# AMERICA 3.0
# THE RESILIENT SOCIETY

## A SMART THIRD INDUSTRIAL REVOLUTION INFRASTRUCTURE AND THE RECOVERY OF THE AMERICAN ECONOMY

A Report Prepared for Senator Charles Schumer, U.S. Senate

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# HIGHLIGHTS

## THE AMERICA 3.0 INFRASTRUCTURE TRANSFORMATION (2020 – 2040)

- A $16 TRILLION DOLLAR INVESTMENT TO SCALE, DEPLOY, AND MANAGE A SMART DIGITAL ZERO-EMISSION THIRD INDUSTRIAL REVOLUTION INFRASTRUCTURE FOR A 21ST CENTURY ECONOMY
- THE CREATION OF AN AVERAGE 15 TO 22 MILLION NET NEW JOBS OVER THE PERIOD 2022 to 2042
- EVERY DOLLAR INVESTED IN THE AMERICA 3.0 INFRASTRUCTURE IS PROJECTED TO RETURN $2.9 DOLLARS IN GDP BETWEEN 2022 AND 2042
- AN INCREASE IN THE ANNUAL GROWTH RATE OF GDP FROM A BUSINESS AS USUAL 1.9% GDP TO 2.3% GDP, AND A $2.5 TRILLION LARGER GDP IN 2042, (MOVING FROM $29.2 TO $31.7 TRILLION IN THAT YEAR)
- 377 BILLION TO LAY DOWN 22,000 MILES OF UNDERGROUND CABLE AND INSTALL 65 TERMINALS TO BUILD OUT AND MANAGE A STATE-OF-THE-ART HIGH VOLTAGE DIRECT CURRENT CONTINENTAL ELECTRICITY INTERNET ACROSS THE COUNTRY
- 2.3 TRILLION TO INSTALL AND MAINTAIN 74,000,000 RESIDENTIAL MICROGRIDS, 90,000 COMMERCIAL/INDUSTRIAL MICROGRIDS, AND 12,000 UTILITY-SCALE MICROGRIDS IN COMMUNITIES ACROSS AMERICA FOR THE GENERATION AND SHARING OF RENEWABLE ELECTRICITY
- $97 BILLION DOLLARS TO INSTALL FIBER-BASED BROADBAND IN ALL 121 MILLION HOMES ACROSS THE UNITED STATES
- $1.4 TRILLION TO BUILDOUT AND MAINTAIN A NATIONWIDE EV CHARGING INFRASTRUCTURE TO POWER THE MILLIONS OF ELECTRIC VEHICLES COMING INTO THE MARKET BETWEEN 2020-2040
- $4.4 TRILLION TO RETROFIT THE NATION'S COMMERCIAL AND INDUSTRIAL BUILDINGS
- $4.3 TRILLION TO INSTALL SOLAR PV ON OR AROUND COMMERCIAL BUILDINGS
- $1.8 TRILLION TO RETROFIT RESIDENTIAL BUILDINGS
- $1.61 TRILLION TO INSTALL PV ON OR AROUND RESIDENTIAL BUILDINGS
- A ROUGHLY DOUBLING IN AGGREGATE EFFICIENCY – THE RATIO OF POTENTIAL WORK (AMOUNT OF REAL GDP) COMPARED TO USEFUL ENERGY – ACROSS THE AMERICAN ECONOMY
- THE AVOIDANCE OF $3.2 TRILLION IN AIR POLLUTION AND HEALTHCARE COSTS AND $6.2 TRILLION IN CUMULATIVE CLIMATE-RELATED DISASTER COSTS
- PRIORITIZATION OF THE AMERICA 3.0 INFRASTRUCTURE IN THE NATION'S DESIGNATED 8,700 OPPORTUNITY ZONES – THE POOREST AND HIGHEST-RISK DISADVANTAGED COMMUNITIES
- THE SHIFT IN THE BUSINESS MODEL FROM OWNERSHIP TO ACCESS, MARKETS TO NETWORKS, SELLERS AND BUYERS TO PROVIDERS AND USERS, PRODUCTIVITY TO REGENERATIVITY, GDP TO QUALITY OF LIFE INDICATORS, AND NEGATIVE EXTERNALITIES TO CIRCULARITY ACROSS THE VALUE CHAINS

# AMERICA 3.0

# NEW ECONOMIC OPPORTUNITIES
# AND MILLIONS OF NEW JOBS

## Working Narrative with Indicative Results
## for the America 3.0 Transition

ECONOMIC AND HUMAN DIMENSIONS RESEARCH ASSOCIATES

*See Appendix for a description of Economic and Human Dimensions Research Associates's scope of work

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# 1 THE ROLE OF OPPORTUNITY COST IN AN ECONOMIC FUTURE

Choices have consequences, whether directly or indirectly. For example, the oil and gas industry now supports as many as 10.3 million jobs within the United States.[174] The statistics bear that out. But it is also true that our use of oil and gas resources contributes about two-thirds of the nation's energy-related carbon dioxide emissions.[175] Moreover, one recent study by the International Monetary Fund (IMF) suggests that gasoline usage may create a series of climate, air quality health, and other economic burdens which have a cost of roughly equal to $1.94 per gallon of gasoline. While natural gas is considered a significantly cleaner fuel, that same IMF study indicates that it might have a climate and environmental health burden of 33 to 44 cents per gallon of gasoline equivalent.[176] So natural gas is cleaner but still has a significant cost.

With that backdrop, the question that may naturally arise is whether the trade-off or the benefit of 10.3 million jobs is worth the health and environmental damages driven by the large-scale consumption of oil and gas resources? In other words, what is the "opportunity cost" of continuing any given level or pattern of energy consumption? And might we pose an even better question by asking whether we can get more jobs, with even greater additional economic benefits, by investing in alternative energy strategies other than conventional fuels—in this case a of combination greater energy efficiency and renewable energy resources on the same scale of current oil and gas consumption. If we step back and actually explore the full array of the evidence now available to us, it appears that the same money we now spend for oil, gas, and coal might actually produce substantially more employment opportunities if scale up our investments in both energy productivity improvements and the green energies. More critically, it does appear that if we ask the right questions, we can provide an increase in total jobs, even as the new series of choices allow a significant reduction in greenhouse gases and other air pollutants. This will all, in turn, facilitate the transition to a generally healthier environment. . . and economy.

In this analytical narrative we explore the logic and consequences of investing in two different kinds of energy infrastructures. The first is an infrastructure that depends on the more conventional development of fossil fuels as part of the 20th century buildout. The second is a more complex, vibrant and smart Third Industrial Revolution Infrastructure which our colleague Jeremy Rifkin calls *America 3.0 The Resilient Society*. Among the key factors that will enable this 21st Century transition is the more productive use of clean energy resources as their higher level of aggregate efficiencies allow "ever-larger collectivities of human beings to

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[174] See, for example, "Execs' Open Letter to 2020 Candidates Promotes Oil & Natural Gas 2/24/2020." As explained in subsections 4.2.2 of this narrative, the 10.3 million jobs cited here reflects not simply the direct jobs in the oil and gas industry, but also the indirect and induced jobs also supported by the larger industry's revenues. https://www.westernenergyalliance.org/pressreleases/execs-open-letter-to-2020-candidates-promotes-oil-natural-gas

[175] *Annual Energy Outlook 2020 with projections to 2050* (AEO 2020). Table 18 on Energy-Related Carbon Dioxide Emissions by Sector and Source. Washington, DC: U.S. Energy Information Administration. https://www.eia.gov/outlooks/aeo/tables_ref.php

[176] Parry et al. (2014). This was a book which explored how energy prices might be adjusted to reflect the costs of air pollution, the impacts of climate change, and other economic burdens. The original values for gasoline were listed as $0.43 per liter, and for natural gas as $2.30 per gigajoule and $3.10 per gigajoule—in 2010 U.S. Dollars. Using appropriate heat values and the rate of inflation from 2010 to 2020, the values were adjusted for easier comparison as shown in the text.

engage in more complex, integrated, and inclusive economic, social, and political life as an extended social organism."[177]

We explore these choices in four separate ways. First, we provide an initial backdrop to understand how greater energy and resource productivity—what we call higher levels of aggregate efficiencies—can promote a more robust social and economic well-being. Second, we look at the way jobs might be supported by different patterns of investments and energy expenditures. Next, we explore potential impacts of air pollution and the consequences on the health and economy nationally. And finally, we explore the possibility of severe climate disruption. All of these have very real social, economic, climate and other environmental consequences.

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[177] The America 3.0 Framing document.

# 2 OVERVIEW OF U.S. ENERGY CONSUMPTION

In 2019, the 331 million people living within the United States spent an estimated $1.2 trillion to meet their combined needs for an array of energy services (EIA 2020)[178]. That is equivalent to an economy-wide per capita energy bill of about $3,600 per person per year (with costs expressed in 2019 constant dollars). The many payments that were made each day, or each month, for energy services that enabled U.S. residents to cool and light their homes, drive to work, listen to music, or watch television. For some, the payments simply provided the means to maintain a comfortable home. For others, the disbursements powered their many business enterprises. Purchases of electricity enabled access to the Internet, as well as filtering and purifying the water that was delivered to local homes, schools, and businesses each and every day. In short, the variety of energy services impacted almost every element of our social and economic well-being.

Although the U.S. economy derives important benefits from the use of the many different forms of energy resources, the inefficient use of all forms of energy also creates an array of costs and constraints that burden our economy. As one critical example, the incomplete combustion of fossil fuels releases massive amounts of pollutants into the air. The current mix of energy resources used to support worldwide economic activity will also result in more than $100 billion of health and environmental damages annually within the United States (Harvey 2016). According to the Energy Information Administration, the nation's energy consumption also dumped 5.1 billion tons of energy-related carbon dioxide into the atmosphere in 2019 alone (EIA 2020). This contributes to an acceleration of global climate change. In addition, a 2014 report published by the International Energy Agency (IEA) noted that the inefficient use of energy imposes an array of costs which can weaken or constrain job creation and the development of a more robust economy (Campbell, Ryan et al. 2014).

As detailed in a variety of other recent studies, it turns out that both the U.S. and the global economy may only be 16 percent energy-efficient (Laitner 2019, based on Ayres and Warr 2009, Laitner 2015, and Voudouris and Ayres et al. 2015; see also, Blok et al. 2015). Said differently, of all the high-quality energy resources consumed within both the U.S. and international markets, an estimated 84 percent of that energy is wasted as it is consumed. Research by economist Robert Ayres and his colleague Benjamin Warr (2009) documents that improvements in both the quality and efficiency of delivered energy services may be the critical factor in the well-being of an economy. They further suggest that a greater level of what we might call energy productivity, aggregate energy efficiency, or simply "aggregate efficiency," may be one of the primary drivers that supports meaningful social and technological progress.

So, whether concerns are about energy costs, energy security, lagging job creation or global climate change, there is an increasing emphasis on, and review of, the role that energy plays within any national economy—or even the global economy more generally. And while there are large opportunities to promote the more efficient use of energy and other resources—for example, shifting to a smart, more productive electricity grid which supports 80 percent or more renewables—the mere existence of an opportunity does not guarantee a positive outcome. In a nutshell, the more productive use of energy and resources will not automatically

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[178] EIA 2020. Op. Cit. See Table 3. "Energy Prices by Sector and Source."

happen. *It will take purposeful effort, guided by smart policies and programs, to drive the necessary activities and investments to achieve optimal, large-scale benefits* (Laitner et al. 2018, and also Lebot and Weiland 2020).[179]

But how to do things differently? What is needed to accelerate the more productive use of energy and other resources—at sufficient scale—over the next two or three decades? And equally critical, what is needed to achieve the deep reductions in energy-related carbon dioxide emissions over the next decade as suggested by the International Panel on Climate Change in a report released in October 2018 (IPCC 2018)? In the sections that follow, we briefly explore what we call the "economic imperative of much greater aggregate or resource efficiency."

Within this short narrative, especially given the time constraints to respond to a national inquiry, we cannot undertake a full-blown jobs and economic assessment which examines the magnitude of effort, the investments that are essential to elevating the performance of the American economy, and then fully document the likely very positive impacts on future employment and career development opportunities. Rather, as Rifkin highlights in the opening narrative of what we might now call the America's "innovation strategy", or the "America 3.0 roadmap," here we focus especially on *the compelling logic* of how the transformation of America's infrastructure will likely ensure a more robust social well-being and job creation process within the American economy. Equally important will be the large scale of the policies and programs required to support that transition. In this regard we then explore the employment and other economic benefits that will result from the more productive investments in the nation's appliances, equipment, and infrastructure.

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[179] As the term is used here, "at scale" generally means a reduction of energy use by 40 percent or more over a projected level of consumption by the year 2040. Examples of international scenarios which achieve that scale of reduction can be found in European Climate Foundation (2010), Laitner et al. (2012), Teske et al. (2017), and Metropolitan Region of Rotterdam and Den Haag (2017). It might be worth noting that, as an update to an earlier study (Laitner et al. 2012), Nadel (2016) found that 13 efficiency specific measures in the United States, if pursued aggressively, would reduce 2050 energy use by 50 percent relative to currently predicted levels. But as he also noted, achieving those energy efficiency savings would require an expansion of energy efficiency efforts and policies well-beyond business-as-usual. And in this case, greater aggregate energy efficiency would also be enabled by a more productive infrastructure.

# 3 THE IMPERATIVE OF A MORE ENERGY PRODUCTIVE ECONOMY

The American economy sits at the crossroads of both challenges and opportunities. On the one hand, the U.S. market shows signs of a lagging performance—among other things, weakened by the inefficient use of resources, whether capital, materials, water and especially energy. The newly released report by the American Society of Civil Engineers (ASCE 2021), for example, indicates that a weakened and outdated infrastructure will cost the average household more than $3,300 per year in disposable income through 2039. If we step back and explore the issue more deeply, we can see a slow erosion of our economic well-being over a longer historical period. Over the period 1970-2007, for instance, the nation's real per capita personal income—a useful proxy of economy-wide productivity—grew at a reasonable rate of 2.1 percent per year. Over the next 12-year period through 2019, however, the growth of per capita income weakened significantly, dropping to 0.9 percent per year (Woods and Poole 2020). Recent projections indicate the growth rate might pick up again, but it will move at perhaps a more sluggish rate of 1.3 percent over the period 2019 through 2050 (Woods and Poole 2020). The difference between a 2.1 percent rate of improvement compared a 1.3 percent implies an economy that may be 25 percent smaller than otherwise expected by the year 2050. A weaker economy means less revenue for education and healthcare, as well as likely fewer investments that can support future infrastructure improvements and upgrades.

Figure 1, below, highlights the central and critical role of energy productivity or aggregate efficiency as it supports or drives greater per capita incomes within the United States. Long-story short: there is a critical link between higher levels of aggregate efficiency as it enables a reasonable improvement in real per capita income over time. As we look at the data in Figure 1, we can see the straightforward positive connection between aggregate efficiency (i.e., energy productivity as it is defined below) and our overall economic well-being. The latter is reflected in the rise of real per capita personal income within the United States.

In 1950 the consumption of one million Btus of total energy supported only $63 of economic activity (Gross Domestic Product, or GDP, expressed in constant 2012 dollars).[180] That scale of productivity enabled an average personal income of about $10,700 per person in 1950 (also expressed in 2012 dollars). While the economic transition that followed World War II displayed an uneven improvement (though still a relatively tight pattern in those years), in the 1980s a lock-step relationship emerged. By 2019 one million Btus of energy buttressed economic activity so that it supported both $190 of GDP, together with an average income of nearly $46,000 per year. While the improvement is a highly positive outcome, the bad news—as we have already hinted—is that the rate of improvement for both income and energy productivity appears to be declining.

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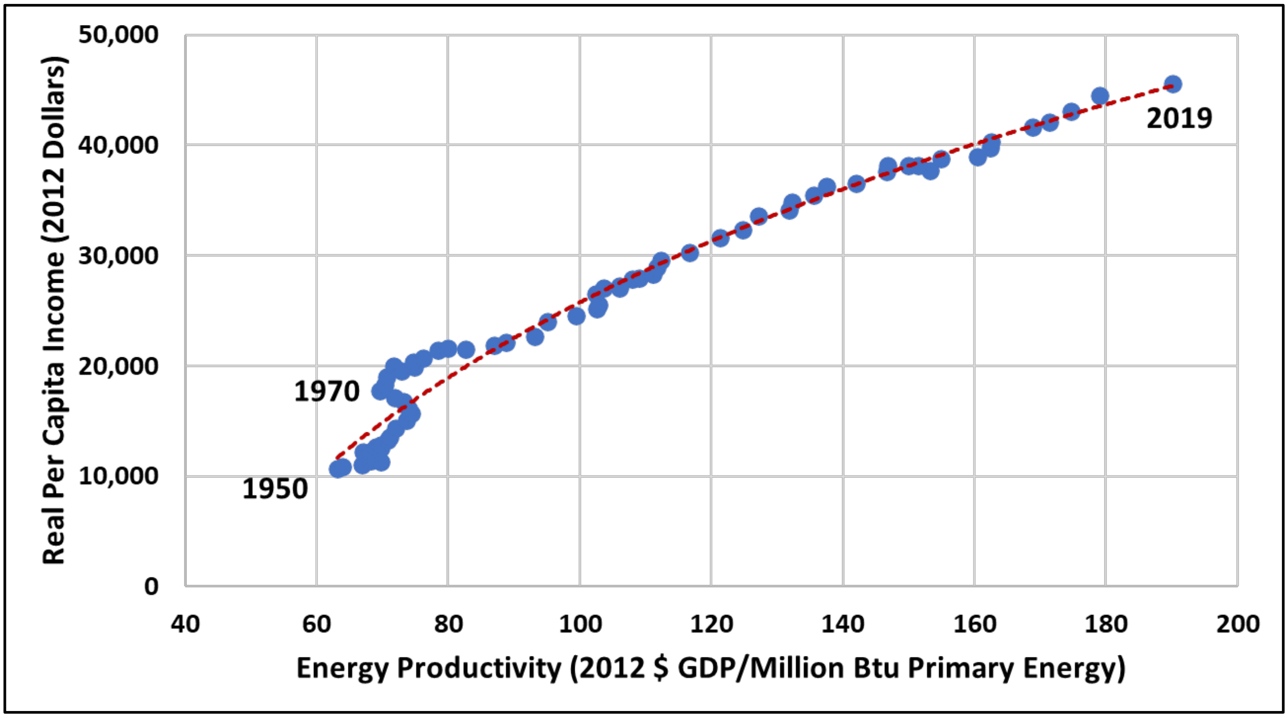
[180] Drawing from information published by the Energy Information Administration we learn that one million British Thermal Units (MBtu) is equal to 8.8 gallons of gasoline or 293 kilowatt-hours of electricity.

*Figure 1. Trends in U.S. Energy Productivity as it tracks Per Capita Income (1950-2019)*



***Source:*** *Calculations by John A. "Skip" Laitner using EIA and BEA data for the United States (July 2020).*

As measured here, aggregate efficiency (i.e., again "energy productivity") is a function of three key elements. The first is the familiar energy efficiency improvements at the end-use level. By this we mean more efficient household or business lighting, more efficient heating and air-conditioning systems as well as the more energy-efficient appliances and equipment within our homes and businesses. It also includes the more efficient use of heat and electricity within our industrial processes. And it means greater fuel economies in our vehicle stock. The latter include not only cars and trucks, but also buses, trains, airplanes and shipping.

A second category of aggregate efficiency is greatly improving the efficiency of electricity generation. The current generation of electric power plants as well as the transmission and distribution system within the U.S. is only about 35 percent efficient. That is, for every single kilowatt-hour (kWh) of electricity delivered to our homes and businesses, the electric utility industry requires the energy of about 2.9 kWh (of heat equivalent) to generate and deliver that electricity to end-users. What our nation wastes just in the production and distribution of electricity is more than Japan uses to power its entire economy (EIA 2021).

What is the solution in this second case? We can move toward the much greater deployment of renewable energy systems. The reason? Renewable energies can transform the ratio of primary energy needs from a needlessly high level of 2.9 to a much lower and much more productive index closer to 1.0. That move alone could eliminate the need for more than 23 quadrillion Btus of energy (or Quads),[181] or on average, about 23

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[181] One quadrillion ($10^{15}$) British Thermal Units, or a quad, is sufficient energy to power ~5.8 million homes or ~20 million cars for an entire year.

percent of both current and future energy requirements through the year 2040. In effect, the transition to renewable energy systems opens up a critical energy productive pathway.

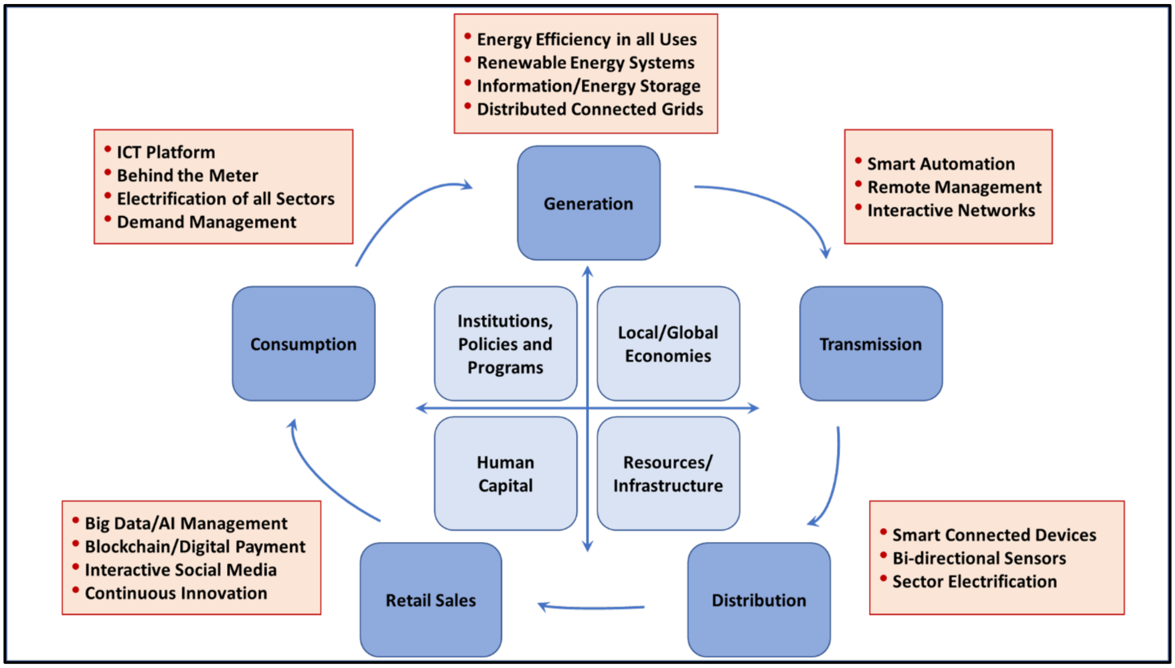
The last element of these three variables is the more productive use of capital, materials, chemicals and water. By reducing the aggregate of wastes in all of those categories, we can further reduce the energy necessary to transform such resources into the desired goods and services and distribute them in ways that support our social and economic well-being. Adding up all of these three elements—(i) greater end-use energy efficiency, (ii) the bigger deployment of renewables; and finally, (iii) the full reduction of waste in the use of all other resources—can greatly lower total energy needs, even as the nation's economy can become a more robust and a more sustainable social enterprise in the decades ahead. In other words, the elimination of waste of all kinds would amplify our aggregate efficiency that, in turn, can drive up the potential for an even greater levels of job opportunities and average personal income.

# 4 CRITICAL BUILDING BLOCKS AND JOBS

Notwithstanding a slow erosion in the robustness of the U.S. economy, two critical ideas emerge in how we might encourage a more positive outcome, including an expanded, renewables-oriented national grid for electricity. This follows an ongoing set of interviews and discussions with more than 100 people since August 2018,[182] as well as a detailed review of several major assessments (see, especially the narratives provided by Black & Veatch and Smith + Gill Architecture in the larger framing document of this document, as well as Laitner et al. 2012, and also 2018; Jadun et al. 2018; and IRENA 2019; among many others).[183]

First, greater aggregate efficiency, and therefore an increasing social and economic well-being, is a clearly desired outcome. Second, the transition toward that desired outcome will require a substantial upgrade in both existing and also new capital stock and infrastructure to enable the more productive use of all resources. Underpinning that transition, as highlighted in Figure 2, is an array of information and communication technologies which support a highly productive electrification of the economy.[184]

*Figure 2. Array of Systems and Technologies to Transform the Energy Ecosystem*



***Source:*** *Graphic Illustration adapted from the World Bank by John A. "Skip" Laitner (July 2020).*

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[182] The many interviews began as part of an invitation to help lead a three-day deep dive, "Rethinking Energy Demand," initiated by colleagues with a European team from the International Institute of Applied Systems Analysis (IIASA) and the Japanese-based Research Institute for Innovative Technologies for the Earth (RITE). This was convened September 2018 with literally dozens of interviews and discussions since that gathering.

[183] A variety of other critical assessments of future opportunities might include Blok et al. (2015), Hawken (2017), Ekins and Hughes et al. (2017); Jacobson et al. (2017), MRDH (2017), Teske et al. (2015), and Zuckerman et al. (2016).

[184] As discussed more completely in the Black & Veatch contribution to the America 3.0 assessment.

## 4-1 Buildout of a More Productive Infrastructure

The United States is the largest global economy with an annual Gross Domestic Product (GDP) in 2019 of more than $19 trillion per year (in constant 2012 US dollars). As big as the economy may be, a variety of documents and assessments suggest a reasonable transition of an economy, from one that uses ~100 quads of energy today, into an economy that is perhaps 80 percent larger by 2050 (EIA 2020), but also one that uses as little as 65 quads of energy in that year (as adapted from Laitner et al. 2012). This is about 40 percent less than we might otherwise require in that year. What may be less appreciated, however, is the scale of the nation's existing capital stock—a financial accounting of all fixed assets (roads, buildings, electrical generating units, as well as other structures and equipment) and consumer durables (cars and appliances with a three-year or longer life). According to data from the Bureau of Economic Analysis, our physical assets are on the order of $60 trillion (again, in constant 2012 dollars; BEA 2020). This is about 3.1 times the size of the overall scale of our economic activity. Most would agree that is a very tall order. And even more judiciously, that transformation will require a number of critical interconnected attributes as highlighted in Figure 2 above.

To drive that transition, a working estimate from IRENA (2019) suggests a total expenditure of perhaps 60 percent of one year's GDP. That is, to ensure the upgrade of the nation's infrastructure, also enabling the transition toward a more productive electrification of the economy, may require on the order of $10 to $12 trillion expended over the period 2019 through 2050.[185] The investment would enable a greater level of energy and resource productivity—again, aggregate efficiency—even as it supports a larger number of jobs as discussed in the next section that follows.

Nevertheless, a much greater level of energy and resource productivity, together with a conversion to 86 percent renewables in the generation of electricity (as suggested in IRENA 2019, but especially with contributions from Black & Veatch and Smith + Gill highlighted in this report), might lower total energy demand in 2050 to as little as 65 quads of primary energy equivalent (adapting further insights from Laitner et al, 2012). Following the assessment published by IRENA (2019), for every $1 spent for the energy transition, there would be a payoff of between $3 and $7 over the current period through 2050. This might actually increase overall GDP by 2.5 percent relative to the 2050 Reference Case published earlier this year by the Energy Information Administration (EIA 2020). If that logic holds, the implication is an economy that uses 40 percent less energy but does so in ways that greatly boosts overall economic activity. Nonetheless, a central question to be explored is how investments might actually drive new job creation, an issue explored in the next subsection.

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[185] This estimate is to provide more insight than precision at this point. While various studies (see, for example, Laitner et al. 2018) support a magnitude of this scale, a better estimate would require further and a deeper analysis. This is also true for the illustration of an innovation scenario shown in Figure 2.

## 4-2 Exploring the Jobs Creation Benefits

The United States has a number of promising opportunities that can point the way to a more productive use of its many resources; and to do so in ways that build a more robust, resilient, and sustainable economy. Yet, in the opening of this report it was noted that the current oil and gas industry now supports about 10.3 million jobs in the United States. So, the question becomes, how might we imagine or understand the possibilities of providing an even larger number of jobs through aggregate efficiency?[186] The data in Figure 3, on the following page, provides the first really big clue of what might be possible.

Based on 2019 data from the IMPLAN U.S. national-level data sets (which, in turn, draws on public data made available through a variety of agencies and institutions), we can explore what are called total job coefficients. A subsequent discussion will identify what are called the direct, the indirect, and the induced jobs which add up to a total gain of employment for every million dollars spent within a given sector which is part of the national economy. From the summary Figure 3 graphic we can quickly see that the array of energy resources within the U.S. economy supported an estimated 11.3 total jobs for each one million dollars of purchased energy. That compares to a somewhat larger 14.7 total jobs per million dollars of manufactured goods which might be purchased, as well 19.9 jobs in the construction industry.

In a similar way, for every one million dollars spent on all other goods and serves, the nation's economy supports an average of 18.2 total jobs per million dollars of goods and services that might be purchased within a given year (IMPLAN 2021).[187] Hence, for every one million dollars of energy bill savings generated and that is spent within the country, through greater cost-effective energy efficiency improvements and investments in cost-effective renewable energy technologies, the national economy will gain a net increase of 6.9 new jobs. So, instead of supporting 11.7 total jobs for conventional supplies of energy, the economy will support an average of 18.2 jobs as the energy bill savings are spent, instead, for other goods and services within the United States.

If we did the math, we conceivably can imagine more total jobs from the transition to a higher level of aggregate efficiency, but the story is much more complicated so we turn to what we might call "indicative analytics" or "indicative narratives" that describe four different links of an employment chain as a first step to understanding the full job creation potential, again within the United States. In successive order they are: (i) the seven economic drivers; (ii) the three job effects; (iii) the four substitution impacts; and finally (iv) a set of three deployment variables—all of which can affect the net job benefits. Table 1, that follows, helps open a discussion around the list of at least seven key drivers

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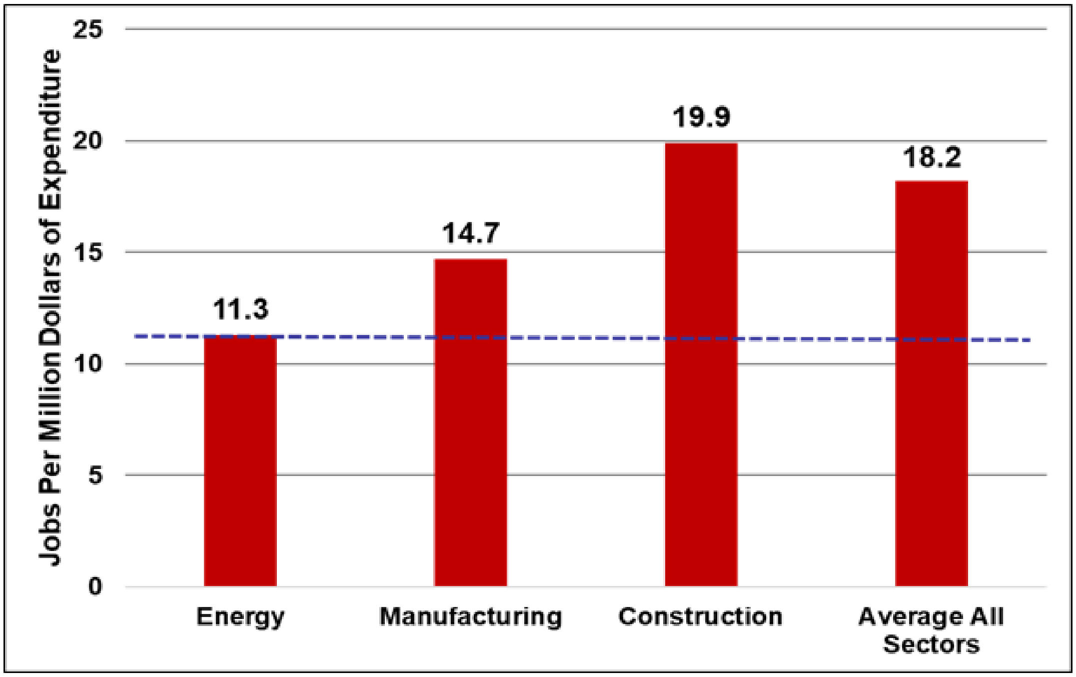
[186] Critical to the explanation that follows is understanding that aggregate efficiency is the result of 3 key drivers, as explained in the discussion explaining Figure 1 of this report, including: (i) greater end-use energy efficiency, (ii) the move to renewable energy technologies which eliminates the need for significant magnitudes of primary energy otherwise lost in the conventional combustion process, and (iii) an improved use of capital, materials, water, and food—further reducing energy needs as part of the production process.

[187] IMPLAN LLC, Huntersville, NC. https://implan.com/. Users of the input-output economic data include academia, federal, state, and local governments, and the private sector.

that are likely to enable a more robust economy as a result of any given Innovation Scenario .

*Figure 3. Total Labor Intensities for Key Sectors within the United States Economy*



**Source:** *John A. "Skip" Laitner, using IMPLAN 2017 Data for the United States (July 2020).*

### 4-2-1 Understanding the Major Drivers of Employment and Economic Benefits

The economy is not any one isolated element or even an array of investments and expenditures; rather it is a system of many interdependent interactions. We can begin to get a sense of those interactions by exploring in Table 1 at least seven different interactive influences or drivers which can positively or negatively help shape the nation's long-term social and economic well-being.

*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:** *John A. "Skip" Laitner as described and discussed in the text of the manuscript.*

**(1) 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 coal, while renewable energy resources produce no direct emissions compared to any form of fossil fuels—different economic sectors have different income and employment intensities. As already reviewed in the Figure 3 discussion, one million dollars' worth of expenditures in various economic sectors supports different levels of employment. Although not explored in detail here, these data demonstrate the idea that the more capital-intensive energy sectors tend to support fewer jobs than almost all other sectors within the U.S. economy.[188]

**(2) Supply Chain Build Up:** The United States generates, perhaps not surprisingly, a large rate of value-added from the intermediate goods and services it purchases (IMPLAN 2021). To the extent that the nation is able to increase its local production capacity for key goods and services, this will increase both the resilience and vitality of the nation's economy. In the context of energy markets, reducing imports of the renewable energy systems, fostering local markets for efficiency and renewable-related industries, further enhances local economic development.[189]

**(3) Energy Cost Reduction:** Investments in energy efficiency and renewable energy reduce the demand for traditional energy sources, generating benefits associated with reduced purchases of traditional energy. Additionally, this reduced demand puts downward pressure on the price of traditional energy, spreading the benefits of clean energy beyond those that consume that energy. This is often referenced as the "Demand Reduction Induced Price Effects," or DRIPE (Taylor, Hedman and Goldberg 2015). Lower prices largely stem from two complementary outcomes. The first is that as less conventional energy may be required, only the lesser-cost marginal resources will be necessary for purchase. That can reduce the total wholesale costs for consumers. Second, greater productivity will place an otherwise downward pressure on other remaining resource costs.

Drawing on data from the EIA's *Annual Energy Outlook 2020* (EIA 2020), for example, if energy demand in 2050 is 70 percent of the projected level, then energy prices might be 15 to 20 percent lower than would otherwise be the case. The reduced quantity of energy that is consumed, assuming the changes are cost-effective, will directly benefit those who make improvements. The lower cost of energy will benefit all remaining uses of energy which translates into cost reductions in the purchase of other goods and services—whether food and household appliances or business equipment and industrial feedstocks. Again, as both the direct energy savings, together with the savings of less-costly resources

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[188] In economics, an input–output model is a quantitative method that represents the interdependencies between different sectors of a national economy or different regional economies. We can think of this as an economic recipe for how different sectors buy or sell goods and services to each other, and how their unique pattern of spending might support total jobs. For a more complete look at the input-output analytical technique, see Miller and Blair (2009).

[189] We can illustrate how building up greater local supply capacity can increase the robustness of the U.S. economy by adapting the idea of the Keynesian multiplier. In this case we substitute the use of domestic resources (DOM) in place of the marginal propensity to consume (MPC). Hence the formula, OUTPUT = [1 / (1 – DOM)]. For example, if a 45% of a given sector's total output is the value-added component (including profit and labor income), and if the sector imports 13% of its needed resources, then 42% of its output recipe is the domestic or local use of resources. In that case, the formula of [1 / (1 – 0.42)] suggests a base economic multiplier of 1.72 for each dollar spent by local businesses and consumers. But if that sector reduced its economy-wide imports, and if it increased the domestic purchase coefficient from 42% to 47%, then the base multiplier increases to 1.89. In other words, instead of a $100 consumer purchase that supports $172 of overall economic activity, a more internally resilient sector might support $189 of activity, without any other additional costs to the market. Presumably, the number of job opportunities will increase at roughly the same rate.

more broadly, are respent on more labor-intensive activities within the economy, the demand for employment also tends to increase.

**(4) Productivity Boost:** Investments in efficiency and renewable energy may impact broader economic productivity as well. For example, a given business might upgrade a variety of industrial processes that not only reduce energy needs, but a more energy-efficient industrial process might also lower the need for quantities of chemical feedstocks and water, even as it also lowers other operating and maintenance costs (Worrell et al. 2003). This, in succession, can also expand further economic opportunity.

Focusing not on GDP, but total economic output (of which GDP is a significant share), we can examine the potential scale of energy-led productivity gains within the United States as a whole. The Bureau of Labor Statistics estimated that the United States generated a 2019 economic output of $34.0 trillion as measured in 2012 constant dollars. Total wage and salary employment that year was recorded at 163 million jobs (BLS 2020). This implies that each one million dollars of economic activity supported 4.78 direct jobs within the 2019 economy. Had the nation's economic productivity been just 0.5 percent higher over the period 2009 through 2019, total output would have been $1.7 trillion larger (in 2019). Despite normal growth in labor productivity (as opposed to productivity gains in energy or capital), that extra $1.7 trillion might have supported an additional 8.2 million more jobs in that year. This underscores the importance of the productive use of all resources—whether capital, labor, materials, water, and especially energy.

**(5) Managing Price Volatility and (6) Minimizing Supply Disruption:** These benefits include reducing the disruption in the availability of energy and other resources, while also minimizing the negative impacts of unexpected price volatility. As the U.S. supports a more productive economy that uses fewer or less-costly energy resources, as well as other goods and services, both the nation and the global markets will enjoy a reduced exposure to unexpected market risks and price volatilities. This ensures, therefore, a greater certainty in the availability of those resources which, in turn, provides a strong foundation for both career opportunities as well as a more resilient economy.

**(7) Innovation Plus:** Although harder to quantify, the seventh major driver summarized in Table 1 is the greater employment and economic benefits that likely will follow a productivity-anchored energy transition which stimulates the prospects for continuous learning and the encouragement of new innovations. The likely consequence of catalyzing a broader set of improvements—whether the development and deployment of new general-purpose technologies, or innovative changes in business models—can better satisfy the social, economic, and environmental needs within a nation's economy. Equally critical, the America 3.0 Innovation Scenario and infrastructure buildout 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*.

### 4-2-2 The Three Effects of Job Creation

Each of the economic drivers described in the preceding section has a series of three separate, but interconnected, job coefficients which are described next. At this point, then we now have a series of 21 separate interactions (7 drivers, each with their three different job effects) which must be accounted for in determining the opportunities for net job creation. These interactions will be further expanded depending on the number of sectors involved in any analysis or modeling system which might be used to estimate net jobs. While the IMPLAN database has as well over 500 sectors, for example, Table 2 reports the direct, indirect, and induced effects for 6 aggregated sectors within the entire U.S. economy for 2019, the base year of this analysis.[190]

*Table 2. Jobs Per One Million 2019 Dollars for Key Sectors of the U.S. Economy*

| Key Sectors | Direct Jobs | Indirect Jobs | Induced Jobs | Total Jobs | Average Gains in Labor Productivity/Year |
|---|---|---|---|---|---|
| Construction | 6.7 | 3.1 | 10.2 | 19.9 | 0.91% |
| Manufacturing | 2.1 | 4.1 | 8.5 | 14.7 | 1.89% |
| Energy | 1.3 | 2.4 | 7.6 | 11.3 | 2.62% |
| Finance | 3.0 | 4.0 | 10.1 | 17.0 | 1.32% |
| Government | 8.8 | 0.5 | 11.5 | 20.8 | 0.91% |
| All Other Sectors | 5.3 | 3.2 | 9.7 | 18.2 | 1.47% |

***Source:*** *IMPLAN U.S. 2019 data and BLS estimates of labor productivity improvements (January 2021).*

The three separate effects for different categories of total job impacts affected by the spending in any given sector, include:

**Direct Effect:** These are the on-site jobs created by any given investment. In the case of building a renewable energy system, the direct effect would be the on-site jobs of the construction contractor hired to carry out the work, as well as others who might be carrying out related tasks to ensure the successful completion of the project. In the construction sector shown above, for each $1 million dollars spent on a new utility-scale renewable energy system, 6.7 people might be employed on average. For Manufacturing it would be 2.1 jobs while for the energy industry as a whole, it would be about 1.3 jobs.

**Indirect Effect:** When a contractor receives payment for installation of the PV system, he or she is able to pay others who support their businesses. This is the indirect effect which includes the staff of vendors who delivered the PV system, the banker who finances the contractor, the accountant who keeps the books for the vendor, and wholesale suppliers who provide the construction firm with other needed goods and

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[190] In effect, all of IMPLAN's 544 sectors have been aggregated using a weighted average of each sector's output. Construction, for example, has 13 different subsectors combined into the single sector characterized here, and manufacturing has about 329 different subsectors which are averaged into the single sector shown in Table 2.

services. Again, for the construction sector these indirect jobs add up to about 3.1 jobs per million dollars received.

**Induced Effect:** The people who are directly and indirectly employed by the construction firm are able to turn around and spend their weekly paychecks within their communities. Hence, they are said to "induce" other economic activity. This refers to money received by the grocer, for instance, who hires people to work in his or her store. Referring once again to construction, the induced effect shows 10.2 jobs for each million dollars spent.

The sum of these three effects within construction yields a Total Effect of 19.9 jobs supported by a single construction expenditure of $1 million. A final category of impact is the anticipated rate of sector labor productivity as drawn from the BLS (2020) data.[191] Even at this point, however, the analysis is still incomplete since it only deals with the direct, indirect and induced effects of the investment upgrade itself. The substitution impacts must now be considered.

### 4-2-3 The Four Changeover Impacts of Job Creation

Following the story logic to this point, there is a third category of what we might call the four changeover impacts in how total employment can be affected by large-scale changes in the way a country might transition its overall energy services. There are two equal components, each with their positive and negative elements. The first is project implementation such as installing new commercial building upgrades or building a new photovoltaic energy system; the second are changes in energy spending patterns that result from the change or turnover in energy systems. The implementation component includes both the impact of construction and the purchase of new manufactured technologies as well as the influence of programs, policies, and practices (whether done by the private or the public sectors) to enable a desired set of upgrades to happen.

The energy expenditure component includes changes in the type of energy saved or used as they affect overall consumer costs. This incorporates both changed patterns of commodity purchases (e.g., renewable energy compared to, say, natural gas combustion generation), as well as the influence of (presumably) lower unit costs of the energy services that are delivered. Both components, in turn, are affected by linkages to other sectors, the capacity to deliver local versus imported goods and services, and an array of non-energy benefits that might also follow.

In this section we begin with an analytical (rather than the conceptual) review of how an input-output analysis might unfold by exploring the impact on different economic sectors of a nation which invests an assumed $100 million dollars in some form of a technology upgrade. For example, let us suppose (in a highly

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[191] As explained more fully in Appendix B, about the DEEPER Modeling System, labor productivity means that while, say, in the average sectors of the larger economy there are 5.3 direct jobs in 2019, by 2040, at an annual rate of productivity improvement of 1.47% per year, there may be only 3.9 jobs per million dollars. The critical element is whether information technologies, greater energy productivity and productive infrastructure investments can stimulate the economy at a greater rate than gains in labor productivity. If so, and the data currently suggests, then employment can, indeed, be greater than under more conventional patterns of investments.

simplified example) that a utility-scale photovoltaics (PV) system is installed at a cost of $100 million. Drawing on data from Lazard (2020), let us further suggest that the PV installation has a 9-year payback over a 20-year lifetime. This is a conservative estimate as PV systems might now cost as little as $29/megawatt-hour (MWh), or less, while conventional generation technologies may have a cost of $42/MWh, or more (again, Lazard 2020). But if the more conservative comparison holds, then it is possible to save about $11.1 million year in lower wholesale electricity costs which are then passed onto businesses and household consumers.

The first set of job impacts occur when the utility purchases the system and then pays a construction firm to install the new system as part of the utility's generation assets. The construction firm, in turn, may buy PV equipment from an array of manufacturing industries. Those with jobs in both the direct and indirect categories then spend their incomes which induces even more employment benefits. Pulling information from Figure 3 in our example, then each $1 million of investment in the PV system supports a total of 19.9 jobs. Again, this is the sum of interconnected direct, indirect and induced effects made possible by the system upgrade. Consumer spending on local goods and services for each $1 million chunk of savings (made possible by the variety of lower energy costs) might support a total of 18.2 jobs. At the same time, each $1 million in lower utility revenues might also reduce total employment by 11.3 jobs.

In the meantime, a utility might also delay or defer all or some spending on conventional power plants or other needed upgrades in the utility system. That represents an interim economic loss to the economy. But once the new system is installed, businesses and consumers will be able to spend about $11.1 million each year for other goods, equipment and services. While that $11.1 million of savings benefits the local economy, the energy company may lose some part of its revenues which represents a loss to the overall economic activity. At this point, then, we have identified four separate changes in normal purchase patterns. Two were positive and two were negative.

As already alluded to, there are more effects than simply those directly created, for example, by the money paid to a construction firm to install the new PV system.

**Investment Impact:** This is the outlay for a potential system upgrade, including both equipment and labor costs as well as related services necessary to carry out the construction effort. In the case just described, it is the $100 million cost of the PV system.

**Revenue Impact:** This refers to the transfer of funds from one place to another which must be recorded as a loss in the overall set of transactions. In the system upgrade described here, while the construction firm receives $100 million, the energy company might defer or delay other investments or expenditures to enable building of the new systems. For this example, we might imagine the deferral of $60 million (or some other amount) that might have been spent elsewhere.

**Substitution Impact:** With the PV system now installed, the improvements are effectively "substituted" for some amount of conventional energy use. If that amount generates a net savings, the result is increased local spending equal to some portion of the energy savings. In this example, the assumption is that wholesale energy costs might be reduced by $11.1 million per year as the new system begins to generate electricity. As those savings are passed on to businesses and consumers, they may buy another appliance, replace some clothing, or provide a bonus to employees.

**Displacement Impact:** Any money saved by the lower wholesale cost of electricity may create a loss of income for the energy provider. If it occurs, such displacement may create an economic forfeiture that leads to an economic loss to the community, which will also have indirect and induced effects. In this case, a local utility may find revenues sufficiently reduced so that open jobs slots are unfilled or that some employees are asked to retire early.

From a discussion of these terms, it can be seen that a complete multiplier analysis captures the direct, indirect and induced effects of each major change in local expenditure patterns. Thus, there are two major tasks in completing an employment analysis of this type. The first is to understand just how the expenditure patterns affect each sector of the economy. The second is to identify and calibrate an appropriate economic model to reflect the total impacts of those four spending changes, both positive and negative.

Two major steps in the input/output analysis have been completed — setting up the initial dollar amounts associated with the energy system upgrade, and then developing the initial set of multipliers. We can understand how these steps fit together within an analysis by setting up a simple problem to solve.

The multipliers already referenced, and found in both Table 2 and Figure 3, reflect the direct, indirect and induced effects of an expenditure made (or lost) for each sector of the economy. At this point all we need to do is match the proper change in spending with the correct multiplier. In this example there are four such calculations to be made and summed. The steps for the first year in which the PV system is built and operated are shown next (in millions of dollars):

(1) Investment Impact = + $100 PV System * 19.9 Construction = + 1,990 Job Gains
(2) Revenue Impact = - $100 PV System * 0.6 Interim Deferral * 11.3 Utility = - 678 Job Losses
(3) Substitution Impact = + $11.1 Lower Energy Costs * 18.2 Other Sectors = + 202 Job Gains
(4) Displacement Impact = - $11.1 Energy Revenue Loss * 11.3 Utility = - 125 Job Losses
Net Impact = 1,389 net employment gains in year one

In this highly simplified example, overall employment will be strengthened by a net gain of about 1,389 jobs compared to current patterns of electricity production. This includes the direct, indirect and induced effects of all four sets of expenditures. Similar calculations also can be done for net value-added or net GDP contributions to the economy.

Under the (unrealistic) assumption that the PV system is up and running quickly in the first year, and even with paying for the system over the next 20 years but with a continued bill savings for the electricity that is generated, the benefit to the economy would be driven by equations 3 and 4. This suggests an ongoing net employment benefit of 77 jobs.

On the other hand, if a second PV system or equivalent were installed in year 2, then the economy would again benefit, in this illustration, by a net gain of 1,389 jobs PLUS the 77 jobs from the year 1 investment, or for a net total of 1,466 jobs in year 2. And should new PV systems continue to be constructed at the same scale over a 20-year period, by the year 20 the net employment gain would be 2,852 total jobs. Although that may seem a rather small number of jobs within a given economy, as the America 3.0 Transformation emerges, those $100 million upgrades would actually require a transition on the order of many billions of dollars. Hence, the scale of net jobs could accumulate to hundreds or thousands of times (or more) in the example used in this explanation.[192]

### 4-2-4 Three Key Deployment Variables of Job Creation.

The set of the calculations to explain and illustrate the overall methodology of an input-output analysis nicely illustrate the direct, indirect, and induced effects as they might influence the outcomes of the investment, revenue, substitution and displacement impacts. And as much has been explained to this point, there are still a few more angles to the story. They include: (i) an accounting of policy and program costs to help drive an optimal scale and resource mix; (ii) how the investment will be paid for or financed; as well as (iii) the actual payback and/or expected returns on the anticipated investments. If we can also integrate these sets of variables into our calculations, we are likely to have a more robust estimate of the employment benefits which can emerge from different technology scenarios.

**Policy and Program Costs:** As the old adage suggests, “It takes money to make money.” In this case, it takes policy and program efforts necessary to drive the required scale of investment and the optimal mix of resources necessary to ensure the desired outcome (Laitner et al. 2018). Lebot and Weiland (2020) comment that it will take an adequately funded set of smart policies and effective programs, including a skilled work force, to drive the optimal scale of energy efficiency investments. Early in any given economic scenario, they note policy and program costs might require about 20 percent of needed investment. But they also suggest this might decline to perhaps 8 percent over the following two or three decades once the programs are launched. Long-time designer and implementer of community energy programs George Burmeister agrees. He notes, for example, that in May 2020 a one-megawatt (MW) photovoltaics farm cost about $1 million to build and install. At the same time, the convening local government incurred a variety of employment and other soft costs amounting to $200,000, or 20 percent of the required investment. Burmeister also indicated that the mix of policy and program costs, depending on the financial involvement of the local government and the market response, might decline to 10 percent in years 2 and 3, and even ‘approach zero’ over the next two decades.[193]

**Financial Costs:** A significant level of investment will have to be provided through some form of public funding or borrowing. That will clearly add to the overall cost of any upgrade. For example, if investment funds are borrowed, over a 20-year period, at an interest rate of 4.36 percent within that time-span, this will effectively increase the cost by approximately 50 percent compared to funds with a zero-interest rate or through some other form of out-of-pocket expenditures. And if the interest rate rises to as high as 7.95

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[192] As economic activity actually unfolds over time the pattern of investment and spending will actually differ compared to the very simplified example discussed above. Construction will likely proceed over a period of a couple years before energy bill savings begin to accrue. And as noted in the previous footnote, rates of future labor productivity will reduce the number of jobs in year 20 compared to year one. But while a simplified example, the logic still holds.

[193] Memo and personal communication from George Burmeister, President of the Colorado Energy Group. May 21, 2020.

percent over that same 20 years, it will effectively double the cost of investment. By way of comparison, current home interest rates are within the 3 to 9 percent range, depending on levels of down payment that might be made, credit scores and other variables.[194] As it turns out, investor-owned utilities are allowed to earn a Return on Equity invested (ROE), which is typically around 9 to 10 percent per year.[195] Given the scale of impact likely supported by the financial community, a financial cost variable, including interest or borrowing rates, should be included in any jobs assessment.

**Energy Cost Savings:** From an investment standpoint, whether a household consumer or an established business enterprise, the reduction in energy costs should outweigh the combination of both program and policy costs as well as the cost of financing the upgrades. For example, a 2012 study by the American Council for an Energy-Efficient Economy (Laitner et al. 2012) found that to cost-effectively reduce energy costs by 42 to 59 percent compared to business-as-usual projections for the year 2050, that annual investments would need simple energy savings paybacks on the order of 6-8 years. In simple terms, a $100 investment should lower overall energy and operating & maintenance costs on the order of $12.5 to $16.7 per year. In effect, some form of cost-effectiveness of any investment portfolio should become part of the employment analytics.

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[194] When accessed on January 15, 2021, a typical range of home mortgage interest rates of ~3-8 percent can be found at: https://www.valuepenguin.com/mortgages/average-mortgage-rates

[195] https://newenglandcleanenergy.com/energymiser/2018/02/22/how-electric-utilities-make-money/

## 4-3 Laying Out a Representative Analytical Framework

Garrett-Peltier (2017) provided a thoughtful review that compared the employment impacts of energy efficiency, renewable energy, and fossil fuels using U.S. Bureau of Economic Analysis Input-Output tables to create a model that compared conventional fossil fuel (FF) and Energy Efficiency and Renewable Energy (EERE) expenditures. She then posed the question of what might happen if we shifted $1 billion out of fossil fuel subsidies and into public spending for EERE technologies. Her model found that there were 2.65 direct and indirect jobs/$Million while EERE expenditures supported 7.72 direct and indirect jobs/$Million. Her policy scenario, not surprisingly, found that removing $1 billion in fossil fuel subsidies cause a loss of 2,650 total jobs. Employment in EERE industries, alternatively, would increase by a total of 7,720 jobs. That change, therefore, implies a net employment increase of 5,070 total jobs per million dollars throughout the full economy.

While the Garrett-Peltier model provides a useful first approximation, it is an incomplete assessment. It does not include the induced effects of employment, nor does it include the likelihood of lower energy costs that might emerge over a 20-year period. Moreover, it does not include program costs, financing costs, the expected gains in labor productivity, and other parameters described in section 4.2 above.

### 4-3-1 A More Complete Assessment

In providing a more complete assessment of the job benefits which might be driven by a given America 3.0 "Innovation Scenario", one can imagine a large number of variables that will likely impact any estimate of the absolute number of jobs created for a given year. In the illustration that follows, we demonstrate the impacts using five critical variables (with subsection 4.3.6, that follows, highlighting other variables which may also affect the job benefits reported here—both negatively and positively). As a means to explore the full scale of employment opportunities associated with the transition to an America 3.0 economy more completely, an employment assessment tool was developed for this exercise. The tool is a modified version of what is called "DEEPER Lite" within the DEEPER Modeling System.[196] The core of that tool consists of five critical components. The first, following the example of replacing fossil fuel subsidies with a share in EERE technologies, is a one-time $1 billion investment stimulus. The second is a policy and program stimulus of $200 million to drive ahead the effort in the first year of a 20-year time horizon. The third element of the DEEPER Lite employment tool is to set a range of both payback periods and interest rates to see how these might impact the net employment benefits over time. A fourth element is to include the appropriate sector job coefficients as well as their anticipated labor productivity rates. Both the job coefficients and the projected rates of labor productivity used in the employment assessment tool are those shown in Table 2. The final component summarizes the results as shown in Tables 3A, 3B, and 3C that follow.

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[196] The DEEPER Modeling System stands for the **D**ynamic **E**nergy **E**fficiency **P**olicy **E**valuation **R**outine which is consistent with the idea of "aggregate efficiency" referenced in footnote 13, and as discussed more completely within Appendix B of this manuscript. In short, here "Energy Efficiency" means all three forms of aggregate efficiency: (i) end-use energy-efficiency, (ii) the transition to renewables, and (iii) the productive upgrade to the nation's infrastructure in a more circular economy.

*Tables 3A, 3B, 3C. Annual Net Benefits from a $1 Billion Energy Upgrade over 20 Years*

**Table 3A. Net Energy Savings (in Millions of Dollars)**

| The Key Assumptions (Payback/Interest Rates) | | 20-Year Loan Interest Rate | | |
|---|---|---|---|---|
| | | **3%** | **5%** | **7%** |
| **Simple Payback (in Years)** | **5** | 104 | 89 | 72 |
| | **7** | 50 | 34 | 17 |
| | **9** | 20 | 4 | -13 |

**Table 3B. Net Average Annual Jobs**

| The Key Assumptions (Payback/Interest Rates) | | 20-Year Loan Interest Rate | | |
|---|---|---|---|---|
| | | **3%** | **5%** | **7%** |
| **Simple Payback (in Years)** | **5** | 2,127 | 2,073 | 2,014 |
| | **7** | 1,529 | 1,475 | 1,417 |
| | **9** | 1,197 | 1,144 | 1,085 |

**Table 3C. Benefit-Cost Ratio (BCR)**

| The Key Assumptions (Payback/Interest Rates) | | 20-Year Loan Interest Rate | | |
|---|---|---|---|---|
| | | **3%** | **5%** | **7%** |
| **Simple Payback (in Years)** | **5** | 2.38 | 2.00 | 1.70 |
| | **7** | 1.73 | 1.45 | 1.23 |
| | **9** | 1.37 | 1.15 | 0.97 |

***Source:*** *Results from the DEEPER Lite Employment Assessment Tool as described in the narrative.*

With the DEEPER Lite employment tool properly benchmarked and calibrated, the tables shown above provide the reader with an overview of three different economic impacts over the years 1 through 20: (i) Table 3A, the average net energy bill (or other) savings in millions of 2019 dollars for the 20-year timeframe; (ii) Table 3B, the net annual average of jobs which might be gained; and (iii) Table 3C, the benefit-cost ratio—if we assume a discount rate of 5 percent over the same 20-year time horizon.

More critically, the tables also show how each of the three impacts might be affected under a different set of interest rates (ranging from 3 to 7 percent) and different payback periods (ranging from 5 to 9 years). Theoretically, we could show results which might stem from interest rates ranging from zero to 25 percent or more, and payback periods from six months to 20 years or more; yet, this set of results focuses on what we might think of as a central tendency—based both on common sense, as well as a larger number of studies cited here and as shown in the literature. From this backdrop, there are a number of outcomes that are worth examining.

The first big outcome is that as interest rates rise from 3 percent to 7 percent, the benefit-cost ratio (BCR) in Table 3C declines significantly; but that same ratio especially declines if there is a change in the payback period. For example, a 3 percent interest rate with a 5-year payback shows a discounted benefit-cost ratio over the 20-year period of 2.38. If we simply change the payback to 9 years, the benefit-cost ratio changes to a significantly lower value of 1.70. Similarly, if we assume a 7 percent interest rate and a 9-year payback then the benefit-cost ratio drops to below one.

From a consumer perspective—whether a household or a business—those who must pay for both the program costs, likely through some form of taxes, and similarly the investment through some combination of taxes and/or borrowing, a 0.97 BCR indicates a greater cost than benefit to the consumer. But from a macroeconomic perspective, a 0.97 BCR (Table 3C) still returns a net gain in employment for the American economy. That result is shown in Table 3B in which there are 1,085 net jobs on average per year.

### 4-3-2 Evaluating the Economy-Wide Net Job Benefits

Although the consumer vantage point suggests a less than desirable return from a Benefit-Cost Ratio of less than 1.0, the economy-wide perspective continues to show net positive job benefits. In fact, there is a net job creation benefit within all nine versions of the assessment calculations. One big reason as suggested in Table 2, stems from *cost-effectively changing the spending patterns away from capital-intensive energy industries to more labor-intensive sectors of the economy*. One possible interpretation of these outcomes? A positive macroeconomic outcome may be a smart reason to provide individual incentives so that consumers benefit more widely as individuals, even as the economy is also better off.

We can use the array of Table 3 insights in a variety of ways to determine the potential net job creation if we scale up from a simple one-year perspective, and then examine the full possibilities of net job creation over the full 20-year time horizon. To begin this scaling effort, we first turn to the separate investment analytics within this report provided by Adrian Smith + Gordon Gill Architecture (ASGG) and Black & Veatch Management Consulting LLC (Black & Veatch). Among their tasks was to determine the financial scale necessary to build out the *America 3.0 Next Generation Pathway*. ASGG reviewed the likely cost of the residential and commercial buildings performance upgrades. Black & Veatch examined the magnitude of the investments necessary to create the next generation of an interconnected ICT, electricity, and mobility grid. Both examined the investments required over a 21-year period. The total for all components evaluated in this report is $16.4 trillion (in 2020 dollars).[197]

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[197] The reader can review and evaluate the ASGG and Black & Veatch separate assessments by turning to their contributions elsewhere in the report. Their engineering assessments focused on a 21-year period over the years 2020 through 2040 to determine the scale of investment which might be necessary. The deployment scenario characterized here also assumes a 21-year period, but it covers the years 2022 through 2042.

With a robust "first order" estimate of the investment magnitude, the DEEPER Lite Employment Assessment Tool can provide what we might again call "indicative analytics" to imagine the potential scale of jobs should, as suggested: (i) the nation increase the stimulative investment, and (ii) evaluate a cost-effective energy bill savings with other economic benefits emerging from that stimulus. Two initial first steps are helpful in building a first approximation of the likely job creation process. The first is to ensure that the $16.4 trillion is a reasonable magnitude. The second is to convert that total to the 2019 base-year dollars of the model, and to provide the equivalent of an annual stimulus over the 21-year period.[198]

As to the first step, recall that to drive a global energy transition, the IRENA (2019) study suggests a total expenditure of perhaps 60 percent of one year's GDP, or on the order of $12 trillion expended over the period 2019 through 2050. In fact, the $12 trillion magnitude fits nicely with the ASGG estimate of $12.14 trillion for the revamping and upgrading of the nation's building stock. This also includes installation of solar photovoltaic systems as part of the building upgrades. Black & Veatch has provided a detailed engineering assessment for four different components of upgrades not generally integrated into the analysis: (a) roadmapping the continental electricity internet; (b) building out microgrids; (c) deploying high-level broadband infrastructure; and (d) advancing mobility and electric vehicle support. Their total investment is $4.23 trillion. Consequently, the $16.4 trillion dollars (rounded) seems like a reasonable aggregate sum that, if properly invested, would enable a greater level of energy and resource productivity for the U.S. economy.

In the deployment scenario explored here, the assumption is that the first policy and program efforts begin in 2022 while the initial investments to upgrade the nation's infrastructure start in 2023. Over the 20-year period (2023 through 2042) the aggregate investment of $16.4 trillion becomes an average annual $820 billion stimulus.[199] And following the logic explained in section 4.2.3, each of the 20 years for which an investment is made, and in the remaining successive years of that investment, the energy and other productivity benefits add up cumulatively over time. Rather than assume an average of $820 billion per year for all years, however, the first investments begin at a lower initial effort of $300 billion in 2023, growing to $850 billion by 2027, and continuing with an annual investment of $900 billion through 2042—with all the years from 2023 through 2042 summing to the same $16.4 trillion previously noted. In effect, the scenario starts slowly and smaller in the first several years, but as more experience and successes are actually achieved, it then continues with a solid pattern through 2042.

In the assessment that follows, the first policy and program efforts are launched in 2022 with an initial spending of about $60 billion with first upgrade investments of $300 billion beginning in 2023.[200] These first

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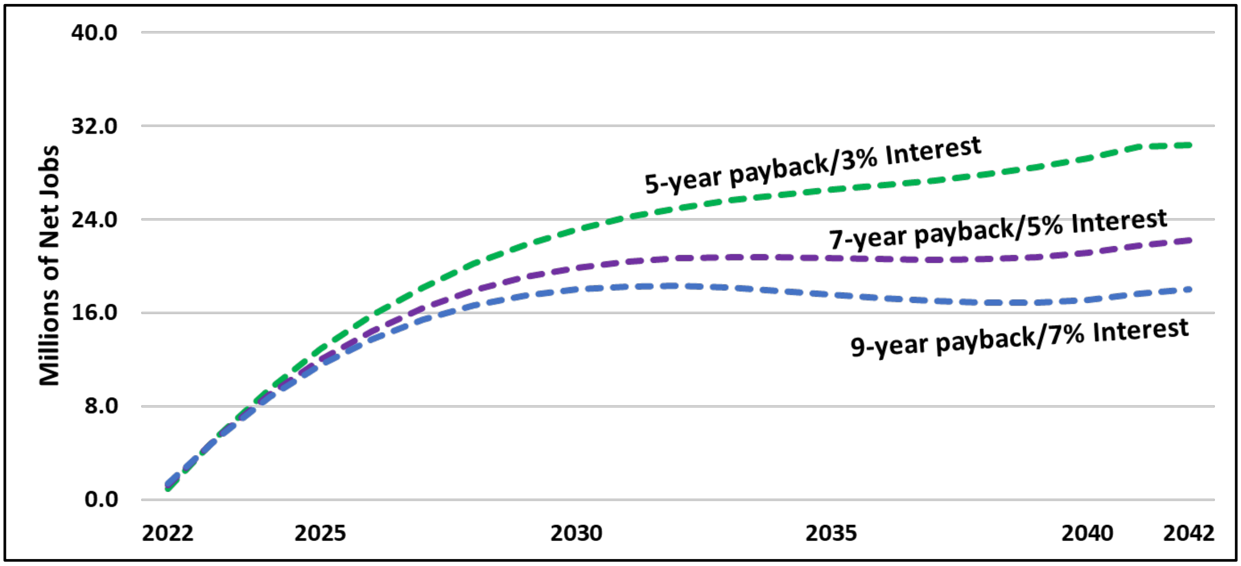
[198] Because the DEEPER Lite employment tool is benchmarked to the year 2019 IMPLAN data, we necessarily convert all 2020 financial values to 2019 constant dollars. However, the analysis will report findings based on either 2020 dollars, or in the case of GDP or other impacts using 2012 constant dollars since the America 3.0 Innovation Scenario is compared to the to the business-as-usual AEO 2020 macroeconomic scenario which is reported in 2012 dollars.

[199] The conversion of the $16.4 trillion assumes a deflator in which $100 reported in 2020 are equal to $92.05 for the year 2019. Hence, for modeling purposes, therefore, the aggregate investment total reflected in DEEPER Lite is more like $16.2 trillion.

[200] There is nothing magical about these numbers. The first policy and program expenditures, as well as the first investment amounts, could be more; and they could be less. This assessment provides only what we previously referred to as a set of "indicative analytics" to explore the logic of a major performance upgrade and its likely positive benefits. As

expenditures drive an increase of about 70,000 net new jobs in 2022 which jump to a much larger increase of 6 million new jobs in 2023 as construction and manufacturing activities begin to take hold. As highlighted in Figure 4 below, a somewhat different pattern of employment will emerge as a function of, not only the annual investments, but the different scale of benefits which might be driven by those investments. For example, and as explained further, if investments drive technologies with a high productivity benefit suggested by a 5-year payback, and if they are also financed at a low 3 percent interest rate, the transition might drive as many as 30 million new jobs by 2042 (the green line in Figure 4). On the other hand, if those investments show a lower rate of return, or a 9-year payback, and if they are financed at a significantly higher 7 percent interest rate, the net employment benefits might fall to 18 million new jobs by 2042 (the blue trajectory). Figure 4 summarizes the array of three different patterns of a net employment benefit for the U.S. economy. Rather than focus only on the number of jobs in any given year, the average number of net jobs across the full 21-year period (including the first policy and program jobs deployed in 2022) is 15 to 22 million jobs within the United States across all three scenarios.

*Figure 4. The Possible Range of Jobs Given Different Payback Periods and Interest Rates*



***Source:*** *Scenario Results from the DEEPER Lite Employment Assessment Tool.*

Again, to summarize the potential employment opportunities driven by the America 3.0 Innovation Scenario, we've identified three trajectories that approach a near-zero greenhouse gas emissions target by 2042, but each with different assumptions on what the cost-effective different technologies might be (represented by the idea of a simple payback),[201] and what the interest rates might be over a 20-year investment period as

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the U.S. Congress and the Administration begin to lay out more concrete plans, both the timing and the values in any given year would vary in a pattern consistent with the actual strategy which might be implemented.

[201] We can think of the inverse of a simple payback as an indication of the annual return on investment. A 5-year payback, for example, indicates a 20 percent annual return based on some combination of energy savings and/or other economic benefits. Likewise, a 7-year payback indicates a roughly 14 percent return while a 9-year payback reflects an 11 percent return.

consumers and businesses borrow funds to drive the many different ventures.[202] Under even the more conservative assumptions, however, the productive investment in the America 3.0 infrastructure strategy should lead to a highly positive "jobs, jobs, jobs" outcome for the entire nation.

### 4-3-3 The Scale and Categories of Employment Benefits and Opportunities

To help us better understand how the jobs might grow, and which sectors of the economy might be affected more than others within the America 3.0 Innovation Scenario, this subsection investigates a more specific mid-range scenario. In this case, the first assumption begins with an initial 5-year payback in 2023 which grows to a 9-year payback by the year 2042. The intent is to show that as early investments rely on first returns that are more productive, later investments may have somewhat fewer benefits. It also assumed all investments are funded over 20-years at a 3-percent interest rate. To quickly review, the America 3.0 innovation upgrade begins with an initial policy and program effort in 2022, followed by the initial investment of $300 billion in 2023 which grows to $900 billion by 2028 through 2042. The annual investments then sum to the aggregate $16.4 trillion previously referenced. Again, the large initial employment benefit is estimated to be 6 million net jobs in 2023, rising to 22 million net jobs by 2042. The average annual gain of this more specific scenario, over the full 21-year time horizon, is 18.7 million net jobs.

While the analytical methodology described in earlier subsections pointed to as many as 17 key variables driving the overall result, we can more easily summarize and explain the results by referring here to three major catalysts which propel a net positive job increase in support of the nation's workforce.[203] These three catalysts are summarized next.

The first catalyst is the result of the "Stimulus Spending" itself, again with a direct and indirect benefit to the nation's demand for employment. It begins with a multi-year set of policies and programs which encourage both private and public investment, as well as workforce development, training and deployment in support of an optimal investment pattern.[204] Hence, the key sectors for this phase of the catalyst consists of

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[202] To the extent that investments may be supported by grants or zero interest loans, the net consumer savings would likely drive an even larger net-benefit for household and business consumers. As shown in Table 2, the energy industry has a total jobs coefficient of 11.3 per million dollars, while finance and the "all other sectors" show higher total coefficients of 17.0 and 18.2, respectively. So, if consumers—whether households, businesses or government enterprises—pay some level of interest on their necessary loans, that will drive more jobs than energy expenditures; but if the interest levels are lowered more completely, that will leave more consumer spending at the highest job coefficient. Hence, a small but also larger demand for labor.

[203] Again, as described in subsections 4.2.1 through 4.2.4, the 17 analytical and highly interdependent variables are (i) the 7 economic drivers; (ii) the 3 job effects; (iii) the 4 substitution impacts; and finally (iv) a set of 3 deployment variables.

[204] The assumption here is that the stimulus is exactly that—a set of policy and program expenditures, as well as investments, which drive infrastructure upgrades above business-as-usual levels. Hence, there are likely few negative impacts. On the other hand, as greater productivity enhancements take both revenue and work from existing patterns of business and employment, and then channels them into other sectors, there are indeed job losses in some sectors—although, as we shall see, there are greater job benefits elsewhere in the economy so that the net gain in jobs are entirely positive gains. Presumably, there will be programs in place to retrain workers and to ease their transitions into a new set of job skills or careers. See UAW (2020) for one useful discussion on the value of an industrial policy which emphasizes workforce retraining and deployment as part of the needed transition.

*Government, Professional Services, Technical Support, and other Consulting Service* sectors, each with their direct and indirect employment demands. As the policies and programs encourage the actual investments, the second phase of this catalyst draws primarily on the *Construction, Manufacturing, Technical Services and Finance* sectors.[205]

The second catalyst is what we might call the "Transition Influence." This has both a positive and a negative consequence, also with their direct and indirect effects, consisting of: (a) fewer jobs in the current conventional energy-related sectors; and (b) more jobs supported by the purchase of the many goods and services other than the conventional energy supplies. Because conventional energy services tend to be more capital than labor-intensive, and because the purchase of other goods and services tend to be more labor-intensive, lower energy costs will drive greater employment benefits.[206]

The final catalyst is a more resilient and "Enhanced Economy" in which the direct and indirect jobs create additional consumer income that is spent on the typical pattern of goods and services throughout the economy.[207] With an appropriate accounting, and based on more conservative mid-range assumptions, again referencing an average of just under 19 million net new jobs over the period 2022 through 2042, all of these impacts are summarized in Table 4 that follows.

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[205] As described more Table 2, the direct effect is the number of immediate jobs per million dollars of spending from policies and programs as well as the actual buildout of the nation's infrastructure. Government efforts, for example, might provide 8.8 direct jobs per million dollars of spending while construction activities might support 6.7 direct jobs. As both government programs and construction sector activities get underway, they must rely, in turn, on other sectors to support these efforts. These are sometimes referred to as the indirect jobs. Government programs may turn to other professional and technical services, for example, to enable a positive outcome. The construction sector will purchase equipment from manufacturers and other technical services to complete its efforts. These are sometimes referred to as "supply-chain" jobs. As shown in Table 2, construction activity creates an indirect 3.1 jobs per million dollars of spending while government programs may need only 0.5 indirect jobs.

[206] As also highlighted in Table 2, spending for conventional energy supports tend to support about 3.7 jobs directly and indirectly for each million dollars of revenue while other sectors tend to support about 8.6 jobs directly and indirectly. In this example, reducing conventional energy costs by one million dollars will initially reduce employment by 3.7 jobs, but as those savings are spent elsewhere within the economy, employment will increase by 8.6 jobs. In this simplified example, this becomes a net gain of 4.7 jobs throughout the economy.

[207] In this final example, the direct and indirect jobs created by the first two catalysts are said to induce an estimated 9.7 jobs per million dollars of typical consumer spending. It should be noted that this is a simplified estimate as each sector will actually "induce" a slightly different effect ranging from 7.6 induced jobs in the existing energy sectors to 10.2 and 8.5 jobs from spending by the construction and manufacturing sectors, respectively.

*Table 4. Employment Catalysts – Average Impacts 2021-2040*

| Catalysts of Job Creation | Key Sectors | Average 21-Year Share | Net Job Creation (Millions) |
|---|---|---|---|
| Stimulus: Policy/Program Jobs | Government, Education, Technical Services, Consulting | 5.3% | 1.0 |
| Stimulus: Investment/Finance Jobs | Construction, Manufacturing, Technical Services, Finance | 39.5% | 7.4 |
| Transition: Redirected Energy Spending Jobs | All Sectors Supporting Households, Businesses, Government | 8.3% | 1.6 |
| Transition: Energy Jobs | Mining, Production, Processing, and Utilities | -1.7% | -0.3 |
| Enhanced Economy: Induced Jobs | All Sectors Supporting Households, Businesses, Government | 48.6% | 9.1 |
| **Totals** | | **100.0%** | **18.7** |

***Source:*** *Author calculations based on the narrative described within the text (January 2021). The totals are not consistent because of rounding.*

As already alluded to, the stimulus-related jobs are, perhaps, a surprisingly smaller part of the net increase in employment than most policymakers might imagine within the United States. The policy and program jobs drive an increase of 1 million jobs on average while investments and financial activities support 7.4 million jobs. The combined 8.4 million jobs is about 45 percent of the total 18.7 million jobs realized in the America 3.0 Resilient Society. Yet, the remaining 55 percent, or the 10.3 million net jobs, while a hugely positive impact for the American economy, would not be possible without the work of the investment stimulus.[208] Because of greater aggregate energy efficiency (including the more productive use of capital and other resources), the current mix of energy services would lose an average of 0.3 million (or 300,000) jobs per year.[209] Nonetheless, the respending of the energy bills savings on other goods and services tend to support 1.6 million jobs per year. And with an enhanced consumer spending made possible by the 9.7 million stimulus and transition jobs, an "enhanced economy" supports just under half of the total 18.7 million jobs within the 21-year period.[210]

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[208] The 10.3 million jobs cited here are coincidental to the 10.3 million jobs supported by the Oil & Gas industry referenced in the "Execs' Open Letter" found in footnote 1.

[209] We can think of the loss of 300,000 jobs more as a transition than a net loss to any given sector. In other words, while the current operation of any given utility may lose one set of jobs—say the operating staff of a coal-fired combustion turbine, those jobs can be replaced as that same utility moves to greater utility-scale photovoltaic systems. Or as that utility shifts its staffing requirements way from electricity production to provide other customer services which may also require a comparable scale of labor activities.

[210] In one sense this appears to be a large number of jobs. But including both wage and salary workers, as well as proprietor jobs, the Bureau of Economic Analysis documents as many as 203.8 million full, part-time, and proprietor jobs in 2019 alone. Hence the average increase of 18.7 million jobs is only 9.2 percent of the 2019 total jobs. For more information in this regard, see table SAEMP25N on total employment. https://apps.bea.gov/.

### 4-3-4 Impact of Various Occupations

Although the initial focus of this supplemental review explores how an investment stimulus, together with the resulting improvement in aggregate efficiency and greater resource productivity, can increase the social and economic well-being within the many sectors of the economy, each sector may require hundreds of different occupations or categories of jobs to support the larger activities of the economy. For example, what we might call the "utility sector" – requiring in 2019 an estimated 549,000 jobs to maintain electricity, natural gas and water services within the United States – actually requires more than 200 different occupations. And the 7.5 million jobs found within the various construction sectors also require an estimated 200 separate occupations or more to provide its many different categories of services. The occupational categories range from operation managers, human resource specialists, and clerical support to software developers, architecture and engineering professionals and a long list of production workers. Indeed, the Occupational Employment Statistics (OES) program of the Bureau of Labor Services produces employment and wage estimates annually for nearly 800 occupations.[211]

In many ways it is not so much the specific sectors that provide the benefit of a more resilient and productive economy. Rather it is combination of productive labor (given its many occupational enterprises), capital (including an array of appliances, equipment, machines together with the new infrastructure), and the more productive use of clean energy resources that animate both labor and capital. One recent study by researchers with the Brookings Institution suggests that as many as 320 unique occupations may be needed to fully promote a productive combination of clean energy production, energy efficiency, and environmental management.[212] Most of these jobs, they note, will require some level of "both vocational and professional training in design, engineering, and mechanical knowledge."

Perhaps more interestingly, the Brookings study suggests that hourly wages in these "new green jobs" exceed the national average by 8 to 19 percent. And equally important, they indicate that workers at the lower end of the income ladder can make $5 to $10 more per hour than in comparable jobs in the old economy. One big problem, they note, is that much of the existing infrastructure workforce is nearing retirement age. This poses an important question of how the U.S. might prepare the new generation workforce with the skills necessary to contribute to the active development of the America 3.0 Resilient Society. State, municipal, and county governments are just now beginning to establish what has been called "infrastructure academies" that can both retrain the existing workforce and also prepare a younger generation for the new infrastructure jobs.

Black & Veatch, on the other hand, notes that deploying this infrastructure will require a considerable focus to successfully integrate and optimize numerous hardware, software, and firmware systems from an ecosystem of multiple vendors and service providers. This will, in turn, require a new array of occupations which may: (i) either not currently exist, or (ii) may be wholly underdeveloped at this time. These new jobs may include grid update design & planning, logistics management, distributed energy resources installation, intelligent electronic device controllers, cloud architects, fiber design specialists, power quality engineers,

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[211] For more details on the many occupational and industry aggregations, see generally, https://www.bls.gov/oes/.

[212] "Advancing Inclusion Through Clean Energy Jobs." April 2019. Washington, DC: Brookings Institution. https://www.brookings.edu/research/advancing-inclusion-through-clean-energy-jobs/

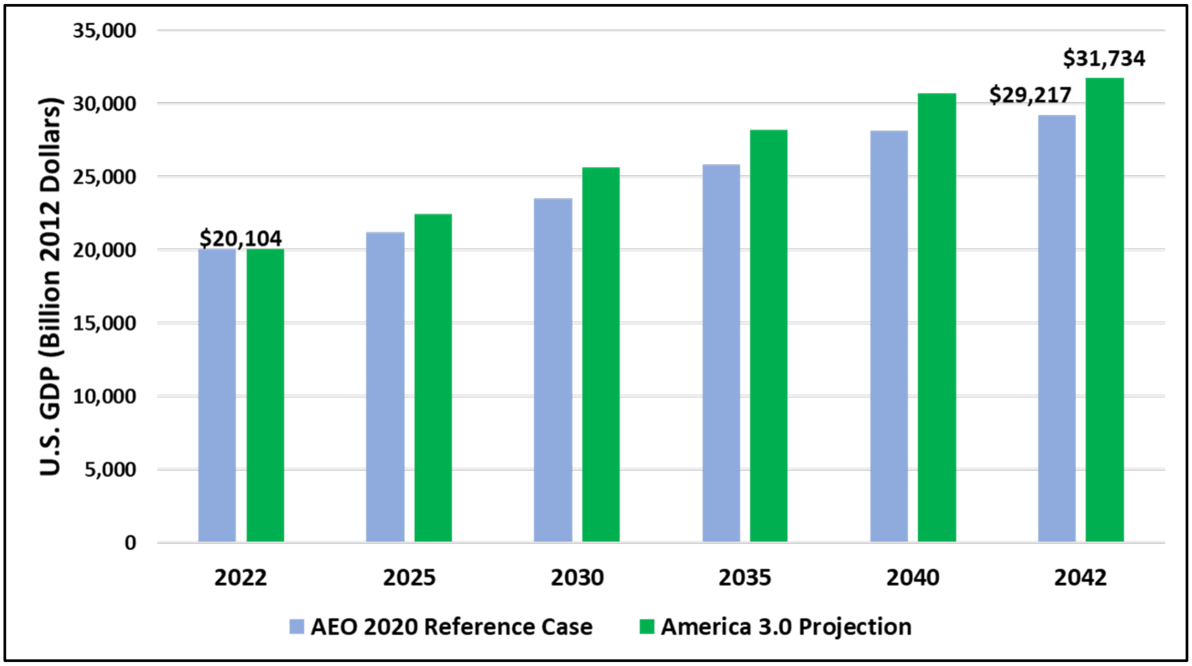
and distribution automation specialists, to name but a few.[213] To advance the deployment of an America 3.0 paradigm shift, communities across the country will need to create planning roadmaps, both to develop the new occupational skills as well as to deploy a more productive infrastructure that brings together telecommunications, smart sensors, cybersecurity, data science and new analytic skills.

### 4-3-5 Translating Employment into GDP Impacts

Even as we understand the positive employment benefits of an America 3.0 strategy, people will want to also know what job increases of this magnitude might imply for the larger economy – in this case, as measured by Gross Domestic Product, or GDP. Although the DEEPER Lite employment tool is exactly that—an employment assessment tool which did not evaluate the investments necessarily for their contributions to GDP, we can provide some useful metrics which point to the scale of potential GDP benefits, as they might otherwise ensure a more robust and resilient economy. Figure 5 illustrates the results of this step in the analysis.

As it turns out, a number of economic projections for the nation's GDP suggest a slow erosion of economic activity compared to post-World War II activity. In fact, the AEO 2020 forecast suggests that the nation's economy may increase by a rather lackluster performance of 1.9 percent economic growth, between 2022 and 2042 (measured in constant 2012 dollars).[214] By comparing a projected increase in GDP per job by 2042, we can – with appropriate caveats – suggest a more vigorous economic well-being as a result of the America 3.0 stimulus. Again, Figure 5 underscores the scale of that potential GDP bonus.

*Figure 5. Comparing US GDP Reference Case Projections with an America 3.0 Stimulus*



***Source:*** *Scenario Results from the DEEPER Lite Employment Assessment Tool.*

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[213] See "Interconnected Infrastructure," pages 46-98, of *America 3.0 The Resilient Society*, TIR Consulting Group, LLC, Jeremy Rifkin, President.

[214] Historically, U.S. GDP has increase about 2.8% annually over the period 1970-2019 (Woods and Poole 2020).

How did we estimate the GDP implications? The Annual Energy Outlook 2020 (AEO 2020) underpins a significant portion of the energy and economic projections used in the America 3.0 assessment. Based on the pre-Coronavirus pandemic, AEO 2020 pointed to the U.S. economy, as measured by GDP, going from $19,342 billion in 2020 to $29,217 billion by the year 2042 (in constant 2012 dollars).[215] As already indicated, that scale of change implies a growth rate of 1.9 percent per year. Analytics from Wood & Poole Economics (2020) indicate that GDP activity supported by each job within the U.S. economy will grow from $97,249 in 2022 to $112,922 in GDP outcomes by 2042 (still in 2012 constant dollars). While there are further nuances and caveats to be observed or respected, by adapting middle of the three job growth categories – that is, a net increase of 22.3 million jobs by 2042, those gains to the employment figures could boost GDP by about $2.5 trillion dollars compared to a "reference case" forecast for that year. That would, in effect, bump up the nation's GDP in 2042 to $31,734 billion. That extra bump in GDP would mean that the annual growth rate would increase from 1.9 percent, to a somewhat more robust 2.3 percent increase per year.

### 4-3-6 The Many Other Variables Impacting Jobs and GDP Estimates – Plus and Minus

The key macroeconomic and employment impacts described to this point—that is, an America 3.0 Innovation Scenario that positively impacts GDP by more than $2.5 trillion by 2042 (reported in constant 2012 dollars), and with an initial net gain of 6 million jobs in 2023, rising to as many as 22.3 million jobs also by 2042—is the result of what we refer to as "indicative analytics" or an "indicative narrative." That is, there currently is no set of national, state, or local plans which actually identify the actual scale and timing of investments, together with their resulting outcomes as they circulate throughout the US economy. Nor is there an actual set of programs and policies that can drive those results. Moreover, the analytic efforts are the function of only a few key economic coefficients and variables. These include the set of investments, the anticipated returns on those investments, the cost of financing the infrastructure upgrade, and relevant sector job coefficients. Yet, there are many other influences which might affect, positively or negatively, the range of benefits characterized here. They can range not only from the magnitude of capital and operating costs as they may vary over time, or the cost of financing the investments whether through incentives, tax credits, and guaranteed low-cost loans, but also the degree of imported goods and services which might support both construction and operation of new systems and the magnitude of supporting policies, programs, workforce training and deployment efforts which might drive the eventual outcomes.

While many of the emerging occupations will provide improved hourly wages and salaries, there may also be a number of lower paying jobs. But presumably, a more productive economy will lower the cost of living by a significant margin. This can help stretch the value of even lesser incomes throughout the entire workforce. For example, lower air pollution and healthcare costs, a much lower economic burden associated with improved climate change mitigation and adaptation strategies can reduce what might be termed "defensive expenditures" which give rise to a more positive spending through available personal and family income. Among other indicators are the lower costs of commuting, the reduced direct costs of pollution control, fewer automobile accidents, significantly less water pollution, a lower cost of noise pollution, and

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[215] See "Table 20. Macroeconomic Indicators" in the AEO 2020 (EIA 2020).

reduced long term environmental damages.[216] Finally, as we become more productive through the Internet of Things (IoT), and related communication platforms, we can think about transitioning more of the returns on investment in ways that further benefit increased wages and salaries. And this is even before we review the lower costs of climate and air pollution impacts which we consider next.[217]

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[216] Among the first efforts to compare defensive expenditures with personal income was a 1989 book by Herman Daly and John B Cobb Jr, *For the Common Good: Redirecting the Economy Toward Community, the Environment, and a Sustainable Future*. Boston, MA: Beacon Press (Second edition 1994).

[217] It is worth noting that the scale of macroeconomic benefits reported here are broadly consistent with other recognized assessments completed by the Economic Policy Institute (Biven 2017) and the Business Roundtable (BRT 2019). Bivens notes, for example, that “each $100 spent on infrastructure boosts private-sector output by $13 (median) and $17 (average) in the long run.” Meanwhile, the BRT comments that “every additional $1 invested creates $3.70 in economic growth over 20 years.” Also worth noting, however, is that the America 3.0 strategy similarly drives more employment and economic well-being, but in ways that also increase aggregate efficiency, and dramatically reduces both greenhouse gas emissions and air pollution. The overall benefit-cost ratio this scenario described in Table 4 is a rather conservative 1.4. In other words, each dollar of cost generates a benefit of $1.4 over the 21-year period of analysis (assuming a 5 percent discount rate).

# 5 AIR POLLUTION AND CLIMATE BENEFITS

As good as the larger employment outcome appears to be, it is merely one aspect of the benefit from a stimulus investment that also results in a lower total cost of energy-related services. We can also account for other social, economic, health, and environmental costs that will impact the nation's 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 the nation as a whole. 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 America's GDP by the year 2050 (Jacobson et al. 2017).

Adopting the Stanford methodology as it might be applied to the anticipated energy consumption patterns and scale of GDP by 2042, the combined avoided air quality health effects and global climate-change could exceed $500 billion in just the year 2042 alone (with values expressed here in constant 2020 dollars). But this is a point estimate based on one published assessment. How might other studies and assessments better help us understand what those environmental, health and climate costs might be?  And what exactly might the scale of those impacts be? Because of the dynamic interaction between the dispersion of aerosols and particulate matter, and the changing patterns of heat, wind, and rain, there is an overlap in many studies which examine the impacts of both air pollution and climate change. In the brief sections that follow, we principally focus, first, on the avoided costs of air pollution (or clean air benefits) and then the prospective damages that might unfold from the growing burden of climate change.

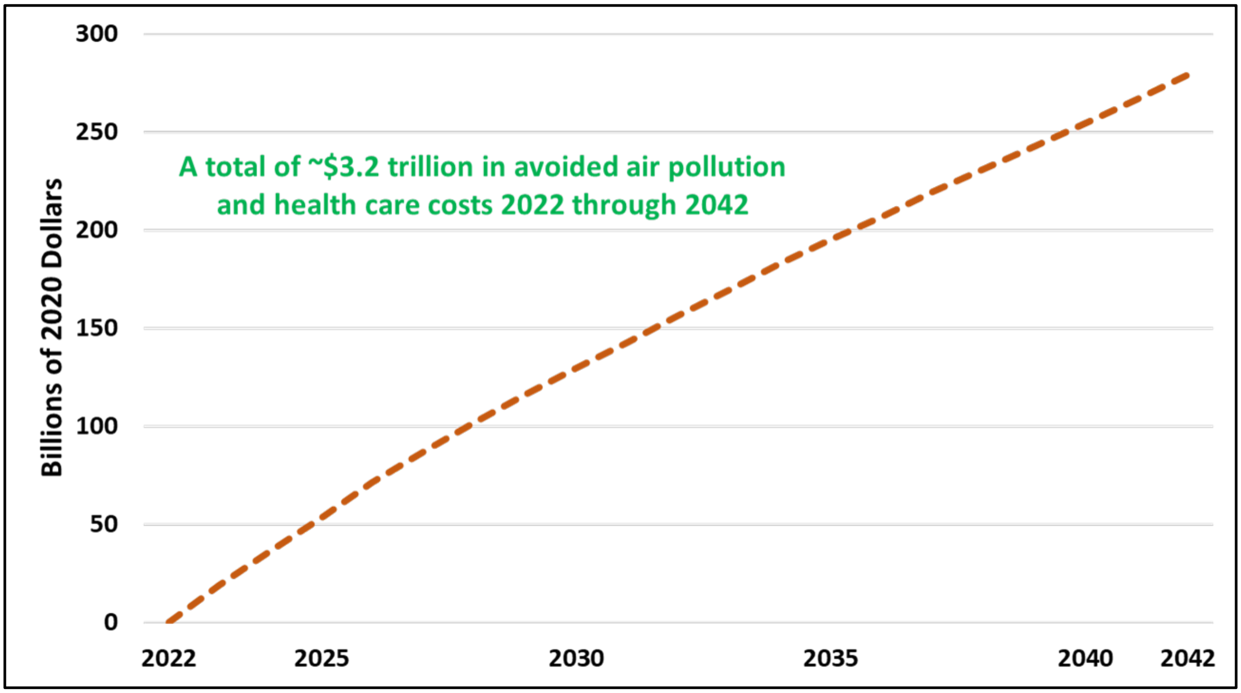
## 5-1 Evaluating the Clean Air Benefits

The impact of air quality can affect our lives in many unexpected ways. As but one example, the annual labor income losses from premature mortality due to air pollution exposure totaled nearly $179 billion globally in 2015. This was an increase of about $47 billion, or 36 percent in real terms, since 1995 (in constant 2014 dollars). For North America, the annual labor income losses were estimated to be $21 billion in 2015, a $5 billion or 30 percent increase since 1995 (Lange et al. 2018). The International Renewable Energy Agency documents an array of fossil fuel externality costs that range globally from $5.7 trillion to $7.7 trillion per year (IRENA 2019). On the other hand, the International Energy Agency reports that fossil fuel dependence costs of $450-900 billion per year (counting costs for health impacts of fossil fuel combustion, macroeconomic costs, and military costs for securing fossil fuel supplies) might create an economic penalty 1.5 to 4 percent of US GDP (IEA 2011).

We can bring these types of projections closer to home by using a series of air pollution externality cost factors as they might be applied to the America 3.0 strategy.  There is a surprisingly large literature and research data available for this purpose. Some of the difficulty in using the different assessments is that they all use different metrics, with different base years and different time periods against different currencies. For example, the Parry et al. (2014) book cited in the opening of this narrative evaluated the impacts for coal and natural gas in terms of $/gigajoule, but they used $/liter for both gasoline and diesel fuel. Those were reported in 2010 dollars. At the same time, the U.S. Environmental Protection Agency uses current year benefits per kilowatt-hours (BPK), as measured against 2017 dollars (EPA 2019). The Stanford University report of a 100 percent renewable energy scenario evaluates the health and climate externality costs of fossil fuels in 2050 using $/kWh as reported in 2013 dollars.

The range of cost estimates vary widely. When converted from other units to dollars per Million Btu ($/MBtu), and then weighted to the same mix of fossil fuel consumption and the same year currency (2020 $), the air pollution externality for EPA is around $3.80/MBtu with a range of $1 to $8 per MBtu. The IMF cost appears to be $10.60/MBtu with a range of $2.90 to as high as $20.50 per MBtu (again in 2020 $). The central estimate for the Stanford University study is $6.50/MBtu. Some reasonably central appraisals, derived from a series of European assessments, are reported in the Regional Center for Renewable Energy and Energy Efficiency based in Cairo, Egypt (RECREE 2013). Adjusted again to 2020 dollars, they note externality costs of $2.02, $6.42, and $7.01 per MBtu for natural gas, coal, and oil, respectively. Given the current pattern of fossil fuel consumption in the United States, the fuel-weighted average is $4.75 per MBtu. This compares to an estimated average price of $15.72/MBtu for delivered energy in the United States.

*Figure 6. Potential Scale of Air Pollution/Health Benefits from Reduced Fossil Fuel Usage*



***Source:*** *Scenario results as described in the narrative.*

If we apply these externality costs to the projected pattern of energy consumption within the United States over the years 2022 through 2042, adjusting for decreasing energy intensities and improved electric generation efficiencies over time, Figure 6, above, highlights the avoided air pollution and health costs annually, as the America 3.0 strategy reduces fossil fuel consumption to zero by 2042. Current AEO 2020 projections indicate that while total energy consumption is likely to rise from about 100 quadrillion Btus (Quads) of energy in 2022 to 104 Quads by 2042, fossil fuel usage is likely to remain at ~80 quads over that time horizon. But as the America 3.0 scenario begins to unfold over that same time period, and the demand for fossil fuels year-after-year begins to drop, the avoided externalities slowly begins to increase. By 2025 the benefits have grown to more than $50 billion in that year, rising steadily to just under $280 billion by 2042. The cumulative total over that time, as emphasized in Figure 6, suggests a total air pollution and set of health benefits on the order of $3.2 trillion over the 20-year period (all in 2020 dollars).[218]

## 5-2 Understanding Climate Opportunities

December 2020 marked the 432nd consecutive month in which nominal temperatures were above the 20th century average. The year 2020 marks the 44th consecutive year (since 1977) with global land and ocean temperatures, at least nominally, above the 20th-century average. The average temperature in 2020, across both global land and ocean surfaces, was 1.76°F (0.98°C) above the twentieth-century average of 57.0°F (13.9°C). That makes 2020 the second-warmest year on record. More critically, the annual global land and ocean temperature has increased at an average rate of +0.14°F (+0.08°C) per decade since 1880; however, since 1981 the average rate of increase is more than twice that rate (+0.32°F / +0.18°C).[219] Many assessments of externality costs, as noted above, integrate elements from both air pollution and climate change; and they are indeed interactively connected. Greenhouses gases, as one example, catalyze a heating up of the atmosphere while the increased releases of particulate matter compromises human health making people more susceptible to the coronavirus.[220]

*Table 5. Period Comparisons of United States Climate Disasters Statistics*

| Time Period | Deaths/Year | Cost/Year (Billion 2020 $) |
|---|---|---|
| 1980s (1980-1989) | 287 | 18 |
| 1990s (1990-1999) | 305 | 27 |
| 2000s (2000-2009) | 309 | 52 |
| 2010s (2010-2019) | 522 | 81 |
| Last Year (2020) | 262 | 95 |

***Source:*** *Data from NOAA (January 2021)[221] with a working projection out to the year 2042 as described in the text.*

In this last subsection of the narrative, however, we can focus more closely on the climate burden that is growing in real time, and we can then get a sense of how large that impact might be if continued

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[218] Because of the large variability in unit externality costs, coupled with many uncertainties on energy intensities and pollution control technologies, and other variables over time, there is likely a wide variation in potential outcomes. With time and resources, we could run a series of Monte Carlo simulations to integrate more variables and a wider range of those variables to see what that central tendency would be. Yet, this is an indicative result which is highly consistent with many other study outcomes.

[219] A more complete review of the shifting burden climate impacts is available from NOAA's Climate.gov website. At https://www.climate.gov/news-features/understanding-climate/climate-change-global-temperature.Additional information and background can also be found at https://www.ncei.noaa.gov/news/global-climate-202012..

[220] See a New York Times story that, among other things, explores the links link between air pollution and coronavirus risks, https://www.nytimes.com/2020/04/07/climate/air-pollution-coronavirus-covid.html.

[221] https://www.ncdc.noaa.gov/billions/summary-stats. Statistics valid as of January 2021.

unmitigated. The investigation begins with some useful insights shown in Table 5 (above) from the National Oceanic and Atmospheric Administration (NOAA). While people and businesses are generally aware of the threats from wildfires, droughts, flooding and severe storms, they are less likely to be aware of the rising tide of such events.

Looking closely Table 5 we can see the economy-wide impacts are growing. The climate-related disasters rang up a cost of $18 billion per year in the 1980s (with 287 deaths per year), jumping to $81 billion per year by the 2010s (522 deaths per year), and in the last year alone (2020) rising to $95 billion per year (with a somewhat lower but still significant 262 deaths in that year). Without the use of any formal statistical trending technique, one could easily imagine the number of deaths per year rising into the thousands with damages which could grow hundreds of billions of dollars per year.

The question then becomes, how might we compare these historical data with magnitudes reported from other projections? We can first recall the $500 billion (also referenced in 2020 dollars) estimate from the Stanford University study mentioned in the introduction to this subsection. At the same time, we can also integrate insights from Nobel Prize economist William Nordhaus. In 2017, Nordhaus published a useful paper in the *Proceedings of the National Academy of Sciences of the United States of America* (PNAS), entitled "Revisiting the social cost of carbon" (Nordhaus 2017).

Without laying out the analytic details of the Nordhaus PNAS article, he suggests that if we move perhaps from 1°C above the twentieth-century average (where we are roughly now) to 3°C above (where we could be by 2042, if not higher), the economy may weaken by perhaps $319 billion dollars (also in 2020 dollars), which is just a little bit under the adjusted costs suggested by the Stanford University assessment. On the other hand, if we assume what is termed the *social cost of carbon* (SCC) with an average economic impact of $135 per metric ton of carbon dioxide emitted in the United States (IWG 2016), that may cost the market perhaps $640 billion by 2042 (in 2020 dollars). If that cost moves annually along the suggested pace of energy-related greenhouse gas emissions as suggested by the Annual Energy Outlook (EIA 2020), it could imply a cumulative climate cost of about $12.8 trillion over the period 2022 through 2042 (expressed in 2020 dollars). On the other hand, if America 3.0 succeeds in reducing the use of fossil fuels to near zero by 2042, that could save taxpayers, businesses, and households as much as $6.2 trillion over that 21-year period of effort. So, we have several different approaches which converge on an exceptionally large and potentially negative impact on the U.S. economy – if we do not act immediately within the framework of America 3.0.[222]

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[222] The $135 per metric ton of $CO_2$ is an average of two data series, reflecting the rising costs of carbon over time, as documented in a working paper published by a U.S. International Working Group (IWG 2016). The original values were expressed in 2007 dollars, here updated to 2020 values. Other studies suggest that the current social costs of carbon represent a less than complete assessment which indicates an even higher social cost of carbon (Howard 2014; also, Howard and Sterner 2017). Perhaps a more disturbing report by climate research scientists (Ricke et al. 2018) underscores the importance of confronting, mitigating, and adapting to climate change. They note that the global social cost of carbon, including both climate and other health effects, may be on average $417 per metric ton (in 2005 dollars) of carbon dioxide. If those costs are paid as we purchase each tankful of gasoline, for example, that might raise the cost of gasoline by about $3.78 per gallon.

## 5-3 A Graphic Summary of the Potential Benefits

As highlighted in Section 4.3 of this report, and summarized in Figure 7, below, a hefty stimulus investment in the upgrade of the nation’s infrastructure can deliver a large benefit to the nation’s economy – both in terms of a larger return on GDP and also a greater number of jobs. In a preliminary assessment, mobilizing an upgrade of $16.4 trillion over the years 2022 through 2042 could lead to an average annual employment increase of 18.7 million net new jobs even as the nation’s GDP might increase more than $2.5 trillion (in constant 2012 dollars) by the year 2040.

*Figure 7. Estimated Cost and Benefits of a More Resilient, Resource Productive America 3.0*

| **Mobilized Investment** | **Net Job Creation** | **More Resilient Economy** | **Clean Energy Cleaner Air** |
|---|---|---|---|
| $820 billion per year over the period 2022 through 2042 | An average of 18.7 million net new jobs over a 20-year period | A $2.5 trillion boost in GDP by the year 2042 | Near zero emissions with a $3.2 trillion savings in avoided air pollution costs and $6.2 trillion in avoided climate damages |

***Source:*** *As summarized here, and Sections 4.0 and 5.0 of the main narrative for the years 2022 through 2042.*

In annual terms, over the period 2023 through 2042, the $16.4 trillion investment (expressed in 2020 dollars) is assumed to be spent evenly throughout each of the 20 years of the assessment. Although the main analysis reviews three different scenarios, for the purposes of this supplemental review the focus is on a mid-range scenario in which employment quickly increases by 6.2 million in 2021. By the year 2042 this grows to a total of 22.3 million new jobs. In effect, the resulting work that must be undertaken, together with other benefits which also boost employment, is estimated to drive an average net gain of 18.7 million new jobs over that 21-year period. Given the increased productivity of each job, total GDP in the year 2042 is projected to grow by $2.5 trillion (expressed here in constant 2012 dollars).

At the same time, both greenhouse gas emissions and the array of fossil fuel air pollutants are expected to approach near zero by 2042 under an America 3.0 strategy. That could result in a cumulative benefit of a further $3.2 trillion in avoided air pollution and health costs (expressed in 2020 dollars). Finally, the cumulative cost of avoided climate damages conservatively estimated might be on the order of $6.2 trillion, also through 2042 (with these last costs also reported in constant 2020 dollars).[223] Indeed, these findings are consistent with many other assessments. Among the more recent studies, the House Select Committee on the Climate Crisis (2020), determined that by 2050, the cumulative estimated health and climate benefits might reach almost $8 trillion (in real 2018 dollars). In 2050 alone, the House Committee report noted, the estimated health and climate benefits would exceed $1 trillion.

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[223] While the investment magnitudes were first provided in 2020 dollars, the economic projections in the reference case of the *Annual Energy Outlook 2020*, op cit., were provided in constant 2012 dollars. Hence, the reference to different base-year dollars provided in this supplemental analysis.

# 6 POLICY IMPLICATIONS

As noted in the "Part 1: The Vision" of *America 3.0: The Resilient Society*, there is growing awareness of the possibility of a large number of programs and strategies which can enable a more skilled and more productive set of occupations.[224] As one immediate example, there is interest in establishing green academic apprenticeships in the 50 states—a Green Corps, a Conservation Corps, a Climate Corps, an Infrastructure Corps—that will provide "a living wage" and technical and professional certification and / or clinical learning credits toward academic degrees upon completion of service, allowing a younger generation of Americans to advance careers in the emerging green economy. These academic apprenticeships should be universally available, but they should also prioritize student engagement in the most disadvantaged communities. There is ample precedent for these initiatives in the United States. The Peace Corps, VISTA, and AmeriCorps have proved invaluable in encouraging public service and providing opportunities for young people to learn new skills, which have helped them find career paths and employment. Universities, trade schools, unions, and local governments across the US will play an important role in partnering with the various service corps in preparing the new green workforce of the twenty-first century.

Granting paid apprenticeships, technical and professional certification, and clinical learning credits toward academic degrees to millions of young people will provide the coming generation with the talent and skills to engage in trade, technical, and professional employment in a climate change economy increasingly focused on new resilient business models and accompanying careers. These proposed clinical learning agencies at the state, county, and local level will also be among the first responders in climate events and disaster relief and recovery missions that will increasingly be a constant reality rather than a rare anomaly.

Priorities should also be given to a "Just Transition Fund" to assist the coal regions and other regions tightly coupled to the fossil fuel civilization in making the transition into the resilient economic paradigm and the new business opportunities and employment that accompany it. Prioritizing these heavily impacted regions will be critical to securing widespread acceptance of the inevitable transformation into a new ecological era. All of this will require effort and investment beyond the working estimate of $16.4 trillion. Yet, the returns are clearly worth the added investment.

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[224] See "Part I: The Vision," pages 5-44, of *America 3.0 The Resilient Society*, TIR Consulting Group, LLC, Jeremy Rifkin, President.

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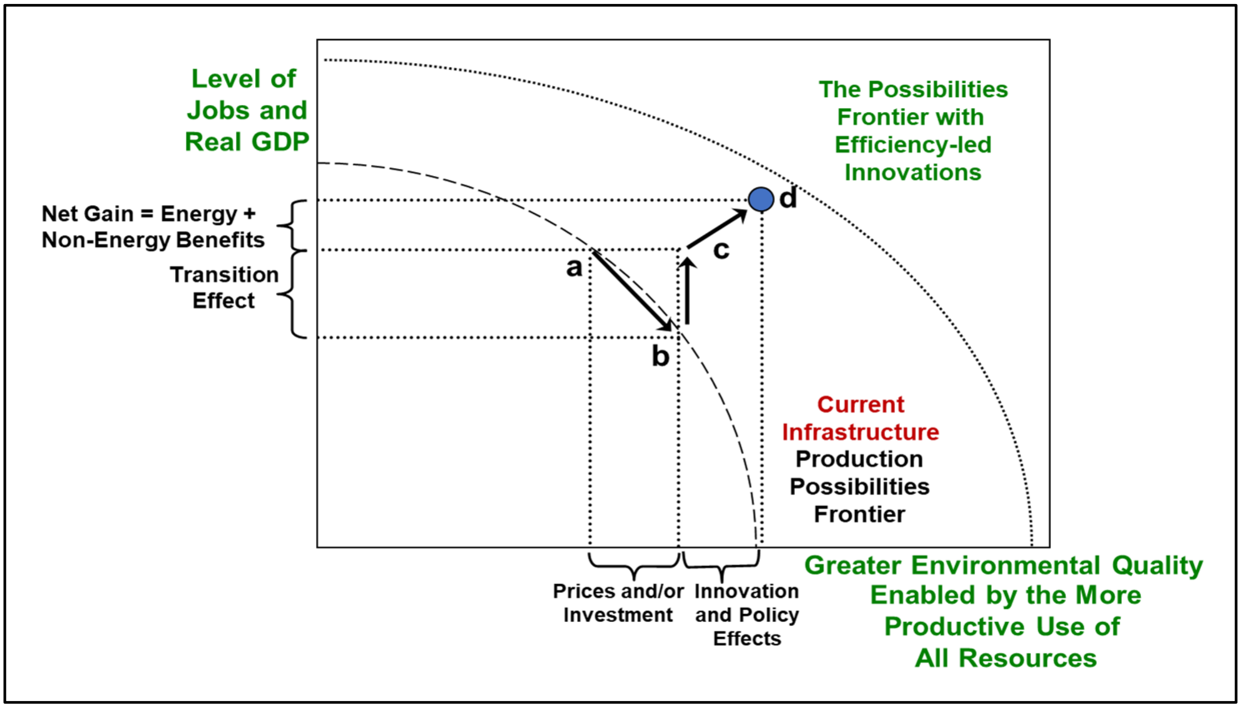
# APPENDIX A
# FURTHER INSIGHTS ON AGGREGATE EFFICIENCY AND THE ECONOMY

Table 1 in Section 4.2 of the main report lays out the seven major economic and employment drivers, which fully understood can help promote a more robust and sustainable economy. We can conceptually summarize all elements in Table 1 as the graphical illustration shown the diagram below which helps pull the key ideas of any likely America 3.0 "Innovation Scenario" into a useful perspective. While we cannot know at this time the scale of detectable responses to the complete set of economic stimuli, we can offer a positive overall explanation of how multiple benefits are likely to emerge through the implementation of a collaborative and productivity-led investment strategy.

*Conceptual Framework for Evaluating the Global Energy Transformation*



***Source:*** *John A. "Skip" Laitner, adapted to illustrate the equivalent of an America 3.0 Transition as cited in the narrative.*

Assuming that current energy consumption and production patterns continue indefinitely would imply that the U.S. economy is already optimized on what is called a production frontier at point "a" in the above diagram. If all resources are, indeed, optimally arrayed and utilized, the country faces a tradeoff whereby increasing economic growth can only come at a cost to the environment (e.g., through the increased consumption of fossil fuels) and vice versa (i.e., that improving environmental quality means a reduction in our social and economic well-being). Any change to satisfy a demand for greater efficiencies, or the demand for large reduction in greenhouse gas emissions, must likely result in a move down and to the right to a point like "b." Although the U.S. might achieve some mix of isolated productivity improvements, and there might be some reduction in greenhouse gas emissions, conventional wisdom suggests that this must surely come at the cost of a reduction in jobs and GDP.

Alternatively, a shift to increased deployment of energy efficiency and renewables may instead allow the economy to shift to a point like “c.” The transition toward cleaner and more efficient energy systems can improve the environment while also spurring increased local economic growth. The result is an improvement in overall aggregate efficiency, especially with the more productive use of clean energy 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 the figure in this appendix is not drawn to scale, the migration from point “a” to the eventual point “d” might represent an eventual doubling of energy productivity that drives a concomitant increase in economic activity or per capita GDP. Hence, a net energy savings, together with a transition to an economy powered by 80 percent or better renewable energy systems, in turn, might rouse a significant boost in net jobs, career opportunities and GDP. Equally critical, a clean energy transition can become a way to catalyze the seventh benefit of such strategies—an enhanced push of the production frontier so that future technologies and markets are encouraged, developed, and implemented to the long-term benefit of jobs and the economy.

# APPENDIX B
# NARRATIVE ON THE DEEPER MODELING SYSTEM

The foundation for the overall economic assessment that has been completed as part of America 3.0 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 in early 1992, is a compact 15-sector dynamic input-output model of a given regional or national economy. 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, in this case, the United States shifts from a less productive infrastructure to the higher level of performance that is likely to be associated with what we have called here the *America 3.0 Innovation Scenario*.

Although it has been updated here to reflect the economic dynamics specific to the United States, the formal "DEEPER model" has a 29-year history of development and application while even earlier versions of the tool were used by entities like the Arizona Energy Office and the Nebraska Energy Office in the mid-1980s. The model was utilized to assess the net employment impacts of 2012 proposed automobile fuel economy standards within the United States. It also underpinned the 2012 Long-Term Energy Efficiency Potential Study previously referenced in this narrative (Laitner et al. 2012). It has been employed to evaluate the macroeconomic impacts of a variety of energy efficiency, renewable energy, and climate policies at the regional, state, national and international levels. 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 (MRDH 2017).

The timeframe of the model for evaluating energy efficiency and renewable energy technology policies and investments is 2018 through 2050. The years 2018 through 2020 (or earlier as needed) provide a useful historical benchmark. The period 2021 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 which might be undertaken as a result of the America 3.0 roadmap. The Innovation Scenario relies on a variety of data made available by IMPLAN (2020), Woods and Poole Economics (2020), the Bureau of Labor Statistics (2020), and the U.S. Energy Information Administration (2020). The Figure below provides a diagrammatic view of the DEEPER Modeling System as it was reflected within the dynamics of all previous assessments.

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.[225] More to the point of this exercise, the model can specifically explore the energy and non-energy productivity benefits from what may often be characterized

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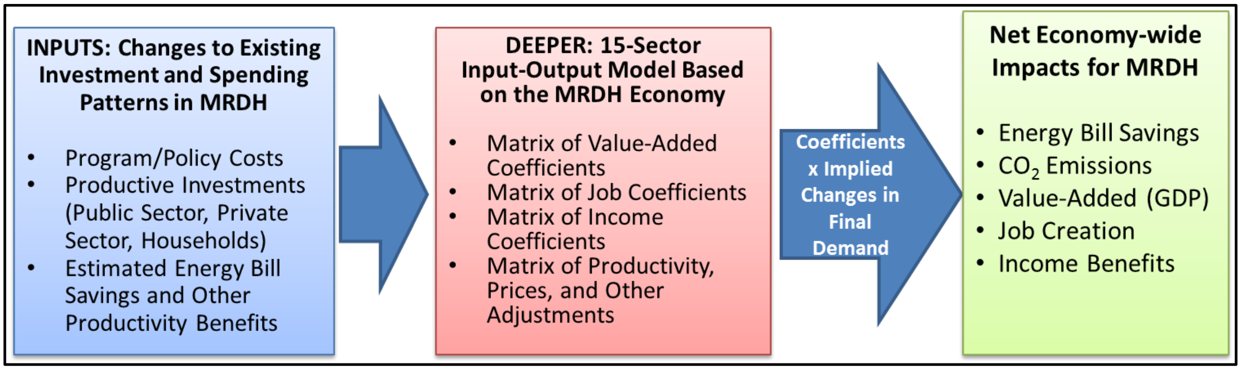
[225] When both equilibrium and dynamic input-output models use the same technology, investment, and cost assumptions, both sets of models should generate a reasonably comparable set of outcomes. For a diagnostic assessment of this conclusion, see, "Tripling the Nation's Clean Energy Technologies: A 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.

as Innovation Scenarios—especially as those scenarios are 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 nation's 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 3, the redirecting of $1 million in spending away from energy suggests there may be roughly a net gain of about 6.9 jobs. Depending on the many sectoral interactions, as well as the complete assessment of the many effects summarized and discussed in Tables 3A, 3B, and 3C 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.[226]

### *The DEEPER Modeling System*



***Note:*** *As discussed within this Appendix.*

Once the mix of positive and negative changes in spending and investments has been established for the America 3.0 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 (above), the full array of changes will drive a dynamic input-output analysis according to the following predictive model:

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

where:

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[226] 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 1.5 percent labor productivity improvement over the 23-year period from 2019 (the base year of the model) through 2042, the last year of the assessment, the 19.9 construction jobs supported by spending of $1 million within the United States in 2019 may support only 12.1 jobs by the year 2042. The calculation is $19.9 / 1.015^{(2042-2019)}$ = 14.1 jobs (rounded to the nearest tenth).

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.[227] 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).[228] 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.

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[227] 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.

[228] "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.

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