Challenge

ISSN: 0577-5132 (Print) 1558-1489 (Online) Journal homepage: http://www.tandfonline.com/loi/mcha20

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To cite this article: Amanda Page-Hoongrajok, Shouvik Chakraborty & Robert Pollin (2017) Austerity Versus Green Growth for Puerto Rico, Challenge, 60:6, 543-573, DOI: 10.1080/05775132.2017.1399644

To link to this article: https://doi.org/10.1080/05775132.2017.1399644

Published online: 02 Jan 2018.

Challenge, 60(6):543–573, 2017

ISSN: 0577-5132 print/1558-1489 online
DOI: 10.1080/05775132.2017.1399644

Austerity Versus Green Growth for Puerto Rico

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Well before Hurricane Maria wrought devastation on Puerto Rico, the island's economy was in crisis. Puerto Rico's economic output had already fallen sharply from its 2005 level. Even after what is hoped to be a successful recovery from the hurricane's damage—no small task—proposals to reform the Puerto Rican economy being discussed by the government would make matters worse. The authors discuss how Puerto Rico descended into its prehurricane distress and offer a bold set of counterproposals based on green investments, a carbon tax, and debt forgiveness by Puerto Rico's creditors.

Hurricanes Irma and Maria pummeled Puerto Rico in quick succession last September. Hurricane Maria collapsed the electrical grid, and much of the water supply became undrinkable. On September 20, President Trump declared Puerto Rico an official disaster zone, which enabled the island to receive federal support from the Federal Emergency Management Agency (FEMA). As of this writing, officials on Puerto Rico worry that it will be too little and too late.

But even before Irma and Maria hit, Puerto Rico had been experiencing years of severe economic and social crisis. The crisis conditions began emerging in the late 1990s after the unraveling of an economic growth model that was dependent on U.S. corporate handouts. This model delivered few benefits to the Puerto Rican people, but because it was the only growth model the island followed, its failure led to relentless increases in public borrowing by the commonwealth and its numerous public and semipublic agencies. The island was thus saddled with an overwhelming and unpayable level of public debt.

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According to the Government Development Bank of Puerto Rico's own data, overall economic activity began falling in mid-2005—notably, more than two years before the onset of the global financial crisis—and was 23 percent below the 2005 peak before the hurricanes hit in September 2017 (Oversight Board 2017). The labor force participation rate had fallen from 47.4 percent at the beginning of 2008 to 39.4 percent as of mid-2017, and the number of people employed has fallen by 10 percent. Puerto Rico's population dropped from 3.8 million in 2006 to 3.4 million by mid-2017, as economic opportunities on the island evaporated. Of course, the devastation wrought by Irma and Maria only exacerbated these trends.

Meanwhile, the commonwealth and its instrumentalities owe approximately $74 billion—about 70 percent of GDP—with debt-servicing costs ranging from $3.5 billion to $3.8 billion between 2017 and 2019 (Puerto Rico Fiscal Agency and Financial Advisory Authority 2017). Of that total, about $60.7 billion is owed by public corporations and other quasi-government entities (Merling et al. 2017). Beyond these figures are $49 billion in public-sector pension liabilities, of which only about 1.6 percent were funded as of mid-2015 (Oversight Board 2017, 9–10).

Various proposals for solving the crisis have been fought over by the Puerto Rican government, its creditors, and the Financial Oversight Board established by the U.S. Congress in 2016 to manage the crisis. But thus far, nearly everything being proposed in these discussions promises to only make conditions worse, even after Puerto Rico regains the minimal working order undone by the hurricanes. This is because the proposals under discussion are based on the false premise that what Puerto Rico will need is austerity. Austerity for Puerto Rico will specifically entail sharp cuts in government spending, including in the areas of health care, education, and the overall number of jobs and the pay levels for public employees. Up to now, 20 percent of employed workers now hold government jobs.

In fact, this austerity plan for Puerto Rico will deepen the economic crisis because, as with all such austerity programs, it will lead to declining incomes, private spending, and business sales, and thereby a diminishing tax base for servicing debt. Even the Puerto Rican government's own analysis, presented in their March 2017 "Fiscal Plan" that was approved by the Oversight Board, projects further economic contraction through 2024.

That Fiscal Plan before the hurricanes also includes a "structural reform" program for restoring economic growth to the island that offers at least a glimmer of possibility. The structural reform program focuses initially on a three-year, $5 billion program in public/private partnership investments, with the new investment areas including energy (43 percent), transportation (22 percent), waste management (20 percent), water management (8 percent), and social infrastructure (7 percent).

Yet even this proposal suffers from two fundamental flaws. The first is straightforward: few private investors will want to commit long-term to an economy that has failed to grow for nearly twenty years, even if the hurricane devastation is corrected, and where policy makers are actively implementing austerity policies that will squeeze the economy further. But even if the government is able to escape from its current austerity trap, its proposed structural reform program still needs to be developed much more carefully before anyone can be confident that it is not simply a new vehicle for channeling financial giveaways to U.S. corporations. An aggressive plan for recovery from Irma and Maria will represent only a first step toward advancing an effective structural reform program.

On the positive side, with Puerto Rico's energy infrastructure being identified as the single most important area for targeted investments, the fiscal plan recognizes that the island's existing energy system is dysfunctional, acting as a major drag on competitiveness and growth—and again, this was *before* the electrical grid system was collapsed by Irma and Maria. Thus, as of mid-2017, electricity prices for industrial consumers were three times higher than those in the U.S. mainland. Puerto Rico also imports all of its energy supply, with these imports constituting an outflow of aggregate demand ranging about 4–6 percent of GDP most years.

We propose to build upon the government fiscal plan and develop a "green growth" program for Puerto Rico. Like the government's own proposal, our green-growth plan is designed to serve as a framework for the structural transformation of Puerto Rico's economy. In its essentials, our green-growth plan consists of large-scale annual investment in two simple elements: energy efficiency and clean renewable energy. Through these investments, low-cost, domestically produced clean energy will steadily supplant imported fossil fuels, with the target being that by 2050, clean energy sources will have replaced fossil fuels entirely in Puerto Rico.

Especially in the aftermath of Irma and Maria, Puerto Rico's green-growth program will also need to incorporate aggressive climate adaptation and resilience policies. These will include water storage and water-demand management programs; building retrofits and land zoning policies to reduce vulnerability to high winds and flooding; and creating buffer zones in coastal areas and alongside the island's major rivers that are capable of diverting or withstanding water surges (United Nations Framework Convention on Climate Change 2007; Puerto Rico Climate Change Council Working Group 3 2013. See United Nations Framework Convention on Climate Change (2007) for general perspectives on adaptation and resilience for small island developing states).[1]

Most of the specific areas for development targeted in the government's structural reform program can be effectively integrated into this green-growth framework. Transforming the island's energy infrastructure is clearly the single most important priority. But the transportation system can also be overhauled within the green-growth project through expanding public transit and subsidizing the local market for high-efficiency private vehicles, including hybrids and electric cars. Waste management can be utilized for generating clean sources of bioenergy. Incorporating small-scale hydro power projects into the island's water management system can produce cheap electricity. Climate adaptation and resilience measures can also be incorporated into all of these targeted investment areas.

Overall, this green-growth program is capable of delivering much lower energy costs on the island, while also steadily reducing, and finally eliminating altogether, its dependence on fossil fuel imports. The green-growth program will also be a major new source of job opportunities and will create widespread opportunities for small-scale ownership firms to flourish within the island's energy sector. It should also significantly reduce Puerto Rico's vulnerability to severe hurricanes such as Irma and Maria.

A critical component of the green-growth plan, as we discuss below, will be a carbon tax. This will concurrently discourage the consumption of fossil fuel energy through higher retail prices while also generating a level of tax revenues that would be adequate to, at once, finance the long-term investment and adaptation program, provide tax rebates for lower-income households, and still have significant funds available for servicing the public sector's debt. Finally, the green-growth program will enable Puerto Rico to make a positive, if modest, contribution to reducing global carbon dioxide (CO_2) emissions and fighting climate change. This should help restore Puerto Rico's reputation as a desirable tourist destination. The island's luster had already been sagging due to the economic crisis and will inevitably suffer more in the aftermath of Irma and Maria.

Yet despite all these positive benefits, it is still the case that, as with the government's own structural reform proposals, this green-growth program cannot successfully launch under austerity conditions. Major debt write-downs will be necessary to enable the green-growth program to move forward at a significant scale along with viable posthurricane recovery initiatives. To understand the justification for major debt write-downs, which requires forgiveness from creditors, it will be useful to review how Puerto Rico got into its debt trap and fiscal crisis in the first place.

ORIGINS OF THE DEBT CRISIS

Puerto Rico's current debt crisis can be traced to the phaseout of a major tax subsidy for U.S. business corporations that had been operating since 1976. This subsidy, known as IRS Section 936, exempted from U.S. federal taxation any profits earned in Puerto Rico. Investments into Puerto Rico by U.S. firms increased sharply as a result of this policy. Thus, as of 1974, U.S. corporate direct investment on the island was at 80 percent of GDP (Economic Research Group of the Secretariat of Information and Propaganda, The Puerto Rican Socialist Party 1976, 53). Four years later, subsequent to the passage of Section 936, that figure jumped to 97 percent of GDP

(Ayala and Bernabe 2007, 269).The primary firms taking advantage of the 936 subsidy were capital-intensive high-tech U.S. manufacturers, in particular such pharmaceutical giants as Abbott Laboratories, Pfizer, and Merck (U.S. Department of the Treasury 1978).These companies along with the rest of the pharmaceutical sector received about half the tax benefits of the subsidy over the years 1985–89(Government Accountability Office 1993).The subsidy saved U.S. businesses an average of about $2.5 billion per year (in constant 1991 dollars) throughout the 1980s. This equaled about 10 percent of Puerto Rican GDP over these years and was sufficient, for example, to fully cover the payroll costs of these businesses in 1989.

The Section 936 program clearly provided huge benefits to the investing corporations. It was also a major source of the island's economic growth. Over the thirty years—1976–2006—that the subsidy was in place, Puerto Rico's GDP growth averaged 3.5 percent per year (World Bank 2017). There were only three years—1982, 1983, and 2006—of negative GDP growth during the years that 936 operated.

It is, however, critical to emphasize here that the benefits from economic growth that did occur under 936 were heavily skewed in favor of U.S. corporations as opposed to the local Puerto Rican economy and its people. In fact, the official figures measuring Puerto Rico's GDP overstate the level of economic growth that occurred within the domestic economy as opposed to the gains that accrued to U.S. corporations. Godoy (2016, 1) explains:

> Since 1965, the 936 tax incentive did little for the people of Puerto Rico but lots for mainland U.S. corporations. Most eye-opening is the mega difference between Puerto Rican GDP and GNP. The growth of GNP is a much better measure of the improvement of the Puerto Rican economy, but the economic gains of U.S. corporations have been confused with gains for the island. For example, GNP fell to 76 percent of GDP in 1980, 68 percent in 1990, 67 percent in 2000, and 66 percent in 2010. To put these figures in some perspective, in 2004, for only 15 countries was GNP less than 90 percent of GDP, and for only 2 was the GNP-GDP ratio less than 70 percent—Puerto Rico at 67 percent and Equatorial Guinea at 30 percent. The benefits of 936 flowed to shareholders and not Puerto Rican residents.

But even this relatively weak and lopsided growth framework began unraveling with the phaseout of 936 beginning in 1996 under President Bill Clinton and continued through 2006. The Clinton administration argued for the 936 phaseout as a measure to reduce the U.S. fiscal deficit. It was estimated that the phaseout would save the U.S. Treasury $10 billion over 10 years, or roughly $1 billion per year (Dayen 2015). In 1996, the federal budget was $1.95 trillion, and the fiscal deficit was $144 billion (Office of Management and Budget 2016). Abolishing 936 could obviously have only a trivial impact on the U.S. federal budget one way or another. But because

Puerto Rico had become dependent on U.S. investments through 936, the phaseout left the island without anything resembling an economic growth strategy, even a weak and inequitable one.

Thus, from 2007 to 2016, Puerto Rico's average annual GDP growth rate—which, again, itself overstates growth within the domestic economy—was −1.1 percent (Puerto Rican Planning Board 2006–2016). On a year-by-year basis, Puerto Rico experienced only one year of positive GDP growth over this period, in 2012, and that year growth, at 0.03 percent, only barely reached positive territory. It is true that the years since the ending of 936, starting in 2007, coincided with the global financial crisis, Great Recession, and weak recovery. However, Puerto Rico's growth performance since 2007 has been weaker than even the worst-performing states in the U.S. mainland. The two most sluggish U.S. state economies, Connecticut and Nevada, averaged annual growth rates of −0.70 percent and −0.39 percent respectively over the same period. Small countries in the Caribbean grew at a positive average rate of 0.5 percent over these years (World Bank 2017). In Europe, the only country that compares with Puerto Rico in terms of growth performance is Greece, where its debt crisis and punishing austerity program has delivered an average growth rate of −2.6 percent during this period (World Bank 2017).

Not surprisingly, the most directly hit sector in Puerto Rico due to the Section 936 phaseout was manufacturing. From 2001 to 2007, Puerto Rico had an average of 3,000 manufacturing establishments (Bureau of Labor Statistics 2017). By 2012, that number had dropped to 2,000—a decline of one-third within a period of five years after the 936 phaseout. Manufacturing employment fell commensurately, from an average of 150,000 between 1990 and 1997 to less than 74,000 as of 2015.[2]

The loss of U.S. manufacturers also brought a deterioration in Puerto Rico's fiscal conditions. This is because while 936 was still in effect, the island instituted a 10 percent repatriation tax known as the tollgate tax. Since much of the income generated on the island was repatriated back to the United States, the tollgate tax provided a major source of government revenue. As of 1994, the tollgate tax generated $225 million, or 5 percent of the commonwealth's general revenue funds (Puerto Rican Planning Board 1994). As of 2015, the tollgate tax had dwindled to $4 million.

It is within this context that the Puerto Rican public sector began to increase its reliance on debt. Thus, as of 1997, the year the 936 phaseout began, total public debt, including that of the commonwealth itself as well as the various public and quasi-public corporations, was at 60.3 percent of GNP. That figure rose during the phaseout period through 2006, to 70.4 percent. From 2007 to 2015, the public debt/GNP ratio rose sharply, peaking in 2015 at 95.1 percent.[3]

But more significant than the rising debt level per se has been the interest obligations on the overall debt level. According to the commonwealth's most recently released financial statement (2014), its level of debt servicing had reached fully 5 percent of the island's GDP and 23 percent of total expenditures (Gomez and Galarza 2014). It is within this framework that Puerto Rico's current debt obligations are clearly unpayable.

The single largest group holding Puerto Rican bonds is U.S. hedge funds, with their holdings estimated to be 25–50 percent of all outstanding debt (Dayen 2015). As Merling et al. (2017) write:

> In 2014, hedge funds began to buy up debt at a steep discount on the secondary as well as on the primary market .... This buying spree continued through late 2014 and into 2015 .... Among this group of hedge funds is the Ad Hoc Group of Puerto Rico's General Obligation Bondholders, which aggressively offered to buy more bonds as Puerto Rico's access to credit markets deteriorated. The investors lobbied against Puerto Rico's access to bankruptcy proceedings and promoted austerity policies as the crisis deepened in 2015 and 2016. (16–17)

In short, these U.S. hedge funds understood full well that they were buying into a high-risk proposition. This is precisely why they were able to purchase the outstanding loans on the secondary market at steep discounts.

ENERGY AS STRUCTURAL PROGRAM

The severity of Puerto Rico's structural problems created by its current energy system can be understood clearly by considering evidence on both comparative energy prices between the island and the U.S. mainland as well as the island's trade deficit in energy.

Energy Prices

Table 1 presents current comparative figures on energy prices. As we see first, the price differences are modest in the case of gasoline. Average retail gasoline prices in San Juan in mid-2017 (prior to the September hurricanes), at $2.50 per gallon, were only about 4 percent higher than the average U.S. price.

However, with electricity, prices in Puerto Rico were 58 percent higher for residential consumers, 113 percent higher for commercial users, and 275 percent higher for industry as of mid-2017. It is clear how these price differentials, especially those for commercial and industrial consumers, are capable of greatly weakening Puerto Rico's competitiveness.

This problem becomes more dramatic still when considering the opportunities that are available to the island through investing to create large-scale renewable energy resources. The lower panel of Table 1 shows the most recent figures on electricity prices from clean renewable energy

TABLE 1 Comparative Energy Prices for Puerto Rico and U.S. Mainland

Gasoline and Electricity Prices, Mid-2017

	Puerto Rico	U.S. Average	Puerto Rico relative to U.S.
Gasoline per gallon	$2.50 *(in San Juan)*	$2.40	+4.2%
Electricity per Kilowatt Hour			
Residential	20.1 cents	12.7 cents	+58.0%
Commercial	22.1 cents	10.4 cents	+112.7%
Industrial	18.2 cents	6.6 cents	+275.1%

Average Projected U.S. Renewable Energy Electricity Prices, 2022

	U.S. average, *per kilowatt hour*	Current Puerto Rico residential relative to 2022 U.S. renewable average
Onshore wind	5.6 cents	+357.1%
Solar PV	7.4 cents	+270.2%
Geothermal	4.4 cents	+454.5%

Source: U.S. Energy Information Agency 2016; U.S. Energy Information Agency 2017.

sources, as reported by the U.S. Energy Information Agency (EIA). The EIA figures are projections of renewable electricity prices for U.S.-based projects beginning operations in 2022. As we see, these prices are 5.6 cents per kilowatt hour (kWh) for onshore wind, 7.4 cents for solar, and 4.4 cents for geothermal (U.S. Energy Information Agency 2017).[4] The current electricity prices in Puerto Rico range three to four times higher than these figures. It is therefore apparent that advancing a green-growth strategy aiming to achieve 100 percent renewable energy supply represents a major opportunity to lower the cost of living for both households and business competitiveness.

Energy Trade Deficit

Table 2 shows figures on Puerto Rico's trade deficit in energy, providing the most recent available full set of figures for 2011–15. As we see, the trade

TABLE 2 Puerto Rico Net Energy Imports and GDP, 2011–15

	Net Energy Imports	Net Energy Imports as Share of GDP
2011	$4.4 billion	4.4%
2012	$6.3 billion	6.3%
2013	$6.1 billion	5.9%
2014	$5.5 billion	5.4%
2015	$3.7 billion	3.6%

Source: Trade data from U.S. Census Bureau 2017; GDP data from World Bank 2017 and Puerto Rico Planning Board, various years.

deficit over these five years is very large, ranging between 3.6 and 6.3 percent of the island's GDP. That is, Puerto Rico is shipping out, roughly, 4–6 percent of its national income to purchase imported energy. With a decently functioning domestic energy system, these are resources that could be channeled into promoting domestic investments, expanding job opportunities, and raising living standards for Puerto Rico's residents. This level of imports might be justifiable if it were delivering low-cost energy to the island. But, as we have seen, the opposite is the case: Puerto Rico is draining its national income to purchase imported energy, while residential, commercial, and industrial consumers are all paying exorbitant electricity prices.

BASIC ASSUMPTIONS OF GREEN-GROWTH PROGRAM

As we see in Table 3, as of the most recent 2015 data, GDP in Puerto Rico was $103 billion, equal to about $30,000 per capita. We assume that GDP will remain flat through 2020, the first year of the green-growth program. From 2020 to 2050, we then assume that GDP grows at an average rate of 2 percent per year. Of course, this growth rate represents a major improvement over the negative growth that the island has experienced over the past decade. But it is also well below the 3.2 percent average growth rate that was maintained between 1995 and 2005 (World Bank 2017).[5]

With GDP at $103 billion, total energy consumption in Puerto Rico from all sources equals 0.38 quadrillion British Thermal Units (Q-BTUs),[6] and CO_2 emissions are at 28 million metric tons.[7] The aim of the green-growth program is to support a healthy rate of long-term economic growth while energy efficiency investments and clean renewable energy replace fossil fuel

TABLE 3 Basic Data and Assumptions of Puerto Rico Green-Growth Framework

GDP, 2020–2050	
1. GDP, 2015 actual and 2020 projected	$103 billion
2. Average annual GDP growth, 2020–50	2%
3. Midpoint GDP—2035	$140 billion
4. Endpoint GDP—2050	$185 billion
Energy Consumption and Emissions	
5. Energy consumption, 2014	0.38 Q-BTUs
6. CO_2 emissions, 2014	28 million tons
Estimated Average Costs for Clean Energy Investments	
7. Average costs for increasing energy efficiency	$20 billion per Q-BTU of energy savings
8. Average costs for expanding clean renewable energy supply	$125 billion per Q-BTU of energy supply

Sources: Pollin et al. 2015; U.S. Energy Information Agency 2016; U.S. Energy Information Agency 2016.

consumption, and CO_2 emissions fall steadily toward the zero emissions goal by 2050.

In rows 7 and 8 of Table 3, we present our assumptions as to the average costs of achieving one Q-BTU of energy savings through efficiency investments and of building one Q-BTU of clean renewable energy supply. As we see, the assumptions we use are that achieving 1 Q-BTU of savings will cost an average of $20 billion, and that expanding the supply of clean renewable energy will be $125 billion. The energy efficiency investments include the areas of building retrofits, public transportation, industrial efficiency, and electrical grid upgrades. The renewable energy investments include wind, solar, geothermal, small-scale hydro, and low-emissions bioenergy.

These cost estimates are derived from a range of sources examining these issues, including the World Bank, McKinsey and Company, the U.S. Energy Information Agency, the U.S. National Academy of Sciences, and the International Renewable Energy Agency. The 2015 study *Global Green Growth*(Pollin et al. 2015) presents a full discussion of these estimates for a range of countries. The figures that we are applying to Puerto Rico are the same as those Pollin et al. applied for the South Korean economy in the 2015 study. These cost figures are higher than those that we had assumed for Brazil, Indonesia, and South Africa in the 2015 study.

ENERGY SUPPLY AND DEMAND WITH CLEAN ENERGY INVESTMENTS

In Table 4, we present figures on energy supply and demand over the 2020–50 period, starting with our projections for energy demand. Given that we are assuming economic growth will average 2 percent per year, we first also assume that energy demand will grow at a 2 percent average annual rate—that there will be no gains in energy efficiency as the Puerto Rican economy grows. Under this scenario, as we see in row two, total energy consumption rises to 0.7 Q-BTUs by 2050. We then assume that energy consumption will grow at only 1 percent per year over our thirty-year period, with investments in energy efficiency cutting the growth rate of energy consumption to be one-half the growth rate of the overall economy. We see that in row three, with energy consumption growing at 1 percent per year as opposed to 2 percent, overall energy consumption as of 2050 will be 0.5 Q-BTUs as opposed to 0.7 Q-BTUs.

In other words, the Puerto Rican economy will now need to invest sufficiently in energy-efficiency measures to reduce the island's energy consumption by 0.2 Q-BTUs as of 2050. Since we are assuming that the costs of achieving 1 Q-BTU of efficiency gain will be $20 billion, it follows that Puerto Rico will need to spend a total of $4 billion over the thirty-year

TABLE 4 Impact of Clean Energy Investments on Energy Demand and Supply

Energy Efficiency Investments and Energy Demand	
1. Energy consumption, 2014 actual	0.38 Q-BTUs
2. 2050 Energy consumption with 2% average annual consumption growth	0.7 Q-BTUs
3. 2050 energy consumption with 1% consumption growth	0.5 Q-BTUs
4. Total costs of reducing 2050 energy consumption by 0.2 Q-BTUs	\$4 billion *((= row 2–row 3) × \$20 billion)*
5. Average annual 2020–2050 costs of reducing 2050 energy consumption by 0.2 Q-BTUs	\$133 million *(= row 4/30)*
Renewable Energy Investments and Energy Supply	
6. Investment costs to build 0.5 Q-BTUs of renewable energy capacity	\$63 billion *(= \$125 billion × 0.5)*
7. Average annual 2020–2050 costs of building 0.5 Q-BTUs of renewable capacity by 2050	\$2.1 billion
Overall Investment Costs and GDP	
8. Total clean energy investment costs	\$67 billion *(= rows 4 = 6)*
9. Average annual investment costs	\$2.2 billion *(= rows 5 + 7)*
10. Average annual costs as pct. of 2035 GDP	1.6% *(= row 9/\$140 billion)*

Sources: U.S. Energy Information Agency 2016; Table 1 figures.

investment cycle. As an average over the thirty-year period, this amounts to \$133 million per year.

We next calculate the total costs of creating 0.5 Q-BTUs of clean renewable capacity in Puerto Rico as of 2050 in order to supply 100 percent of the island's energy demand through clean renewables. As noted above, we are assuming that the average costs of building clean, renewable capacity in Puerto Rico will be \$125 billion per Q-BTU. Under this assumption, Puerto Rico will therefore need to spend a total of \$63 billion as of 2050 to create this level of renewable energy productive capacity. This amounts to \$2.1 billion per year, as an average investment spending level over the thirty-year investment period.

We can now add up the total costs of this green-growth investment program. As we see in rows eight and nine of Table 4, these total costs are \$67 billion for the full thirty-year period, or \$2.2 billion per year on average. This \$2.2 billion average annual figure is equal to 1.6 percent of Puerto Rico's midpoint GDP in 2035 over the full thirty-year investment period. We, again, also assume that substantial investments in climate change adaptation measures are incorporated into this overall green growth investment program.

JOB CREATION

There will be two sources of net job creation as the Puerto Rican economy pursues large-scale investments to both raise the economy's level of energy efficiency and expand its supply of renewable energy. The first will be the jobs generated by the energy efficiency, renewable energy, and climate adaptation/resilience investments themselves. The second will be the jobs created through energy import substitution, with the economy's spending on energy imports declining steadily and those funds being redirected into the economy's aggregate spending stream. We consider these in turn, and present our results in Tables 5 and 6 respectively.

Job Creation Through Clean-Energy Investments

We have worked with the input-output tables for Puerto Rico to derive these estimates. From the input-output tables, we are able to generate employment/output ratios for investments in both clean renewable energy and energy efficiency. We present the full derivation of these employment/output ratios in the technical appendix. For both the renewable-energy and energy-efficiency investments, the figures we present in Table 5 are weighted averages of employment/output ratios for specific sets of activities in the Puerto Rico input/output tables. For renewable energy, we assume investment shares as being 40 percent each for wind and solar energy, 7 percent each for geothermal and low-emissions bioenergy, and 6 percent for small-scale hydro. With energy efficiency, we divide the full level of spending equally between building retrofits, public transportation, industrial efficiency, and electrical grid upgrades.[8]

Based on these investment profiles, we then show in Table 5 the employment levels generated by investing an average of $2.1 billion annually in renewable energy and $133 million annually in energy efficiency. As we see first, in row one, our estimate of job creation through renewable-energy investments in Puerto Rico is 10.4 jobs per $1 million in spending. Assuming average spending is at $2.1 billion, this generates an average of about 21,800 new jobs per year through renewable investments.

TABLE 5 Employment Creation Through Clean Energy Investments

Renewable Investments, 2020	
1. Job creation per $1 million in investments	10.4 jobs
2. Job creation through $2.1 billion in investments	21,800 jobs *(= 10.4 × 2,100)*
Energy Efficiency Investments, 2020	
3. Job creation per $1 million in investments	12.5 jobs
4. Job creation through $133 million in investments	1,700 jobs *(= 12.5 × 133)*
5. Total job creation through clean energy investments, 2020	23,500 jobs *(= rows 4(+(5)*
6. Total job creation in 2050, with 1% average annual labor productivity growth	17,500 jobs

Sources: See Technical Appendix.

In row three, we show that energy-efficiency investments in Puerto Rico generate an average of 12.5 jobs per $1 million in spending. Spending $133 million per year in these four energy-efficiency areas thus generates about 1,700 jobs per year.

Adding up the annual investments in both renewable energy and energy efficiency respectively will therefore produce about 23,500 jobs within the existing productive processes, as presented in the current input/output tables. We then also allow that production processes in all areas of both energy-efficiency and renewable-energy production improve incrementally over time, generating an annual gain in labor productivity of 1 percent per year. Because of this steady improvement in labor productivity, the same $2.2 billion in clean-energy investments will then produce a reduced level of job creation as of 2050, that is, 17,500 jobs in total, as opposed to 23,500 as of 2020.

Job Creation Through Energy Import Substitution

As we show in Table 6, Puerto Rico's average annual net energy import bill between 2011 and 2015 was $5.2 billion. Through the green-growth program, we assume that these imports will steadily decline to zero between 2020 and 2050. This pattern would imply a reduction in imports of $174 million per year for the thirty-year period. These are funds that we assume will be redirected into Puerto Rico's aggregate spending stream. We assume that this aggregate spending stream will continue to include imports of products other than energy at their existing levels.

TABLE 6 Job Creation Through Energy Import Substitution

Basic Data	
Average annual energy import bill, 2011–2015	$5.2 billion
Average reduction per year in energy import bill, 2020–2050	$173 million *(= $5.2 billion/30)*
Job creation per $1 million through aggregate spending	11.3 jobs per million
Job losses per year through contraction of imported energy marketing and distribution	180 jobs per year

Net Employment Creation, 2020–2050

	Job Creation with Existing Employment/Output Ratios	Job Creation with 1% Average Annual Labor Productivity Growth
Job creation in 2020	1,800	1,800
Job creation in 2035	31,300	27,000
Job creation in 2050	61,000	45,000

Sources: See Technical Appendix for sources and detailed calculations. Figures reported here are rounded.

According to the Puerto Rico input/output tables, increasing spending in the aggregate economy generates 11.3 jobs per $1 million of new spending. As we show in Table 6, this means that when $174 million is redirected away from import purchases and into the Puerto Rican economy, about 1,700 jobs will be created. At the same time, the decline of Puerto Rico's energy imports will produce domestic job losses in activities tied to marketing and distributing the island's imported energy. The largest source of employment loss will be in the management of retail gasoline stations. Overall, a total of about 5,400 people are employed in Puerto Rico's fossil fuel marketing and distribution sectors. As the imported fossil fuel industry steadily contracts, these jobs will also steadily contract. Over the thirty-year transition period, about 180 jobs per year will be lost in these fossil-fuel related marketing and distribution sectors.

Taking account of both the job increases through import substitution and the job losses through contraction of the island's fossil fuel marketing and distribution activities, the net impact in 2020, the first year of the transitional program, will be about 1,800 jobs. But the net job expansion will increase cumulatively over time, as imports decline steadily and an increasing level of funds is maintained within the Puerto Rican economy rather than lost through energy imports. As such, by 2021, the net job expansion will increase to about 3,800 jobs by 2021 and to 5,700 jobs by 2022. As we show in Table 6, the net job expansion rises to about 31,300 at the 2035 midpoint in the thirty-year clean energy investment program, and to 61,000 by 2050, assuming that labor productivity in the Puerto Rican economy remains constant over this thirty-year period.[9] But if we again assume that labor productivity will rise by an average of 1 percent per year, then the net job expansion will be about 27,000 as of 2035 and 45,000 by 2050.

Considering now the total net job creation through both clean energy investments and energy import substitution, we reach a figure of about 25,000 jobs in 2020, about 50,000 jobs in 2035, and about 60,000 to 80,000 jobs as of 2050.

The full labor force in Puerto Rico was at 1.1 million as of mid-2017. Moreover, even prior to the September 2017 hurricanes, this labor force size reflected a historically low labor-force participation rate of 40.0 percent. As recently as 2007, labor force participation was at nearly 50 percent. As such, net job creation in 2020 in the range of 25,000 jobs—equal to about 2.3 percent of the current workforce—will have a significant positive impact but will not be transformative in itself. Expanding employment by 25,000 jobs in today's Puerto Rican economy would reduce the unemployment rate by about 2.5 percentage points, from 10 to 7.5 percent.

Moreover, this impact will grow with time, as the cumulative effects of import substitution policies increase. As of 2035, with net job creation through both clean energy investments and import substitution at around 50,000 jobs, this is likely to represent 4–5 percent of Puerto Rico's labor force at that time, after allowing for population changes and an increased labor force participation rate. The impact will be greater still in 2050, with the total net job creation in the range of 60,000–80,000, which will likely represent around 6 percent or more of Puerto Rico's labor force at that time.

FINANCING GREEN GROWTH

To address the question of how to reach the goal of an average clean energy investment level of \$2.2 billion per year, including climate adaptation/resilience measures, we first consider the prospects for establishing a carbon tax for the Puerto Rican economy. We examine both the revenue potential of the tax and the distribution of the revenue between three uses: (1) public investments and subsidies to achieve the overall public and private investment level of \$2.2 billion per year; (2) rebates to lower-income households to minimize negative effects on living standards from the tax; and (3) servicing outstanding government debts.

Revenue Potential from Carbon Tax

We examine the revenue potential of a carbon tax that begins at \$25 per ton of CO_2 emissions in 2020 and rises incrementally to \$150 per ton as of 2050. These proposed tax rates are based on models developed by both the U.S. Energy Department and the International Energy Agency (Pollin et al. 2014, 2015). Our revenue estimates incorporate the key assumption of our overall green-growth framework, which is that the level of CO_2 emissions in Puerto Rico will decline steadily from its present level of 28 million tons to zero emissions as of 2050.

In Table 7, we show the results of these two assumptions—CO_2 emissions declining steadily from their current level of 28 million tons to zero emissions as of 2050, while the carbon tax rises steadily from \$25 to \$150 per ton as fossil fuel consumption and emissions decline. As the table shows, revenue begins in 2020 at \$700 million, then rises to \$1.3 billion as of 2029. The revenue remains at that peak level until 2035, then starts declining gradually. As we see, total revenue from the tax for all 30 years will be \$28.9 billion. This averages to \$933 million per year over the full thirty-year period.

Distributing Revenue

As an initial working framework for distributing the carbon tax revenue, we propose that the revenues be divided evenly between three purposes: on average, about \$300 million per year each could be used for, respectively, clean energy investments and climate adaptation/resilience; rebates for lower-income households; and debt servicing. How can such a framework

TABLE 7 Revenue from Carbon Tax

Year	Emissions *(million metric tons)*	Carbon Tax Rate (dollars/ton)	Revenue
2020	28.0	$25.0	$700 million
2021	27.1	$29.3	$793 million
2022	26.1	$33.6	$879 million
2023	25.2	$37.9	$956 million
2024	24.3	$42.2	$1.0 billion
2025	23.3	$46.6	$1.1 billion
2026	22.4	$50.9	$1.1 billion
2027	21.5	$55.2	$1.2 billion
2028	20.5	$59.5	$1.2 billion
2029	19.6	$63.8	$1.3 billion
2030	18.7	$68.1	$1.3 billion
2031	17.7	$72.4	$1.3 billion
2032	16.8	$76.7	$1.3 billion
2033	15.9	$81.0	$1.3 billion
2034	14.9	$85.3	$1.3 billion
2035	14.0	$89.7	$1.3 billion
2036	13.1	$94.0	$1.2 billion
2037	12.1	$98.3	$1.2 billion
2038	11.2	$102.6	$1.2 billion
2039	10.3	$106.9	$1.1 billion
2040	9.3	$111.2	$1.0 billion
2041	8.4	$115.5	$970 million
2042	7.5	$119.8	$895 million
2043	6.5	$124.1	$811 million
2044	5.6	$128.4	$719 million
2045	4.7	$132.8	$620 million
2046	3.7	$137.1	$512 million
2047	2.8	$141.4	$396 million
2048	1.9	$145.7	$272 million
2049	0.9	$150.0	$140 million
2050	0.0	0.0	–
Total			$28.9 billion
Annual Average			$933 million

Note: Proposed tax rate rises from $25 to $150 per ton between 2020 and 2049.
Source: Projections based on program to reduce emissions incrementally to zero by 2050.

be effective in achieving the goals of advancing a sustainable and equitable growth path for Puerto Rico?

INVESTMENTS

As noted above, the clean energy investment program would need to be financed primarily through private investments, with public investments serving to attract private investors and subsidize private investment costs. With an overall investment project scaled at roughly $2.2 billion per year, having $300 million per year in public funding available means that these funds will need to leverage private investments at a ratio of roughly $1 in public investments and subsidies incentivizing $7 in private investment. As we discuss below, this level of leveraging is realistic, both within a broader framework of policy measures established to support private-sector clean energy investments as well as global funding sources available to support green-growth initiatives.

Rebates

Establishing a carbon tax will exert upward pressure on retail prices for fossil fuel energy. Indeed, this is one main purpose of the measure, with rising fossil fuel prices serving to discourage consumption of fossil fuel energy and correspondingly encourage the consumption of clean renewable energy. But this also creates a problem. All else equal, the rise in fossil fuel prices generated by the carbon tax will lower the net after-tax incomes for the residents of Puerto Rico. In particular, it will disproportionately lower the net incomes of lower-income households, since these households spend a higher share of their overall income on gasoline and electricity.

Focusing on gasoline prices, a rule-of-thumb for estimating the impact of a carbon tax on retail prices is that every one dollar in a carbon tax will add about one cent to the retail price per gallon of gasoline. Thus, starting the tax at $25 per ton will add about 25 cents to the price of a gallon of gasoline in Puerto Rico. As we have seen, the current average price of gasoline in San Juan is about $2.50 per gallon. The price increase due to the carbon tax would therefore be around 10 percent. The highest level for the tax, at $150 per ton, would add about $1.50 to a gallon of gasoline. At current retail gasoline prices, that would imply a 60 percent increase in gasoline prices. But, of course, by the time the tax would rise to $150 per ton in 2049, the Puerto Rican economy will have almost completely transformed itself into a clean renewable energy economy.

As of 2015, the median household in Puerto Rico spends about $4,000 per year on energy, which amounts to about 20 percent of the median household income of $19,400. Because the average household size is a bit less than three people, this implies that median per capita spending on energy is $1,333. The 10 percent price increase resulting from the initial carbon tax would therefore increase median per capita energy spending by $133. The carbon tax would also put upward pressure on other retail prices in the economy, as wholesale prices incorporate the energy-cost increase at the business side of the economy.

Considering these factors, the $300 million in rebates can be utilized as follows to counteract the increases in living costs. If we allow that the $300 million per year in rebates is divided equally among all Puerto Rican residents in the lower half of the income distribution, it would imply a $176 rebate for 1.7 million people. This level of rebate should fully compensate those in the lower half of the income distribution for all retail price increases resulting from the carbon tax, especially since these lower-income households should also be benefiting from clean energy investments incorporated into the economy, such as expanded and less expensive public transportation systems.

Under this proposal, the Puerto Ricans in the upper half of the income distribution will have to absorb the energy price increases resulting from the carbon tax. At the same time, higher-income residents are better positioned to take advantage of the benefits that will become increasingly available through clean energy investments on the island. For example, they will be able more readily to install solar panels on their rooftops, greatly reducing, if not eliminating altogether, their level of electricity consumption generated by fossil fuels. They will also be better able to purchase more energy-efficient automobiles, including hybrids and electric vehicles, as well as more efficient lighting equipment and home appliances. Indeed, these initiatives will be a major factor supporting the economy-wide clean energy transition.

Debt Servicing

The government's Fiscal Plan that was endorsed by the Oversight Board last March is projected to generate total fiscal surpluses of $7.9 billion through 2026. These are the funds that the Oversight Board proposes to channel into repaying Puerto Rico's creditors. But as we have discussed, the government aims to attain these surpluses through enacting a severe austerity program, with large-scale cuts in health care, education, and public employment overall. According to the Fiscal Plan's own projections, this program will not restore the economy to a positive growth trajectory until 2024. This is almost certainly an optimistic scenario, since austerity will entail losses of household income, business profits, and thus government tax revenues.[10]

The alternative we are proposing here is to devote $300 million per year from the carbon tax revenue to debt servicing. Considered over a decade, the $3 billion that would be available for debt servicing would amount to nearly 40 percent of the $7.9 billion that the Fiscal Plan claims is feasible through its austerity agenda. More importantly, within the green-growth framework, overall government revenues from all sources will expand as a by-product of the growing economy, as opposed to contracting as a by-product of a no-growth economy operating under austerity.

Overall Growth Impacts

We must finally consider whether the carbon tax will act as a drag on the growth prospects within the green-growth framework. All else equal, the carbon tax would dampen economic growth through raising energy prices. However, within the greengrowth framework, the carbon tax will be operating in conjunction with the expansion of investments in renewable energy and energy efficiency. These clean energy investments will directly lower energy costs by at least as much as the carbon tax will raise them. In addition, as discussed above, the expansion of renewable energy supply and the rise in efficiency will enable Puerto Rico to steadily reduce its fossil fuel imports. That import dependency acts as a constraint on growth. Finally, as we have just proposed, two-thirds of the revenue from the carbon tax will be injected back into Puerto Rico's economy in the form of rebates as well as clean energy investments, while one-third would leave the economy through debt-servicing payments.

EXPANDING PRIVATE INVESTMENTS THROUGH LEVERAGING PUBLIC FUNDS

Puerto Rico already has in place a range of policies that, at least on paper, provide a starting framework for promoting private clean energy investments on a large scale(Energy Transition Initiative 2015).These include the following:

- ***Renewable energy and energy efficiency portfolio standards.*** These are regulatory guidelines that establish goals for expanding renewable energy and raising efficiency levels for utilities and other large-scale energy consumers. The renewable energy goal was 12 percent of electric power supply by 2015, 15 percent by 2020, and 20 percent by 2035.
- ***Net metering.*** Net metering is the compensation arrangement between a utility and a customer with an on-site generating system, typically a solar photovoltaic system. Net metering gives the customer credit for power generation at the utility's retail rate and allows a customer to bank generation during hours or months when it exceeds the customer's consumption. Net metering is available in Puerto Rico for residential customers for up to 25 kilowatts and other systems up to 1 megawatt. These are generous terms. As a comparison point, the average residential photovoltaic system in the United States is 5 kilowatts.
- ***Public loans/grants/tax incentives.*** The Puerto Rico Green Energy Incentives Act of 2010 created the Green Energy Fund. Under this fund, the government committed to coinvest up to $185 million in the development in renewable energy projects. It also offers tax rebates in the range of 40–50 percent for private investment projects. However, the fund started with only $20 million in total funding in 2011.

While these measures should be effective in advancing clean energy investments in Puerto Rico, especially operating in combination, the reality is that, to date, progress has been modest. Thus, though the goal for renewable energy–generated electricity was 12 percent as of 2015, in fact, renewables supplied only about 2 percent of the energy for electricity generation in that year. Especially in the aftermath of Irma and Maria, the island will certainly not reach its next established goal of 15 percent renewable electricity as of 2020.

The point here is that with funding available through the carbon tax in the range of $300 million per year, these policies could be capable of growing to a scale that could make them effective. Within such an effective policy environment, it would then be reasonable to expect that Puerto Rico could leverage $300 million a year in public funds to generate a total of around $2 billion per year in private clean energy investments.

As a case in point, the U.S. Energy Department's renewable energy loan guarantee program under the 2009 American Recovery and Reinvestment Act —the Obama stimulus program—helped underwrite about $14 billion in new renewable energy investments between 2009 and 2013. Total losses from this program that the government had to guarantee amounted to about $300 million, equal to about 2.1 percent of the $14 billion in new loans for clean energy investments that the government guaranteed. This means that the leverage rate for the loan guarantee program was about $47 in additional clean energy investments underwritten by $1 of federal support(Pollin et al. 2014).[11]

Given both that Puerto Rico has been in an economic slump for a decade and that the clean energy industry on the island is still in its infancy, one cannot realistically expect this investment incentive program to achieve a leverage ratio anything close to the $47 in total clean energy investments for every dollar of government financing support that was reached under the Obama-era loan guarantee program. But it is realistic to expect that, through the effective execution of clean energy policies already in place, in combination with the $300 million in annual funding from the carbon tax revenues, Puerto Rico could reach a leveraging ratio of 7/1—approximately one-seventh as large as that attained through the Obama loan-guarantee program. In short, under an effective policy environment, Puerto Rico could realistically expect to generate in the range of $2 billion per year in private clean energy investments through providing $300 million in public investments as well as incentives, loans, and loan guarantees for private investors.

PROSPECTS FOR ALTERNATIVE OWNERSHIP FORMS

The green-growth program for Puerto Rico will open up a wide range of opportunities for new business ventures to support the economy's clean energy transition. In fact, throughout the world, the energy sector has long operated under a variety of ownership structures, including public/municipal ownership, and various forms of private cooperative ownership in addition to private corporate entities. The alternative ownership forms operate in all areas of the energy industry, including both the fossil fuel and renewable sectors.

Indeed, in the oil and natural gas industry, publicly owned national companies control approximately 90 percent of the world's reserves and 75 percent of production. They also control many of the oil and gas infrastructure systems. These national corporations include Saudi Aramco, Gazprom in Russia, China National Petroleum Corporation, the National Iranian Oil Company, Petroleos deVenezuela, Petrobras in Brazil, and Petronas in Malaysia.

At the same time, the development of clean energy systems has already opened up opportunities for smaller-scale enterprises, which have been organized through various combinations of public, private, and cooperative ownership structures. The European industry, in particular, operates with a high proportion of private cooperative ownership forms. The performance of these noncorporate private business enterprises has generally been quite favorable relative to the traditional corporate firms. One area where this has been clear is community-based wind farms in Western Europe, especially Germany, Denmark, Sweden, and the United Kingdom.

Mark Bolinger at the U.S. Department of Energy, along with other researchers, has highlighted four important advantages to community ownership structures in the wind industry over traditional corporate ownership (Bolinger 2001, 2005; Pollin 2015). These include:

1. *Acceptance of lower rates of profit*. Community-based wind projects in Europe have been able to rely on a wide array of relatively small-scale local investors, whose profit requirements are lower than those of private corporations. This in turn means that the costs of expanding wind power capacity will fall, promoting a more rapid expansion in new investments.
2. *Increased public support*. Direct community ownership of wind projects has raised public awareness in Europe and increased the number of local people who have direct financial stakes in such projects. This has reduced community resistance to projects at the planning and permitting stages.
3. *Potential for lower electricity transmission costs*. The relatively small size of community-owned projects enables them to be more easily located within, or nearby, the communities themselves. This makes possible significant reductions in the costs of transmitting energy over the grid.
4. *Electricity price stability*. Community-owned wind projects operate at arm's-length from the two forces that are most responsible for creating instability in electricity prices: the global market for oil and the speculative commodities futures market for energy, including electricity. Because, by their basic ownership structure, community-based wind projects will continue to operate independently of the global price of oil as well as

the commodities futures markets, this should create long-term conditions supportive of electricity price stability.

Community-based energy projects do also come with disadvantages. The most significant is that because community-owned projects will tend to be smaller in scale than corporate-owned operations, they are not as well equipped to spread the costs of any given project, including permitting and legal costs and the full range of construction and transmission costs. On balance, though, for a small island economy such as Puerto Rico, the relative benefits attainable through economies of scale will be more modest than in a larger economy setting. Moreover, as one aspect of prioritizing a green-growth program, the Puerto Rican government can commit to minimizing the regulatory burdens associated with advancing clean energy investment projects.

The development of affordable renewable energy is also, increasingly, creating realistic prospects for private individuals, businesses, and small-scale community organizations to own their own renewable energy supplies. In some cases, these systems operate entirely separately from the electric utility grid. These *distributed energy* supply systems are powered by solar, wind, and other renewable sources. The prospects for individual household ownership of solar panels, in particular, are quite favorable in Puerto Rico, given the island's year-round sunny climate.

CONCLUSION

Economic crises often create opportunities for transformational change. Puerto Rico had clearly arrived at just such an historical juncture even before Irma and Maria. But now, especially in the aftermath of the hurricanes, continuing to proceed along the austerity path that still dominates economic policy on the island —or an even more severe version of austerity, if its creditors prevail in the ongoing debt negotiations—offers a dead end of further economic contraction, outmigration and declining average living standards. It also creates overwhelming obstacles to successfully implementing any kind of viable structural reforms of the economy, including the structural reforms proposed in the government's Fiscal Plan and approved by the U.S. Oversight Board.

But Puerto Rico also has an opportunity to pursue transformational structural reform through a green-growth path. As we have shown, green growth offers Puerto Rico the opportunity to create a sustainable independent economy as opposed to recreating the type of dependent relationship that prevailed through the Section 936 framework of U.S. corporate giveaways. Under the green-growth path, Puerto Rico can produce a viable domestic energy infrastructure, capable of slashing the price of electricity on the island from about twenty cents to four to seven cents per kilowatt hour. Building a domestic energy infrastructure will also free the island from having to ship out 4–6 percent of its GDP every year to purchase imported petroleum and natural gas and will create a framework for implementing effective climate adaptation and resilience measures.

The investments in energy efficiency, renewable energy, and climate adaptation/resilience will produce a large-scale expansion in job opportunities, with new job creation growing per year from about 25,000 to as high as 80,000 as investment projects continue between 2020 and 2050 and as imported energy purchases steadily decline. Building a domestic clean energy infrastructure will also create widespread opportunities for new business ventures, including small-scale community-owned and cooperative enterprises. By committing itself to embracing the global climate stabilization project through steadily driving down CO_2 emissions to zero as of 2050, Puerto Rico will also enhance its reputation as a desirable tourist destination.

Still, this green-growth project cannot launch successfully under anything close to the austerity conditions now prevailing on the island. The devastation due to the hurricanes makes matters significantly worse. Puerto Rico's creditors simply have to accept the fact that major debt write-downs are necessary. The options facing Puerto Rico at present are therefore clear. One option is to accept deepening economic and social decline within a framework of inadequate investment to rescue the island from the hurricane devastation and the proposed ongoing austerity policies. Another option, as we have shown, is to begin building a viable independent economy within the framework of green growth.

TECHNICAL APPENDIX

Estimating the Employment Effects from Clean Energy Investments

The employment multipliers for each of the energy categories studied in this paper have been constructed through an input-output, or commonly known as I-O, model. This methodology of calculating the employment multipliers had also been previously employed in a study of the U.S. economy (Pollin et al. 2014) and that of other developing countries like Indonesia and India (Pollin and Chakraborty 2015; Pollin et al. 2015). Input-Output models estimate the economy-wide and sectoral impact on the output, employment, and value added of changes in the final demand for goods and services produced by a sector or combination of sectors. The limitations and the advantages of using the I-O model over other, similar ones like Computable General Equilibrium (CGE) have been discussed earlier, at great length, in Pollin et al. (2014).

One challenge with using the I-O models to evaluate the employment multiplier effects through expenditure on clean energy investments is that the renewable energy sectors like solar, wind, bioenergy, and related sectors do not occur in the I-O models. Since the I-O family of models is structured using the sector as the building block, it poses a significant challenge. To overcome this challenge, we pursue the approach of using the real sectors in the I-O model to construct a synthetic sector that reflects the composition of industrial activities associated with the activity in question. We document here, in detail in Table A1, the relative weights used to construct these various synthetic energy sectors.

Spending on the clean energy program, as with every other activity in the economy, creates jobs through three channels: direct, indirect, and induced. I-O models are instrumental in documenting the indirect and induced employment that a current level of productive activity supports. Suppose that these three effects of investments in home retrofitting and building wind turbines can be described in the following manner:

- Direct effects: the jobs created by retrofitting homes to make them more energy efficient or by building wind turbines to generate electricity
- Indirect effects: the jobs associated with the industries that supply intermediate goods for the building of retrofits or wind turbines, such as lumber, steel, and transportation.
- Induced effects: the expansion of employment that results when people employed in the construction or steel industries or the truck drivers spend the money they have earned from producing these immediate and intermediate goods on products in the economy like food, clothing, and other everyday expenditures.

For each energy sector, the approach in this paper has been to assign weights on each sector based on the earlier studies done by Pollin et al. (2014) and Pollin et al. (2015). The justification for these weights for the various clean energy sectors in these previous studies has been based on the identification of a source document or a set of source documents that contained detailed cost information for the equipment and installation costs of the concerned technology. Next, those cost structures were mapped into the industrial categories within the I-O model. These categories include industries such as hardware manufacturing; capacitor, resistor, and other inductor manufacturing; concrete pipe manufacturing; and so on.

In this paper, we have used the IMPLAN 3 software with the IMPLAN 2015 database for the Puerto Rico economy compiled by the Minnesota IMPLAN Group. This database is an exhaustive set of data that provides 526 industry-level details. The IMPLAN database based on the I-O model allows us to observe relationships between different industries in the production of goods and services. It further allows observing relationships between consumers of goods and services, including households and governments, and the various other manufacturing industries. The I-O modeling approach enables us to estimate the effects on employment resulting from an increase in the final demand for the products of a given industry. For example, we can estimate the number of jobs directly created in the construction industry for each $1 million of spending on building weatherization. We can also estimate the jobs that are indirectly generated in other industries through the $1 million of the expenses on building weatherization—industries such as insulation, windows, and hardware. Overall, the I-O model allows us to estimate the economywide employment results from a given level of spending in any one industry or combination of industries. Table A1 gives the details of the weights used to construct each of the renewable and energy efficient sectors within the I-O models from the IMPLAN database of Puerto Rico for our employment estimates.

The total employment multipliers generated along with the figures for direct, indirect, and induced employments in each energy sector using the various weights are calculated and given in Table A2.

Jobs Creation Through Energy Import Substitution

The IMPLAN database contains industry-based figures of various industries for the economy of Puerto Rico. Using the IMPLAN database and aggregating the employment figures for various industries associated with the fossil fuel sector, like natural gas distribution, gasoline retail stores, pipeline transportation, and so on, we estimate that the total employment figure related to the fossil fuel sector stands at 5,364. We assume that with the contraction of the fossil fuel industry, these jobs will diminish over a period of thirty years at an annual average of 179 jobs per year. Since the annual average energy trade balance of the Puerto Rico economy is $5.23 billion, which slowly reduces to 0 until 2050, we assume that there is an annual average decline of the fossil fuel import bill by $174.3 million. From the IMPLAN database, we estimated that the Puerto Rico economy generates 11.3 jobs in the domestic economy per million dollars of investment. It implies that with an annual savings and reinvestment of $174.3 million, the Puerto Rico economy can generate 1,969 jobs annually through import substitution. In net terms, it means that the net jobs created in 2020 will be around 1,790. Since the number of jobs created will accumulate over the years and considering the number of jobs lost through contraction of the fossil fuel industry, the Puerto Rico economy will experience a net generation of employment to the level of 61,034 by 2050 through import substitution of fossil fuel energy. We show the full annual time series of net job creation through energy import substitution in Table A3.

NOTES

1. SeePuerto Rico Climate Change Council Working Group 3 2013 for discussions on Puerto Rico specifically.

2. But in considering these impacts on Puerto Rico's manufacturing sector specifically, we must again emphasize the limited and lopsided features of the island's 936-led growth model. Thus, MacEwan (2017, 16) argues that "the Puerto Rican government's devotion to manufacturing appears to have inhibited the development of economic activities that are more labour-intensive. The employment-generating examples of tourism and agriculture . . . demonstrate the point."

3. The comparable ratio is lower when GDP, as opposed to GNP, is the denominator, following from our discussion above on the fact of Puerto Rico's GNP having grown much more slowly than GDP during the 936 period. The comparable ratios when GDP is in the denominator are: 40.5 percent in 1997, 46.2 percent in 2006, and 64.2 percent in 2015.

4. It is notable that the EIA's cost estimates for 2022 have fallen by more than half relative to their 2012 estimates for plants entering service in 2017. Thus, for plants entering service in 2017, the EIA had projected in 2012 that average prices would be 9.6 cents per kWh for onshore wind, 15.3 cents for solar PV, and 9.8 cents for geothermal (Pollin et al. 2014, 126–27).

5. The green-growth program can also be implemented successfully within a more slowly growing economy. Indeed, the challenges of building a 100 percent clean energy infrastructure are greater in many ways under more rapid economic-growth conditions, since this entails keeping up energy efficiency and renewable energy investments with the expansion of energy demand resulting from growth. One key point in considering a green-growth program within the context of a modestly healthy growth trajectory is to show that reducing, then eliminating altogether, the demand for fossil fuel energy supply is fully compatible with economic growth.

6. BTUs are the most convenient unit in which to measure energy, since they are a measure that can be readily applied across all energy sources. For purposes of scaling, burning a wood match to its end generates about 1 BTU of energy. As of 2016, the U.S. economy consumed a bit less than 100 Q-BTUs of energy, and the global economy consumed about 600 Q-BTUs.

7. Hereafter we drop the word "metric" in referring to tons. All figures reported in "tons" throughout the paper refer to metric tons.

8. We also assume that climate adaptation and resilience investments are integrated into the energy-efficiency and renewable-energy spending programs. The employment effects of these programs are thus reflected in the results that follow.

9. In the technical appendix, we show our full results on employment creation through energy import substitution. The figures we report in Table 6 provide a summary of our main results.

10. (Guzman and Stiglitz (2017) describe several aspects of the Fiscal Plan's projections that are unrealistically optimistic.

11. This program is discussed in Pollin et al. (2014).

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TABLE A1 Weighting Assumptions for Specifying Clean Energy Within Puerto Rico's Input/Output Model

Category	I-O industry (based on IMPLAN)	Weights
	Grain farming	25%
	Support activities for agriculture and forestry	25%
	Construction of other new nonresidential structures	25%
	Petroleum refineries	12.5%
Bioenergy	Scientific research and development services	12.5%
	Construction of new power and communication structures	30.0%
	Hardware manufacturing	17.5%
	All other industrial machinery manufacturing	17.5%
	Capacitor, resistor, coil, transformer, and other inductor manufacturing	17.5%
Solar PV	Marketing research and all other miscellaneous professional, scientific, and technical services	17.5%
	Construction of other new nonresidential structures	50.0%
	Concrete pipe manufacturing	10.0%
	Machine tool manufacturing	15.0%
	All other industrial machinery manufacturing	10.0%
	Other communication and energy wire manufacturing	5.0%
Hydro -Small	Architectural, engineering, and related services	10.0%
	Construction of new power and communication structures	26.0%
	Plastic material and resin manufacturing	12.0%
	Fabricated structural metal manufacturing	12.0%
	All other industrial machinery manufacturing	43.0%
Wind	Marketing research and all other miscellaneous professional, scientific, and technical services	7.0%
	Other chemical and fertilizer mineral mining	15.0%
	Construction of other new nonresidential structures	45.0%
	Other communications equipment manufacturing	10.0%
Geothermal	Scientific research and development services	30.0%
	Maintenance and repair construction of residential structures	50.0%
Weatherization	Maintenance and repair construction of nonresidential structures	50.0%
	Heating (except warm-air furnaces) equipment manufacturing	10.0%
	Air conditioning, refrigeration, and warm-air heating equipment manufacturing	10.0%
	All other industrial machinery manufacturing	30.0%
	Environmental and other technical consulting services	30.0%
Industrial Energy Efficiency	Maintenance and repair construction of nonresidential structures	20.0%

(*Continued*)

TABLE A1 Continued

Category	I-O industry (based on IMPLAN)	Weights
	Construction of other new nonresidential structures	25.0%
	Mechanical power transmission equipment manufacturing	25.0%
	All other miscellaneous electrical equipment and component manufacturing	25.0%
Smart Grids	Other electronic component manufacturing	25.0%
	Construction of other new nonresidential structures	30.0%
	Motor vehicle body manufacturing	3.4%
	Motor vehicle electrical and electronic equipment manufacturing	3.3%
	Motor vehicle steering, suspension component (except spring), and brake systems manufacturing	4.3%
	Motor vehicle seating and interior trim manufacturing	0.5%
	Other motor-vehicles part manufacturing	8.2%
	Shipbuilding and repairing	3.0%
	Transit and ground passenger transportation	43.0%
	Water transportation	3.0%
Public Transport	Scenic and sightseeing transportation and support activities for transportation	1.3%
	Wind and solar	40% each
	Geothermal and bioenergy	7% each
Renewable Energy	Hydro-small	6%
Energy Efficiency	Smart grids and grid upgrades, public transport, industrial energy efficiency, and building weatherization and retrofitting.	25% each

Source: Authors'estimations of weights based on Pollin et al. (2014) and Pollin et al. (2015).

TABLE A2 Employment Multipliers Generated in Puerto Rico's Clean-Energy Sector

Clean Energy Program	Sectors	Direct Effect	Indirect Effect	Induced Effect	Total Effect
	Wind	5.1	1.6	2.2	8.8
	Solar	5.9	1.5	2.9	10.3
	Hydro-Small	7.5	1.6	2.9	12.0
Renewable Energy	Bioenergy	11.4	1.2	3.5	16.0
	Geothermal	8.1	1.6	3.3	13.0
	Smart Grids	3.5	0.8	1.4	5.7
	Public Transport	11.1	1.6	3.6	16.3
	Industrial EE	8.0	1.5	3.9	13.4
Energy Efficiency	Weatherization	9.0	2.4	3.3	14.7

Note: Figures are jobs created per $1 million in expenditure.
Source: Authors' calculations based on Table A1 figures.

TABLE A3 Annual Job Creation Estimates Through Puerto Rico Energy Import Substitution, 2020–2050

Year	Employment generated due to import substitution	Jobs lost due to fossil fuel industry	Net jobs
2020	1,969	179	1,790
2021	3,938	179	3,759
2022	5,907	179	5,728
2023	7,875	179	7,697
2024	9,844	179	9,665
2025	11,813	179	11,634
2026	13,782	179	13,603
2027	15,751	179	15,572
2028	17,720	179	17,541
2029	19,688	179	19,510
2030	21,657	179	21,478
2031	23,626	179	23,447
2032	25,595	179	25,416
2033	27,564	179	27,385
2034	29,533	179	29,354
2035	31,501	179	31,323
2036	33,470	179	33,292
2037	35,439	179	35,260
2038	37,408	179	37,229
2039	39,377	179	39,198
2040	41,346	179	41,167
2041	43,315	179	43,136
2042	45,283	179	45,105
2043	47,252	179	47,073
2044	49,221	179	49,042
2045	51,190	179	51,011
2046	53,159	179	52,980
2047	55,128	179	54,949
2048	57,096	179	56,918
2049	59,065	179	58,886
2050	61,034	0	61,034
Annual Average	31,501	173	31,328

Source: Authors' estimations based on IMPLAN database.