

*An Integrated Approach to Support National
Energy Policy in Ecuador*

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Introduction

The Environmental Studies Senior Seminar seeks to bring together diverse perspectives, while examining a central theme or environmental issue. Traditionally, the seminar has focused on local Vermont communities, but given the increasing interconnectedness of today's communities and the complexity of global environmental problems, this semester we broadened our scope to encompass Global Civil Society. Addressing problems such as climate change, poverty, and resource use will require an integrated global approach, calling on a multitude of perspectives and possible solutions.

Allan Baer is a social entrepreneur from Chelsea, Vermont who works with SolarQuest, a U.S. NGO working in the Galapagos Islands to develop the Renewable Energy Applications Laboratory. His mission is to advance renewable energy and energy efficiency technologies, both on the islands and in mainland Ecuador. For the future, Allan envisions developing a Renewable Nations Consortium as a way to enhance communication between civil societies of various nations on energy issues. In developing this vision he has been collaborating with the United Nations, the Millennium Institute and the World Bank. Social entrepreneurs, like Allan Baer, use innovative entrepreneurial qualities and personal passion to achieve changes for the greater social good.

The Stern Report, an economic analysis of the costs of mitigating global climate change, posits that an investment of 1% of GDP annually would be sufficient to stabilize the climate at 550ppm of CO₂ by 2050.¹ Our project examined the effects of this level of investment in Ecuador. Specifically, because Mr. Baer's expertise is in Ecuador's electricity sector, we applied this 1% investment to energy efficiency measures. Andrea Bassi, a System Dynamics expert from the Millennium Institute, developed Threshold 21 customized to Ecuador, an integrated development model that takes into account the interactions between social, economic, and environmental factors.² We used the model to run scenarios—based in part on potential national policies—to understand how investments in demand-side efficiency measures in the electricity sector could help move Ecuador away from an increasing fossil fuel dependence.

Although our model uses a large scale approach, one of the implications of improving energy efficiency and implementing projects like Allan's is a move towards decentralized energy and the concept of "micropower". In his book, *Power to the People*, global correspondent for the Economist Vijay Vaitheeswaran praises energy efficiency and the liberalization of energy markets to achieve more efficient, decentralized and localized energy networks, and to help relieve the dependency on fossil fuels and OPEC.³

Additionally, in *Seeing Like a State*, author James Scott warns of the dangers of high modernism and top-down approaches to state control.⁴ High modernism is when governing bodies impose a centrally planned organizational scheme that assumes progress and does not

¹ Stern, Sir Nicolas. 2006. *Executive Summary, Stern Review on the Economics of Climate Change*. New Economics Foundation.

² Threshold 21 (T21) is a dynamic simulation tool designed to support comprehensive, integrated long-term national development planning. See www.millennium-institute.org

³ Vaitheeswaran, Vijay V. *Power to the People: How the coming Energy Revolution Will Transform an Industry, Change Our Lives, and Maybe Even Save the Planet*.

⁴ Scott, James C. *Seeing Like A State: How Certain Schemes to Improve the Human Condition Have Failed*.

take into account local context. Although the T21 model is a useful tool for predictive analysis, it inherently reduces very complex issues to simple terms, mirroring some of the qualities of high modernism. The T21 model should not be a replacement for metis, or practical “on the ground” knowledge. Instead, the T21 model should be used as a starting point to appreciate the large-scale interactions between different sectors before addressing issues at a finer scale.

Background

In February of 2007, the Intergovernmental Panel on Climate Change released their fourth report, concluding that it is now ‘unequivocal’ that the world is warming, with eleven of the twelve past years being the hottest on record.⁵ The impacts are global, evidenced by the rise in air and ocean temperatures, increasingly severe hurricanes, rising sea levels, and the widespread melting of the earth’s snow pack and glaciers. Greenhouse gas emissions are the main driver of catastrophic anthropogenic climate change, a serious threat to human and natural systems around the world that calls for serious action in this century to mitigate its effects.

In general, developing countries are more vulnerable to the effects of global warming. They are less equipped to cope with—and protect their populations from—rising sea levels, increasingly severe weather, and devastating effects on agriculture such as severe droughts and desertification. Ecuador is and will be impacted in its main ecosystems—its low-lying coastal zones, the Andes, and the tropical Amazon basin. In the Andes, glaciers are melting fast, reducing the amount of fresh water available and hydroelectric power generation capacity. Agricultural lands will also be affected by water availability and increasing droughts. Rising temperatures may severely affect the biodiversity of the Amazon, as species become unable to live in hotter climates. In the Galapagos Islands, ocean surface temperature has reached over 81.5 degrees Fahrenheit, causing widespread bleaching of coral reefs. Human populations will be effected by increased vectors of disease, especially insect-driven diseases.⁶

While the impacts of climate change are already affecting Ecuador, so too are the drivers of climate change. Ecuador is heavily dependent on its oil reserves, as the fifth largest producer

⁵ Ezwurkel, B. *Findings of the IPCC Fourth Assessment Report: Climate Change Science*. 2007. The Union of Concerned Scientists.

⁶ Watson, R.T., M.C. Zinyowera, and R.H. Moss. 1997. *Intergovernmental Panel on Climate Change Special Report on The Regional Impacts of Climate Change: An Assessment of Vulnerability*.

of crude oil in South America and the second largest provider of South American crude to the US. Forty percent of the country's export earnings and 33% of the central government budget revenues come from the petroleum trade. They produce 540,000 barrels/day of crude oil, and use 152,000 barrels/day. Their crude oil distillation capacity is 176,000 barrels/day. The disparity between production and distillation capacity is the main reason they export primarily crude oil and fail to benefit fully from high oil prices. The majority of their electricity is generated with fossil fuels, approximately 81% in 2001. Northeastern Ecuador possesses the most productive oil fields, but its two major pipeline systems (SOTE and OCP) are often interrupted by earthquakes and landslides. Future increases in production are likely to come from exploration in the Ishpingo-Tapococho-Tiputini (ITT) block, which is expected to hold at least 190,000 barrels/day. There are several major companies which pump oil from Ecuador's reserves, comprising both state-owned and private enterprises. Petroecuador, the government-run corporation, controls 46% of crude oil production. The others, Repsol-YPF, Andes Petroleum, Chinese National Petroleum Corporation (CNPC), Perenco and Agip, control much smaller proportions.⁷

The oil industry has had very negative effects upon indigenous populations and there has been a strong resistance by indigenous groups towards petroleum development in Ecuador, especially in portions of the Amazon. Ecuador's geography has isolated the Shuar, Achuar, and Kichwa tribes, and therefore much of their cultural traditions and lifestyles have stayed intact. These groups are weary of the environmental, social and cultural effects that such development would have, and the possibility for the extinction of indigenous people. Indigenous federations representing these people point to the forest communities near major oil producing regions such as Peruvian and Ecuadorian Amazon, where wide-spread oil and toxic contamination has caused increases in the rates of cancer and other illnesses among local tribes. These people have no

⁷ Organización Latinoamericana de Energía (OLADE). 2004. *Final Energy Review 2004*.

option but to fish, bathe, and drink from the polluted waters. Weak environmental regulations have also led to extensive deforestation, loss of biodiversity and natural habitat destruction from the opening of road and pipeline networks into previously roadless rainforest territories. In addition, throughout the northern Ecuadorian Amazon, the draw and infrastructure of oil projects has resulted in the large-scale displacement of indigenous peoples and the dispossession of their land by migrants from other regions. Part of the problem is that Ecuador's constitution allows for an individual or community to hold legal title to land, but the minerals below the surface are property of the state. This, coupled with the fact that Ecuador is one of South America's poorest nations, has led to continued oil exploration and production to ensure the country's economic well-being.

Typically, current developing nations have experienced only the impacts of global warming, and few of the benefits that come from industrialization, yet the most recent report from the IPCC projects that two thirds to three quarters of emissions growth until 2030 will come from developing nations. Since 1990, carbon emissions in Ecuador have risen approximately 60% from 13.8 million tons per year to 20.7 million tons per year.⁸ As economic development in the country continues, Ecuador's rapidly increasing emissions are unlikely to abate. Developing nations such as Ecuador have numerous options for reducing their emissions, all with different political, social and economic benefits and consequences.

Our project focused specifically on Ecuador's electricity sector, examining the outcomes of investing in demand-side energy efficiency, renewable energy, subsidies, and imports to the electricity sector to reduce greenhouse gas emissions. Total electricity production for Ecuador is 11.27 billion KWh. Electricity production is primarily dominated by hydroelectric plants (63.5%

⁸ Ezwurkel, B. *Findings of the IPCC Fourth Assessment Report: Climate Change Science*. 2007. The Union of Concerned Scientists.

as of 2005) and Thermal Plants producing the rest (36.5 % as of 2005). More specific numbers of electricity production are 7412 GWh from hydro, 4100 GWh from oil and 1073 GWh from gas. Ecuador exports very little electricity and imports 1680 GWh. The interconnection between Quito and Pasto made it possible to export 35 GWh, and 1643 GWh have been imported from Columbia. The new imports from Columbia have helped electric shortfalls during the low-water season. The electricity consumption per capita is 707 KWh as of 2005 and has only increased by 50 KWh over the past five years. Average domestic prices for electricity, with tax and in US dollars, for commercial, industrial and residential customers, at December 2004, amounted to US\$ 0.108, US\$ 0.087 and US\$ 0.126 per KWh respectively. It is estimated that 90% of the housing in Ecuador has electricity. In 2004 The National Electricity Council (CONELEC) decided to reduce tariffs by 5%. CONELEC and the government are committed to rural electrification by using private/public partnerships. It is expected that grid extension will connect about 750,000 additional households by 2012.

The Stern Report, released in the fall of 2006, posited that 1% of GDP annually invested would cause 50% reductions of carbon emissions by 2050. This assumption was the frame of our entire project, asking the question, “Is 1% of GDP (for Ecuador) sufficient to transition Ecuador to a carbon-free electricity sector?” Our project was driven by Allan Baer, social entrepreneur for clean and efficient energy, who works in the Galapagos Islands and is based in Vermont. Allan works with SolarQuest, the United Nations, the Millennium Institute, and the government of Ecuador to help the Republic of Ecuador transition away from fossil fuels. We chose to focus on Ecuador in our project because of Allan’s knowledge and pre-existing network in the country. Also, Ecuador provides a great case study for resource-rich developing countries

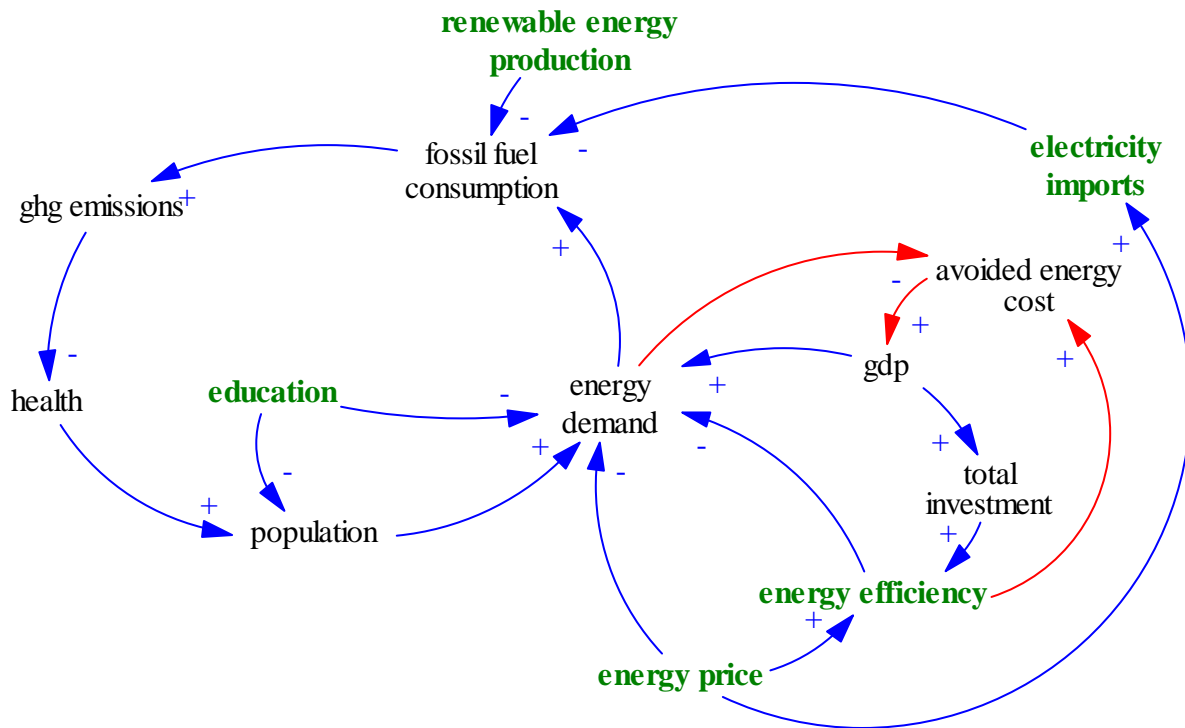
transitioning away from fossil fuel dependence and attempting to reduce greenhouse gas emissions.

The Millennium Institute's T21 Model is based upon systems dynamics, which is a methodology used to describe and represent complex systems through causal relationships and feedbacks. Systems dynamics allows for the simulation of a number of different equations over time. Using both linear and non-linear modeling techniques, the model represents feedback loops and the accumulation of flows into stocks. There are extremely few institutions in the world that teach and use systems dynamics and it is still a very underdeveloped field, yet it is a very powerful way to describe and project the behavior of complex systems. With Andrea Bassi, modeler for the Millennium Institute, and Allan, we were able to develop our own simplified model of the energy sector in Ecuador, and use that model to build our different scenarios.

The Threshold 21 is not only an integrated development model, but also a highly sophisticated tool that incorporates over 800 parameters from society, the economy, and the environment in order to describe past and current trends on the national scale and to project into the future. The Millennium Institute uses systems dynamics and the T21 model within governments and across ministries in order to understand current trends and test the outcome of proposed policies and community-driven development programs. The T21 model is unique compared to other models because of its non-linearity, feedback loops, transparency, and ability to causally trace changes. Because it is customizable to a set of issues for a country or a region, it is possible to model different policy options, and to determine which actions most impact the development of the country by identifying the strongest feedback loops and tipping points triggering growth.

Research Problem

With the help of Andrea Bassi and the T21 model he built for Ecuador, we created the following causal loop diagram to determine which factors affect electricity use and greenhouse gas emissions, and what feedback loops exist.



Focusing on designing a closed-loop system, we started with the broad problem: *how does Ecuador reduce greenhouse gas emissions*. Greenhouse gas emissions have negative impacts on the health of human populations. Energy demand is positively correlated with population and GDP. Education however, tends to decrease energy demand, both by influencing behavioral change as well as by decreasing population size. Energy price and energy efficiency also tend to decrease energy demand, but energy efficiency has higher avoided costs than the current energy demand. High avoided costs however, will have a positive effect on GDP, which

in turn will increase energy demand and total investment. Renewable energy production and electricity imports decrease fossil fuel consumption.

Baseline Scenario: *Business As Usual*

Our baseline scenario assumes no changes in any of the current patterns or policies, and projects behavior of these variables from 2007 to 2025. Therefore we project that greenhouse gas emissions will continue to rise well into the 21st century, driven by growing fossil fuel consumption. This consumption tracks increasing energy demands, which grow both as a result of population trends and continued growth in GDP. Conversely, we also project that a natural rise in technology will lower energy demand by increasing the efficiency of consumer appliances. Efficiency was set externally to rise 60% by 2025. We also held electricity imports steady at the 2007 level of 6%.

Assuming the current trends continue in Ecuador, greenhouse gas emissions will have increased to 35.6 million tons/yr by 2025, a 50% growth from 2007 (23.63 million tons/yr) levels (Figure 1). The immediate cause of this rise is an increase in fossil fuel consumption to 472 trillion Btu from a 2007 value of 309.2 trillion Btu. This fossil fuel consumption occurs partly due to a rise of total energy consumption from 424.6 to 676.6 trillion Btu (Figure 2, 3). Ecuador's population growth from 10 million in 1990 to 17 million in 2025, is partly responsible for this rise in energy demand. Energy consumption, however, is rising at a much faster rate, driven more by the increase in real GDP. Doubling of GDP occurs near 2015, the same period when energy consumption doubles. Retail sales of electricity in the residential sector begin at 4 million Kwh in 2007 and grow to 7 million Kwh by 2025 (Figure 4). Electricity sales are growing at a faster rate than overall energy demand, reflective of a disproportional increase in

the demand for residential electricity as population and GDP grow. In order to meet this rising electric power demand, fossil fuel installed capacity increases to 5500 MW (Figure 5).

Hydroelectric generation shows minimal potential to increase in Ecuador, meaning that increased demand for electricity must be met by augmenting fossil fuel capacity (Figure 6).

Correspondingly, the fraction of electricity generated by hydro decreases to 27% from its 50% share in 2007 (Figure 7).

In 2006, total government expenditures (in nominal USD) totaled \$8.57 billion, \$30.67 million of which are spent in the energy sector. Again assuming no policy changes by 2025, government expenditures on energy will total \$66.46 million. Total government investments in 2006 are \$1.93 billion, compared with \$5 billion of private investments. Per capita real disposable income in Ecuador remained nearly constant from 1990-2007 as the country recovered from the 1999 financial crisis. After 2007, per capita income rises, assuming the Ecuadorian currency remains strong. Ecuador's expenditures in health, education and roads rise with increasing government spending, producing 100% average adult literacy rates by 2021, and 95% in 2010. Kilometers of functioning roads also oscillate normally, gradually increasing until 2025. Access to basic health care also reaches 100% by 2010.

Therefore, maintaining business as usual in Ecuador will cause gradual improvements in quality of life met by growth in fossil fuel consumption and carbon emissions. Part of these emissions result from increases in residential electrical demand. The following scenarios analyze the impact of several policy initiatives within this sector and their impacts on greenhouse gas emissions.

Scenario 1: *Subsidies for Electricity*

Ecuador's newly elected president Correa has indicated that when the new Congress convenes in October he will advocate government subsidies to reduce the price of electricity. Lowering the cost for consumers is a political move designed to increase his draw with voters. This policy, although it will increase the disposable income of the population, may conversely increase electricity demand and worsen greenhouse gas emissions. It may also cause a short-term rise in GDP as total factor productivity decreases, but in the long term GDP may decline.

In our model we designated a subsidy of \$0.01 per KWh, paid for from government revenues. All other parameters were identical to the baseline scenario. The yearly cost of implementing this model beginning in 2007 would be \$101.38 million, approximately 1.5% of total government revenues. A small reduction in expenditures of this magnitude produced no significant effects in government services and expenditures as measured by average literacy rate, access to basic health care or roads. There was also little impact on debt. It did, however, raise the per capita disposable income by 1.5%, to a value of \$15. Contrary to our projections, a \$0.01 per KWh decrease in prices did not substantively raise electric power demand or increase fossil fuel emissions. This scenario is therefore not depicted in the graphs of model outputs, as projections never substantially differed from the baseline. A \$0.04 reduction in the energy price, however, did have a noticeable effect on emissions. This level of subsidy is unlikely based on current prices, which range from \$0.08-0.10 (excluding taxes and final mark-ups) per KWh depending on the customer.

Correa's motive in introducing a subsidy is alleviating burdens on the poor, as well as increasing his popularity. Subsidies such as this one, which are tied to KWh consumption, will

produce unequal benefits favoring the rich. Customers who consume less will receive substantially less than the projected \$15 and the wealthy customers will receive far more.

Scenario 2: *Investing 1% of GDP to Improve Consumer's Efficiency*

Our first policy recommendation takes 1% of Ecuador's GDP and invests it in energy efficiency within only the electric sector. We anticipate this adoption of efficient capital has the potential to reduce electricity demand even as population and affluence increase, as well as produce customer savings through avoided costs. "Avoided cost" is the amount of money saved on a household's electric bill through the reduction of their electric power demand, which is available for reinvestment elsewhere, increased consumption, or savings. Reducing the demand for electricity will correspondingly decrease the need for increasing fossil fuel capacity and consumption, thereby producing a net decrease in emissions.

Our model calculated an initial (2007) investment level of \$203 million, which reaches \$450 million by 2025. This 1% investment in efficiency produces a corresponding 38% reduction in overall electricity demand relative to the baseline scenario. Annual avoided costs for the customers will reach a total of \$600 million by 2025, around \$40 annually per capita (Figure 8). This is three times larger than the personal savings produced by the subsidy in Scenario 1—an increase in per capita disposable income of 2.6% as opposed to 1.5% with subsidies. Annual household savings will probably be nearer to \$60. Accumulated over the years of the simulation, the total avoided costs will be nearly \$5 billion. According to the system of national accounts (SNA) in which households can allocate disposable income into consumption, savings or investment, we assume that 33% of these avoided costs will be reinvested into efficiency technology, which amount to a \$1.6 billion investment in efficiency from 2007-2025 (Figure 9).

This additional investment adds another 7% to the reduction in electric power demand, yielding an overall 45% decrease in electricity demand (Figure 2, 3).

Decreasing electric power demand via these investments in efficiency is able to produce a 1500 MW reduction in fossil fuel electricity generation capacity compared to the baseline scenario (Figure 5). This indicates that through implementing this policy, Ecuador will greatly decrease the amount of capacity they have to build in the upcoming years. Emissions of greenhouse gases, however, are not significantly reduced from 2007 levels. Rather, they increase at a fractionally smaller rate compared to the baseline scenario, reaching 32 million tons/yr, 10% less than in the base (Figure 1). This is a change of 35% from 2007, a remarkable stabilization considering the projected economic and growth. Decreases are not possible, because our efficiency investments are targeted only at the fossil fuel contributions of the electrical sector, about 15% of the national fossil fuel consumption in 2007 (Figure 10, 11). True reductions in emissions will need to address emissions in the non-electric sector.

Scenario 3: Increasing Electricity Generated Using Renewable Technology

In our second proposed policy scenario, we added an additional layer to our preceding assumptions. Keeping the 1% investments and 33% avoided cost investments as detailed above, we maintained the contribution of renewable energy at 2007 levels or 50%. Therefore, in order to meet increasing power demand, renewable energy installed capacity will have to increase alongside fossil fuel capacity. In all other scenarios, the contribution of renewables declined over time. This measure has little direct impact on population or energy demand; it is designed only to reduce the fossil fuel consumption of the electricity production sector.

By 2025, 10 million Mwh of consumption will have to be met by renewable energy. Assuming that the amount provided by hydroelectricity cannot increase much from 7 million Mwh, an additional 3 million Mwh of equivalent capacity will need to be installed, a 45% increase from the current levels. The fossil fuel consumption produced by electricity generation stabilizes at 2007 levels, representing 20% of total fossil fuel consumption, therefore stabilizing emissions from the electrical sector (Figure 10, 11, 12). The continued increase in non-electric petroleum demand, however, causes carbon emissions to maintain their steady, incremental rise reaching 30.26 tons/yr (Figure 1). This is 27% higher than 2007 levels, although 17% less than projected in the base scenario. Although reduced from both the baseline and the former scenario, emissions have still not reached a point of decline.

Scenario 4: *Increasing Electricity Imports*

In a climate of rising oil prices, Ecuador's government generates a good portion of their revenues by exporting petroleum rather than using it to generate domestic energy. The balance of their energy demand is then met by imports from Colombia and Peru. Assuming that oil prices remain high, Ecuador is likely to continue their policy of importing electricity and may even expand into the future. In such a way, the government records higher revenues, obtained through increasing oil exports, and can afford to import expensive electricity. This will reduce fossil fuel consumption and emissions in Ecuador, although it may not address the problem at a global scale.

In 2006 5.8% of Ecuador's energy electric power demand was met by imports. We projected that this level would rise to 15% by 2025, provided that oil prices increase or remain stable. All other parameters were maintained as they were in Scenario 3. This change further

decreased fossil fuel consumption used in electricity generation and per capita electricity demand (32 million Btu/person/yr) relative to baseline levels (Figure 3, 11, 12). It also further reduced greenhouse gas emissions, although not enough to produce a significant decline. The observed emissions were only 2.5% less than Scenario 3 in 2025 (Figure 1).

Analysis

While each of these scenarios provides its own benefits and disadvantages, the most effective policy recommendation must take into account the realities of each of the spheres that comprise society. Thus, the political reality that President Correa will seek popularity with voters must be taken into consideration as well as the environmental goal of reduced emissions and the economic tools available. Our recommended policy seeks to take all of these factors into consideration and provide the present, near-future, and long-term benefits associated with each of the described scenarios.

For the short term, President Correa should increase subsidies for electricity. As discussed, this will decrease energy prices and increase disposable income for the citizens of Ecuador. If this measure works as intended, it will provide President Correa with another term in office and more political stability for Ecuador. With respect to emissions, the danger of increasing subsidies for energy is that it will increase energy consumption, and thus increase fossil fuel emissions. However, our model shows that the increase in emissions from this measure was negligible overall.

In order to address lowering emissions, we propose the implementation of both of our recommended policies. As discussed earlier, these are increasing consumer energy efficiency through increased investment in technology, and decreasing production of electricity with fossil

fuels by investing in renewable energy sources. In order to increase consumer energy efficiency, we propose investing 1% of GDP in energy efficient technology. This money would probably come from the domestic private sector. Three possible means of securing this investment include taxes, private investment, and attracting industry through reducing interest rates. Once secured, these funds would increase technology available, thus increasing efficient use of electricity, which would decrease demand for electricity. This decreased demand for electricity then represents a near-future decrease in fossil fuel consumption and carbon emissions. Because technology to increase efficiency is available in the market, this measure could be adopted soon, and would have an impact on carbon emissions in the near future.

In order to effect a long term reduction of emissions, the role of fossil fuel in the energy profile must be drastically reduced. To do so, we propose capping the use of fossil fuels for energy production at 50%. The other half of energy production would come from increased investment in renewable energy production capacity. Because increasing capacity requires years of development of infrastructure, this policy is intended to take effect in 5-10 years. Possible sources of funding for this measure were not addressed in our analysis.

Our analysis indicated that the combination of this comprehensive policy recommendation would stabilize carbon emissions generated by the electric sector around 2010 levels. It is worth noting that these measures, while they would reduce emissions, only stabilize emissions from the electricity sector and do not lead to an eventual decrease. To reach the 1990 emissions levels set as the standard in the Kyoto Protocol would require a much greater investment of funds. This conclusion derives from the observation that investing in energy efficiency in non-electric sectors is trivial. In fact, when looking at transportation or industry, capital is characterized by a long lifetime and its replacement value is higher than in the electric

sector. In other words, a car lasts longer and costs much more than a refrigerator or TV. Investing in the electricity sector does not put a heavy load on the citizens, while acting in non-electric sectors requires a strong and active participation (investment) of a population that is facing poverty issues. The overall results in reducing emissions may be more encouraging when investing also in non-electric sectors, but delay times would be higher and the economy would suffer significantly, with the risk to slow down the growth of disposable income observed in the baseline scenario. Thus, our analyses indicate that a much greater investment than the Stern Report's suggested 1% of GDP will be necessary to achieve quick significant reductions in greenhouse gas emissions.

Acknowledgements

We would like to thank Jon Isham and Diane Munroe for all the time and effort they have put into this project. Also, many thanks to Allan Baer for facilitating and guiding this project. We greatly appreciate Andrea Bassi for building the T21 model and for spending three days straight with us in the basement of McCardell Bicentennial Hall. Other people who contributed "secrets" include Byron Fonesca, Peter Richardson, Robert Taylor, and Efficiency Vermont.

Appendix A: Figures

Figure 1: Overall annual greenhouse gas emissions for Ecuador. In this graph and all following graphs, the historical data from 1990-2007 is shown and compared to the behavior of the model in those years. This reflects the accuracy of the model. None of our scenarios achieved a reduction in the annual emissions, only a slowed the rate of increase.

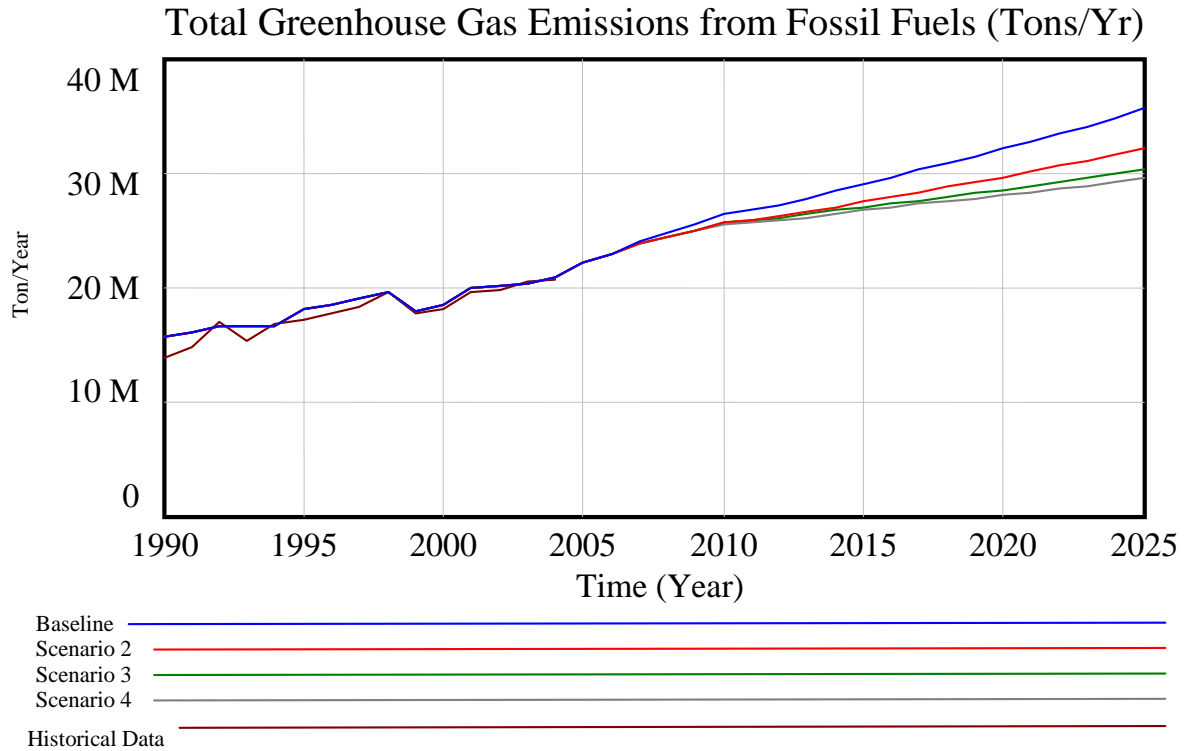


Figure 2: Total annual energy consumption in Ecuador. Includes residential, commercial and industrial customers.

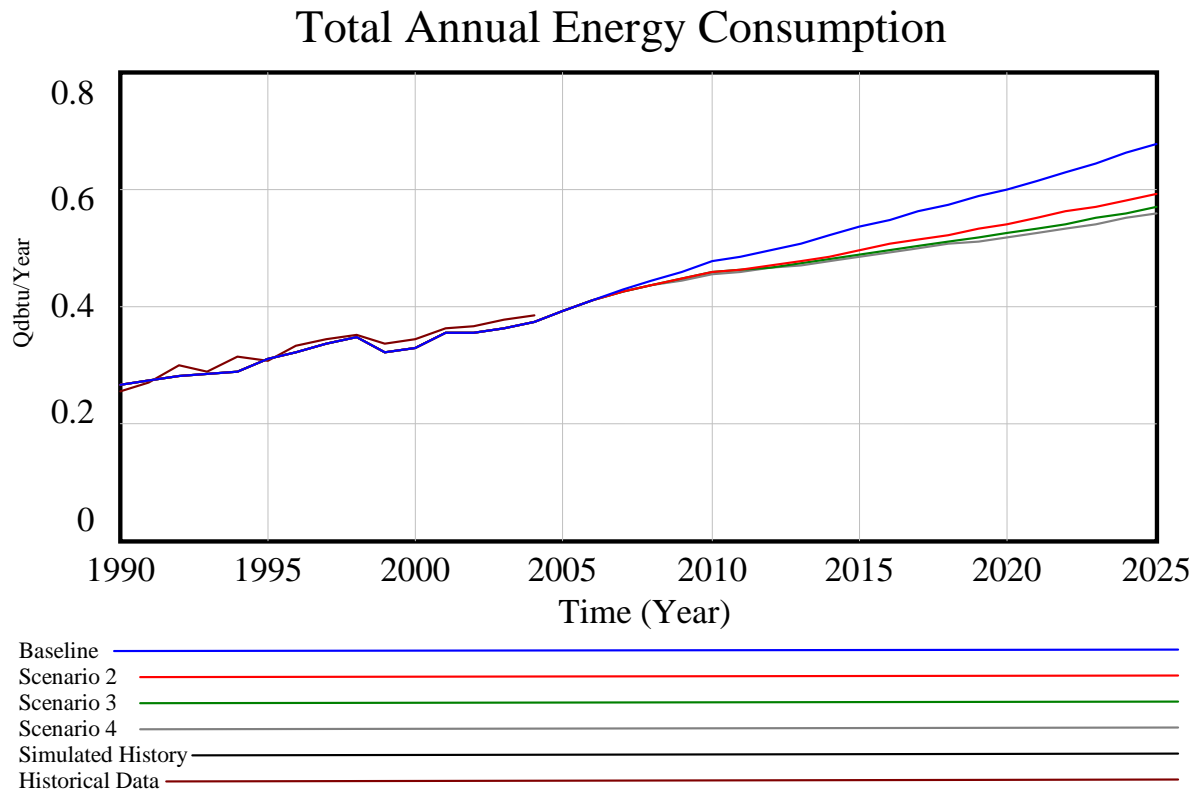


Figure 3: Per capita annual energy consumption in Ecuador. We used this to indicate electric power demand. As population increases, however, the observed decline in demand will cause overall consumption to rise (see Figure 2).

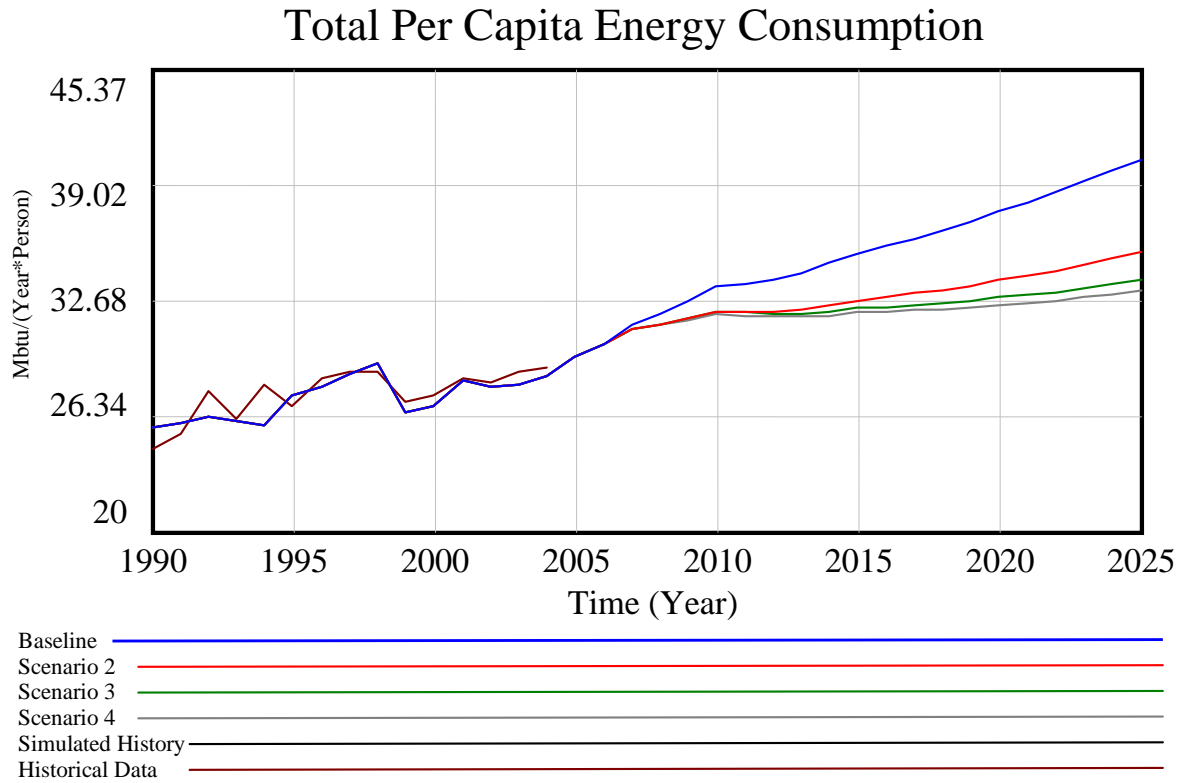


Figure 4: Total amount of electricity (in MWh) sold yearly in Ecuador.

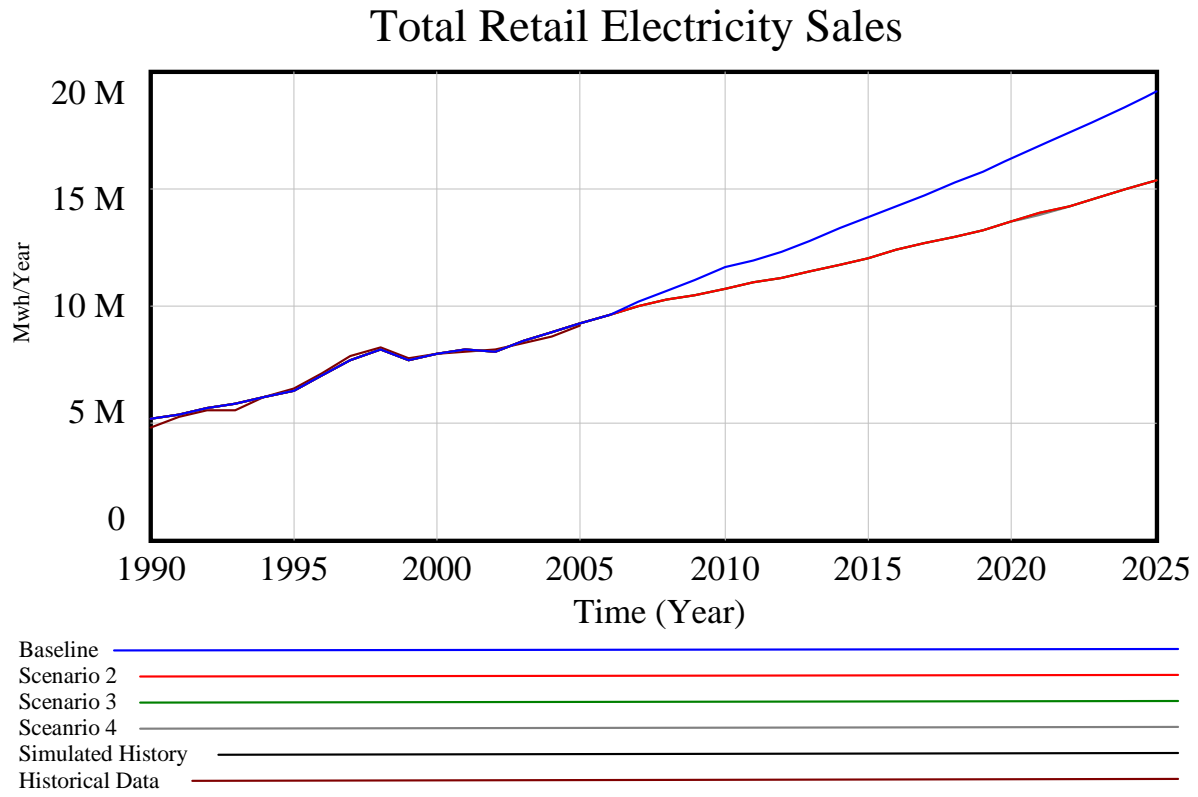


Figure 5: The potential effective fossil fuel capacity installed in Ecuador, or the total amount of electricity (in MW) generated by installed power plants using fossil fuels. Our scenarios could enable the government to spend substantially less on increasing capacity and building new power plants.

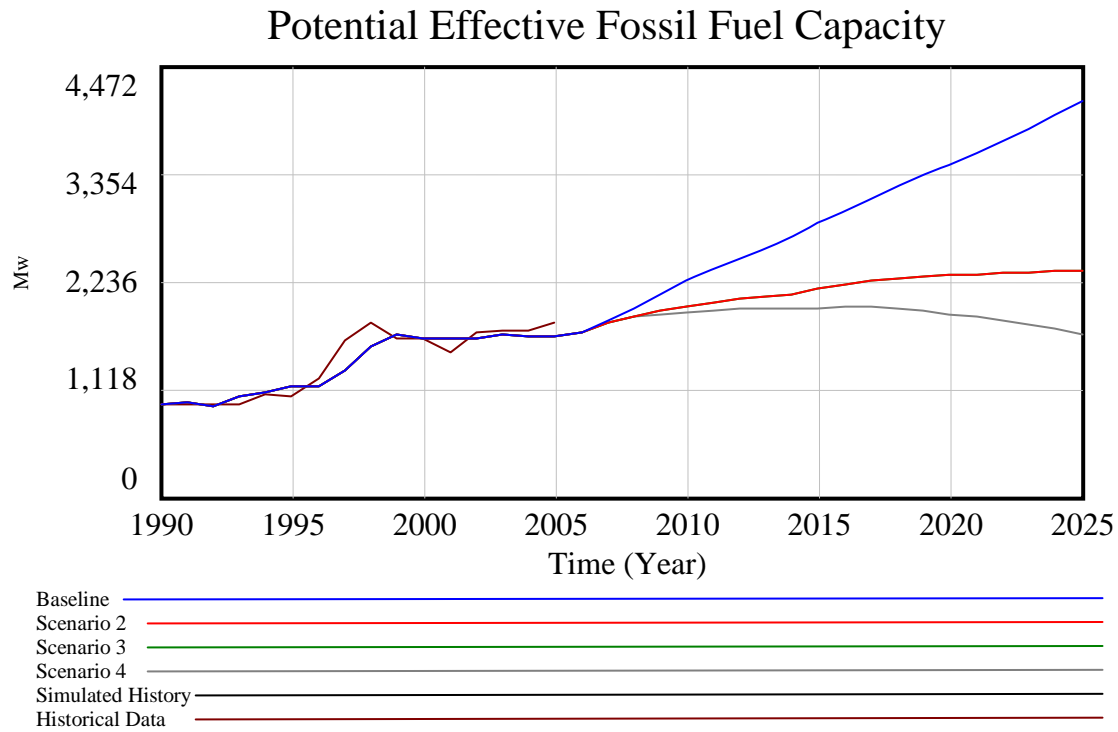


Figure 6: The proportion of total electricity generated that is produced using fossil fuels. This continues to increase with electric power demand in all scenarios.

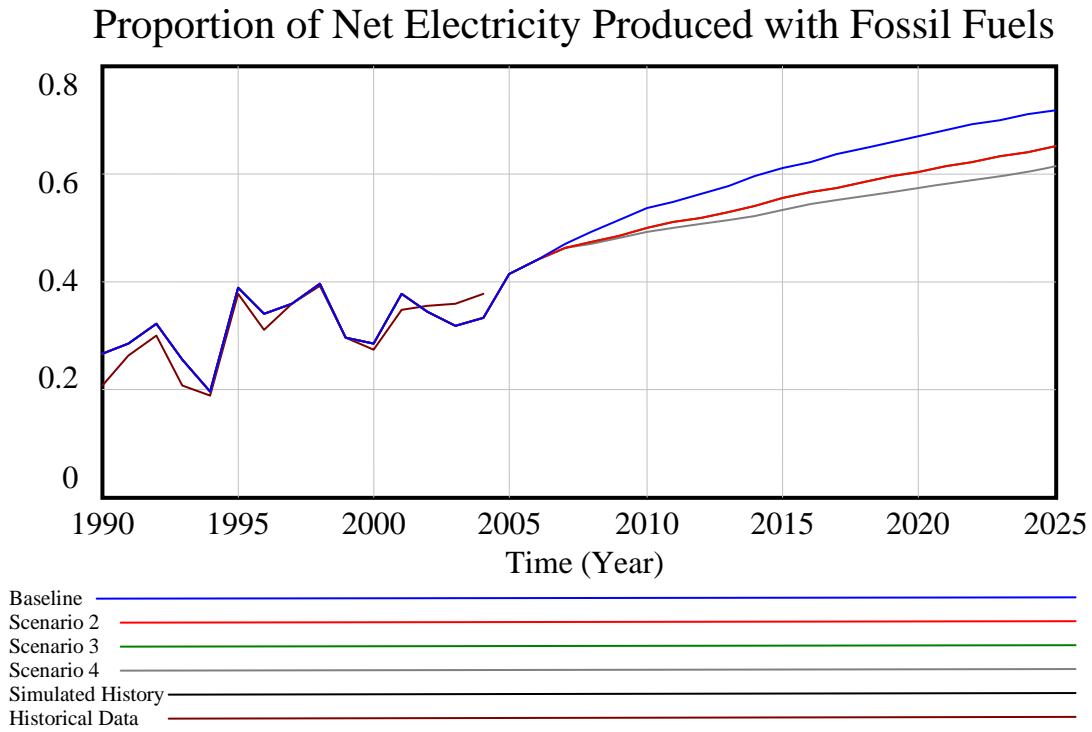


Figure 7: Proportion of net electricity produced with hydropower plants. This assumes that installed capacity remains at 2007 levels. In scenario four, which mandates a 50% share of renewable sources, increasingly large volumes of renewable sources will have to be built to account for rising electric power demand. This represents a significant cost to the government, which we did not calculate.

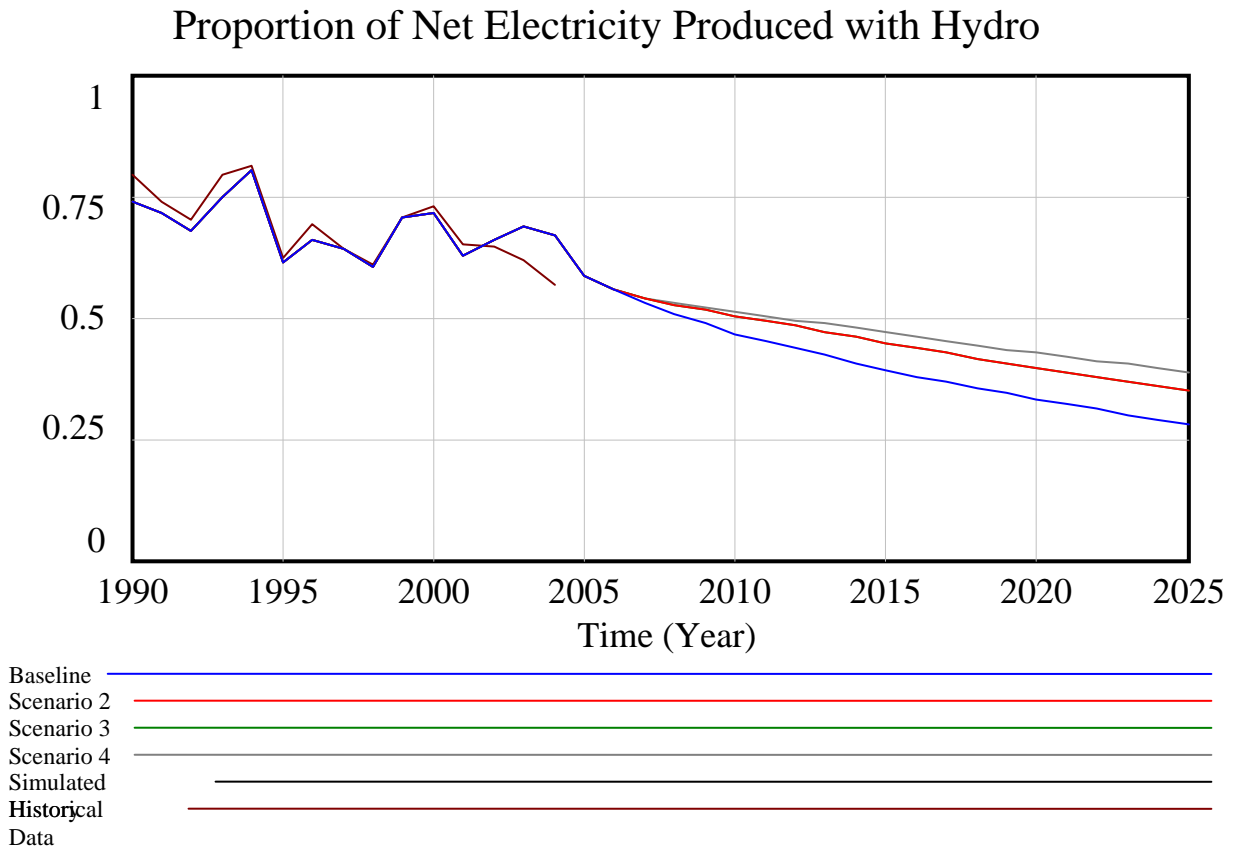


Figure 8: Cumulative avoided costs for the consumers in billions of US dollars through implementing a 1% investment of GDP into energy efficiency.

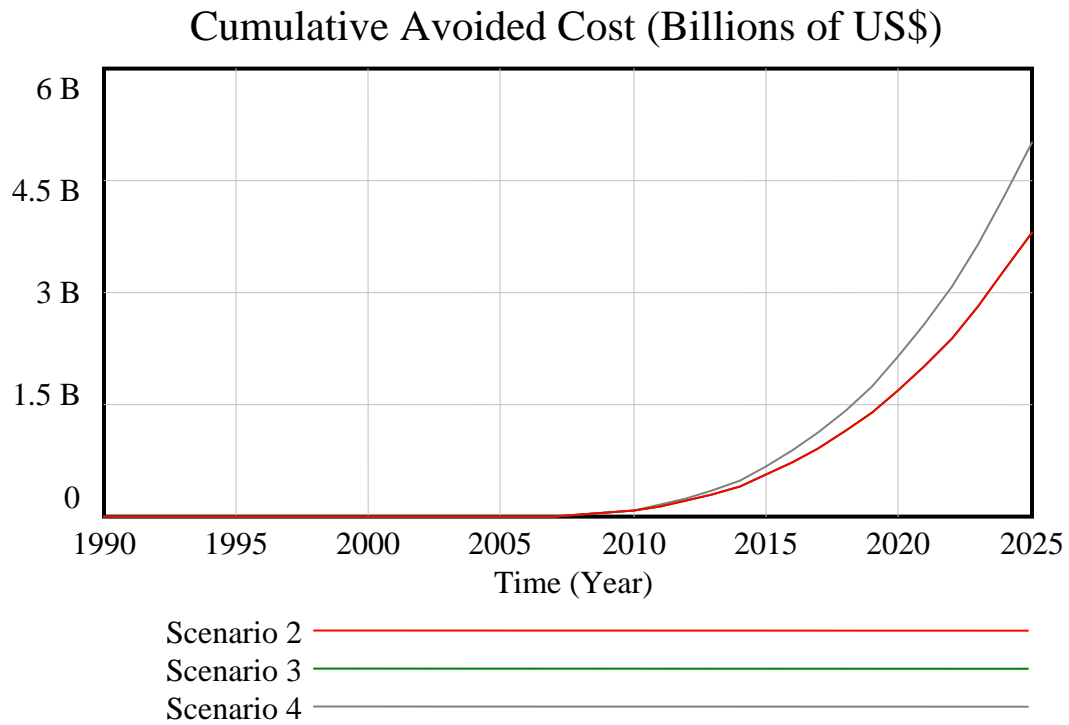


Figure 9: Amount of avoided costs re-invested in energy efficiency in billions of US dollars.

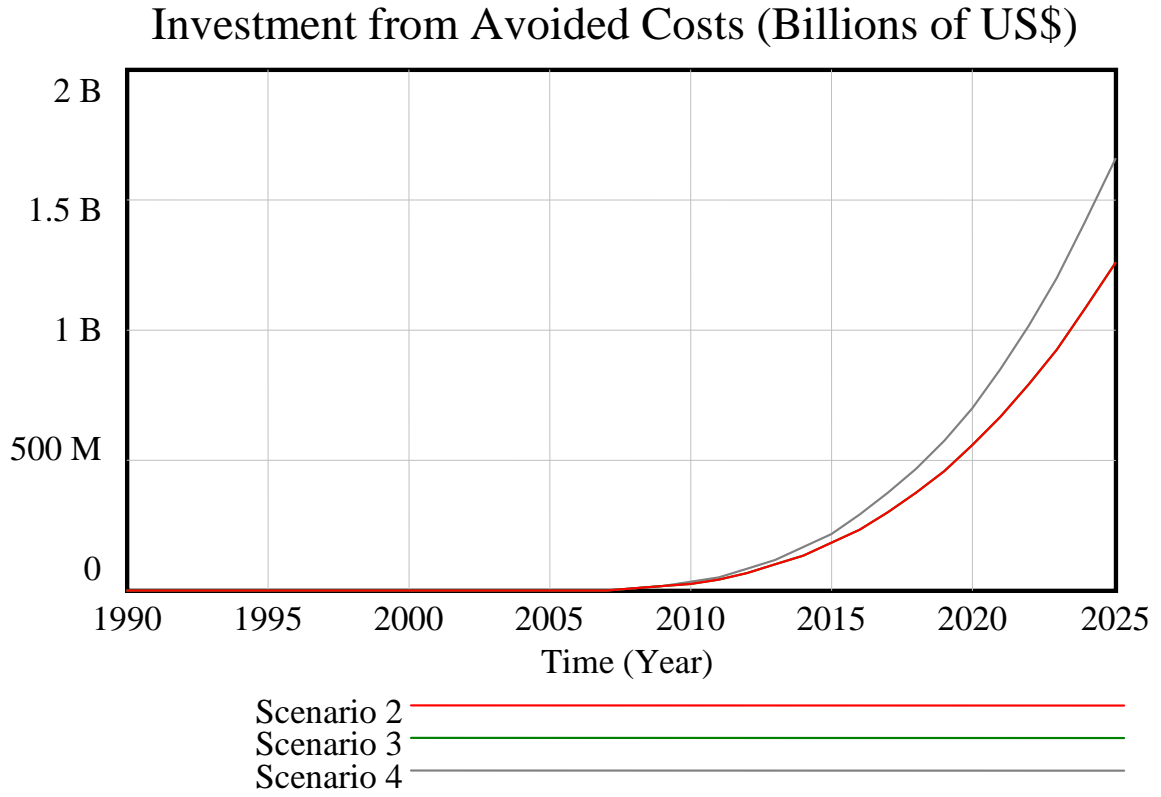


Figure 10: Annual petroleum consumption in the electric and non-electric sectors of Ecuador. The electric sector only makes up a small fraction of petroleum consumption.

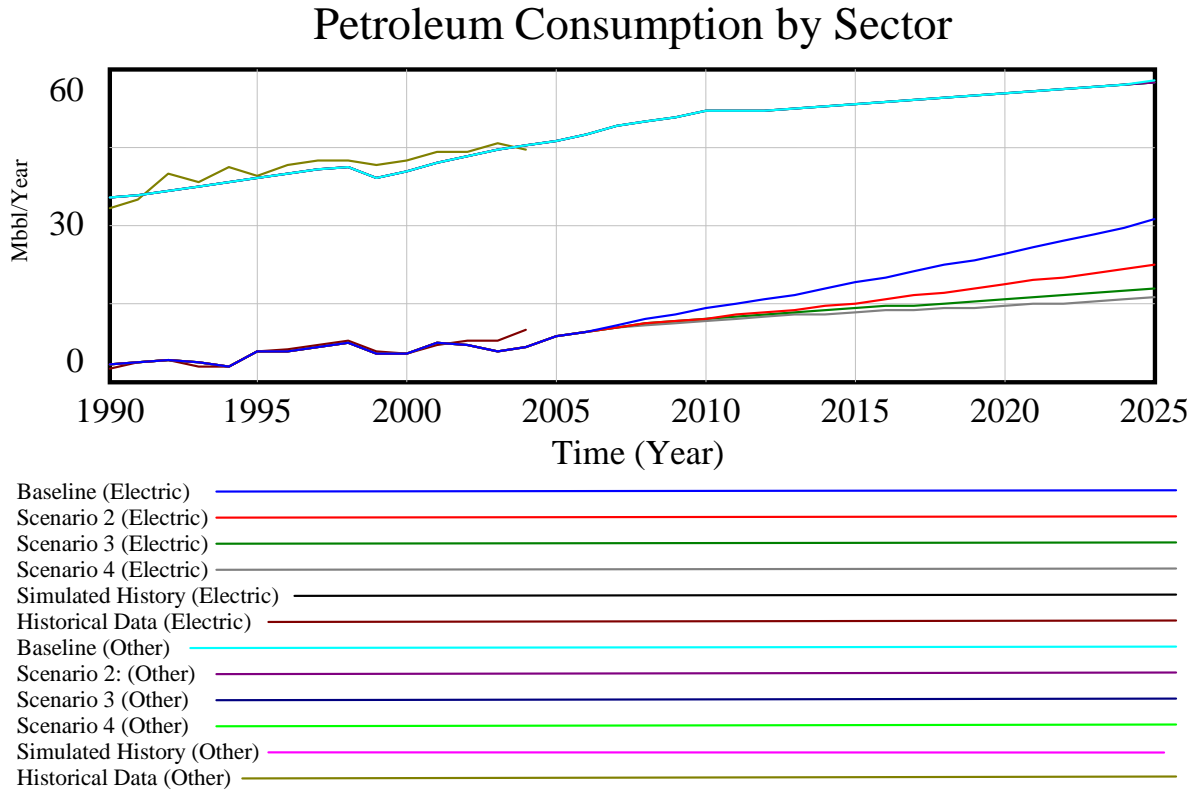
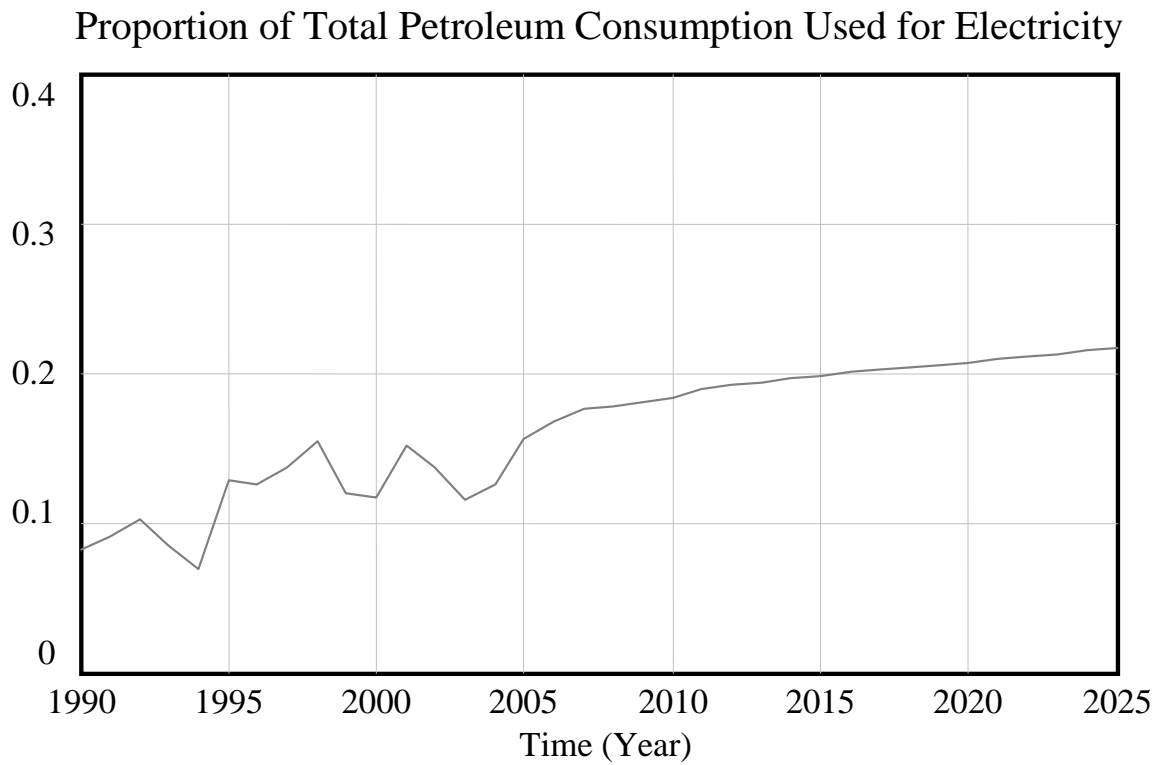
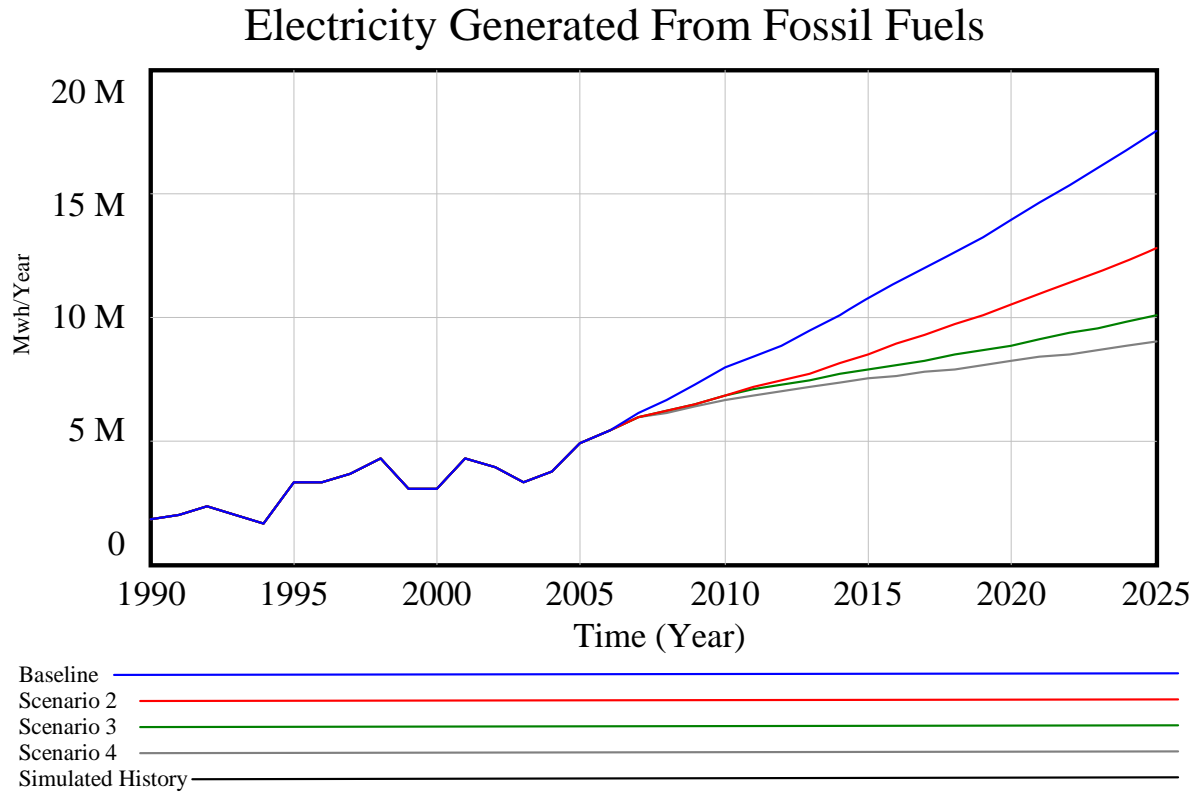


Figure 11: Proportional amount of Ecuador's total petroleum consumption used for generating electricity



Scenario 4

Figure 12: Annual volume of electricity generated using fossil fuels.



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