Estimating the Economic Benefits of Productive Investments to Curb Greenhouse Gas Emissions in Arlington County, Virginia

An Economic Narrative

Provided by
Economic and Human Dimensions Research Associates under contract with ICF

Prepared for Arlington County, Virginia
Office of Sustainability and Environmental Management
Department of Environmental Services

October 24, 2019

What is the purpose of this report?

With a greater emphasis on energy efficiency and energy productivity, together with clean, renewable energy resources, this economic assessment reviews the employment and economic impacts of key energy trends for Arlington County, Virginia over the next 30 years. The trends reflect what are referred to as "business-as-usual" economic patterns and aggregate energy expenditures, and how the larger economy might benefit from implementation of the County's 2019 draft revised Community Energy Plan (CEP) through the year 2050.

What is the scope?

The report lays out evidence on the future of energy expenditures and their impact on the Arlington County economy. The intent is to provide insights from which local, state, and national officials, and their constituents, might develop approaches that can lead to a comprehensive energy transition market – one that will boost the performance of a more productive, robust, and sustainable economy over the long-term.

What sectors does the report cover?

The report broadly covers the residential, commercial, industrial, transportation and energy production sectors of the Arlington County economy.

Who is it for?

The assessment provided here is intended primarily for officials and business leaders in, and working with, Arlington County, Virginia. The findings will also be of interest to the energy sector, investors, other government and business partners, as well as the roughly 230,000 residents of the county.

What methodology was used?

Three primary forms of evidence and analysis were used in producing this report. First, the assessment draws on economic and energy data for the United States, the Commonwealth of Virginia, and the Arlington County economy. It provides a county-wide estimate of the likely magnitude of energy expenditures (absent new policies or unexpected market dynamics). It highlights the major trends and the likely costs and benefits of business-as-usual (BAU) trend through 2050. It then compares this BAU to an *Energy Innovation* Scenario (with a goal of 1 $MtCO_2e$ per capita), based on Arlington County's 2019 draft Community Energy Plan. Second, it draws upon a wide range of interviews, analytical critiques, and literature reviews to validate the assessment. These efforts were conducted during the period July 2019 through September 2019. Finally, it uses an energy-economic input-output model, documented in Appendix B of the report, to evaluate the CEP for its likely economic impacts and benefits.

Who are the authors?

The underlying research tasks, analysis, and writing of the report was carried out by a team associated with Economic and Human Dimensions Research Associates, in collaboration with ICF as well as the County's Energy Program of the Department of Environmental Services. Both the economic modeling and resulting assessment were undertaken by John A. "Skip" Laitner.

Disclaimer

This report has been prepared, for informational purposes only, by the team at Economic and Human Dimensions Research Associates, at the request of Arlington County. The information contained in this report is intended as an indicative assessment of likely outcomes should the County successfully catalyze the appropriate program efforts and technology investments; and while believed to be correct as of the date of publication, it is not a substitute for appropriate business and financial advice, detailed research, or the exercise of additional professional judgment in the development of specific policies and programs that might accelerate the momentum within the larger energy productivity market. The insights and opinions expressed in this report are those of the analytical team, and do not represent an official position of Arlington County. For questions or further information, contact the lead study author, John A. "Skip" Laitner at EconSkip@gmail.com.

Contents

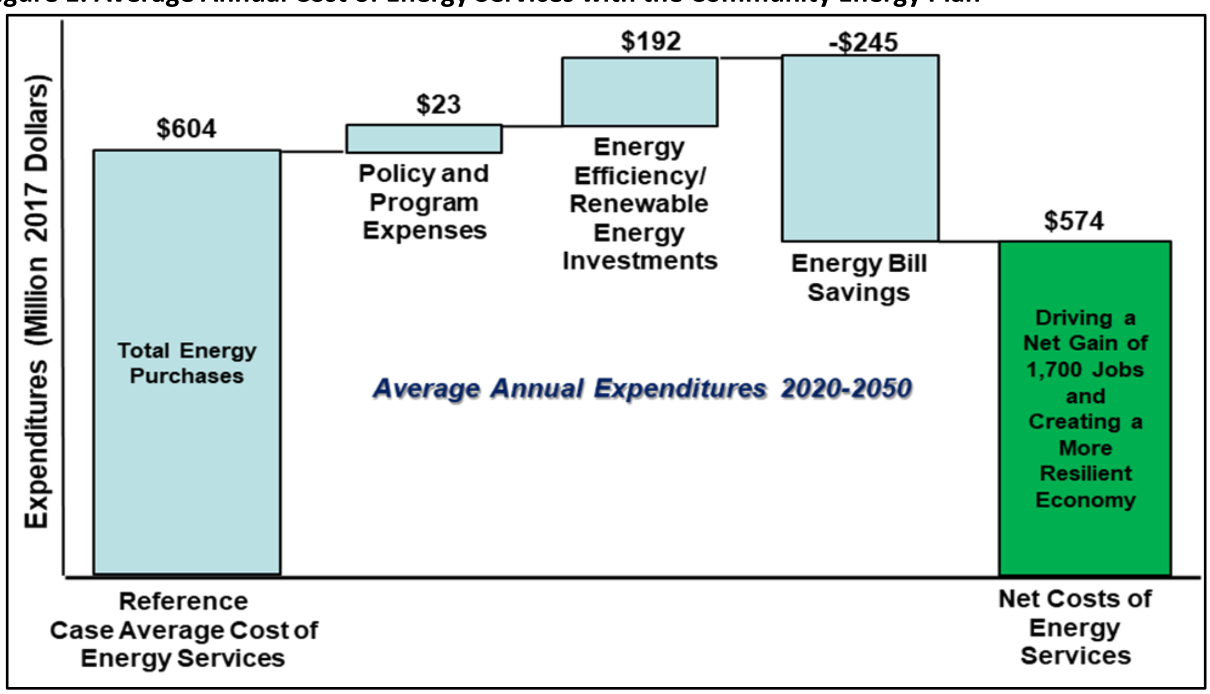
Executive Summary

Arlington County's workers, consumers, and businesses, and a variety of government operations at work in the region, will together spend an estimated $531 million in 2020 to meet their combined energy needs. As energy use and prices rise over time, this might average $604 million annually through the year 2050. The many payments made each day, or each month, enable people to:

- Cool and light their homes,
- Drive to work, listen to music or watch TV,
- Power the region's many commercial enterprises,
- Have access to the Internet, and
- Pump and purify the water that is delivered to local homes, schools, and businesses every day.

Although residents of and businesses in the county derive these and many other benefits from the energy services paid for in their energy bills, there is a significant opportunity to save money through an array of productive investments in energy efficiency and renewable energy technologies. Based on an economic assessment of the 2019 Draft Arlington County Community Energy Plan these investments could drive an average energy bill savings of $245 million per year (see Figure 1 below). The combination of program efforts, investments and energy bill savings across the Arlington economy will also drive a net positive gain of 1,700 jobs within the county.

Figure 1. Average Annual Cost of Energy Services with the Community Energy Plan



Source: John A. "Skip" Laitner based on ICF data for the Arlington Community Energy Plan and results from the DEEPER Modeling System (September 2019).

The County's cumulative net benefits might exceed $2 billion over the 30-year period of this study. This report provides a more detailed discussion of these key ideas as they might positively shape the larger social, environmental, and economic well-being of the county.

On a wider scale, while this analysis focused primarily on the economic benefits and costs that would occur in the County, there are wider effects that ripple through the regional, state, and national economies. For example:

- Investment in manufactured items such as building materials, heating and cooling systems, solar energy arrays, and electric vehicles would generate new economic activity through those supply chains, which can extend to national and global levels.
- Closer to home, employment benefits would accrue to design firms and installation and service contractors in the region that gain new work from designing, installing, and servicing the manufactured goods mentioned above. While some of these firms would be County-based, many would operate from other jurisdictions on the region.
- Finally, County clean energy efforts can benefit the Commonwealth of Virginia's economy in the form of new clean energy facilities, reduced utility grid costs, and cleaner air. For example, if the County were to enter a renewable energy purchase contract similar to that recently announced by the Governor for state-owned facilities, new solar or wind projects could be developed in Virginia, generating new investment and jobs while reducing utility bills and power section emissions.

These benefits, while not quantified in this study, are an important and understated part of the economic good news that this analysis provides.

I. Overview

In 2020, Arlington County businesses and consumers together will spend an estimated $531 million to meet their combined energy needs. Indeed, the many energy payments made each day, or each month, enable people to:

- Cool and light their homes,
- Drive to work, listen to music or watch TV,
- Power the region's many commercial enterprises,
- Have access to the Internet, and
- Pump and purify the water that is delivered to local homes, schools, and businesses every day.

As energy use and prices rise over time, however, the total expenditures might average $604 million annually through the year 2050. Although residents and businesses of the county derive many important benefits from the energy services paid for in their energy bills, there is a significant opportunity to save money through an array of productive investments in energy efficiency and renewable energy technologies. This report provides a macroeconomic assessment of the Arlington County Community Energy Plan (CEP).[1] More specifically, the analysis examines the prospective employment and other economic benefits within the county economy if households and businesses were to shift from current consumption patterns to pursue a more productive and cleaner energy future. The analysis examines the scale of investment that will be necessary to drive those improvements.

With that backdrop:

- **Section II** of this assessment provides the overall framework that reinforces the analysis found later in this report.
- **Section III** then explores the current patterns of economic activity and energy consumption—especially as the investigation points to evidence of previous inquiries, surveys and studies that inform a proactive, forward path based on the idea of a more productive infrastructure. It also explores the scale of purposeful effort and investments that can enable the county and the nation as a whole to build up those future opportunities.
- **Section IV** includes an overview of the methodology used to estimate the net job and other economic impacts of the greater diversity in the use of energy resources and, in particular, the greater level of renewable energy and energy efficiency improvements. In addition, a short narrative offers further details about the economic model used to complete this assessment for the Arlington economy.

II. Framework of the Economic Assessment

The appropriate assessment of the economic impacts of different energy policy opportunities for the Arlington County community—what we call in this document an *Innovation Scenario* driven by the County's Community Energy Plan (CEP) (to meet at 1 $MtCO_2e$ per capita goal per year), is a function of (1) perspective, (2) data, and (3) logic.

1. The perspective is an understanding of how an economy can become much more productive and robust in the use of capital, materials, and especially energy.
2. The data reflect both the economic underpinnings of Arlington County as well as the specific costs and benefits associated with the development and deployment of new technologies, systems, and infrastructure.

[1] The September 2019 Draft Revised *Community Energy Plan (CEP)* was designed to reduce per capita greenhouse emissions from 9.1 metric tons carbon dioxide equivalent (CO2e)/capita in 2016 down to 1.0 metric tons CO2e/capita in 2050. In this assessment we focus on the energy implications of those critical reductions. This includes both the greater level of energy efficiency and the use of an array of clean energy technologies that enable such improvements, and especially the costs and the savings associated with those reductions. In September 2019, the Arlington County Board voted to move toward carbon neutrality as the goal for 2050. The additional reductions needed to get to net zero carbon emissions – whether greater deployments of innovative technology, carbon offsets, or carbon sequestration – are not included in this analysis.

3. The logic of any assessment is driven by knowledge of how jobs and incomes are supported by a transition to a lower-cost economy despite initial upfront costs. It still takes money to make money, and in this special case of the Community Energy Plan, it takes knowledge and purposeful effort, together with a new pattern of investments that can enable Arlington to build a more resilient and higher quality of economic activity over the next three decades.

Rethinking the Underpinnings of Energy Consumption in Arlington Economy

Trends at a Glance: Slowing Economic Growth

- From **1970-2008 GDP** per inhabitant for Arlington County **2.2% increase per year**
- From **2008 to 2018 GDP** was essentially **flat**
- **Projected GDP** growth per year could be **1.2%**

Arlington sits at a moment in history in which doing nothing about current trends in energy production and consumption is not an option. The International Panel on Climate Change (IPCC), for example, highlights several reasons for concern from the growth in greenhouse gas emissions—driven largely by the inefficient use of fossil fuels as they heat up the climate. These range from threatened plant and animal species, extreme weather events and impacts on the economy.[2] The Arlington County Board has chosen to act on energy and climate, through its adoption of a Community Energy Plan as an element of its Comprehensive Plan in 2013, its Climate Action Resolution of 2017[3], and its adoption in September 2019 of an updated Community Energy Plan.[4]

At the same time, the U.S. and the regional economies are showing a slow erosion in overall performance. Over the period 1970-2008, for example, the volume of Gross Domestic Product (GDP) per inhabitant within Arlington County—a useful proxy of economy-wide productivity—grew at a highly positive rate of 2.2 percent per year. With a population growth of about 0.3 percent, that meant the economy as a whole grew, on average, by nearly 2.5 percent per year over that 38-year period. Over the next 10-year period through 2018, however, growth in per capita GDP was essentially flat.[5]

While many standard economic projections suggest a continuing 3.0 percent annual growth globally through 2050 (the last year explored in the CEP Innovation Scenario), there are other indications which suggest the possibility of a weaker and less robust level of economic activity. The latest analysis from the Organization of Economic Cooperation and Development (OECD), as

---

[2] See, IPCC (2018). *Special Report: Global Warming of 1.5 ºC. Summary for Policymakers. Geneva, Switzerland:* World Meteorological Organization. https://www.ipcc.ch/sr15/chapter/spm/
[3] See, https://countyboard.arlingtonva.us/climate-action-resolution/
[4] See, https://newsroom.arlingtonva.us/release/arlington-sets-ambitious-goals-in-updated-community-energy-plan/
[5] Woods and Poole Economics, Inc. Historical Data and Projections through 2050 for Arlington County, VA. May 2019. https://www.woodsandpoole.com/

one cautionary note, suggests that "growth is taking a dangerous downward turn."[6] This could mean perhaps lowering the annual growth of the Arlington County GDP to as low as 1.2 percent.[7]

This last projection is consistent with other indicators, all of which point to a lagging rate in the more productive use of capital, energy, and other resources. If we also fold in the many steps that need to be taken to address climate change and other environmental concerns, failure to explore these very possible outcomes may leave Arlington County, the Commonwealth of Virginia, and the United States as a whole at risk. In this context, the CEP Innovation Scenario can be thought of in two different ways. First, "innovation thinking" can become an insurance plan which enables Arlington to maintain a healthy economy; and second, the CEP Energy Innovation Scenario can provide insights into the kind of economic platform that may well safeguard a resilient and sustainable economy over a longer period of time.

Notwithstanding some early warning signs of a less robust economy over the next decades, Arlington has a number of promising opportunities that can point the way to the more productive use of its many resources; and to do so in ways that build a more robust, resilient, and sustainable economy. These many transition pathways are described elsewhere in the Community Energy Plan. But we might ask how these options generate a net positive return compared to the standard business-as-usual or reference case assumptions. The table below highlights at least seven key drivers that can support a more robust economy as a result of any given Innovation Scenario and resulting roadmap. The individual effects and each of their primary impacts are described next.

Table 1. The Seven Major Drivers of Employment and Economic Benefits

Driver	Primary Impact
Intensity Shift	Moving away from capital-intensive to labor-intensive activities
Supply Chain Build Up	Building up greater local production and local services
Energy Cost Reduction	Both unit cost and total cost savings for efficiency and non-efficiency
Productivity Boost	Expanding non-energy benefits
Managing Volatility	Smoothing out price shocks
Minimizing Disruption	Avoiding the inconvenient interruption of supply
Innovation Plus	Cost and service breakthroughs in the delivery of energy and other services

Source: As described and discussed in the text of the manuscript.

[6] OECD Chief Economist, Laurence Boone, highlighted this concern in a statement released September 19, 2019. See, https://oecdecoscope.blog/2019/09/19/growth-is-taking-a-dangerous-downward-turn/

[7] Again, see Woods and Poole, May 2019, op cit.

The Catalysts to a More Robust Economy (Seven Major Drivers)

Trends at a Glance: Intensity Shift Driver

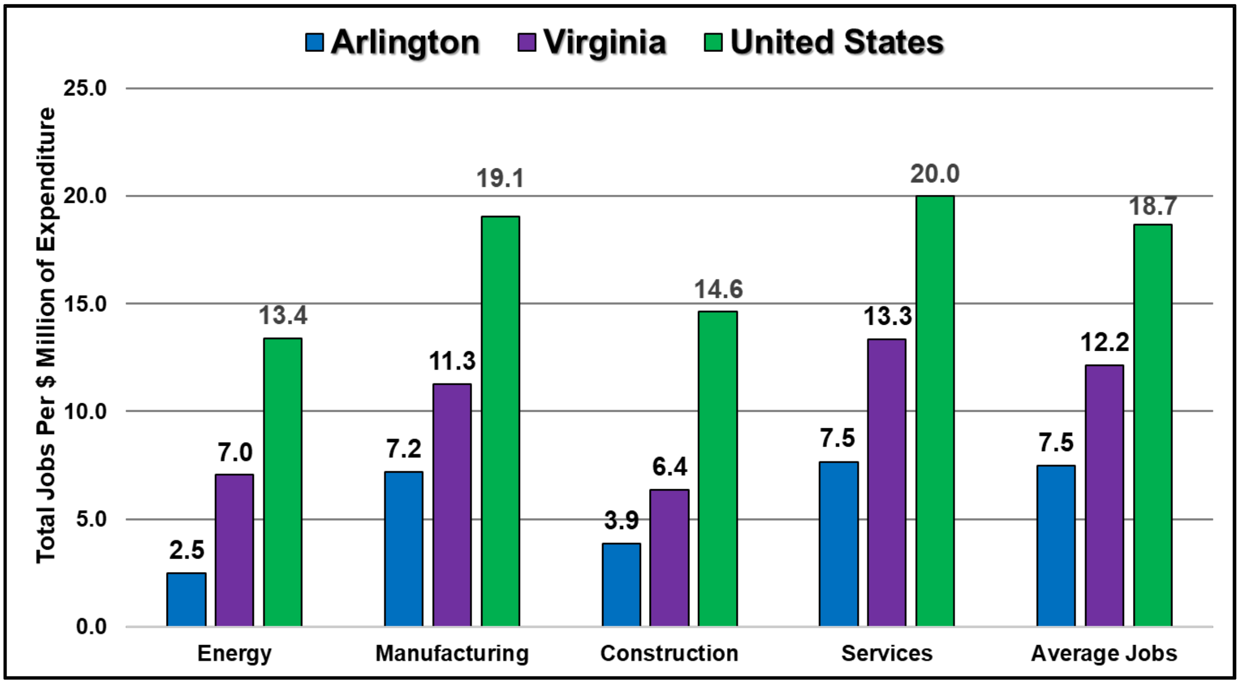
- In 2017 in Arlington County:
  - **Energy Resources** supported **2.5 jobs per million dollars of economy activity**
  - This is compared to **3.9 jobs in construction** as well **7.2 jobs in manufacturing**, and **7.5 in many different service sectors** and also on average throughout the economy, including innovations in clean energy services.
- Arlington will gain **a net increase of 5.0 new jobs for every one million dollars of energy bill savings generated and that is spent within the county**, through greater cost-effective energy efficiency improvements.

The first key driver is referred to as the intensity shift. Just as some energy resources are more carbon-intensive than others—for example natural gas produces less carbon-dioxide per million Btus of energy than does an equivalent amount of coal -- while renewable energy resources produce no direct emissions compared to any form of fossil fuels -- different sectors of the Arlington economy have different income and employment intensities. In other words, different sectors support either more or fewer jobs incomes per unit of economic activity than other sectors to which they might be compared. We can follow this logic as shown in Figure 2 on the following page.

Based on 2017 data from the IMPLAN county-level data sets (which, in turn, draws on public data made available through a variety of agencies and institutions), the array of energy resources within Arlington County supported on the order of 2.5 jobs per million dollars of economy activity, compared to 3.9 jobs in construction as well 7.2 jobs in manufacturing, and 7.5 in many different service sectors and also on average throughout the economy, including innovations in clean energy services (IMPLAN 2019).[8] Hence, for every one million dollars of energy bill savings generated and that is spent within the county, through greater cost-effective energy efficiency improvements, Arlington will gain a net increase of 5.0 new jobs. So, instead of supporting 2.5 jobs for energy purchases, the economy will support an average of 7.5 jobs as the energy bill savings are re-spent for other goods and services in the regional economy.

[8] IMPLAN LLC, Huntersville, NC. https://implan.com/. Note that the job intensities increase as the data shift from an individual county to state and national assessments. This is because there are increasingly fewer imports and more sectoral interactions at the state and national levels. But also note that the difference between average jobs and energy-related jobs remains close to the net gain of 5 jobs shown for Arlington County.

Figure 2. Labor Intensities for Key Economic Sectors and Regions



Source: John A. "Skip" Laitner, using IMPLAN 2017 Data for the United States and Regions, 2019.

> **Trends at a Glance: Supply Chain Build Up Driver**
>
> - The **County imports ~43 percent** of its supply chain of goods and services
> - The **United States**, as a whole, imports **only 10 percent** of its production resources

In regards to the second key driver (supply chain build-up), the Arlington economy is unlike the rest of the state or nation. It has no industrial or manufacturing sector s to speak of. On the other hand, it has a disproportionate "new collar" (information technology and health-related occupations) and white collar (lawyers and consultants) workforce that earns above-average incomes. This provides a high-level value-added return to the region.[9] While Arlington generates a large rate of value-added, it also imports an estimated 43 percent of its supply chain of goods and services. By comparison, the United States, as a whole, imports only 10 percent of its production resources.[10] To the extent that the county increases local production capacity for goods and services, this will increase both the resilience and vitality of the regional economy.[11]

---

[9] Drawing on data from both Woods and Poole (previously cited), we note that 97 percent of all jobs in Arlington County are within the service sector of the economy. This compares to 87 percent and 85 percent for the Commonwealth of Virginia and the United States, respectively.

[10] The import ratios are estimated from data provided for these two economies by IMPLAN, again, previously cited.

[11] As a thought experiment we can imagine how building up greater local capacity and supply can increase the robustness of the Arlington economy. For example, as the region now provides an initial 40% of its resources through local purchases, we can use a multiplier formula of [1 / (1 – 0.40)] to suggest a base economic multiplier of 1.67 for each dollar spent by businesses and consumers. But if the regional economy moves the local purchase coefficient from 40% to just 45%, then the base multiplier increases to 1.82. In other words, instead of a $100 consumer

A third area of opportunity is the likely positive impacts of greater energy and resource efficiencies on both energy and non-energy expenditures (i.e., energy cost reduction). Even as Arlington will benefit from cost-effective reductions in the use of energy and other resources, the remaining resource requirements also will (more than likely) benefit from lower total costs. This is because greater productivity will reduce demand in ways allows less costly resources to be deployed, and it tends to place an otherwise downward pressure on other remaining resource costs.

A related fourth area of benefit is the prospect of greater productivity which can expand economic opportunity—especially with the more productive level of resource consumption at all levels. For example, the county's total economic activity in 2017 (the base year of our model) was an estimated $37 billion.[12] Had the productivity of the region's economy been just 0.5 percent higher over the period 2000 through 2017 (to pick a timeframe), the regional GDP would have been $3 billion larger (in 2017). Again, checking Figure 2 on the jobs per million dollars, a $3 billion gain from that higher productivity would have led to higher employment of about 22,500 jobs (all else being equal). In effect, $3 billion is 3,000 million times 7.5 jobs per million dollars which equals 22,500 more jobs.[13]

Trends at a Glance: Productivity Boost Driver

- In **2017** Arlington County's **economic activity totaled $37 billion**
- If the productivity of the region's economy been just **0.5 percent higher over the period 2000 through 2017**, regional **GDP would be $40 billion** resulting in **22,500 more jobs**.

A fifth and sixth set of impacts include managing (or reducing) the disruption in the availability of energy and other resources, while also minimizing the unexpected effects of price volatilities. As the demand for goods and services is reduced in Arlington County and the U.S. market more generally, and especially as the need for imported resources is reduced, the regional markets will enjoy a reduced exposure or market risk. That means, in turn, a greater certainty in the availability and cost of those resources. That is clearly a positive benefit.

Finally, the seventh major driver of greater employment and economic benefits that are likely to follow from the CEP Energy Innovation Scenario is the continuous learning and encouragement which will catalyze greater innovations, whether the development and deployment of new general purpose technologies, or the innovative changes in business models that can satisfy a

purchase that might support $167 locally, with a more resilient economy it might support more like $182, without any other additional costs to the market.

[12] Woods and Poole (previously cited).

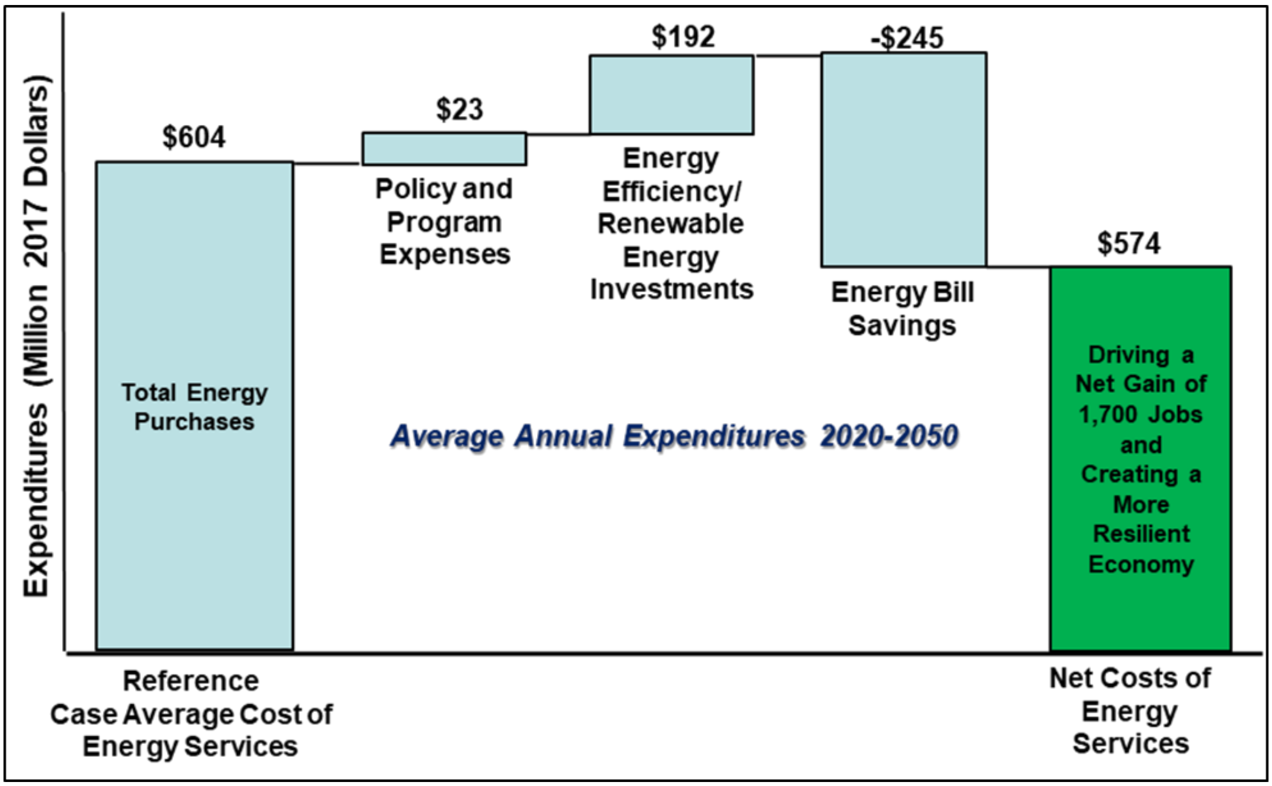
[13] Technically that 0.5 percent increase in value-added, or GDP, might produce even more than the 22,500 jobs referenced in this simple example. As in all economies, value-added is a subset of total financial activity, or output, with the purchases of other goods and services also part of the local economy. In the case of Arlington County value-added contributes about 74 percent of the total sales of goods and services. Hence, the 22,500 jobs should be expanded by dividing the number of jobs by 0.74 since the job requirements are a function of total output, not just value-added. Ergo, 22,500 divided by 0.74 roughly equals 30,405 jobs for that extra boost in market activity.

combination of social, economic, and environmental needs within the county.

Equally critical, the CEP Innovation Scenario can become a way to catalyze the seventh benefit of community-based plans—an enhanced push of the economy-wide production frontier. In effect, future technologies and markets are encouraged, developed, and implemented to the long-term benefit of the economy. This thought is explored more fully within Appendix A of this report, *Further Insights on Energy Productivity and the Economy*.

Potential Effects of the Seven Major Drivers in Arlington County in the Energy Innovation Scneario

Figure 3. The Average Annual Cost of Energy Services (2020 through 2050)



Source: John A. "Skip" Laitner based on ICF data for the Arlington Community Energy Plan and results from the DEEPER Modeling System (September 2019).

Because greater energy (and economy-wide) productivity is central to the advancements envisioned by the CEP strategy, Figure 3 above summarizes the potential gains which are likely to result from a lower cost of energy services. As we look forward to the information provided in Table 2 and Table 3 (discussed in the next section of this manuscript), Arlington County appears to have an average annual energy bill of about $604 million (reflecting data from the annual accounts for the year 2020 looking forward to 2050). As it turns out, and as we shall see yet again more fully in the section that follows, the CEP Innovation Scenario can generate an initial savings of about $245 million per year.

At the same time, to enable the savings requires that the county and local businesses create a series of programs, policies, and incentives averaging about $23 million per year.[14] It is these initiatives which, in turn, will drive the requisite large-scale investments as they are amortized over time, much like a family might pay for a new home or building. This will bump up the cost to an estimated $192 million (also reflecting average annual payments for those relevant investments over time). All of this means that, although total savings might be $245 million each year on average, paying for the investments, programs, and policies reduces the gross savings of $245 million to a net savings of $30 million. The first result in exploring the costs of energy services is an average energy bill that is lower by about $112 per capita per year with the concomitant benefit of significantly reduced greenhouse gas emissions.

Other Benefits and Costs to Consider

As good as that outcome appears to be, it is merely the benefit from the lower total cost of energy-related resources. We can also account for other social, economic, health, and environmental costs that will impact both the Arlington and the area economy. As one example, a Stanford University study assessed the economic benefits that might arise should cities transition to a 100 percent renewable energy strategy. The analysis included specific impacts and benefits for Arlington, Virginia. Among other things, the analysts found that the cleaner air resulting from the full mix of clean energy technologies might avoid health costs generally the equivalent of 1.5 percent of GDP by the year 2050.[15] Adopting the Stanford methodology as it might be applied to the Arlington County changes in energy, the combined avoided air quality health effects and global climate-change could approach $64 million in just the year 2050 alone (with values again expressed in constant 2017 dollars). This does not include potentially sizable GDP and employment gains that are likely to accrue from the more productive pattern of infrastructure investments, energy efficiency upgrades, as well as the deployment of large-scale renewable energy systems.

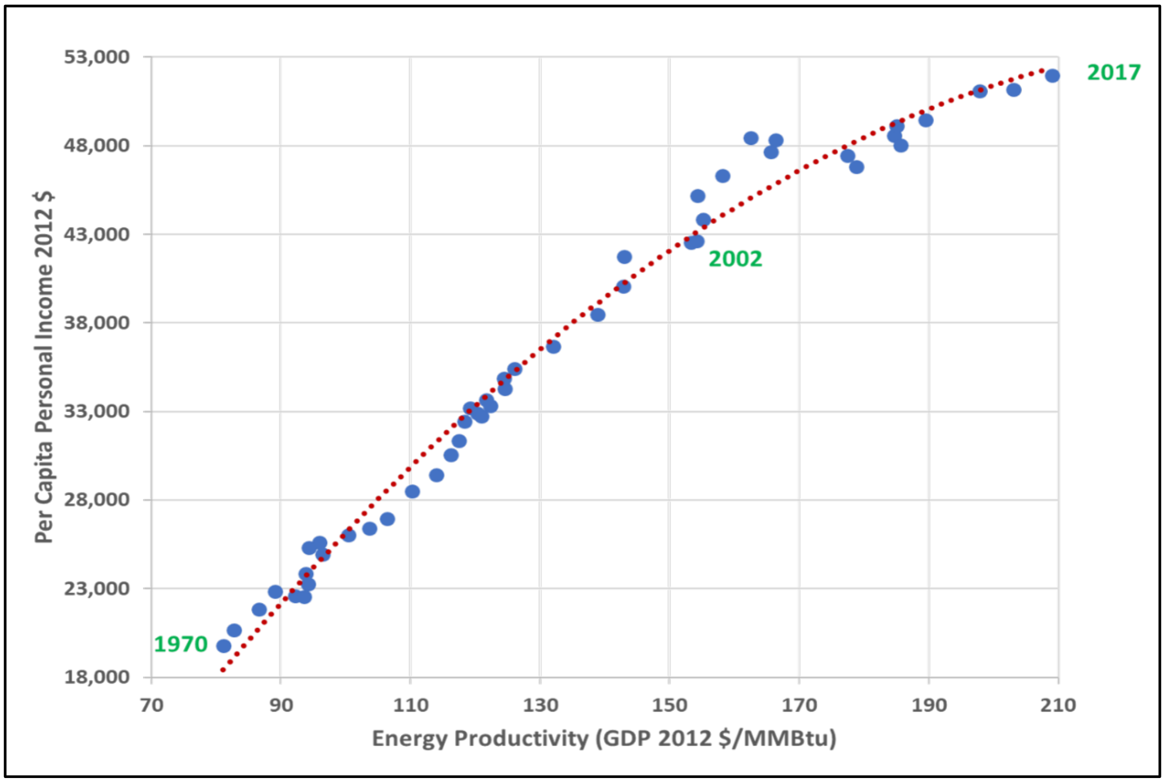
[14] This infographic reflects expenditures within the public, private, and non-profit sectors to educate, train, market, promote and evaluate the relevant programs and policies which will be necessary to elevate the larger performance of the Arlington economy. For a more complete discussion on the importance of policies and programs which drive productive investments, see John A. "Skip" Laitner, *Smart Policies and Programs as Critical Drivers for Greater Energy Efficiency Investments* (2018). This analysis for Arlington County used the working hypothesis from this research which holds that the mix of policy and program costs might be 20 percent of investments in the early years, but decline to about 8 percent by 2050. The slow reduction in program costs over time, presumes a form of "learning" as well as "economies of scale" and "economies of scope." That is, both experience and expansion of the market decreases this form of fixed costs over time. It also reflects working estimates that include public and private costs. https://theresourceimperative.com/2018/02/15/smart-policies-and-programs-as-critical-drivers-for-greater-energy-efficiency-investments/

[15] Mark Z. Jacobson, et al. 2018. "100% clean and renewable Wind, Water, and Sunlight (WWS) all-sector energy roadmaps for 53 towns and cities in North America." *Sustainable Cities and Society* 42 (2018) 22–37. http://web.stanford.edu/group/efmh/jacobson/Articles/I/TownsCities.pdf.

The systemic build-out, scale-up, and convergence of a digitally-connected infrastructure will enable, in turn, the region to achieve dramatic gains in aggregate efficiency and resource productivity, and the equally dramatic reduction in marginal costs and ecological footprint, as well as providing the new business models that will enable a more robust local economy. It is this new high-tech infrastructure that affords the opportunity for more beneficial investments to reduce the total cost of energy services so that any remaining net costs become substantially smaller. The important element in all of this is that if Arlington is to maintain a robust economy, there will need to be a convergence of new resource and energy efficiencies that, in turn, reduce the real cost of energy services in each successive year—from today through the year 2050.

Figure 4 provides a further graphical illustration of such possibilities as it impacts the Commonwealth of Virginia as a whole, with strong parallels to Arlington County.

Figure 4. Exploring the CEP Energy Productivity Link to Increasing Per Capita Income



Source: Economic and Human Dimensions Research Associates using National Income & Product Accounts for Virginia published by Woods and Poole (2019) and from the U.S. Energy Information Administration (2019).

In Figure 4, the blue dots represent actual energy consumption data published by the Energy Information Administration (EIA) for Virginia as a whole, and the Woods and Poole per capita income and GDP data, over the period 1970 through 2017. The smaller set of red dots highlight the curve of a fitted trend with the available data. The statistics show a reasonably tight link between energy productivity (that is, the level of GDP supported by each million Btu of energy consumption) as it compares to per capita personal income (with all financial values here expressed in constant 2012 dollars).[16]

In the lower left corner of the graph, for example, an energy productivity of $76 per million Btu (MMBtu) of total primary energy consumed within the state supported a per capita income of $20,000 in 1970. In a fairly tight pattern, rising energy productivity can be seen to catalyze an increase in income per inhabitant. The end result is that by 2017 an energy productivity of around $210 per unit of energy supported a per capita income of just under $53,000.

At the same time, however, an astute observer might note a flattening of the blue curve. In effect, this is the set of diminishing returns we might observe from the use of current, still largely 20th century, technologies and infrastructure. It is getting harder to generate economic and social well-being from the existing array of building, transportation and industrial equipment—together with their associated productivity benefits. Hence, there is a very real need to turn to promote 21st century investments and strategies that can accelerate greater levels of both energy and economic productivity. By redirecting purposeful effort and new technology investments, consistent with the Community Energy Plan, we can imagine the possibility of lifting Arlington economy to a higher level of performance.

III. Comparing Business-As-Usual and the CEP Innovation Scenario

Beginning in the late 1960s and early 1970s, Royal Dutch/Shell developed a technique known as ‘‘scenario planning.’’ Rather than attempting to forecast a precise estimate of the global business environment, the intent was to create a series of narratives—the so-called *Rivers of Oil* scenarios—to help Shell's management anticipate the eventuality (if not the timing) of future oil crises. The scenario building activity proved to be an effective tool. Armed with foresight, and with an agility and internal capacity to respond to the 1981 oil glut, Shell sold off its excess before the glut became a reality and prices collapsed.[17]

The critical question we ask here is how the Arlington County Community Energy Plan might compare with a typical or standard projection of the region's population and economic performance as measured by GDP, as well as anticipated energy consumption patterns. Table 2 summarizes the reference case projections for key energy and economic variables over the period 2018 through 2050 for three benchmark years, 2018, 2030 and 2050.[18]

---

[16] Explained further in footnote 19, when expressed as heat equivalents, one million Btu (MMBtu) is the approximate energy contained in ~8 gallons of gasoline, or about 293 kilowatt-hours of electricity.

[17] The development of the Shell scenarios was led by Pierre Wack, an economist, who was then the head of the business environment division of the Royal Dutch/Shell Group planning department from 1971 to 1981. For a deeper review of these early successful efforts in scenario planning, see: Wack, Pierre. 1985. Scenarios: Uncharted Waters Ahead. Harvard Business Review. No. 85516. September-October, pages 72-89.

[18] The complete time series of data can be made available on request.

Table 2. Arlington County Business-as-Usual Projections for Key Economic and Energy Data

BAU Economic Indicators	Metric	2018	2030	2050	Growth/Yr
Resident Population	Thousand Persons	237.1	261.1	291.2	0.64%
Per Capita GDP	Real Dollars$_{2017}$	156,489	166,880	187,274	0.56%
Gross Domestic Product (GDP)	Million Dollars$_{2017}$	37,105	43,579	54,531	1.21%
BAU Energy Indicators					
Total Energy Demand	Trillion Btus (TBtu)	38.4	38.4	41.6	0.25%
Energy Expenditures	Million Dollars$_{2017}$	498.7	576.9	683.8	1.0%
Energy Expenditures/Capita	Real Dollars$_{2017}$	2,103	2,209	2,349	0.35%

Source: Woods and Poole for Population and GDP, and ICF Incorporated for Energy metrics (September 2019).

According to Census estimates, Arlington County had an estimated 237,100 inhabitants. Current forecasts show a population growth rate of 0.64 percent per year. If that projection holds, it means that the populace will reach 291,200 persons by 2050. That small increase in the number of inhabitants, and especially with a weak 0.56 percent increase in per capita GDP, is anticipated to drive total GDP, up from just over $37.1 billion in 2018 to a somewhat larger economy of $54.5 billion by 2050, an annual growth rate of 1.21 percent over that time horizon (with both values expressed in real 2017 rather than nominal dollars).

At the same time, building on energy consumption patterns provided by the ICF team, total energy consumption is estimated to be 38.4 trillion Btus (TBtu) in 2018.[19] Because of various energy policies and programs now in place, together with business-as-usual (BAU) market trends, the overall energy productivity of the Arlington economy is expected to approach 1 percent per year which will offset some of the energy demands that stem from a growth in economic activity. Still, overall energy demand is expected to increase by only 3.2 TBtu, as will energy expenditures. Indeed, as prices increase slightly (in real terms) through 2050, the reference case projection suggests that total energy expenditures will increase from just under $500 million in 2018 to about $684 million by 2050.

There are several questions that can be raised, including:

1) how many more energy efficiency improvements are possible;
2) how much of the remaining energy demands can be met by an array of renewable energy technologies (whether wind, solar photovoltaics, solar heating, and biomass resources); and
3) how much might all of this cost?

In such a case it is often helpful to begin with a thought experiment to provide a working estimate of magnitudes to place these questions in context.

[19] All energy forms – whether coal, oil, natural gas or nuclear energy – can be characterized by their "heat equivalent" or British Thermal Units or Btus. A kilowatt-hour of electricity, for example, is roughly equal to 3,412 Btus. One trillion Btu (TBtu) is the amount of energy contained in 8 million gallons of gasoline. A total of 38.4 TBtu, therefore, is just over 300 million gallons of gasoline equivalent; or in the case of Arlington County, about 1,300 gallons for all combined uses of energy for each resident who lives within the county.

Following a review of the Community Energy Plan, it appears there are about ten different transition pathways to enable the County to reach a more resilient, robust, and sustainable economy—even as greenhouse gases (expressed in carbon dioxide or CO_2 equivalents) decline from 9 metric tons of CO_2 per capita to just 1 metric ton of CO_2 per person by 2050. Preliminary estimates indicate that to move the County into a higher level of economic performance, the region would need to invest a cumulative of about $6 billion to upgrade the combination of existing energy technologies and local infrastructure between now and 2050.[20]

Table 3 provides a more complete "scenario context" by underscoring the larger macroeconomic metrics associated with key differences between the Business-as-Usual, or Reference Case, and the County Energy Plan Innovation Scenario.

Table 3. Illustrative Financial/Economic Outcomes for Arlington County's Energy Innovation Scenario

Energy/Economic Impact	Metric	2020	2030	2040	2050	Average 2020-2050
Efficiency Gain	Savings from BAU	2.4%	18.7%	22.4%	26.5%	18.4%
Policy/Program Costs	Million Dollars $_{2017}$	20.6	29.2	21.8	18.1	23.0
Technology Investments	Million Dollars $_{2017}$	103.2	198.0	200.8	226.6	185.4
Annual Payment (with interest)	Million Dollars $_{2017}$	8.3	127.1	277.3	334.0	191.9
Energy Bill Savings	Million Dollars $_{2017}$	17.1	151.0	264.5	377.5	203.0
O&M Savings	Million Dollars $_{2017}$	8.9	32.1	56.7	78.0	42.4
Net Total Savings	Million Dollars $_{2017}$	-2.9	26.8	22.1	103.4	30.5
Energy Plan Employment	Net Jobs	800	1,418	1,188	1,407	1,213
Productivity Employment	Net Jobs	681	864	314	304	536
Total Employment Gains	Net Jobs	1,482	2,283	1,502	1,711	1,749
Net GDP Impacts	Million Dollars $_{2017}$	108	139	51	50	87

Source: ICF Consulting energy cost and savings data, and the DEEPER Modeling System for employment and GDP impacts (September 2019).

First, note the row that is labeled "Efficiency Gain." As first, the energy efficiency investments kick in beginning in 2018 and 2019 (not shown here), and second, the "Clean Energy Demand" technologies begin to penetrate the market (effectively, the array of renewable energy technologies enabled by improved grid and off-grid management), the Innovation Scenario starts with a small annual energy savings of 2.4 percent in the year 2020. This grows to 26.5 percent by 2050. The three-decade average energy savings is 18.4 percent over the BAU, or Reference Case. This result is driven by: (i) a combination of policy and program spending, and (ii) the scaled-up set of investments for energy efficiency and renewable energy technologies.

[20] Working Memo, ICF Incorporated, on costs and savings of the CEP, September 2019. Available on request.

Program costs begin with a $21 million effort in 2020 (which includes an aggregate estimate of initial government and private sector efforts). This increases while investments accelerate in the early years. But 2050 program costs decline to $18 million as experience and economies of scale reduce the need for such activities compared to the bigger technology outlays. On the other hand, infrastructure and equipment upgrades require an initial deployment of an estimated $103 million in 2020, expanding to $227 million by 2050 (with all values again in 2017 dollars, the base year of the model).

Over the period 2020 through 2050, assuming that funds for technology deployments are provided by investors and lenders, repaid at an average 5 percent interest over a 20-year period, the annual payments for investments within Arlington County average about $192 million per year.[21] Also embedded in Table 3 are data that show a significant reduction in the county-wide overall cost of energy services. While the year 2020 shows a net cost (i.e., negative savings) of $3 million as program costs and investments exceed the initial energy bill savings, the Innovation Scenario yields a small net positive gain by 2021 (not shown in Table 3). This rises to $27 million by 2030 and averages about $31 million over the full 31-year time horizon. In a similar way, rather than a suggested 2050 annual cost of $684 million reflected in the Table 2 Reference Case data, the Innovation Scenario shows a 2050 energy bill savings of $378 million together with an operating & maintenance savings of $78 million, also in that year. Again, there is a minor caution in that this represents what might be termed gross energy savings. A more useful metric is the "net energy bill savings" in a given year. This reflects the costs of related programs and policies, as well as the amortized payments made for the energy efficiency upgrades which will reduce the gross savings in 2050 down to a net savings of $103 million in that year.

This last point is very similar to the discussion surrounding Figure 2 in which the average annual energy savings of $245 million over the period 2020 through 2050 is actually closer to a net of $30 million when the added program costs together with the amortized energy efficiency upgrades are also included.[22] As all of this data is then fed into the DEEPER Modeling System (described more fully later in the report), and as shown in both Figure 3 and Table 3, it appears Arlington County will enjoy a projective net gain of about 1,700 jobs over the study time horizon. At the same time, however, there are large costs of externalities that will further extend the benefits of the CEP Innovation Scenario. While referenced also as part of the Figure 3 discussion, on the link between larger energy productivity gains as they affect per capita income, these elements are not discussed until the next section that follows in this assessment.

---

[21] The assumption here is that municipal-type investments at 3% interest rates might comprise 65% of the total costs while the private sector might be repaid at 9%. The weighted average is 5%. There is obviously a fluidity and uncertainty in the interest rate but a higher weighted rate of 7% does not appreciably change the results.

[22] Note that rounding errors may yield results that my not add up perfectly in the narrative. For example, Table 3 shows a net average savings of $30.5 million over the period 2020 through 2050 while Figure 3 indicates a net average savings of $30 million in that same period.

IV. Reviewing the Economic Impacts of the CEP Innovation Scenario

The foundation for the overall economic assessment that has been completed as part of the Arlington County planning process is the proprietary modeling system known as the **D**ynamic **E**nergy **E**fficiency **P**olicy **E**valuation **R**outine (DEEPER). The model, developed by John A. "Skip" Laitner, is a compact 15-sector dynamic input-output model of a given regional or national economy.[23] The model is essentially a recipe that shows how different sectors of the economy are expected to buy and sell to each other; and how they might, in turn, be affected by changed investment and spending patterns. Setting up that production recipe is a first step in exploring the future job creation opportunities and other macroeconomic impacts as Arlington County shifts from a less productive infrastructure to the higher level of performance that is likely to be associated with the CEP Innovation Scenario.

Although it has been updated here to reflect the economic dynamics specific to Arlington County, the DEEPER model has a 30-year history of development and application. The model has been utilized to assess the net employment impacts of proposed automobile fuel economy standards within the United States.[24] More often, it is typically employed to evaluate the macroeconomic impacts of a variety of energy efficiency, renewable energy, and climate policies at the regional, state, and national level. As a recent illustration, it was used in 2017 to assess the potential outcomes and economic benefits of the Third Industrial Revolution in the Metropolitan Region of Rotterdam and Den Haag, an industrial region 2.3 million people in South Holland.[25]

The timeframe of the model for evaluating energy efficiency and renewable energy technology policies and investments is 2018 through 2050. The years 2018 and 2019 (or earlier as needed) provide a useful historical benchmark. The period 2020 through 2050 affords an assessment of future trends. As it was implemented for this analysis, the model maps in the changed spending and investment patterns based on the CEP Innovation Scenario which is reflected in a variety of data made available by Arlington County, by Woods and Poole Economics, and by ICF. Figure 5 below provides a diagrammatic view of the DEEPER Modeling System as it was reflected within the dynamics of the Arlington County economy. A more complete description is provided in Appendix B at the end of the report.

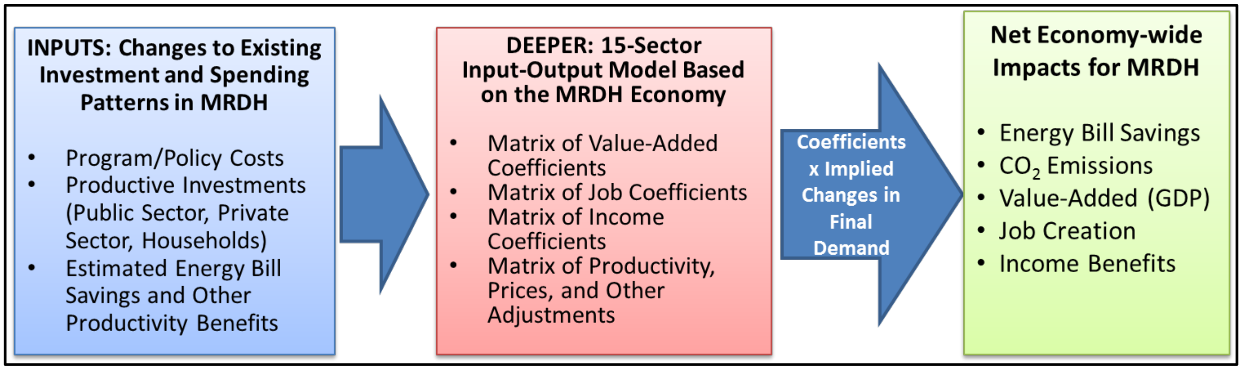
---

[23] There is nothing particularly special about this number of sectors. The problem is to provide sufficient detail to show key negative and positive impacts while maintaining a model of manageable size. Expanding or reducing the number of sectors will require some minor programming changes and adjustments to handle the larger matrix.

[24] *Gearing Up: Smart Standards Create Good Jobs Building Cleaner Cars*, by Chris Busch, John Laitner, Rob McCulloch, and Ivana Stosic, Washington, DC: BlueGreen Alliance, 2012. Based on this analysis and other evidence, American President Barack Obama signed into effect the proposed 54.5 mile-per-gallon fuel economy standards in August 2012.

[25] See, "Exploring the Potential Economic Benefits of the TIR Roadmap Next Economy Innovation Scenarios," by John A. "Skip" Laitner, in Jeremy Rifkin et al., *The Third Industrial Revolution Roadmap Next Economy for The Metropolitan Region of Rotterdam and The Hague*, Bethesda, MD: TIR Consulting Group LLC. 2017.

Figure 5. The DEEPER Modeling System



Note: See Appendix B for a more formal discussion of the DEEPER Modeling System

Understanding the CEP Innovation Scenario

Table 3 integrates the scenario cost data found in Table 2 and elsewhere. It then lays out the larger economic benefits that might be expected to emerge with the CEP Innovation Scenario, especially as interactive discussion helps shape a greater understanding of what initiatives may contribute to a more productive community strategy.

Consistent with the discussion surrounding Figure 3, the greater increase in energy productivity by 2050 lifts the Arlington economy to a higher level of performance so that it enables a net gain of employment—an estimated 1,200 net jobs per year by 2050 resulting from the upgrade of the region's energy infrastructure. These jobs are complemented by another 500 net jobs made possible by further non-energy and larger productivity benefits that will be stimulated by the CEP Innovation Scenario. The "average annual net gain" in employment over the analytical time horizon is 1,700 jobs.[26] Another way to look at these job estimates is to imagine what might happen if the CEP scenario scaled to an equivalent success in the entirety of all 50 states within the United States. In that case, instead of 235,000 inhabitants in 2017 (the base year of the model), the economic ripple effect might work through an US population base of 326 million people. Assuming a similar magnitude of success throughout the nation, we might find a net gain of more than 2.4 million net jobs within the U.S. as a whole (including the 1,700 jobs within Arlington County).[27]

---

[26] One item of note in Table 3 is both the net positive job gains from energy-related investments and savings in the years 2020 through 2050. At the same time, as the economy shifts resources from existing spending patterns into the more efficient use of energy, there is net temporary loss of jobs in other sectors. This reflects a period of adjustment that is overcome as both energy other resource gains result in a total net positive gain for Arlington County. But those are the jobs associated with direct energy investments and savings. There are also jobs from a more robust economy. Although the totals vary over the years, rounded to the nearest 100 jobs, roughly 1,200 net employment gains are supported by upgrades to the energy the energy infrastructure while another 500 jobs are the result of a more robust economy. Hence the average annual benefit of 1,700 net jobs as highlighted in both Figure 3 and Table 3.

[27] To those unfamiliar with these kinds of assessments, an employment benefit of 2.4 million jobs might seem like an unexpectedly large number. Yet, a sizeable number of studies show comparable results. A 2012 assessment of energy efficiency improvements only within the United States, for example, suggested as many as 1.9 million by

While not a primary focus of this economic assessment, it is worth integrating a short overview of the complementary relationship between changes in energy consumption patterns that might also bring about an array of other social, economic, health, and climate benefits. Here, we cite several key references, together with the reported results from the more conventional economic assessment of energy-related costs and benefits. The first draws on the combination of perspectives offered by Ayres and Warr (2009)[28], Kümmel (2011)[29] and Stanford University which highlights the findings in the assessment published earlier last year by Jacobsen et al. (2018), *100% Clean and Renewable Wind, Water, and Sunlight (WWS)*.[30] With several caveats, but following the logic of net benefits that might follow from both Figure 2 and Figure 3, the table below explores this relationship.

Table 4. Cost and Benefits for Arlington County Community Energy Plan

Regional Impact	Million 2017 $
1. Program/Investment Costs	2,609
2. Aggregate Benefit of Energy Bill Savings	2,977
3. Health Benefits (Avoided Health Externalities)	548
4. Non-Energy Productivity Benefits	1,138
5. Net Total Benefits (Row 2 through 4 less 1)	2,055
6. Implied Benefit-Cost Ratio (Row 2 thru 4 divided by 1)	1.79

Source: Results are *net present values of a 5% discount rate* over the period 2020-2050. Rounding errors yield different sums.

Table 4 shows the expanded categories of three sets of benefits as they are created through productive investment, and as those benefits are then summed over time in the years 2020 through 2050. With a net present value taken over those 31 years at a 5 percent discount rate, the CEP Innovation Scenario might show a net annual benefit of $369 million from reduced energy expenditures alone. That is, after borrowing funds, and paying the finance costs over time (as estimated here), a discounted investment stream of $2,609 million investment might return an energy savings of $2,977 million. This might result in a discounted benefit cost ratio of 1.14. That is a positive result, but the story doesn't necessarily end there.

2050. See, Laitner et al. (2012), *The Long-Term Energy Efficiency Potential: What the Evidence Suggests*. Washington, DC: American Council for an Energy-Efficient Economy. https://aceee.org/research-report/e121

[28] Robert U. Ayres and Benjamin Warr (2009), *The Economic Growth Engine: How Energy and Work Drive Material Prosperity*. Northampton, MA, Edward Elgar Publishing, Inc.

[29] Reiner Kümmel (2011). The Second Law of Economics: Energy, Entropy, and the Origins of Wealth. New York, NY, Springer. See also, R. Kümmel (2013). "Why energy's economic weight is much larger than its cost share." *Environmental Innovation and Societal Transitions*, (9): 33-37.

[30] The Stanford University study was previously cited in footnote 12 in this manuscript. At the same time, however, there is a growing literature and new research which underscores both the scale and importance of the multiple benefits of greater energy productivity and clean energy technologies. See, for example, the July 2019 EPA assessment, *Public Health Benefits per kWh of Energy Efficiency and Renewable Energy in the United States: A Technical Report*. More detail can be found at https://www.epa.gov/statelocalenergy/estimating-health-benefits-kilowatt-hour-energy-efficiency-and-renewable-energy.

Beyond energy savings, the investment flow catalyzes a more dynamic economy so that GDP is expanded another $1,138 million (net of the energy savings). This follows from Ayres and Warr (2009) and Kümmel (2011) as previously referenced, in that the reduced level of wasted energy and other resources adds a greater level of economic productivity beyond the pure energy savings alone. Finally, if we adapt, not the findings of Jacobsen et al. (2018), but the methodology as it applies to the CEP Innovation Scenario, also discounted over time and averaged over the same 31-year period, we might gauge a further annual benefit of $548 million.[31] So, what began as a pure energy savings might now be seen as a larger return from a higher level of productive energy services for Arlington County; or total benefit, net of the program and investment costs, of $2,055 million. In this case discounted benefit cost ratio increases from 1.14 to 1.79.

[31] We note an important caveat here in that the three categories of net benefits are generated from different references that may not fully compare or complement each in either scale or scope, or in a consistent methodology. At the same time, the magnitudes in Table 4 offer insights into the extended benefits that logically follow from a more productive infrastructure. The findings are consistent with the IEA report on multiple benefits of energy efficiency improvements as suggested by Campbell et al. (2014). *Capturing the Multiple Benefits of Energy Efficiency*. Paris, France, International Energy Agency.
http://www.iea.org/publications/freepublications/publication/Captur_the_MultiplBenef_ofEnergyEficiency.pdf.

Appendix A. Further Insights on Energy Productivity and the Economy

On any given weekday, a delivery truck will negotiate the streets of Arlington County to deliver needed goods, or a software engineer might "telecommute" from home rather than travel to the office. And as those activities are underway, a repair technician may power up various equipment to diagnose and then repair a local school bus while a construction worker may be on the way to deliver a replacement part that will allow his team to continue a building repair. These separate work events all share three critical elements as residents and businesses perform an amazing variety of tasks to maintain a $37 billion economy.

The first element is that someone undertakes an activity to get the job done. This is typically referred to as the labor component of economic activity, or perhaps skilled employment. The second is the use of machinery or some type of equipment that facilitates the production of goods and services. This item is the result of annual investments made each and every year in that equipment, or perhaps in the supporting infrastructure that enables all other equipment to be used. Buildings, roads, bridges, pipelines, power plants, and new installations of renewable energy technologies are all examples of supporting infrastructure.

The combined investments in all of the appliances, equipment, and infrastructure together, as they accumulate over time, are often referred to as capital. The third element in the production process is the flow of high-quality energy – electricity, natural gas, diesel fuel or gasoline equivalents, whether they are provided by conventional energy supplies or by renewable energy resources. It is energy in the form of food that animates labor; and it is energy in the form of electricity, natural gas or diesel fuel that enables equipment and devices (i.e., capital) to carry out the desired set of tasks. Depending on the mix and the productive uses of all resources that are put to work, the Arlington County economy is able to deliver an assortment of goods and services to meet the needs of not only regional businesses and the local residents, but also many neighboring cities and counties throughout the United States and the world. This so-called work can be measured as personal income or as gross domestic product (GDP).

In most economic development assessments, labor and capital are often thought to be the main elements that drive economic activity. Yet, it is energy—the third, and the most often overlooked component of the economic process, that may also prove to be the more critical driver of social and economic well-being. To extend our example above, the repair technician cannot assess possible solutions without electricity to power a diagnostic tool. The construction worker cannot effectively carry out assigned tasks without electricity to power equipment or diesel fuel necessary for various work vehicles. When optimally sourced and efficiently used, energy can amplify local economic development and foster a more robust and resilient economy.

There is no question that the production and use of energy are equally critical to the economic well-being of Arlington County, the Commonwealth of Virginia and the United States as whole. But as the International Energy Agency (IEA) underscores, there is also a critical need for greater emphasis on the more efficient use of energy and a more diversified, clean energy resource portfolio. The IEA further noted that the inefficient conversion of energy can create a large array of problems which can weaken or constrain the development of a more robust economy.[32]

German physicist Reiner Kümmel and his colleagues studied the economic process and noted that the economic weight of energy is significantly larger than its cost share.[33] Research by economist Robert Ayres and his colleague Benjamin Warr documented that improvements in both the quality and efficiency of delivered energy services may be the critical factor in the growth of an economy.[34] Indeed, they suggested that a greater level of energy efficiency is one of the primary drivers that support meaningful technological progress, and that sustained technological progress may come only with extensive upgrades in a nation's or region's overall infrastructure as it enables greater energy and resource efficiency.

A recent study on delivering greater economic resilience in urban areas, with analytical results also specific to Washington, DC, Philadelphia and El Paso, amplified these insights. It concluded that the transition to a low-carbon and more robust economy should be done in a way that ensures both the higher accumulation of productive capital and the more productive use of energy.[35] Both principles are wholly consistent with the Community Energy Plan of Arlington County.

As detailed in a 2015 journal article, it turns out that the U.S. economy through 2010 was only 14 percent energy efficient. That is to say, of all the energy consumed within the economic process, 86 percent of it was wasted—released as heat, greenhouse gases and other pollutants.[36] While further updates suggest that that scale of inefficiency might have improved to perhaps an overall of 16 percent efficiency in more recent years, in reality that means the U.S., the Commonwealth of Virginia, and Arlington County all appear to waste over 80 percent of their high quality energy resources. With that magnitude of ongoing energy losses each day, and an over-reliance on fossil fuel resources more broadly, Arlington may face serious economic and competitive challenges should it continue with its current pattern of energy production and consumption.

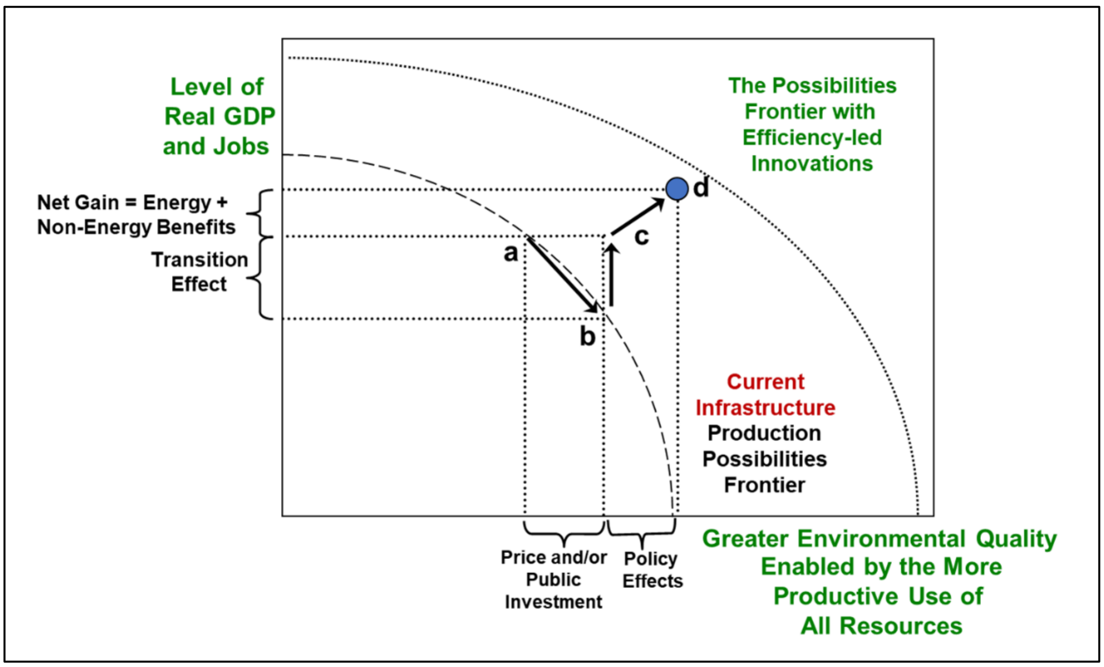
Systematic upgrades in the use of much more energy-efficient technologies and productive investments in renewable energy systems, as suggested in this assessment, can provide a very large part of the County's energy needs by 2050. As also indicated, it is both technically and

[32] See Campbell et al. (2014), cited in the previous footnote.
[33] Op cit., footnote 25.
[34] Op cit., footnote 24.
[35] See, Greg Kats and Keith Glassbrook, Delivering Urban Resilience (2018), Washington, DC: Stay Cool Save Cash Coalition, https://www.staycoolsavecash.com/analysis/delivering-urban-resilience-full-report.
[36] For more background and a deeper discussion on the critical link between the productive conversion of high quality energy and a robust economy, see Robert U. Ayres and Benjamin Warr (2009), op cit., footnote 24. Also see John A. "Skip" Laitner (2015), "Linking energy efficiency to economic productivity: recommendations for improving the robustness of the U.S. economy." *WIREs Energy Environ*, 4:235–252. https://doi.org/10.1002/wene.135. For a European application of these perspectives, read Jeremy Rifkin, Benoit Prunel, J. A. S. Laitner, Solenne Bastie, Francis Hinterman and Shawn Moorhead (2013). *Third Industrial Revolution Master Plan Nord-Pas de Calais, France*. Bethesda, MD, TIR Consulting.

economically feasible to encourage such a transition.[37] In effect, a significant portion of the millions of dollars already spent each year for energy consumption can be used in other ways to more productively strengthen the county's larger economy—provided local business leaders and local policymakers choose to encourage and enable those smarter and more productive investments to be made.

Figure 6, below, provides a conceptual framework that helps pull the CEP strategy and the resulting Innovation Scenario into a useful perspective. While we cannot know at this time the scale of the eventual stimulus, the productive impact of the many positive collaborations that will be necessary, or the precise outcomes that might result from such innovations, we can offer a positive general explanation of how multiple benefits are likely to emerge through the Arlington County plan.

Figure 6. Conceptual Framework for Evaluating CEP Innovation Scenarios



Source: John A. "Skip" Laitner for the Arlington Community Energy Plan (September 2019).

The assumption might be made that Arlington County is already on what is called a production frontier at an optimal point "a" in the Figure 6 diagram. Given the current market structures, technologies and social needs, any change to satisfy a demand for greater efficiencies, or for the reduction in greenhouse gas emissions, must likely result in a downward shift to the right on this

[37] San Diego Gas & Electric Senior Vice-President of Power Supply, James Avery highlighted emerging problems associated with the rapid adoption of photovoltaic energy systems. He noted: we haven't begun "to think of the technologies that will evolve" out of the digitalization of the grid. He said, the "wealth of opportunities far exceeds the programs and applications that exist today." See, http://www.utilitydive.com/news/sdge-if-youre-not-prepared-for-the-change-its-too-late/366979/.For Arlington County, these opportunities might include both domestically-produced resources as well as cost-effective imported energy services that depend on an array of renewable energy technologies–with all resources used more efficiently.

graphic illustration. Arlington County – indeed, the Commonwealth of Virginia and the United States as a whole – might achieve some mix of isolated productivity improvements, and there might be some reduction in greenhouse gas emissions, but it must surely come at the cost of a reduction in jobs, incomes and GDP. While the CEP Innovation Scenario envisions a set of programs, policies, and incentives that may initially shift the economy to point "b", such a shift may also create a productive transition that lifts the economy to point "c." The result is an improvement in energy efficiencies (as well as the more productive use of resources) even as the economy remains at a relatively stable level of GDP.

At some point, however, the various energy and non-energy benefits that result from an array of incentives and policy initiatives can boost the performance of the economy to a higher-than-expected level of performance. Although not drawn to scale in Figure 6, the migration from point "a" to the eventual point "d" might represent a 30 percent reduction in energy requirements per unit of economic activity or GDP. The net energy savings, together with a transition to an 80 percent or better renewable energy system might, in turn, stimulate a significant boost in net gains in jobs and GDP (as already seen in the results shown in Table 4 in the previous section of this assessment).[38]

[38] It is true that a three or four percent absolute improvement over any long-term forecast may seem a very small benefit. In that regard, the $87 million net gain in GDP suggested in Table 3 of this assessment, compared to a reference case projection of more than $54 billion, may seem less than appealing. Yet, equally important is understanding that the "movement to" and the "outward movement of" the production frontier can provide a sustainable basis to ensure a 2.5 percent growth in GDP rather than the prospect of a lagging growth rate of 2 percent growth rate. Indeed, that may be among the more important outcomes of underpinnings of the Community Energy Plan. For instance, the mere subtraction of 0.5 percent from a 2.5 percent growth rate can mean an economy that is ~14 percent smaller by 2050. The OECD is sufficiently concerned about lagging productivity worldwide, including both the United States and other developed economies, that it released a special study on this topic. See, The Future of Productivity, OECD Publishing, Paris, 2015. http://dx.doi.org/10.1787/9789264248533-en.

Appendix B. Narrative on the DEEPER Modeling System

Although the DEEPER Model is not a general equilibrium model, it does provide sufficient accounting detail to match import-adjusted changes in investments and expenditures within one sector of the economy and balance them against changes in other sectors.[39] More to the point of this exercise, the model can specifically explore the energy and non-energy productivity benefits from what is now characterized as a CEP Innovation Scenario—especially as it is transformed into a pro-active "Roadmap Next Economy."

One critical assumption that underpins the core result of the DEEPER analysis is that any productive investment or spending—whether in energy efficiency, renewable energy, and/or a more dynamic infrastructure that pays for itself over a reasonably short period of time—will generate a net reduction in the cost of energy services (as well as a lower cost of other resources which are needed to maintain the material well-being of the Arlington County regional economy). That net reduction of energy and resource expenditures can, then, be spent for the purchase of other goods and services. We noted in the discussion surrounding Figure 2, the redirecting of $1 million in spending away from energy suggests there may be roughly a net gain of about 5.0 jobs. Depending on the many sectoral interactions, as well as the complete assessment of the many effects summarized and discussed in Table 1 of this assessment, the net gain in jobs may widen or close as the changed pattern of spending works its way through the model and as shifts in labor productivity change the number of jobs needed in each sector over a period of time.[40]

Once the mix of positive and negative changes in spending and investments has been established for the CEP Innovation Scenario, the net spending changes in each year of the model are converted into sector-specific changes in final demand. Then, following the pattern highlighted in the diagram of the DEEPER Modeling System, the full array of changes will drive a dynamic input-output analysis according to the following predictive model:

---

[39] When both equilibrium and dynamic input-output models use the same technology, investment, and cost assumptions, both sets of models should generate a reasonably comparable set of outcomes. For a diagnostic assessment of this conclusion, see, "Tripling the Nation's Clean Energy Technologies: A Case Study in Evaluating the Performance of Energy Policy Models," Donald A. Hanson and John A. "Skip" Laitner, Proceedings of the 2005 ACEEE Summer Study on Energy Efficiency in Industry, American Council for an Energy Efficient Economy, Washington, DC, July 2005.

[40] Note that unlike many policy models, DEEPER also captures trends in labor productivity. That means the number of jobs needed per million dollars of revenue will decline over time. For example, if we assume a 1.3 percent labor productivity improvement over the 33-year period from 2017 (the base year of the model) through 2050, 14.6 construction jobs supported by spending of $1 million within the United States today may support only 9.5 jobs by the year 2050. The calculation is 14.6 $/1.015^{(2050-2017)}$ = 9.5 jobs (rounded to the nearest tenth.

$X = (I-A)^{-1} * Y$

where:

X = total industry output by a given sector of the economy

I = an identity matrix consisting of a series of 0's and 1's in a row and column format for each sector (with the 1's organized along the diagonal of the matrix)

A = the matrix of production coefficients for each row and column within the matrix (in effect, how each column buys products from other sectors and how each row sells products to all other sectors)

Y = final demand, which is a column of net changes in spending by each sector as that spending pattern is affected by the policy case assumptions (changes in energy prices, energy consumption, investments, etc.)

This set of relationships can also be interpreted as

$\Delta X = (I-A)^{-1} * \Delta Y$.

A change in total sector output equals the expression $(I-A)^{-1}$ times a change in final demand for each sector.[41] Employment quantities are adjusted annually according to exogenous assumptions about labor productivity. From a more operational standpoint, the macroeconomic module of the DEEPER Model traces how each set of changes in spending will work or ripple its way through the regional economy in each year of the assessment period. The end result is a net change in jobs, income, and GDP (or value-added).

For a review of how an Input--Output framework might be integrated into other kinds of modeling activities, see Hanson and Laitner (2009). While the DEEPER Model is not an equilibrium model, as explained previously, we borrow some key concepts of mapping technology representation for DEEPER, and use the general scheme outlined in Hanson and Laitner (2009).[42] Among other things, this includes an economic accounting to ensure resources are sufficiently available to meet the expected consumer and other final demands reflected in different policy scenarios.

[41] Perhaps one way to understand the notation $(I-A)^{-1}$ is to think of this as the positive or negative impact multiplier depending on whether the change in spending is positive or negative for a given sector within a given year.

[42] "Input-Output Equations Embedded within Climate and Energy Policy Analysis Models," by Donald A. Hanson and John A. "Skip" Laitner, in Sangwon Suh, Editor, *Input-Output Economics for Industrial Ecology*. Dordrecht, Netherlands: Springer, 2009. See also, "A Pragmatic CGE Model for Assessing the Influence of Model Structure and Assumptions in Climate Change Policy Analysis," by Stephen Bernow, Alexandr Rudkevich, Michael Ruth, and Irene Peters. Boston, MA: Tellus Institute, 1998.