future energy needs.³² Contingent on the events of any given year and additional inputs, the Index provides an assessment of risk to U.S. energy security, and assigns the year a number ranging from 1 to 100, with 1 exemplifying the lowest risk to U.S. energy security and 100 the highest. In calculating these values, 37 metrics identified as critical components to the nation's economy and energy security were selected and weighted based on their individual inputs.

The Index of U.S. Energy Security Risk is not the only method that quantifies risks to energy and national security; however, it can be a good starting point in attempting to quantify such a vague concept. Annual energy risk indicators that use quantifiable data, historical trend

³² Institute for 21st Century Energy. (2012, January 22). Retrieved from U.S. Energy Risk Index: <http://www.energyxxi.org/energy-risk-index>.

information, and government projections to identify the policies and other factors that contribute positively or negatively to U.S. energy security can serve to significantly increase the persuasiveness and robustness of the conclusions presented in an LCDS.

Most importantly, when drafting a LCDS, the U.S. should consider the tradeoffs between conducting a detailed assessment of energy security, and whether this analysis will add more value than it will cost. Applying the most rigorous analysis possible for quantifying benefits to energy and national security may seem like the optimal approach for a U.S. LCDS; however, these analyses are time consuming, costly, and often do not focus on absolute carbon emission reductions, which may run counter to the overall intent of the LCDS. Moreover, if energy and national security are quantified in a manner that has little significance to a broader public audience, the data may be less compelling. However, we do not suggest that a U.S. LCDS ignore energy and national security entirely. Rather, we point out that developing an LCDS is not the same as developing a comprehensive energy policy for the U.S., and thus a U.S. LCDS cannot be expected to capture the detailed elements of all things energy-related.

D.1.2.5. Health and Air Quality

Apart from one exception, most of the reports did not attempt to quantify the increased benefits to health and air quality resulting from their strategies. Instead, most provided a broad qualitative discussion of the potential increases in air quality and health resulting from their emissions reductions targets. For example, UCS's *Climate 2030* consistently reiterates that decreased emissions will reduce exposure to sulfur dioxide (SO₂), nitrogen oxides (NO_x), and mercury pollution from power plants, thereby improving air and water quality and providing important public health benefits.

EC's *Low-Carbon Roadmap 2050* was unique among the studies we reviewed in that it estimates the combined effect of the strategy's GHG emission reductions and existing and planned air quality improvement measures in order to determine the impacts from reduced air pollution that would result by 2030. The report then estimates the annual costs of controlling traditional air pollutants in order to determine the amount of money that would be saved by the low-carbon strategy when compared to a business-as-usual approach. Finally, the report quantifies in monetary terms the benefits to society that would result from both lower healthcare costs and reduced mortality. This report states that the combined effect of GHG and air quality measures resulting from the plan could lead to 65% lower levels of air pollution in 2030 compared to 2005. By 2030, the report estimates the annual costs of controlling traditional air pollutants to decrease by €10 billion, and by nearly €50 billion in 2050. The report concludes that these developments would also reduce mortality, with benefits estimated up to €17 billion per year in 2030 and up to €38 billion in 2050.

Discussion of Health and Air Quality as Economic Outputs

Improvements to health and air quality can be important and persuasive arguments for adoption of a U.S. LCDS. Moreover, quantifying the impact of air pollution on the public's health has become an increasingly critical component in a variety of policy discussions related to low-carbon development. Accordingly, an optimal LCDS for the U.S. would include a robust health and air quality assessment (also referred to as a "Health Impact Assessment" or HIA) that clearly outlines the most important costs and benefits to health associated with the any proposed policy or technology options.

Similar to other cost-benefit metrics considered, when drafting a LCDS, the U.S. should be cognizant of the tradeoffs associated with conducting a detailed HIA, and whether this analysis will add more value than it will cost. As discussed above, a U.S. LCDS is not a comprehensive energy report for the U.S., and therefore need not consider all potential impacts related to health. We do not suggest ignoring the most important health impacts; rather, we again point out that a U.S. LCDS is not designed to address all features of public policy, and quantification of all health impacts may consume resources that are better spent addressing other more direct impacts of a particular policy or technology. Enacting a system to prioritize the most significant health impacts will be an important component of any U.S. LCDS.

D.1.3 Prioritization of Cost-Benefit Metrics and Economic Outputs to be Considered in a U.S. LCDS

Under ideal circumstances, with unlimited resources and few financial constraints, an effective U.S. LCDS would analyze each of these aforementioned economic outputs in the modeling process to create a robust analysis of the potential impacts from any proposed policy or technology options that are considered. However, given the recent economic downturn, we expect that Congress will not allocate significant financial resources towards the creation of an LCDS; therefore, we find it unlikely that a U.S. LCDS will be able to successfully model all of these economic outputs. Given likely political and financial constraints, we developed three criteria on which to prioritize these metrics for inclusion in the LCDS. As shown in the following matrix, these criteria include: (1) the metric's level of importance to policy makers, (2) the effect the metric has on the credibility of the analysis, and (3) whether the metric is easily quantifiable. Each metric has been assigned a ranking of "low," "moderate," and "high" for each of the three criteria.

Cost Benefit Metric/Output	Importance to Policymakers	Effect on LCDS Credibility	Quantifiability
Employment losses and gains	High	High	High
Impacts on economic growth	High	High	High
Health and air quality impacts	High	High	High
Cost of Saved Energy	Moderate	Moderate	High
Energy and national security	High	Moderate	Low

Based on these rankings, we conclude that a U.S. LCDS should at a minimum consider and model any potential impacts to employment losses and gains, economic growth and GDP, and health and air quality. Impacts to employment and economic growth are extremely important to policymakers when considering whether to support an LCDS, especially given the recent economic downturn. Accordingly, we conclude that credible information on the potential economic and employment impacts is a necessary component of a successful U.S. LCDS.

However, when combined with a robust estimation of impacts to employment and economic growth, we also found that potential health and air quality impacts were also very persuasive arguments in support of a low-carbon strategy. EC's *Low-Carbon Roadmap 2050* provides a particularly useful example for how to frame health and air quality impacts in a low-carbon strategy.

D.2. EVALUATING BASIC APPROACHES FOR EMISSION REDUCTIONS

The purpose of a U.S. LCDS is to describe how GHG emissions can be reduced. To be effective, the LCDS must show some basis for why a set of policies or technologies can achieve those reductions. A few studies focus on either technology or policies as tools for achieving these reductions, but most of the studies examine both to some extent. Focusing on technology as the means of reducing emissions versus focusing on policy options may affect the study's credibility, accuracy, and usefulness to policymakers, and it is important to consider these effects. Whichever means they emphasize, the majority of the studies surveyed by our team used modeling to demonstrate how emissions targets can be reached.

This section considers the various tools for achieving GHG emissions reductions utilized by the studies we examined. First, the tradeoffs created by the choice to focus on technology or policy are reviewed to set the context for the underlying modeling efforts. Second, the range of modeling schemes used by the studies and their relative advantages and disadvantages are described. Third, some key assumptions that the models are built upon are discussed. Finally, we

analyze the appropriateness of these tools, models, and assumptions in the U.S. context in order to recommend best practices for a U.S. LCDS.

D.2.1. Consequences of Focusing on Technology

Studies that focus on technology consider how emissions reductions can be achieved through the implementation of technologies like renewable electric power generation. In such an approach, the analysis begins by selecting a technology or suite of technologies and proceeds by examining the effects on carbon emissions and other factors of interest.

A few of the studies approached emissions reductions from a purely technological standpoint. Two examples are the German UBA's *Energy Target 2050* and ASES's *Tackling Climate Change*. Although the former asks whether it is feasible to produce all power from renewables while the latter asks what GHG emissions are possible, both take a similar approach in answering their respective questions. Essentially, these studies determine what results are technologically possible to achieve, given physical limitations such as land area and insolation levels, without concern for the real-world actions or expenditures that would actually be needed to implement the technology.

For instance, German UBA's *Energy Target 2050* seeks to reduce carbon emissions by converting the entire power sector to renewable energy, but does not consider whether that is a cost-effective way of reducing emissions. In that sense, a technological focus is useful because it sets the outer bounds of what policy is capable of achieving. Furthermore, reports that focus only on technology may be seen as having a more neutral tone because they neither demand specific emissions reductions nor advocate for any particular policy or transition path for achieving those reductions. Instead, they simply show policymakers and the public what is technologically possible.

On the other hand, the usefulness of this approach is limited because it does not necessarily clarify what needs to be done at the policy level to achieve the technological gains, nor does it prioritize actions which are often competing for scarce resources. This limitation is apparent in ASES's *Tackling Climate Change*, where after describing many possible avenues of emissions reductions, the study simply recommends "a comprehensive national program by the federal government."

In the end, whether it is beneficial for a study on GHG reduction to ignore policy is a function of the study's goals. An LCDS is supposed to be just that: a strategy. An LCDS that merely reviews possible technological options for emissions reductions could not fairly be called a strategy. However, such an analysis may increase the political acceptability of a study to present technological options as a menu of possible solutions.

ECF's *Roadmap 2050* shows how a technology-focus can be taken to the level of a strategy. It examines three scenarios for achieving an 80% reduction in European GHG

emissions using a model that simulates technological implementation and its associated economic costs. While the three simulated pathways in the analysis are essentially feasibility studies, ECF was able to make policy recommendations by analyzing the pathways' common features. The technological pathways were used for setting technology penetration targets, and the study makes general policy recommendations to achieve the pathway features that appear critical for reaching the overall emissions goals. Again, this approach has an air of objectivity because it merely considers some possible ways of achieving the end goals. The policy recommendations are general and do not advocate for any specific conditions except those that appear necessary for any transition path based on the simulations. It is worth noting here that a technology-driven approach may allow substantial involvement of stakeholders in the process because different groups must be consulted to determine technological details and costs. As a result, many studies took this approach. This could indicate that consulting with academic or industry experts on evolving technologies, as in ASES's *Tackling Climate Change*, or consulting with groups like the current power industry (who may be able to shed light on the possibilities for reductions using conventional technologies) would be useful if an LCDS took on a technology focus. Stakeholder involvement in the LCDS process is discussed in Section E of this report.

D.2.2. Consequences of Focusing on Policy

Policy-based approaches consider how emissions reductions can be achieved through the implementation of policies such as a carbon price, tax incentives, or command-and-control regulations. In such an approach, the analysis begins by selecting a policy or suite of policies and proceeds by examining the effects of these policies on carbon emissions and other factors of interest.

A policy-based approach is exemplified by the HBC's *Transportation Study*. That study looked at the impacts on oil consumption and GHG emissions of a carbon tax, a transportation tax, increased CAFE standards, and a vehicle performance-based tax credit. Each policy was considered standing alone and in combination with the others. Without looking directly at any particular technologies, the effects of these policies were assessed using the National Energy Modeling System (NEMS). NEMS is a complex energy-economic model that can simulate the effects of policies on the U.S. energy system. It contains data on different transportation technologies and so can connect abstract policies to real-world results. However, the technologies allowed by the simulation currently exist or are nearing production, and thus there is little or no consideration of technological development or innovation.

The policy-based approach is advantageous over the technology-based approach because, given appropriate political circumstances; it can give policymakers a more precise roadmap of how to proceed. At the very least, it can indicate which among many policy choices are the most effective. HBC's *Transportation Study* illustrates this feature in a straightforward way.

Policymakers trying to choose among the four policies offered in the study can easily understand the tradeoffs among them and their impacts on emissions and other considerations like fuel prices.

This seeming advantage can also be seen as a disadvantage. If a study is based on policies that are not considered politically acceptable, it has limited utility for policymakers. The more specific the policies analyzed become, the greater the danger that those policies will face strong political opposition. Thus, the policy-based approach faces a tradeoff—its usefulness for instructing policymakers is based on the specificity of the policies it describes, but that very specificity may endanger the implementation of the study's conclusions. On top of this problem, the class of policies chosen for analysis may suggest bias on the part of the study's authors. For instance, many of the studies, such as Greenpeace's *Energy [R]evolution*, do not consider nuclear power as an option for electric power production. Because all policy options involve tradeoffs, the wholesale elimination of one set of policies from consideration may taint perception of the study.

D.2.3. Hybrid Approach

Many of the studies reviewed by our team took a hybrid approach by considering the effects of technological and policy changes at the same time. Among these, some of the most thorough were WWF's *Blueprint Germany*, the SEI's *40% Study*, and DECC's *Low Carbon Transition Plan*. *Blueprint Germany*, for instance, considers varying levels of technological innovation across multiple scenarios and all sectors, and also considers the impacts of both broad and specific policies (e.g., carbon pricing and home appliance standards, respectively).

Because it involves technology and policy options, a hybrid approach invites more complication into the analysis. Most of the studies rely on models that allow for both technological and policy variations. That requires a complex energy-economic model. In the three studies above, the entire economy is modeled at a technological level. The results of that analysis are then fed into a general equilibrium economic model to simulate the macroeconomic impact of policy choices and the feedback between the two. The model then calculates the emissions reductions achievable, almost always with the requirement of cost minimization.

The reward for this complication is that hybrid studies capture the benefits of both technology- and policy-based approaches; they have the advantage of demonstrating technological feasibility for achieving emissions reductions while also providing policymakers with a plan for implementing the technologies. The level of detail used in these studies also allows for very specific predictions and recommendations, although that is more a function of their comprehensiveness than their inclusion of technology and policy options. On the other hand, the models that enable this type of analysis are incredibly complex; building an entirely new model would be both time and resource intensive.

D.3. SELECTING MODEL(S) TO PERFORM THE ANALYSIS

D.3.1. Modeling Overview

Nearly all of the studies we have reviewed employ quantitative modeling in some capacity to relate the policy and technology options to emissions reductions. The models span a range from simplistic calculations of emissions reductions to economy-scale simulations of energy consumption and land use. The models reviewed use different kinds of inputs and provide a wide array of outputs. Some studies lack substantial quantitative modeling. Although the authors of these reports likely relied on other sources of information to support the policy recommendations they make, their methodology for arriving at these recommendations is not clear. If the goals of creating an LCDS include persuading stakeholders that the plan will work, the failure to demonstrate how or even *that* the recommended policies or technologies could achieve reductions counsels against taking this approach. From the perspective of policymakers, these reports are not especially useful because they present no information to use for decision making. An official U.S. climate policy will certainly require modeling. The credibility of an independently produced report that did not model its recommendations in some way would be questionable.

In light of these considerations, the following subsection describes the major themes and variations among modeling methodologies used by the studies we reviewed.

D.3.2. Modeling Considerations

D.3.2.1. Timeframe

Reports that make use of modeling do so in a few different timeframes. Most commonly, the model takes inputs and gives outputs during the relevant period of time, usually from present day to 2050. This perspective is probably the most useful because it allows the study to show how the current economy will evolve over time, given certain technological or policy choices. Thus, this approach is used for technology-based, policy-based, and hybrid studies. For instance, ECF's *Roadmap 2050*, HBC's *Transportation Study*, and WWF's *Blueprint Germany* all estimate technology penetration and emissions reductions over time. Given the economic and practical constraints associated with shifting away from the current carbon-intensive economy, a model that at least takes into account the time required to build and replace large portions of our infrastructure is critical. Showing how circumstances evolve under an LCDS can provide an additional sense of urgency for policymakers by demonstrating how long policies may take to have an effect. WWF's *Blueprint Germany* reports the results of the back-cast innovation scenario at several intervals as interim targets. A similar approach could also be used to ensure the U.S. is on course to achieving desired emissions reductions.

An alternative to the evolving timeframe is the "snap-shot" approach taken by the German UBA's *Energy Target 2050*. Instead of showing changes over time, only the end state is

modeled. In other words, the model is not dynamic—it does not identify any transformation pathway, but instead simply calculates the ultimate physical limits on renewable energy production (e.g., an estimated 275 GW capacity for the entire country). This is an effective method for modeling feasibility scenarios but is less useful for making policy decisions because the path for reaching the end state is unknown. A similar method is a “timeless” approach that only examines capacity for reductions from various technologies. Such an approach is less useful for setting policies to achieve emissions reductions for the urgent problem of climate change because there may be no indication of whether they will succeed in the near future.

Number of Scenarios

Studies that used modeling to demonstrate pathways to reduced greenhouse gas emissions generally involved two or more scenarios—as many as ten or more. Many studies simulate a reference scenario that models a business-as-usual case using forecasting along with a preferred approach which may use forecasting or back-casting. To analyze policies separately, as in the HBC’s *Transportation Study*, individual scenarios are needed for each policy choice. Additional scenarios are frequently used to simulate futures with and without particular technologies; nuclear power and carbon capture and storage, which both have potentially large impacts on emissions, are often considered in this way. Similarly, additional scenarios may demonstrate how relaxing various constraints can impact modeling results. For example, the UBA’s *Energy Target 2050* used scenarios to show the effect of allowing importing larger amounts of electricity from a wider geographical area in contrast to completely self-sufficient Germany.

D.3.2.2. Forecasting and Back-casting

A related consideration is whether a model forecasts future states given current circumstances and a set of technologies or policies or whether it begins with a desired end-state and “back-casts” to find potential pathways for reaching that state. The conceptual difference between these two is that forecasting predicts likely future states while back-casting requires a normative choice of the future state.³³ Because forecasting relies on historical trends, models using forecasting may have significant uncertainties. Back-casting approaches can show how drastically a policy must be shifted in order to attain desired emissions reductions, and for this reason may be particularly useful to policymakers.

Nearly all of the studies analyzed used forecasting to set model parameters. HBC’s *Transportation Study*, RMI’s *Reinventing Fire*, UCS’s *Climate 2030*, and Google’s *Clean*

³³ See John Bridger Robinson, *Energy back-casting: A proposed method of policy analysis*, ENERGY POLICY 337–38, December 1982. The term “back-casting” may also refer to a tool for validating models. For example, climate change models are tested on their ability to reproduce the climatic changes of the twentieth century, and this process is called back-casting. In energy and sustainability modeling, as in an LCDS, back-casting refers to running dynamic models with desired terminal conditions. *Id.*

Energy 2030 are a few examples of studies that rely mainly on forecasting to simulate the effects of technology and policy.

Back-casting is also a common modeling approach. The German Advisory Council on the Environment's *100% Renewable Electricity Supply by 2050*, the ECF's *Roadmap 2050*, SEI's *40% Study*, and the DECC's *Low Carbon Transition Plan* all use back-casting to determine possible transition paths for reducing greenhouse gas emissions to the desired level. The DECC's *Low Carbon Transition Plan* is especially thorough in describing its modeling methodology.

A few studies rely on both forecasting and back-casting. WWF's *Blueprint Germany* and Greenpeace's *Energy [R]evolution* make use of forecasts to see what the future may look like under a continuation of current policies. These forecasts are treated as reference scenarios against which desired transformation pathways can be compared. Back-casting is then used to find pathways for achieving the desired greenhouse gas emissions reductions that satisfy other specified criteria such as the elimination of nuclear power from the electric generation pool.

D.3.2.3. Additional Analyses

WWF's *Blueprint Germany* takes an additional step after back-casting to find a pathway to reduced emissions. The study includes a decomposition analysis to determine where further reductions are possible beyond the modeled results. This approach seems to be unique among the studies.

D.3.2.4. Top-down Models vs. Bottom-up Models

While scenario models can be classified according to their use of forecasting or back-casting, scenario models can also be described as top-down and bottom-up. Top-down models simulate entire systems with explicit connections between the parts (e.g., connecting supply and demand on a market or economy level). Bottom-up models, in contrast, use technology-specific information to build individual pieces of the system, usually in more detail, but without the entire system modeled (all the pieces connected). Many studies mention the use of a bottom-up approach to determine achievable emissions reductions as they often possess more technological detail. When interested in assessing economy-wide strategies or estimating macroeconomic impacts of policies, a top-down approach is often used. Although it is not always clear how each study approached this issue, the most complex studies likely make use of both top-down and bottom-up modeling where appropriate.

D.3.2.5. Level of Detail

The level of detail used in a model is tied to whether it makes use of a bottom-up approach. WWF's *Blueprint Germany*, EPRI's *Full Portfolio*, Greenpeace's *Energy [R]evolution*, RMI's *Reinventing Fire*, SEI's *40% Study*, and ECF's *Roadmap 2050* all take a bottom-up approach and model the impacts of various technologies in significant detail.

Blueprint Germany, for instance, models the residential sector down to the appliance level and includes specifications of energy use by microwaves and vacuum cleaners. *Energy [R]evolution* also has a detailed model that can take into account multiple variations on solar power production, for example. The EPA also regularly employs climate economic modeling in their policy making process including the use of economy-wide models, mitigation models, integrated assessment models, and detailed electricity sector models, as discussed below.^{34,35,36,37,38,39,40}

U.S. Climate-Economy Models

The EPA modeled the impacts of the American Power Act and H.R. 2454 (Waxman-Markey) using the Applied Dynamic Analysis of the Global Economy (ADAGE) model and the Intertemporal General Equilibrium Model (IGEM). Both models were able to account for the policy prescriptions in the legislation as well as technological changes that might result.

ADAGE is able to model impacts of policies on international, national, regional, and state levels. ADAGE models firm, government, and household behavior and the flow of goods, labor, and capital on a macroscopic level, while accounting for energy use and technological changes through bottom-up modules. A further advantage of ADAGE is that it's capable of calculating GDP impacts endogenously, thereby avoiding the problem of assumed economic growth.

IGEM models the U.S. economy by dividing it among thirty-five sectors and balancing supply and demand of goods traded between the sectors and households. Like ADAGE, IGEM calculates economic growth (GDP) endogenously.

The EIA maintains the National Energy Modeling System (NEMS), which has been used to model the impacts of a number of laws and regulations, including Waxman-Markey, a federal renewable energy standard, and Corporate Average Fuel Economy standards. NEMS simulates supply, demand, energy flow, and emissions data based on assumptions or projections of energy use. NEMS can model a wide variety of technological changes, and is frequently used to model impacts of policy changes.

The Joint Global Change Research Institute developed the Global Change Assessment Model (GCAM, formerly MiniCAM), which can simulate national or international emissions based on production and use of energy among many sectors as well as impacts of land-use change.³⁸ GCAM includes highly-detailed technological information, and is capable of assessing the impacts of both technological and policy changes; in fact, EPA has used it to study how technology may be used to mitigate climate change impacts.

³⁴ Environmental Protection Agency. (2010, June 4). U.S. Environmental Protection Agency, Office of Atmospheric Programs. Retrieved from EPA Analysis of the American Power Act in the 111th Congress: http://www.epa.gov/climatechange/economics/pdfs/EPA_APA_Analysis_6-14-10.pdf.

³⁵ Ross, M. (2008, September). RTI International. Retrieved from Documentation of the Applied Dynamic Analysis of the Global Economy (ADAGE) Model: http://www.rti.org/pubs/adage-model-doc_ross_sep08.pdf.

³⁶ IGEM. (2011, April 22). Retrieved from IGEM Documentation: <http://www.igem.insightworks.com/docs/190.html>.

³⁷ Office of Integrated Analysis and Forecasting, Energy Information Administration. (2009). U.S. Energy Information Administration. Retrieved from: The National Energy Modeling System: An Overview 2009: <http://www.eia.doe.gov/oiaf/aeo/overview/>.

³⁸ Joint Global Change Research Institute. (n.d.). Retrieved from Global Climate Change Assessment Model: <http://www.globalchange.umd.edu/models/gcam/>.

⁴⁰ U.S. Environmental Protection Agency. (2011, April 28). Retrieved from Climate Economic Modeling: <http://www.epa.gov/climatechange/economics/modeling.html>.

⁴⁰ U.S. Environmental Protection Agency. (2012, January 20). Retrieved from Climate Economic Modeling: <http://www.epa.gov/climatechange/economics/modeling.html>.

D.3.2.6. Sectoral Breakdown

Economy-wide studies must break the economy into sectors in order to build an effective model. Typically, the models contain modules for power generation, industry, transportation, and residential sectors. Buildings are sometimes treated as a separate sector. The extent to which the model divides the economy into sectors may increase the level of detail and hence the robustness of the model. However, the same feature of the economy may be modeled across different studies but attributed to a different sector in each. Most of the studies report which sector is responsible for each portion of the GHG emissions reductions. If results are published in this manner, the perception of where a given plan places the burden of climate change action may be affected by which sectors are charged with reducing their emissions. Of course, the particular sectoral divisions used in the model do not have to match the sectors as reported in a final policy paper. For instance, ECF's *Roadmap 2050* simulates at least fourteen different sectors but simplified most of the output information by attributing the outputs of these sectors to only a few larger categories.

D.3.2.8. Estimation of Employment

The following discussion describes the modeling approaches used to obtain the employment and green growth economic outputs discussed in Section D.1.2.1. above.

A detailed methodology for the employment calculations performed in Google's *Clean Energy 2030* was lacking. The report mentions that the estimates include both direct and indirect jobs in associated industries (e.g., accountants, lawyers, steel workers, and electrical manufacturing), and that the estimates are conservative in that they assume a declining job rate in future years due to productivity improvements. However, additional details on the methodology used to calculate job opportunities are not provided.

Employment calculations for ECF's *Roadmap 2050* were conducted utilizing the Oxford model, which ultimately calculates jobs based on the supply decisions made in each sector of the economy. These supply decisions are, in turn, determined by changes in input prices and capital expenditure (capex) investment. The calculations in Greenpeace's *Energy [R]evolution* report begin with the amount of electrical capacity that would be installed each year, and the amount of electricity generated per year under each of the three scenarios. The report then uses "employment factors" for each technology, which are the number of jobs per unit of electrical capacity (fossil as well as renewable), separated into manufacturing, construction, operation and maintenance, and fuel supply.

CRA International's estimated job losses from both the Lieberman-Warner Bill and Waxman-Markey Bill were calculated utilizing the MRN-NEEM model, a "general equilibrium"

model of the U.S. economy.⁴¹ The job losses estimated by NMA and the ACCF for the Lieberman-Warner and Waxman-Markey Bills were calculated using the NEMS model, a national, economy-wide, integrated energy model utilized by the EIA to analyze energy supply, conversion, and demand.⁴²

D.3.2.9. Key Assumptions

The assumptions underlying the models are likely some of the largest drivers of model results. The following list describes some common assumptions or types of assumptions:

- *Technological development.* Some models assume that only present-day technologies are available while others use learning curves that recognize future technological developments. The former can give more certain results while the latter may be more realistic if the curves are reasonably drawn. For instance, the HBC's *Transportation Study* limits vehicle options to those that are presently available or under development, while RMI's *Reinventing Fire* makes use of learning curves for batteries, fuel cells, and carbon fiber manufacturing to model the light-weight vehicles of the future.
- *Nuclear power generation.* Some models explicitly assumed nuclear power will phase out, as in most of the German studies and Greenpeace's *Energy [R]evolution*.
- *Carbon capture and storage.* The availability of CCS can greatly affect the fraction of power production that comes from conventional fuels. Given the uncertainty over CCS, it may be included in some scenarios and left out of others within a given study.
- *Energy storage.* Many of the studies include some energy storage—usually pumped water or air—to be used in conjunction with renewable power generation.
- *GDP growth.* For most of the studies, GDP growth is an exogenous factor and a rate of growth is based on historical trends. ECF's *Roadmap 2050* and UCS's *Climate 2030* may be the only studies that calculate effects on GDP.
- *Population growth.* Where the models allow population trends to affect demand, population growth rates are estimated based on exogenous projections.
- *Efficiency.* Most studies assume that all known efficiency gains will be achieved in most sectors, including production and end-use efficiencies.

⁴¹ CRA International. (2008, April). Retrieved from Appendix. CRA international's MRN-NEEM integrated model for analysis of us greenhouse gas policies:
http://www.crai.com/uploadedFiles/RELATING_MATERIALS/Publications/BC/Energy_and_Environment/files/MRN-NEEM%20Integrated%20Model%20for%20Analysis%20of%20US%20Greenhouse%20Gas%20Policies.pdf.

⁴² National Association of Manufacturers and American Council for Capital Formation. (2008, March 12). Retrieved from Analysis of the Lieberman-Warner Climate Security Act (S. 2191) Using the National Energy Modeling System (NEMS/ACCF/NAM):<http://www.accf.org/pdf/NAM/fullstudy031208.pdf>.

- *Carbon pricing.* Most of the studies set a price on carbon emissions, usually through a cap-and-trade mechanism. There is wide variation on details like allowance banking and borrowing and carbon offsets.
- *Renewables market penetration.* Many studies assume that a large fraction of power generation can and will come from new renewable technologies.
- *Discount rates.* Discount rates reflect the fact that people generally value a dollar now more than a dollar later; thus, a dollar spent or saved next year is “discounted” a certain percentage to reflect its lower value. Because discounting is compounded with each passing year, benefits and costs far in the future may appear to be nearly valueless. The studies that mentioned discount rates ranged from as low as 3% up to 9%. Because of the long time horizon involved, discount rates can have substantial effects on estimates of costs and benefits.

D.4. RECOMMENDATIONS FOR SELECTING INPUTS, OUTPUTS, AND FOCUS OF A U.S. LCDS

Using Cost-Benefit Metrics and Other Economic Outputs

- **A U.S. LCDS should implement a system to identify the most important costs and benefit metrics to be considered in the analysis.** Criteria for deciding which to calculate include ease of quantification, political relevance, ability of models to account for the feature, and resources available to undertake the calculation.
- **A U.S. LCDS should provide guidance for decision-making based on the results of the CBA.** To assist decision-makers, a U.S. LCDS should include a thorough discussion of the tradeoffs associated with each option, in order to ensure policymakers have sufficient information on which to base their decisions.

Evaluating Basic Approaches for Emission Reductions

- **A U.S. LCDS should follow a hybrid approach that explores both policy and technology options.** Such an approach includes consideration of technological development over time.
- **Disfavored or controversial policy or technology options may be addressed by running modeling scenarios with and without those options.**
- **A U.S. LCDS should attempt to quantify costs and benefits for the most important impact categories.**
- **A U.S. LCDS should present a robust analysis of potential alternatives including alternative means of achieving program objectives by examining different methods of provision and different degrees of government involvement**

Selecting Model(s) to Perform the Analysis

- **A U.S. LCDS should rely on a quantitative model that is capable of a dynamic simulation of the economy so that the transition pathway to a low-carbon future can be described.**
- **Forecasting and back-casting should be used in concert to clarify major shifts that need to take place.**
- **All sectors the LCDS seeks to address should be covered and modeled in as much detail as possible. All reasonable technological options should be considered by the LCDS in as much detail as possible.**
- **Comprehensiveness must be balanced with available resources. The LCDS model should be at least based on an existing model.**
- **Assumptions should be stated clearly and model sensitivity to these assumptions should be tested to avoid criticism.**
- **GDP or other indicators of economic growth should be calculated endogenously by the model rather than assumed.**
- **A U.S. LCDS should consider and maintain the credibility of its economic analyses.**

Using Cost-Benefit Metrics and Other Economic Outputs

A U.S. LCDS should implement a system to identify the most important costs and benefit metrics to be considered in the analysis. Based on our research, the team has developed the following prioritized list, which lists the cost-benefit metrics discussed in this section in order of their importance for a U.S. LCDS:

- Employment losses and gains
- Impacts to economic growth and GDP
- Health and air quality impacts
- Cost of Saved Energy
- Energy and national security

As mentioned above, given the recent economic downturn, we expect that Congress will not allocate significant financial resources towards the creation of an LCDS; therefore, we find it unlikely that a U.S. LCDS will be able to successfully model all of these economic outputs. Accordingly, given likely political and financial constraints, the most important potential impacts that should be quantified include the first three metrics: employment losses and gains, impacts to economic growth and GDP, and impacts to health and air quality. As discussed above, the specific health and air quality impacts to be assessed should be determined based on the best available HIA guidance documents, and should incorporate the results of separate HIA's wherever possible. Consideration should be given to the amount of financial and personnel resources available when considering the scope of the HIA.

Impacts on energy and national security are difficult to quantify and therefore these economic outputs have been placed lower on the priority list above. Nonetheless, an effective CBA should recognize (at least qualitatively) both the tangible and intangible benefits and costs of a particular policy option, as these can become persuasive arguments for climate skeptics. If a robust economic analysis is not possible for a particular impact area, the strategy should consider other ways to quantify impacts, such as through the use of contingent valuation studies.

A U.S. LCDS should provide guidance for decision-making based on the results of the CBA. As discussed above, a CBA for a U.S. LCDS may reveal that the cost of implementing the strategy (or achieving a particular emission reduction target) may outweigh the resulting benefits to society. In such a case, decision-makers will be required to either support the strategy, regardless of the fact that costs could potentially outweigh the benefits, or scale back the ambition of the proposed strategy or emission reduction target. We do not advocate for either option in this paper. Rather, we maintain that this choice should be made on a case-by-case basis and in consideration of all important factors, including short- and long-term goals. In order to assist decision-makers, a U.S. LCDS should include a thorough discussion of the tradeoffs

associated with each option, in order to ensure decisions are based on sound and reasoned judgment.

Evaluating Basic Approaches for Emission Reductions

A U.S. LCDS should follow a hybrid approach that explores both policy and technology options. The overall approach of considering both technology and policy provides the most information to policymakers. Depending on the set of policies considered, it may allow a definitive statement as to which policies are necessary and which are optional. For instance, if modeling of a wide variety of policy options in a number of scenarios shows that the target emissions reductions cannot be reached without a carbon pricing mechanism, policymakers can understand that such a mechanism is necessary. An indication that a particular policy is necessary to achieve the end goal of climate protection over a reasonable range of scenarios could persuade some who do not like that particular policy.

Disfavored or controversial policy or technology options—such as carbon pricing, nuclear power, and carbon capture and storage—may be addressed by running modeling scenarios with and without those options. A comprehensive and detailed treatment of technology options that does not ignore or exclude disfavored technologies (e.g., nuclear and coal power with CCS) may lend credibility to a study. Some studies, like the German reports, rejected nuclear power as an option because that country has a current policy of nuclear phase out. In the U.S., such an assumption is inappropriate because there is no push to phase out nuclear power; in fact, there is support for further development of safe nuclear power.⁴³ In the U.S., lawmakers may disfavor a study that makes policy judgments—e.g., that the safety risks of nuclear power are too great to justify its use as a tool for carbon abatement—that are typically the prerogative of Congress. A better approach may be to simply simulate scenarios with and without disfavored technologies or policies to demonstrate the possibility of avoiding them. For a process that will certainly involve many compromises, taking a hard stance at the outset may be counterproductive, creating opponents where allies could be gained by more careful presentation.

A U.S. LCDS should present a robust analysis of potential alternatives including alternative means of achieving program objectives by examining different methods of provision and different degrees of government involvement. The conclusions should demonstrate the cost/benefit relationships between each alternative, and address how the alternatives were ranked using the criteria developed. Following a clear statement of the conclusions, the analysis should provide a firm recommendation regarding the preferred alternative and the rationale for selecting it.

⁴³ The White House, Office of the Press Secretary. (2011, March 30). Remarks by the President on America's Energy Security [Press Release]. Retrieved from <http://www.whitehouse.gov/the-press-office/2011/03/30/remarks-president-americas-energy-security>.

Selecting Model(s) to Perform the Analysis

A U.S. LCDS should rely on a quantitative model that is capable of dynamic simulation of the economy so that the transition pathway to a low-carbon future can be described. A dynamic model can be used to create interim targets because it shows how emissions progress over time. Moreover, the ability to do both forecasting and back-casting relies on the use of a dynamic model that can relate the changing policies, technologies, energy sources, and emissions over time.

Forecasting and back-casting should be used in concert to clarify major shifts that need to take place. A study showing only that emissions reductions are possible—e.g., a feasibility study like the German UBA's *Energy Target 2050*—may be encouraging but it is of limited use for policymakers. A useful pathway is more easily derived from a model that shows the evolution of the relevant economy or sector over time. The evolution can be shown by either forecasting or back-casting, and each method has its benefits. Forecasting has the benefit and burden of weighing current trends heavily in predicting the future, and so is useful for demonstrating how current policies fall short of the desired goals. Back-casting illustrates where significant departures from the status quo are needed. The use of both methods is therefore probably ideal.

As discussed above, forecasting scenarios allow policymakers to see how a business-as-usual approach will affect emissions, and can also simulate the added impact of policies and technologies on that base scenario. Back-casting, on the other hand, forces the model to make what are likely to be radical changes to the business-as-usual case to reach the desired emissions targets. Both of these perspectives can be helpful in demonstrating the importance of individual policies and of an overall suite of policies and technologies recommended by the LCDS.

All sectors the LCDS seeks to address should be covered and modeled in as much detail as possible. All reasonable technological options should be considered by the LCDS in as much detail as possible. The studies we reviewed all take care to address sources of carbon emissions by considering major sectors that drive emissions. To credibly balance the burden of climate change policy across the sectors, and to reliably determine lowest-cost solutions, all of the sectors that are analyzed should be modeled in detail. WWF's *Blueprint Germany*, EIA's NEMS model, and Greenpeace's *Energy [R]evolution* are three good examples of bottom-up technological modeling of emissions. While a conservative approach might model only existing technologies, a better approach is to include some model of technological progression that is expected. This can lead to more accurate cost projections, as well as serve as an opportunity to involve industry groups by working with them to understand how they see the technology developing.

Comprehensiveness must be balanced with available resources. The LCDS model should be at least based on an existing model. Of course, the studies that evaluate both policy and technological pathways to a low-carbon economy involve the most complex modeling.

Creating a new model from the ground up would require enormous resources. The models involved some of the studies, such as NEMS, MARKAL, ADAGE, and IGEN, have often been developed over the course of several decades to capture the economy in as much detail as possible. These models should be considered to be at least a good starting point. NEMS, for instance, is considered to be credible and Congress often requests NEMS evaluation of proposed energy policies. ADAGE and IGEN are also frequently used.

This is not to say that it is absolutely necessary to use an existing model, but doing so may allow the creators of the LCDS to focus more on areas of policy and technology that have not been considered before, since resources will not be spent “reinventing the wheel.” Additionally, such an approach may signal that the resulting LCDS is not different in quality from other policies, because it will deliver results similar to what policymakers have considered before.

Assumptions should be stated clearly and model sensitivity to these assumptions should be tested to avoid criticism. The best approach to avoid the appearance of questionable assumptions is to perform a sensitivity analysis on the model to ensure robust results. For creating a persuasive LCDS in the U.S., however, there are some assumptions that should be carefully considered. Industry projections of technological development may have a large influence over the long time horizon of the LCDS. Efficiency measures are notoriously difficult to implement, and wide-scale penetration of these efforts may not be realistic.⁴⁴ Many of the low carbon plans we reviewed assume large efficiency achievements which lead to decreased energy use and emissions.

A U.S. LCDS should be explicit about the underlying assumptions used to arrive at estimates of the selected metrics and economic outputs. The analysis should include a statement of the assumptions, the rationale behind them, and a review of their strengths and weaknesses. Key data and results, such as year-by-year estimates of benefits and costs, should be reported to promote independent analysis and review. For example, in order to compute NPV, it is necessary to discount future benefits and costs. The proper discount rate to use depends on whether the benefits and costs are measured in real or nominal terms, and will vary widely depending on the economic analysis being conducted. Discount rates should be carefully devised and the rationale clearly explained. Moreover, the CBA should show the sensitivity of the discounted NPV and other outcomes to variations in the discount rate.

GDP or other indicators of economic growth should be calculated endogenously by the model rather than assumed. One of the chief criticisms of climate action is that it will seriously hamper economic growth, which is especially problematic given ongoing economic turmoil. It is inappropriate to assume away that criticism by adopting the common treatment of GDP as an exogenous variable that is assumed to grow at a “reasonable” rate of 2-3% per year in

⁴⁴ Harder, A. (2010, March 11). National Journal. Retrieved from DOE, Utilities Struggle with Efficiency Efforts: <http://energytopic.nationaljournal.com/2010/03/doe-utilities-struggle.php>

this context. The model for an LCDS should incorporate feedback between climate action and macroeconomic indicators. Both ADAGE and IGEM, discussed above, are capable of treating GDP endogenously.

A U.S. LCDS should consider and maintain the credibility of its economic analyses. As discussed above, an effective U.S. LCDS will be based on the most widely-accepted economic modeling practices used to date. In addition, special attention should be given to the authors of the analysis, which should include leading experts in the U.S. government, industry and academia, in order to further establish the credibility of the report's findings.

E. DETERMINING STAKEHOLDER INVOLVEMENT IN DEVELOPING A U.S. LCDS

The LCDS process, in addition to producing a strategy document, should serve as an opportunity to engage key stakeholders from government, the private sector, and civil society. Crafting an effective LCDS requires substantial technical and political analyses, and soliciting input from an array of diverse and specialized stakeholders early on can help enhance the report's credibility and garner broad-base support. Moreover, to ensure the strategy has strong buy-in, it is imperative that those analyses are aligned and leading experts have been consulted. There are a number of opportunities for government agencies, civil society, and industry groups to provide valuable input, including providing data on current carbon emissions, assessing policy impacts, and modeling supply curves for emerging technologies.

Although most of the reports reflected some level of multi-sector and industry engagement, they were distinguishable by the three types of primary authors: private sector, civil society (e.g., NGO, academic, or think tank), or government. The contributing author(s) and type of report have important implications for government and industry buy-in as well as perceived credibility of the analysis and resulting recommendations. Of the twenty-two reports reviewed, seven were authored or commissioned by the government (these reports were all international), two were industry-driven (ASES & Google), and the remaining thirteen were produced by collaborating NGO's, research institutes, and universities. The following section provides an overview of the differences between report types, outlines possible approaches for stakeholder engagement, and identifies opportunities in which stakeholder input and engagement should be incorporated.

E.1. TYPES OF STAKEHOLDER INVOLVEMENT

E.1.1. Government-Backed Reports

Government LCDSs have largely been utilized to identify the potential opportunities, costs, benefits, and barriers for implementation of low-carbon development. These reports often contain clear recommendations that indicate what policy interventions are needed and what role different government bodies should assume to ensure measures are properly executed and benefits are achieved.⁴⁵ Several reports, including the Danish Government's *Energy Strategy 2050* and UBA's *Energy Target 2050* provide concrete steps for advancing the recommendations presented in the LCDS. In both cases, these recommendations later served as the foundation for the official energy strategy adopted by the government. However, it is important to consider that widespread support for advancing a clean energy path existed in both countries prior to the release of any analysis. This contrasts significantly with the political landscape in the U.S., which currently has a Congress that is highly divided, particularly on the appropriate path for

⁴⁵ Energy Research of the Netherlands. (2011, September). Retrieved from Paving the Way for Low Carbon-Development Strategies. : <http://www.ecn.nl/docs/library/report/2011/e11059.pdf>

developing a new energy policy. Thus, when assessing the collaboration process of these two reports, it is critical to identify how stakeholder engagement could be utilized to enhance support in the U.S. context.

The Danish Government's *Energy Strategy 2050* outlined explicit and fully-financed recommendations for energy initiatives as well as government commitments. Working with public officials to determine what policies or commitments the U.S. government could feasibly undertake and how those policies could be harmonized with existing state and federal regulations will be an important aspect in the stakeholder engagement process.

In UBA's *Energy Target 2050*, nine different energy scenarios were modeled and the resulting recommendations now underpin Germany's current low-carbon development strategy. This strategy, deemed the "Energy Concept," was jointly publicized by the Federal Ministry of Economics and Technology and the Federal Ministry for the Environment, Nature Conservation, and Nuclear Safety. Engaging two reputable research institutions and multiple government agencies enhanced the perception of scientific rigor and demonstrated unified support. The report and the press releases for the Energy Concept do not specify the extent to which the two Ministries collaborated nor do they publicize the process for multi-agency engagement; however multi-agency participation in a U.S. LCDS could also serve to enhance the plan's credibility.

E.1.2. Collaborative Reports

The tone, purpose and impact of the LCDSs produced by NGO and academic communities varied significantly. Some reports sought to develop broad policy frameworks, while others conducted a rigorous analysis of how to achieve emission reductions. Additionally, because these reports were produced by civil society groups, the organizations involved in production matter significantly for public perception and overall credibility of the report's findings.

For example, Greenpeace's *Energy [R]evolution EU-27*, through its demand of an energy revolution, appeared to advocate more principle-based solutions. By encouraging respect for natural limits and equity, the report assumed value positions which could serve to alienate certain constituencies in the U.S. Contrarily, the HBC's *Transportation Study* focused solely on how existing proposals for carbon abatement would impact emissions from the transportation sector. The purpose here was to analyze proposed policies and whether they would have their intended effect on emissions reductions. Given the diversity in the impact and reception of these reports, credible partnerships and a clear identification of intended audience and purpose of the report should be established from the onset.

E.1.3. Private Sector Reports

While the U.S. government has yet to commission its own LCDS, industries have voluntarily proceeded to identify potential pathways for encouraging low-carbon development.

ASES's *Tackling Climate Change* synthesizes a series of nine papers by leading experts in energy efficiency, buildings, plug-in hybrid electric vehicles, concentrating solar power, photovoltaics, wind power, biomass, biofuels, and geothermal power. The authors were recruited from a range of NGOs, from private sector renewable technology firms, and from the NREL to provide information on resource availability, current and expected future costs, and carbon reduction curves for the years 2015 and 2030. Google's *Clean Energy 2030* was released in an effort to generate knowledge and stimulate public debate on the actions needed to foster a low-carbon economy. It creates a forum for innovation, industry engagement, and enhancing public awareness. Both reports provide less targeted policy prescriptions and instead seem to focus on creating momentum in the private sector.

These reports also seemed to provide a platform for collaboration and information sharing among leading experts in the renewable energy and energy efficiency sectors. For example, ASES *Tackling Climate Change* facilitated communication across different industries by encouraging experts to calculate the potential for accelerating the deployment of mature renewable energy technologies. It also provided an opportunity for contributing authors to exchange information on potential carbon emission reductions that could result from aggressive energy efficiency measures in industrial process, transportation, and the built environment.

E.2. OTHER IMPORTANT STAKEHOLDER CONSIDERATIONS

E.2.1. Process of Stakeholder Collaboration Efforts

While stakeholder engagement is often an iterative processes that invariably changes depending on political, economic, and technological developments, the following section examines the collaboration process utilized by different organizations to produce their LCDSs. The intent is to identify important lessons and pitfalls that can inform stakeholder engagement for a national U.S. LCDS.

The Danish Government's *Energy Strategy 2050* established a commission of twelve leading experts to assess opportunities for 100% renewable energy in Denmark's power sector. The commission was largely comprised of university academics with expertise ranging from oceanography, climate change, and agricultural to more technical backgrounds in economics and transportation. A civil engineer from the Danish Energy Agency, a researcher at Statistics Norway, and senior consultant at a European Policy Think Tank were also members of the commission. In the U.S., if a similar commission was to be established, retaining industry executives, utility regulators and government officials may help elevate the credibility of the resulting recommendations.

A distinguishing feature of the GPI's *Power the Plains* (PTP) roadmap was the extensive process of stakeholder engagement. The roadmap was not established with the sole intent of achieving low-carbon development, but instead it also focused on ensuring local ownership of the recommended initiatives and positioning the region so that stakeholders could benefit from a shift toward low-carbon development. Over a five year period, a forum of key interests met to educate themselves on energy and climate related issues and to discuss regional challenges and opportunities. The roadmap, while informed by energy modeling and technical data, was not an analytical exercise, but a multipronged approach to energy development and CO₂ reductions that resulted from consensus among a diverse group of stakeholders.

GPI's Powering the Plains Stakeholder Process

- *Key stakeholder identification:* The PTP committee was comprised of state legislators, utility regulators, state and provincial officials, utility industry executives, agricultural producers, and environmental advocates. The committee utilized computer modeling to explore various energy options, organized site visits to energy facilities in the region, and participated in the energy technology and policy delegation to the region.
- *Development of working groups:* Working groups were formulated based on the composition of the region's energy infrastructure: (biomass working group, energy efficiency, coal gasification, upper Midwest hydrogen initiative, advanced wind).
- *Policy development and goals:* The committee was charged with preparing preliminary scenarios, goals and measurable targets outlining a potential energy transition in addition to identifying legislative measures and institutional arrangements needed to implement that proposed transition.
- *Expected Outcomes:* Three desired outcomes were identified (1) federal government and states/provinces adopt policies to implement roadmap (2) companies get support for pursuing projects in keeping with the roadmap (3) low and no- CO₂ technologies are deployed.
- *Town Hall feedback:* Five town halls were held to solicit citizen feedback.

In ECF's *Roadmap 2050*, the assumptions and recommendations were developed in close collaboration with a total of more than 60 companies, institutions, NGOs and academia. Collaboration was facilitated through topical workshops, broader ranging sessions, and bilateral meetings throughout the entire drafting process. Within this process, ECF recruited a panel of nine academics to review the insights, with a particular emphasis on the power sector. Additionally, ECF retained three experts to conduct a similar review on the grid modeling performed in which their feedback was focused on the modeling input and methodology. Finally, in order to generate effective political buy-in, an Advisory Council consisting of politicians, academics and business leaders was created to review the findings of this report and help to position them in the larger political context.

CSIS/WRI's *Roadmap* focused on reconciling the priorities between fostering energy security and minimizing GHG emissions. In an effort to harmonize perspectives from seemingly conflicting constituencies, the authors sought input from energy, climate, national security, and economic experts and from academia, business, government, non-profit organizations, and international institutions. They were clear to delineate that the proposed recommendations differed from what either CSIS or WRI would have developed on its own, yet reflected "common ground between two different constituencies." Moreover, this report is one of the few LCDSs that publicly engages the security community. Collaboration with the department of defense or other security agencies, where possible, could help breathe a new angle and credibility into the report.

E.2.2. Identification of Opportunities for Continued Stakeholder Involvement

Although most of the reports do not disclose the process for engaging outside stakeholders, the team has sought to identify opportunities in which stakeholder input and engagement could be incorporated.

- ***Selection of policy options (either to be modeled or to be recommended):*** A number of the reports rely on policy changes to achieve LCDS targets. Industries should be engaged to help identify which policies are needed to provide business and market incentives for efficiency, renewables and other low-carbon opportunities. Specifically, agencies such as EPA, Department of Transportation, and Department of Energy should be soliciting feedback from affected sectors. Under the Waxman-Markey proposal, the Secretary of Energy was required to establish a program to deploy and integrate plug-in vehicles in multiple regions and to determine the design elements and requirements for the program. If similar parameters are recommended under the LCDS, program requirements should be informed by regulated industries.⁴⁶
- ***Input for models (technology/cost and learning curve identification):*** Most of the data that underlies the models, assumptions, and recommendations of the different reports is acquired from outside sources. Whether the information is obtained from national databases, federal agencies, consulting firms or industries, data collection comprises a substantial portion of outside stakeholder input and represents an opportunity for engaging the appropriate actors.

E.2.3. Consideration of Appropriate Primary Author for a U.S. LCDS

The contributing authors of a U.S. LCDS will have important implications for both stakeholder involvement and the perceived credibility of the analysis. Many of the international reports we reviewed were commissioned by governments, with significant collaboration from

⁴⁶ Holt, M. (2009, May 14). Congressional Research Service. Retrieved from Summary of Waxman-Markey Draft Greenhouse Gas Legislation: <http://openocrs.com/document/R40597/>.

NGOs, research institutes, and universities. We found that government-backed reports often contain clear recommendations that indicate the required policy interventions and the role that different government bodies must take to ensure measures are properly executed. Accordingly, we conclude that a U.S. government agency should be the primary author of a U.S. LCDS, with significant collaboration from credible outside organizations and academic institutions.

In this section we aim to identify and assess a variety of U.S. federal agencies that have the potential to be lead author of the LCDS. We have based our assessment of each agency on three primary criteria including: (1) the agency's internal expertise and capacity, including staffing resources; (2) the perceived credibility and political visibility of the agency; and (3) budgetary resources. We also identified four candidate agencies that have the technical capability to produce a U.S. LCDS. These agencies include the Environmental Protection Agency (EPA), the Energy Information Agency (EIA), the Council on Environmental Quality (CEQ), and the Council of Economic Advisors (CEA). Table 3 below provides a summary of relevant information for each of these agencies according to the three criteria presented above.

When considering the appropriate author for a U.S. LCDS, we find EIA to be an agency well-suited to undertake both the modeling and technical analysis required of a low-carbon strategy. As the statistical and analytical agency within the U.S. DOE, the EIA specializes in producing independent and impartial energy information to promote sound policymaking, and is experienced in the analysis of energy market trends such as the Annual Energy Outlook. Moreover, with a requested 2013 budget of approximately \$116 million (a 9.2% increase from 2012) and over 380 staff members, the EIA appears to have the resources to undertake the significant effort an LCDS requires. However, past budgetary constraints have threatened to limit EIA's ability to produce the Annual Energy Outlook. Nonetheless, EIA data and forecasts are independent of approval by any other officer of the U.S. government and are generally regarded as credible and non-partisan.

Table 3: Overview of Potential Federal Agencies to Author a U.S. LCDS

Agency/Budget	Internal Expertise and Capacity	Credibility/Political Visibility
<p>EPA</p> <p>2013 budget: \$8.3 billion (1.2% decrease over 2012)</p>	<p>Reports and Analysis: Extensive institutional experience in evaluating and modeling the impacts of pollution controls and economic impacts of climate change legislation and regulation. Established contact with many stakeholders in the energy production and industry sectors due to its mandatory GHG reporting requirements.</p> <p>Staff and Capacity: Consists of many employees across numerous organizational divisions and regional offices. Potential divisions: Office of Atmospheric Program's Climate Protection Partnership Division, Clean Air Markets Division, and Climate Change Division.</p>	<p>Credibility: Agency responsible for regulating, monitoring, and enforcement of legislation in many areas of human interaction with the environment. Long been criticized for implementing regulations that harm business activities. Although substantial internal expertise exists, the agency's divisive perception among the public and politicians alike reduce its ability to be an effective lead author.</p> <p>Political Visibility: EPA has come under fire for undertaking regulation of GHG emissions from large sources, and as a result the agency's budget and existence have been threatened.</p>
<p>EIA</p> <p>2013 budget: \$116.4 million (9.2% increase over 2012)</p>	<p>Reports and Analysis: Develops projections for the Annual Energy Outlook 2012 (AEO2012) focusing on the factors that shape U.S. energy markets in the long term, under the assumption that current laws and regulations remain generally unchanged. The AEO2012 reference case provides the basis for examination of energy market trends and serves as a starting point for analysis of potential changes in U.S. energy policies.</p> <p>Staff and Capacity: Supported by four primary departments. EIA contains approximately 380 staff members.</p>	<p>Credibility: Designated as the primary Federal government authority on energy statistics and analysis. Acts as the statistical and analytical agency within the U.S. DOE that analyzes and disseminates independent and impartial energy information to promote sound policymaking..</p> <p>Political Visibility: By law, EIA data, analyses, and forecasts are independent of approval by any other officer or employee of the U.S. Government. Past budgetary constraints have threatened to limit EIA's ability to produce their annual outlooks.</p>
<p>CEQ</p> <p>2013 budget: \$3 million</p>	<p>Reports and Analysis: Responsible for ensuring Federal Agencies fulfill NEPA requirements. Also oversees an number of environmental initiatives including: the Federal Sustainability Program, America's Great Outdoors Initiative, the Recovery through Retrofit Initiative, and the Interagency Rapid Response Team for Transmission.</p> <p>Staff and capacity: Chaired by Nancy Sutley, CEQ oversees environmental stewardship and sustainability throughout the government. CEQ contains approximately 24 staff members.</p>	<p>Credibility: Coordinates Federal environmental efforts and works closely with agencies and other White House offices in the development of environmental policies.</p> <p>Political Visibility: Office is seen as highly political; however, the CEQ has developed strong partnerships with other environmental agencies including EPA, DOE, and environmental and energy NGOs.</p>
<p>CEA</p> <p>2013 budget: \$4.2 million (no change from 2012 budget).</p>	<p>Reports and Analysis: Conducts analysis on economic and employment trends in the U.S., including the impacts of the American Recovery and Reinvestment Act of 2009 and other pieces of federal legislation.</p> <p>Staff and Capacity: Chaired by Alan Krueger and contains approximately 30 staff members, including a team of economists, research assistants, and statisticians.</p>	<p>Credibility: Established by Congress to advise the President on economic developments, makes various studies upon the President's request, and formulates and recommends national economic policy.</p> <p>Political Visibility: Chairman and members are politically appointed and thus could be seen as partisan. Their focus is generally limited to economic analysis with less specialization in energy.</p>

E.3. RECOMMENDATIONS FOR DETERMINING STAKEHOLDER INVOLVEMENT IN A U.S. LCDS

- **A U.S. LCDS should:**
 - **identify leading industries, experts, and relevant agencies that can provide valuable data and enhance the credibility and buy-in of the report's findings, and should be produced by a credible government agency such as the EIA.**
 - **utilize the stakeholder process to enhance awareness about low carbon development opportunities, align interest, and reduce information gaps.**
 - **ensure benefits are clear and conveyed by credible actors.**
 - **solicit feedback and engagement from industries targeted for regulation.**
 - **begin cultivating political buy-in among both parties early in the stakeholder process.**

A U.S. LCDS identify leading industries, experts, and relevant agencies that can provide valuable data and enhance the credibility and buy-in of the report's findings. A credible LCDS should be produced by a government agency with sufficient resources, expertise, and political neutrality such as the EIA. The EIA's statistical experience and overall credibility make it a good potential author for a U.S. LCDS; however, determining appropriate pathways for low-carbon development must also be informed by a broad range of stakeholders beyond the primary authors producing the report.

A U.S. LCDS should utilize the stakeholder process to enhance awareness about low carbon development opportunities, align interest, and reduce information gaps. Multiple parties are often linked through energy investments which can cause cost and benefits to be diverted to different parties and lead to misaligned incentives. This process should serve as an opportunity to bring stakeholders on the same page and ensure industries or certain communities aren't unfairly disadvantaged.

A U.S. LCDS should ensure benefits are clear and conveyed by credible actors. For many consumers energy is energy, therefore understanding the clear value of increased efficiency and deployment of renewables will be important for crafting a compelling message. These benefits should be conveyed by relevant communities: i.e. Department of Defense on energy security, Chamber of commerce on economic opportunities, etc.

A U.S. LCDS should solicit feedback and engagement from industries targeted for regulation. Resistance by incumbent organizations that perceive transitioning away from fossil fuels as risky and costly could prevent action. Financial or policy incentives to overcome existing barriers may help diffuse potential opposition.

A U.S. LCDS should begin cultivating political buy-in among both parties early in the stakeholder process. Partisan politics can hinder needed incentives or regulatory changes. Transparency and continual dialogue may help diffuse political gridlock and prevent occurrences in which tax incentives are held hostage for political bartering.

IV. CONCLUSIONS

In this report, our analysis focuses on potential advantages and disadvantages of methods used by existing low-carbon strategies in order to better inform the development of a low-carbon strategy for the U.S. In analyzing various components of these low-carbon plans including the scope, targets, approach, modeling, policy options, and stakeholder involvement, we have identified common features and methodologies that are typically used to foster low-carbon development.

Gaining an understanding of LCDS methodologies is important, but must be considered in the context of the current U.S. political climate. We have characterized this context as one defined by: (1) limited political will for addressing climate change, (2) a political system that can be controlled by minority interests even when political will exists, (3) a political system and public that is somewhat distrustful of climate science and international efforts to address climate change, (4) the expectation of strong industry opposition to caps or prices on emissions, (5) a larger and more diverse economy and geography than other nations, and (6) a different mix of embedded technologies than other countries. Accordingly, rather than focus on what would be *ideal* given perfect circumstances, this analysis instead focuses on what is *practical* given the numerous political and economic constraints to low-carbon development in the U.S. Through this approach, we have provided a variety of suggested methods for creating a LCDS that is both credible and supported by stakeholders.

Several overarching messages stand out in our analysis. In the country's current state, economic considerations weigh heavily on policy decisions. Thus, we acknowledge that the scope of a U.S. LCDS should be set with consideration of the greater macroeconomic consequences of an in-depth, economy-wide LCDS, when compared to a single-sector LCDS. However, we also point out that a comprehensive, economy-wide policy approach, especially one involving emissions trading, often facilitates greater flexibility and cost-minimization. In recommending that a U.S. LCDS conduct an analysis that covers all the major emitting sectors of the economy, we do not ignore the expense of implementing economy-wide policies. Rather, we conclude that a more comprehensive analysis is required in order for policymakers to truly understand the consequences of their choices on the U.S. economy and energy system. We also provide recommendations for reducing costs in conducting the analyses, such as prioritizing the consideration of economic outputs, and suggesting the use of existing (rather than new) models.

Secondly, it is important to recognize that momentum in Congress for advancing low-carbon development is minimal compared to official support for climate action in regions like Europe, for example. Accordingly, while some of the international strategies analyzed did ultimately serve as the basis for aggressive low-carbon development abroad, we cannot reasonably expect that the same momentum will result from development of a U.S. LCDS. Therefore, we again emphasize the importance of early consultation with experts, industry

leaders, policymakers, academics, and the public, in order to ensure engagement and support for a proposed U.S. LCDS.

Thirdly, we highlight the importance of ensuring that decision-makers are presented with a menu of flexible policy options that are underpinned by robust technical and economic analyses. Ultimately, the goal of an effective LCDS is to outline viable actions and development pathways that will limit or reduce GHG emissions. However, achieving those emissions reductions should not be predicated on a single path, but instead framed in terms of a multitude of achievable approaches. Our recommendations therefore seek to convey the importance of examining a range of alternative strategies that can achieve the necessary reductions while still being politically viable.

Lastly, we point out that the way an LCDS is framed can shape perception and acceptance of the strategy from the onset. Given the fact that many members of society are skeptical of the impact of climate change and the need for low-carbon development, we also emphasize the importance of not only the content of the LCDS, but also the framing of the LCDS.

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VI. APPENDICES

REFER TO NEXT PAGE FOR APPENDIX A

APPENDIX A: DESCRIPTION OF LOW-CARBON STRATEGIES REVIEWED

Internal Reference and Title	Author/Date of Report	Country	Summary
<p><u>ASES's Tackling Climate Change</u> <u>Tackling Climate Change in the U.S. - Potential Carbon Emissions Reductions from Energy Efficiency and Renewable Energy by 2030</u></p>	<p>American Solar Energy Society (ASES): January 2007</p>	<p>U.S.</p>	<p>Target/Scope: Displace between 1,100 and 1,300 million metric tons of carbon per year (MtC/yr) by 2030. Focuses on the use of renewable energy (RE) in the electricity and transportation sectors, and analyzes energy efficiency EE opportunities in buildings, transportation, and industry. Approach: Technology-focused and framed in terms of what emission reductions are possible based on technological advances in different industries. Findings: The US has the potential to decarbonize its economy through EE and RE. Estimates indicate 57% of total carbon reductions would come from EE and 43% would come from RE.</p>
<p><u>CSIS/WRI's Roadmap</u> <u>A Roadmap for a Secure, Low-Carbon Energy Economy</u></p>	<p>Center for Strategic and International Studies (CSIS) and World Resources Institute (WRI): February 2009</p>	<p>U.S.</p>	<p>Target/Scope: Outlines actions required to ensure average global surface temperatures do not rise more than 2 degrees Celsius (No target specified). Economy-wide coverage. Approach: Does not conduct its own modeling, but rather cites previous studies to estimate the costs associated with limiting global temperature rise to 2 degrees Celsius. Findings: Provides 10 recommendations that emphasize advancing policy choices that support both climate solutions and a secure energy sector.</p>
<p><u>CCCP's Green Energy</u> <u>Green Energy: The Road to a Danish Energy System without Fossil Fuels</u></p>	<p>Danish Commission on Climate Change Policy (CCCP): September 2010</p>	<p>Denmark</p>	<p>Target/Scope: Achieve 100% independence from fossil fuels by 2050. Interim targets: reduce fossil fuel use in the energy sector by 33% (2009 levels), reduce primary energy consumption by 6% by 2020 (2006 levels), and 30% carbon reductions by 2020. Approach: Outlines a three track strategy to assess targets. Benefits assessed in terms of reduction in fossil fuel dependency. Findings: Identifies 14 policies to reach the desired targets, estimates the anticipated reductions in emissions for each policy and outlines specific government actions to support policies.</p>
<p><u>DECC's 2050 Pathway Analysis</u> <u>DECC's 2050 Pathway Analysis 2050 Pathways Analysis</u></p>	<p>Department of Energy and Climate Change (DECC) -- U.K.: December 2011</p>	<p>U.K.</p>	<p>Target/Scope: Achieve 80% reductions in GHG emissions by 2050 (1990 levels). Economy-wide coverage. Approach: Scenario modeling using the DECC's energy model. Findings: Ambitious per capita energy demand reduction is needed in the U.K. in addition to substantial increases in level of electrification for the heating, transport and industry sectors. Electricity supply may need to double to meet the desired target, and will need to be decarbonized. <i>Analysis is based, in part, on the analysis conducted in DECC's Low Carbon Plan (below).</i></p>
<p><u>DECC's Low Carbon Transition Plan</u> <u>The UK Low Carbon Transition Plan: A National Strategy for Climate and Energy</u></p>	<p>Department of Energy and Climate Change (DECC): July 2009</p>	<p>U.K.</p>	<p>Target/Scope: Achieve an 18% reduction in GHG emissions by 2020 (2008 levels) or 33% reduction (1990 levels) and an 80% reduction in GHG emissions by 2050, (1990 levels). Economy-wide coverage. Approach: Scenario modeling using the DECC's energy model. Findings: Concludes that the EU ETS is the single most important policy to reduce UK emissions; one of the key ways to achieve the desired target is by committing to obtain 15% of all energy from renewable sources by 2020.</p>
<p><u>EPRI's Roadmap for a Low-Carbon Power Sector</u> <u>Roadmap for a Low-Carbon Power Sector by 2050</u></p>	<p>Electric Power Research Institute (EPRI) and others: 2009</p>	<p>U.S.</p>	<p>Target/Scope: Guide rapid deployment of technologies to achieve GHG reductions of 60-80% in the power sector by 2050. Approach: Analyzes power sector structure in Australia, Canada, the E.U., Japan and the U.S., and examines technologies and policies required to deliver a low-carbon future. Findings: It is possible to deliver low-carbon power by 2050 in the U.S., but states that the current political timeframes lack recognition of the critical timing for commercial deployment of low-carbon technologies.</p>
<p><u>ECF's Roadmap 2050</u> <u>Roadmap 2050: A practical guide for a prosperous, low carbon Europe</u></p>	<p>European Climate Foundation: April 2010</p>	<p>Europe</p>	<p>Target/Scope: Achieve an 80% reduction in GHG emissions below 1990 levels by 2050. Economy-wide coverage, in-depth power sector focus. Geographical scope: the EU-27 plus Norway and Switzerland. Approach: Scenario modeling assuming varying shares of low/zero carbon supply technologies, using the Energy-Industry Model for the UK (UKEIM). Findings: Europe could achieve its desired target, but fundamental changes to the energy system, including a nearly zero-carbon power supply, are required. Take Action in the next five years.</p>

<p><u>EC's Low-Carbon Roadmap 2050</u> <u>Roadmap for moving to a competitive low-carbon economy in 2050</u></p>	<p>European Commission: August 2011</p>	<p>Europe</p>	<p>Target/Scope: Achieve an 80-95% reduction in GHG emission (1990 levels) by 2050. Economy-wide coverage. Approach: Scenario modeling assuming different rates of technological innovation, fossil fuel prices, and emission reduction targets for each sector studied. Findings: A wide range of existing technologies will be required to reach desired target, and the EU ETS will be critical in driving their deployment. Both a sufficient carbon price signal and long-term predictability are also necessary.</p>
<p><u>EPRI's Full Portfolio</u> <u>The Power to Reduce CO2 Emissions: The Full Portfolio 2009 Technical Report</u></p>	<p>Electric Power Research Institute (EPRI): December 2009</p>	<p>U.S.</p>	<p>Target/Scope: Achieve an 83% reduction in GHG emissions (2005 levels) by 2050 for the U.S. electric power sector only. Approach: Scenario modeling using EPRI's Prism model and the MERGE model. Findings: Optimum economic technology portfolio consists of substantial amounts of renewable electricity generation, significant electricity production from coal with CCS and nuclear, and large reductions in electricity consumption. Retrofit of for existing coal plants with CCS plays an important transitional role between 2010 and 2030.</p>
<p><u>German Advisory Council on the Environment's 100% Renewable Electricity Supply by 2050</u> <u>Climate-friendly, renewable, affordable: 100% renewable electricity supply by 2050</u></p>	<p>German Advisory Council on the Environment: May 2010</p>	<p>Germany</p>	<p>Target/Scope: Assesses technical feasibility of 100% renewable-derived electricity by 2050. Power sector only, although the analysis allows for increased electricity demand from the transportation sector. Approach: Scenario modeling (model information not available in English). Findings: A 100% renewable electric power sector is possible, though difficult. Immediate action is needed to achieve target.</p>
<p><u>German Energy Concept</u> <u>Energy Concept for an Environmentally Sound, Reliable, and Affordable Energy Supply</u></p>	<p>German Federal Ministry of Economics and Technology: September 2010</p>	<p>Germany</p>	<p>Target/Scope: Achieve 40% reduction in GHG emission by 2020 and 80% by 2050, below 1990 levels. The report covers all sectors of the economy. Approach: Scenario modeling assuming different levels of energy efficiency and varying restraints on the availability of nuclear energy. Findings: EE is critical for reducing emissions, and target attainment requires large investments for infrastructure upgrades.</p>
<p><u>UBA's Energy Target 2050</u> <u>Energy Target 2050: 100% Renewable Electricity Supply</u></p>	<p>German UBA (Environmental Protection Agency): July 2010</p>	<p>Germany</p>	<p>Target/Scope: Assesses technical feasibility of 100% renewable-derived electricity by 2050. Power sector only, although the analysis allows for increased electricity demand from the transportation sector. Approach: Scenario modeling using the Fraunhofer Institute for Wind Energy and Energy Systems Technology SimEE model. Findings: A 100% renewable electric power sector is possible. Assumes various policy changes in its analysis that make the desired target possible.</p>
<p><u>Google's Clean Energy 2030</u> <u>Clean Energy 2030 - Google's Proposal for reducing U.S. dependence on fossil fuels</u></p>	<p>Jeff Greenblatt, Google: 2008</p>	<p>U.S.</p>	<p>Target/Scope: Reduce U.S. dependency on coal and oil for electricity generation by 2030 by providing several targets including (but not limited to) by reducing: fossil fuel-based electricity generation (88%), vehicle oil use (44%), and U.S. CO2 emissions overall by 49%. Approach: Models measures and technologies needed to shift away from EIA's "business-as-usual" scenario for 2030, and allows for the use of nuclear and CCS. Findings: It is feasible to transform the economy away from the use of fossil fuels. Proposal is estimated to cost about \$3.86 trillion in undiscounted 2008 dollars (with savings projected at \$4.68 trillion).</p>
<p><u>Greenpeace's Energy [R]evolution EU-27</u> <u>Energy [R]evolution. Towards a fully renewable energy supply in the EU 27</u></p>	<p>Greenpeace and the European Renewable Energy Council (EREC): 2010</p>	<p>Europe</p>	<p>Target/Scope: Achieve an 80-95% reduction in GHG emissions (1990 levels) by 2050. Economy-wide coverage. Approach: Scenario modeling using the MESAP/Planet simulation model. Findings: Target is possible. Presents policy recommendations aimed at obtaining a fully renewable energy system, removing barriers, updating the EU ETS, and redirecting funds for R&D.</p>
<p><u>Greenpeace's Energy [R]evolution</u> <u>Energy [R]evolution: A Sustainable World Energy Outlook</u></p>	<p>Greenpeace and the European Renewable Energy Council (EREC): January 2007</p>	<p>Global</p>	<p>Target/Scope: Achieve 40-80% reduction in global GHG emissions (from all major economies) by 2050. Economy-wide coverage. Approach: Scenario analysis (40% reduction for the basic scenario by 2050 and 80% reduction for the advanced scenario by 2050). Findings: Required energy technologies needed to reduce emissions exist, and a low-carbon strategy should focus on moving toward renewable energy as quickly as possible. Provides policies recommendations to aid the adoption of particular technologies.</p>

<p><u>GPI's Powering the Plains</u> <u>Powering the Plains Energy Transition Roadmap</u></p>	<p>Great Plains Institute: 2010</p>	<p>U.S.</p>	<p>Target/Scope: Achieve 80% reduction in GHG emissions from the U.S. Great Plains regional power sector by 2055 (1990 levels). Approach: Specifies targets for energy efficiency, coal, wind, hydropower, nuclear, hydrogen and biomass, over the next 50 years. Provided seven key strategies for moving forward in the short-term. Findings: Energy efficiency offers the best return on investment, and that meeting the target will require dramatic scale-up of multiple low- and zero-carbon energy technologies. Necessary transition is technically feasible (through multiple approaches), economically affordable and politically achievable if action is taken now.</p>
<p><u>HBC's Transportation Study</u> <u>Analysis of Policies to Reduce Oil Consumption and Greenhouse-Gas Emissions from the U.S. Transportation Sector</u></p>	<p>Harvard Belfer Center for Science and International Affairs: 2010</p>	<p>U.S.</p>	<p>Target/Scope: Assesses GHG emissions and fuel consumption in the transportation sector in order to analyze whether proposed strategies are stringent enough to reduce total U.S. GHG emissions 14% below 2005 levels by 2020. Approach: Scenario modeling using the National Energy Modeling System (NEMS). Findings: Current proposed measures may not achieve desired reductions, and would have minimal impact on fuel consumption and foreign dependence on oil. Increasing the cost of driving is essential to obtaining significant reductions in GHG emissions from transportation, and standards alone cannot mitigate the projected growth in vehicle use during 2010-2030.</p>
<p><u>RMI's Reinventing Fire</u> <u>Reinventing Fire</u></p>	<p>Rocky Mountain Institute (RMI): October 2011</p>	<p>U.S.</p>	<p>Target/Scope: Analyzes the transportation, buildings, industry, and electricity sectors to determine the overall financial and climate implications of transitioning the U.S. economy off coal and oil to efficiency and renewables by 2050. Approach: Sectoral modeling using the Reinventing Fire (RF) integration model. Findings: Identifies policies to shrink the U.S. 2050 energy usage to 71 quads (BAU projected at 117 quads), eliminate the need for oil, coal, nuclear energy, and one-third of the natural gas, and save \$5 trillion in net-present-valued cost. They key barrier for developing a low carbon economy is not inadequate technologies but tardy adoption. Emphasizes business can be more competitive by leading the transition.</p>
<p><u>SEI's 40% Study</u> <u>The 40% Study: Mobilizing Europe to Achieve Climate Justice</u></p>	<p>Stockholm Environment Institute (SEI): November 2009</p>	<p>Europe</p>	<p>Target/Scope: Analyzes the feasibility of achieving a 40% reduction in GHG emission by 2020, and 90% by 2050. Sectors addressed include the households, agriculture, services, industry and transport sectors. Approach: Scenario modeling using SEI's LEAP energy modeling system. Findings: The EU has a need for national climate laws with legally binding targets for annual emission cuts across all sectors and the EU should establish direct penalties for Member States which do not reduce their emissions year by year. Broad and specific climate and energy policy recommendations are provided.</p>
<p><u>UCS's Climate 2030</u> <u>Climate 2030: A National Blueprint for a Clean Energy Economy</u></p>	<p>Union of Concerned Scientists (UCS): May 2009</p>	<p>U.S.</p>	<p>Target/Scope: 80% reduction in GHG emissions from 2005 levels by 2050; constrain cumulative U.S. emissions to the mid-range of a 2000-2050 U.S. "carbon budget" of 165-260 gigatons CO2 equivalent. Interim targets included. Economy-wide coverage. Approach: Scenario modeling using NEMS. Findings: The U.S. needs to implement a comprehensive set of smart policies to jump-start the transition without delay, emphasizes given to making advancements in the wind industry and hybrid vehicles.</p>
<p><u>WWF's Low-Carbon Leaders Project</u> <u>Low-Carbon Leaders Project</u></p>	<p>World Wildlife Fund & Caring for Climate: 2009</p>	<p>U.S.</p>	<p>Target/Scope: Presents twelve illustrative transformative low-carbon solutions that could avoid 10-20 giga tons CO2 emissions by 2020. Covers building/infrastructure, transporting/communicating, food production/eating and consuming/experiencing. Approach: GHG reductions were estimated utilizing Life Cycle Assessment (LCA). Findings: Required solutions already exist, but additional policies are needed to accelerate their uptake.</p>
<p><u>WWF's Blueprint Germany</u> <u>Blueprint Germany: A Strategy for a Climate-Safe 2050</u></p>	<p>World Wildlife Fund (WWF) Germany, Prognos A.G., & Oeko-Institute e.V.: 2009</p>	<p>Germany</p>	<p>Target/Scope: GHG emissions reductions of 40% by 2020, 60% by 2030, 80% by 2040, and 95% by 2050; increases in energy productivity; and increases in the renewables share of electricity production to 20% by 2020, 35% by 2030, 55% by 2040, and 70% by 2050. Economy-wide coverage. Approach: Scenario modeling using an economic model developed by Prognos. Findings: Emissions goals are technically and economically feasible, but require substantial investments and changes to regulation, consumption, infrastructure, and industry that must begin in the near term.</p>