# How ambitious can the Israeli Green Deal be?

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# Abstract

# Israeli policy makers are considering carbon reduction targets for 2050. The goal of this study is to provide a comprehensive, economy-wide analysis of the alternative pathways for energy-related carbon emissions reduction in Israel. An integrated bottom-up, top-down modeling exercise, based on an original MESSAGEix\_IL-MACRO framework, was performed over the Israeli energy system to assess the cost-effectiveness of greenhouse gas (GHG) emissions reduction options—firstly with renewable energy and transport electrification targets and secondly by imposing a carbon tax. The results show that, by the adoption of such a policy or a more ambitious policy (with a higher carbon tax), energy-related GHG emissions could be reduced by about 60% or 90%, respectively, by 2050 relative to the reference year of 2005, with only a minor impact on the growth of the national GDP. Decarbonization of the Israeli economy will necessarily be based on increasing the electrification of transport and industry and on generating power from renewable energy resources (mainly solar). The unique challenge for Israeli policy makers is a population growth rate that is unprecedented in the developed world. The infrastructure should be developed rapidly to keep the growth of the standard of living intact. This challenge also presents the opportunity for a quick transition to a cleaner economy. The modeling tool and its outcomes can provide valuable insights for the design of clean energy policies that permit the fostering of sustainability targets. This methodology results in various scenarios that may help decision makers to understand the options available to them to accomplish the ambitious goals and targets they may set in their political forums.

***Keywords***: carbon emission reduction, 2050 goals, linked bottom-up-top-down modeling

# Introduction

The energy sector in Israel is at a crossroad. Traditional energy sources are in the process of replacement by natural gas (NG) and renewable energy (RE) in power generation, and industry and transport are being gasified and electrified. Long a resource-poor country, Israel now has more NG than it needs for the next thirty years. As Israel's energy bill before the NG discoveries was about $10 billion—more than 5% of the gross domestic product (GDP)—the supply of domestic NG and its export have been contributing to the country's trade balance (Palatnik, Tavor, and Voldman, 2019).

Ultimately, the process is expected to lead to cleaner energy and a better environment. However, concerns about energy reliability and security, the intermittency of RE, and uncertainty about the costs of energy transition and required infrastructure challenge policy makers in committing to the transition.

Globally, smarter technologies and designs that use energy more efficiently could provide the same or better services with far less energy, costs, and risk (Gielen et al., 2019). Moreover, the fossil fuels that provide most of the energy now generally cost more than the modern renewable sources that have already taken over two-thirds of the world’s power-plant market (IEA, 2017).

Recent years have seen tremendous turmoil in regional and global energy markets, with volatile oil prices, geopolitical tensions over oil and NG supply, and tightened environmental regulations.

Those transformations offer remarkable opportunities for policy makers to build a durable economy and to make energy supplies resilient to catastrophic interruptions of supply. Evidence is now emerging in such major economies as China, India, the USA, and the EU that, if based on the lowest-cost available resources, ambitious global climate protection can be profitable rather than costly (NDRC, 2016; Kemfert, 2017; CCC, 2019).

The national carbon mitigation goals for 2050 should be declared at the United Nations Climate Change Conference (UNFCCC COP 26), to be held in Scotland in November 2020. The EU has recently stated ambitious targets of net zero carbon emissions to be reached by the year 2050 (European Commission, 2019). The Israeli policy makers are skeptical as to how far greenhouse gas (GHG) emissions reduction in Israel can go without hampering economic growth. The aim of this study is to investigate the economic impacts of alternative paths for GHG emissions reduction in Israel.

Gielen and others (2019) state that well-designed transition policies should consider the characteristics of energy systems and encompass energy supply and demand. In this study, we propose a unique modeling setup that is the best fit to represent the Israeli energy system and economy. It will be a useful tool to inform debate and to facilitate the decision process for energy-related GHG emissions reduction goals to be set by the future government of Israel.

The remainder of the paper is organized as follows: Section 2 presents the motivation for the methodology used in this study. Section 3 describes the modeling framework. Section 4 outlines the research structure. Section 5 presents the main assumptions for different scenarios, following by key results presented in Section 6. Section 7 concludes with discussion and policy recommendations.

# Methodology: background

Energy is a crucial economic input within the economy, is widely utilized as a production factor, and is consumed in various forms by households. For those reasons, any changes in the energy sector can have a preponderant impact on the entire economy. The challenge in modeling energy markets and policy is to capture adequately the energy system effects, the sectoral and macroeconomic impacts, and the feedback effects (Helgesen & Tomasgard, 2018). The literature provides a variety of approaches to combining economic and energy system models (Arndt, et al., 2016; Bohringer & Rutherford, 2008; Helgesen & Tomasgard, 2018).

Bottom-up engineering models include thorough descriptions of technological aspects of the energy system, including future improvements (Hourcade, Jaccard, Bataille, & Ghersi, 2006). They include interactions among the numerous individual energy technologies that make up the energy system of an economy, from primary energy sources, via conversion and distribution processes, to final energy use. A solution constitutes a partial equilibrium wherein energy demand is fulfilled in a cost-optimal fashion. Energy modeling frameworks commonly consist of technology-rich, bottom-up representations of the energy sector alone, while policy interventions on the latter entail economic and environmental consequences on the whole set of productive sectors within a national economy (SDSN and FEEM, 2019). Thus, partial equilibrium modeling of an energy sector is not sufficient to analyze policy questions (Palatnik & Shechter, 2008).

Top-down general equilibrium (GE) models, on the other hand, describe the entire economy and emphasize the possibilities of substituting different production factors to maximize the profits of firms (Palatnik R. R., 2019). The substitution possibilities between energy and other production factors are captured in production functions, which describe changes in fuel mixes as the result of price changes under certain substitution elasticities. Prices are determined by market clearance conditions, which equalize supply and demand for all commodities in the economy, both energy and non-energy (Siddig & Grethe, 2014). The constant elasticity of substitution (CES)-type production function aggregates economic quantities in a nonlinear fashion, conserving value but not physical energy flows (SueWing, 2006). Even if the scope of top-down models is comprehensive, such models are characterized by a high aggregation level; indeed, energy technologies are usually lumped together in one average “energy sector” (SDSN and FEEM, 2019). For such reasons, that approach should be considered complementary to bottom-up models, rather than the opposite, thus encouraging a new methodology to bridge these tools, often called “links”, which are increasingly proposed in the recent literature (Brown, et al., 2018).

Top-down and bottom-up models represent two contrasting and widespread approaches for quantitative assessment of energy policies. Linking them allows for the strengths of one model to complement those of the other (Bohringer & Rutherford, 2008). Among examples of hard-linking between bottom-up and top-down models are the MESSAGE-MACRO model by IIASA (Messner & Schrattenholzer, 2000; Orthofer, Huppmann, & Krey, 2019) and MARKAL-MACRO (Manne & Wene, 1992). The South African TIMES energy system model (SATIM) has been hard-linked to a detailed dynamic CGE model of South Africa (SAGE) (Arndt, et al., 2016). Another example is provided that created a soft link between the TIMES\_PT energy bottom-up partial equilibrium model and the DGEM top-down model for the Portuguese economy to analyze potential carbon mitigation pledges for Portugal (Seixas, et al., 2017). Kober and others linked a macroeconomic model to an energy system model by considering the decreases in consumer spending resulting from the introduction of carbon taxes (Kober, et al., 2016). As part of the current EU policy of modeling and evaluation, the TIMES model has been integrated with the GEM-E3 CGE model for assessing the economic and environmental consequences of a variety of energy policies (Capros, et al., 2013).

The top-down analyses of the Israeli economy include the CGE model for Israel, IGEM (Palatnik & Shechter, 2008), which has been developed and employed for more than ten years, to analyze the economy-wide impacts of climate change (Baum, Palatnik, Kan, and Rappaport-Rom, 2016; Davidovich, Palatnik, Ayalon, and Shechter, 2015) and climate change mitigation policies in Israel (Palatnik and Shechter, 2008; Palatnik and Shechter, 2010). Other CGE-based analyses include Luckmann and others (2014) and Yerushalmi (2018), who demonstrated the economy-wide costs of water scarcity for the Israeli case study. Siddig and Grethe (2014) used a GTAP-based CGE model to analyze the costs of disruptions of the NG supply from Egypt.

The bottom-up energy-related models for Israel usually focus on a specific sector within energy, that is, the electricity sector (Solomon, Bogdanov, & Breyer, 2018; Tishler, Newman, Spekterman, & Woo, 2008), NG, or oil (Yu, Pearlmutter, & Schwartz, 2018). Those approaches fail to assess major shifts in the energy system and their macroeconomic implications. Due to expected shifts to NG and RE in power generation, as well as to the electrification of transport and industry, a comprehensive representation of the energy sector and the interlink with the macro-economy is required.

MESSAGEix\_IL-MACRO is the first modeling attempt to represent the Israeli energy sector as a whole via MESSAGEix\_IL and to link it to a macroeconomic model, MACRO, to retrieve feedback from the energy demand side.

# Description of the modeling framework

In the present study, we utilize a novel long-term-horizon, linear, least-cost, integrated-assessment model of the Israeli energy system, MESSAGEix\_IL. MESSAGEix\_IL is a country-level application of the integrated assessment model MESSAGEix[[1]](#footnote-1), developed at the International Institute of Applied Systems Analysis (IIASA) over the past four decades (Huppmann, et al., 2019). MESSAGEix is a dynamic bottom-up, technology-based optimization model designed for medium- to long-term energy planning and policy analysis that provides a framework to represent energy systems with all their interdependencies and correlations. MESSAGEix can describe the entire energy system, including resource extraction, trade, conversion, transmission and distribution, and the provision of energy end-use services such as lighting, space conditioning, industrial process heating, and transportation (Orthofer, Huppmann, & Krey, 2019). The optimization model is solved to find the least-cost solution for satisfying energy demand under various technical, economic and ecological constraints.

To obtain macroeconomic feedback for changes in an energy system, MESSAGEix\_IL is linked directly to the MACRO module of the MESSAGE model introduced by Messner and Schrattenholzer (Messner & Schrattenholzer, 2000). MACRO maximizes the intertemporal utility function of a single representative producer-consumer through optimization (Fricko, et al., 2017). The result is a sequence of optimal savings, investment, and consumption decisions. The main variables of the model are the capital stock, available labor, and energy inputs, which together determine the total output of an economy according to a nested production function with constant elasticity of substitution. It considers the six commercial energy demand categories in MESSAGE. The combined model calculates, among other variables, the required capacity investment, the optimal energy system configuration, and the resulting emissions.

In this study, we developed a linked framework of the MESSAGEix\_IL bottom-up energy model for Israel with the MACRO model to obtain the feedback of carbon mitigation on energy demands and the overall economic performance.

# Research structure

The research was conducted in the following steps, as shown in Figure 1. First, the global energy model MESSAGEix-GLOBIOM was rescaled to represent the energy sector in a country-level model. In our case, the global energy model was transformed to represent a small open economy with imports of crude and refined oil and coal together with exports of natural gas and oil products. A series of additional updates to system closure rules was performed.

Second, the key parameters that characterize the Israeli energy sector were updated. Those include NG reserves discovered offshore Israel (900 BCM), energy taxes, power-generation capacity according to fuel mix, costs of power plants, storage, and others (Appendix). The reach historical data is comprised of the technologies in place, capacity, investment, operating and management costs, efficiency factors and more. Close collaboration with the Ministry of Energy resulted in obtaining the most updated data for MESSAGEix\_IL.

Carbon tax

Higher share of RE in power gen.

100% elect. trans.2050

Zero coal start. 2030

Baseline scenarios

Policy scenario

Cost of policy vs baseline in terms of GDP

Scenarios for energy related GHG emission reduction

Ambitious policy scen.

Link to MACRO

From MESSAGEix global to MESSAGEix-IL

Update of data for Israel

Min. of Energy

Min. of Transport

Planning Administration

Min. of Economy and Industry

Figure 1. Research structure

Third, in collaboration with stakeholders, the future development of the energy sector in Israel until the year 2050, following official policy plans, was identified. Accordingly, the “baseline” scenario for the future development of the energy sector in Israel until year 2050 was generated by MESSAGEix\_IL.

Fourth, the “baseline” scenario generated by MESSAGEix\_IL served for calibration of the aggregated macroeconomic model, MACRO. In the baseline calibration of MACRO, the GDP and population growth of Israel follow the official reports, while the energy development is generated by the baseline scenario in MESSAGEix\_IL.

Finally, alternative policies, such as a higher share of power generation from RE, complete electrification of the transport sector by the year 2050, and carbon taxes were imposed as external shocks to the energy system in MESSAGEix\_IL. In response to those shocks, the cost minimization model, MESSAGEix\_IL, rearranged the energy mix. The resulting energy prices were transferred to MACRO, which generated the response of the final demands and transferred the energy demands back to MESSAGEix\_IL. The models were run until the energy quantities converged. The results represent the alternative pathways of energy sector development in Israel that take into account the direct economic costs of energy-related GHG emissions reduction.

Although MESSAGEix\_IL reflects in detail the energy-related carbon emissions, other sources of GHG, such as agriculture, waste, and land use change are not presented in the current version of the model. Therefore, the analysis below reflects the potential change in about 85% of the GHG emissions in Israel.

Notably, the estimations below do not include the co-benefits of reduced emissions of local pollutants that are gained in each policy scenario. The decline in emissions of local pollutants is correlated with the reduction of carbon emissions (Bloomberg & Aggarwala, 2008). Therefore, improved air quality, which leads to gains in health and labor productivity, is not covered in the current analyses.

# Assumptions for Baseline and alternative scenarios

Several scenarios for energy policy are currently being discussed by the Ministry of Energy and the government and are not yet concluded. The plan for Energy Economy Objectives for the year 2030 (MOE, 2018) provides a cost-benefit analysis of transformations in three sectors: (1) removing coal from the energy mix for power generation while increasing the share of NG to 70% and RE to 17%, (2) increasing the NG share for the production of energy and steam in the industrial sector, and (3) shifting to electric vehicles and NG-powered trucks. Positive net economic benefit was observed for the plan. The present study broadens the scope of the policy alternatives and evaluates each of them with the rigorous tool of applied system analysis, specifically developed to represent the Israeli energy sector and the Israeli economy. We employ a multi-scenario analysis to identify the economic prospects of clean energy pathways for Israel and the associated changes in CO2 emissions under climate mitigation policies. The key assumptions for each scenario are summarized in Table 1. A list of the main assumptions is presented in the appendix.

Table 1. Scenario assumptions

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Scenarios | | Baseline I: Low population growth, RE and EV | Baseline II: High population growth, RE and EV | Policy Scenario | | Ambitious Policy Scenario |
| Socio - economic | *Population* (average annual growth) | 1.7% (CBS, 2017) | 2.0% (CBS, 2017) | Follow baselines | | |
| *GDP* (average annual growth) | 2.5% (Argov & Tsur, 2019) | 3.5% (IEC, 2017) | Follow baselines | | |
| Power generation | *RE* | 17% from 2030 on | 30% from 2030 on | 85% in 2050 | | |
| *Coal* | Reduction of the capacity of coal power plants by 2030, remaining 3400 MW available till 2050 | | Graduate reduction to 0 by 2030 | | |
| *Gas* | NG export of 25% of reserves by 2050 | | No limit on NG capacity after 2025 | | |
| Electric Transport | | 30% in 2050 | 60% in 2050 | 100% electric transport | | |
| Carbon tax *(Average annual in a 5-year period, per ton CO2)* | | No Carbon Tax | | 2020 | $0 | $0 |
| 2025 | $23.3 | $61.8 |
| 2030 | $48 | $145 |
| 2035 | $53 | $160 |
| 2040 | $58 | $176 |
| 2045 | $62 | $190 |
| 2050 | $67 | $205 |
| 2055+ | $69 | $212 |

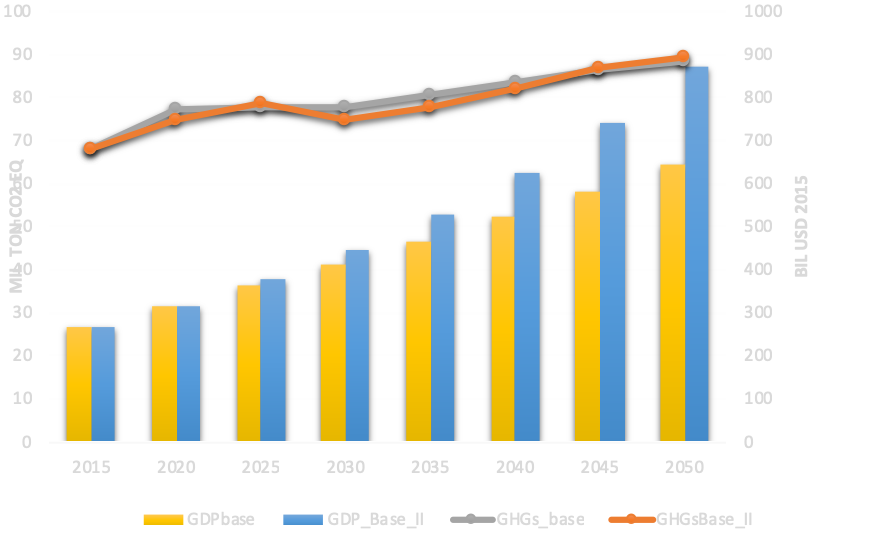
To allow for the considerable uncertainty of future economic development, we produced two “baseline” scenarios for population growth that differ according to differing projections of the Central Bureau of Statistics (CBS) (2017) and corresponding GDP growth. In addition, Baseline Scenario I assumes 17% of RE in power generation by 2030, as per the Israeli commitment to the Paris Agreement (UNFCCC, 2015). Baseline Scenario II implements the recently discussed goal of the Ministry of Energy to reach 30% use of RE by the same year. Baseline Scenario II also contains a higher rate of electric transport by the year 2050.

Starting from each baseline scenario, two alternative policy scenarios were analyzed. The policy scenarios share the same assumptions for the year 2050 about the share of RE in the energy mix for electricity production (85%), the rate of electric transportation (100%), and a complete phase-out of coal by 2030. The only difference between the two policy scenarios is the annual rate of carbon tax levied per ton of carbon (Table 1). Policy Scenario introduces increasing carbon tax that follows the mid-range of EPA (2015), and Ambitious Policy Scenario introduces a higher carbon tax that corresponds more closely to recent estimations of the social cost of carbon (Pindyck, 2019).

# Results

According to the development assumptions (BOI, 2019), the GDP is projected to grow by about 140% to 230% in Baseline Scenarios I and II, respectively, in the period of 2015 to 2050, while the population almost doubles. The corresponding growth of energy-related GHG emissions, as estimated by MESSAGEix\_IL, is 30% and 37%, respectively, in Baseline Scenarios I and II (Figure 2).

*Figure 2. GDP and carbon dioxide equivalent (GHG) emissions in Baseline Scenarios I and II*



**30–37%**

**140%**

**230%**

Key assumptions in comparing Baseline II to Baseline I have offsetting impacts on energy-related GHG emissions. On the one hand, higher population and GDP growth rates increase energy demand. On the other hand, higher rates of RE in power generation and of transport electrification diminish carbon emissions.

As the GDP growth in the baselines is significantly higher than that of GHG emissions, partial decoupling between economic growth and carbon emissions in the Israeli economy might be achieved if currently planned policies are indeed implemented (Figure 2).

Applying Policy Scenario and Ambitious Policy Scenario onto Baseline Scenarios I and II shows that the Israeli economy can reach a significant reduction in energy-related GHG emissions without compromising economic growth (Table 2).

Table 2. Summary of key results for baseline and policy analyses

|  |  |  |
| --- | --- | --- |
|  | **Emissions in 2050 vs 2005** | **GDP vs projection in 2050** |
| Baseline Scenario I | *48%* | *-* |
| Policy Scenario | *-66%* | *-0.31%* |
| Ambitious Policy Scenario | *-92%* | *-0.62%* |
| Baseline Scenario II | *49%* | *-* |
| Policy Scenario | *-61%* | *-0.02%* |
| Ambitious Policy Scenario | *-73%* | *-0.32%* |

Table 2 presents the estimated percentage change in energy-related GHG emissions projected for 2050 as compared to those of year 2005, which was the Paris Agreement reference year for Israel (UNFCCC, INDCs as communicated by Parties, 2015). Evidently, if Israel follows the currently planned development paths (Baseline Scenarios I and II) the energy-related GHGs are projected to rise by half. However, policies that promote reaching 85% of RE in the energy mix for power generation and full electrification of transport by 2050 and are combined with modest carbon tax rates not only prevent the increase in GHGs, but they reduce emissions by about two-thirds (Policy Scenario). A higher carbon tax rate might achieve an even sharper decline of 73% to 92% (Ambitious Policy Scenario), placing Israel in line with NDCs for 2050 of most OECD countries (UNFCCC, Communication of long-term strategies, 2020). The estimated direct economic cost in 2050 is between 0.02% and 0.62% of GDP.

Figure 3. GDP and GHG emissions in Baseline I, Policy, and Ambitious Policy scenarios

The year 2015 is the most recent historical period in the model, which runs in five-year steps. Therefore, the first output of the MESSAGEix\_IL-MACRO framework is obtained for the year 2020. Figures 3 and 4 show the estimated GHG emissions and GDP for each baseline and policy scenario, starting from the observed year 2015 and with five-year-step projections until the year 2050.

Figure 4. GDP and GHG emissions in Baseline II, Policy, and Ambitious Policy scenarios

The government take from the carbon tax (Table 3) has an inverse U shape, as the tax per ton of CO2 equivalent increases while GHG emissions are projected to decline over time.

Table 4. Income of carbon tax from energy-related GHG emissions

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | **Policy** | | | **Ambitious policy** | | |
| *Year* | *Tax*  *$ per Ton*  *CO2eq* | *Emissions*  *Mil. Ton*  *CO2eq* | *Tax Income*  *% of GDP* | *Tax*  *$ per Ton*  *CO2eq* | *Emissions*  *Mil. Ton*  *CO2eq* | *Tax Income*  *% of GDP* |
| *2020* | 0 | 73.30 | 0 | 0 | 72.14 | 0 |
| *2025* | 23.3 | 71.62 | 0.44% | 61.8 | 64.81 | 1.07% |
| *2030* | 48 | 60.61 | 0.65% | 145 | 45.19 | 1.48% |
| *2035* | 53 | 55.47 | 0.56% | 160 | 37.11 | 1.13% |
| *2040* | 58 | 43.41 | 0.40% | 176 | 27.90 | 0.79% |
| *2045* | 62 | 31.63 | 0.27% | 190 | 20.08 | 0.52% |
| *2050* | 67 | 23.69 | 0.18% | 205 | 18.28 | 0.43% |

Checking closely the energy mix in power generation, we see that coal phases out completely in both the Baseline II and Policy scenarios (Figure 5). In Baseline II Scenario, NG use in power generation is expected to increase significantly by 2050, while in Policy Scenario, the energy mix in 2050 is composed of 15% NG and 85% solar energy. (The corresponding needs of storage are included). In total, power generation is projected to rise significantly in the Policy scenarios when compared to the Baseline scenarios. The additional growth is mainly due to storage needs to compensate for higher amounts of solar power.

Baseline II

Policy Scenario

Oil

Solar

Coal

NG

Wind

Figure 5. Energy mix in power generation, Terawatt-hours (TWh)

MESSAGEix\_IL allows investigating the segmentation of the reduction and transformation components that the energy sector undergoes in Policy Scenario relative to the Baseline scenarios.

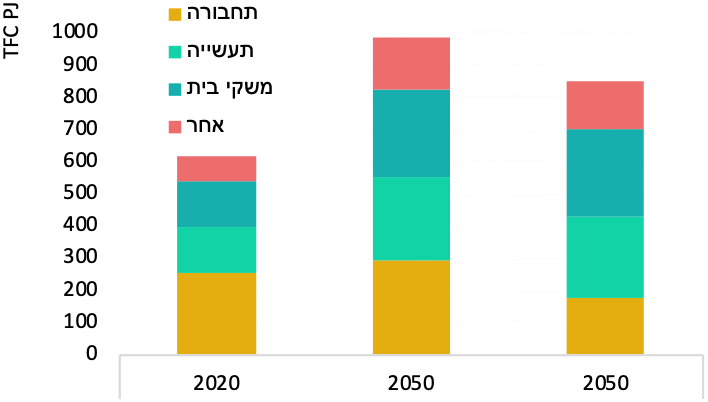
For example, in Figure 6, we compare the total final energy consumption (TFC) between 2020 and 2050 in the Baseline II and Policy scenarios. Evidently, the energy consumption in transport is projected to rise in Baseline II Scenario but to decline in Policy Scenario, even though the number of vehicles is growing significantly in both. That is because electric transport is much more energy-efficient than transport with internal combustion engines.

Transport

Industry

Resid.and Commer.

Feedstock



Policy

Baseline II

Figure 6. Total final energy consumption (TFC) according to final users in Baseline II and Policy scenarios

The main transformation of the energy sector in Israel, as projected in Policy Scenario, is summarized in Figure 7. The share of RE in power generation sharply increases to reach the goal of 85% by 2050. Carbon taxes, enhanced energy efficiency, and transport electrification increase the overall electrification of the economy from about 30% today to 70% in 2050, while the energy intensity declines by 53%. While the decline in energy intensity may seem sharp, 40% of it is reached in the baseline scenario, and only about 13% is driven by policy. This composition of energy intensity reduction indicates that full implementation of all current policy plans and support of the natural efficiency trends are crucial.

Figure 7. Energy intensity, share of electricity in final energy mix, and share of RE in power generation

# Discussion and policy recommendations

Policy makers around the world are in the process of establishing national development plans projected to the year 2050 to combat climate change. In the present study, we simulate the adoption of energy-related carbon emissions reduction targets and their impact on the economic growth in Israel by means of an original dynamic integrated energy-macroeconomic framework, MESSAGEix\_IL-MACRO.

We report the results for six scenarios. Two baseline scenarios served as the starting points for two policy scenarios, Policy Scenario and Ambitious Policy Scenario, which has a higher carbon tax rate. The results show that, by adopting Policy and Ambitious Policy targets, energy-related GHG emissions could be reduced by about 60% and 90%, respectively, by 2050 relative to the reference year of 2005 with only a minor impact on GDP growth. The decline in emissions would be achieved by higher energy efficiency, which contributes about 60% to the reduction in energy consumption per unit of GDP, compared to 2017. Another important step for decarbonization is diverting energy production from the use of polluting fossil fuels to RE while electrifying the economy, so that the rate of electricity use in total final energy consumption increases from about 30% to date to 70% in 2050 in Policy Scenario. The improved efficiency and transition to RE are partly due to the exogenous targets for RE in power generation and full electrification of transport and are partly due to the imposition of a carbon tax.

Importantly, the analysis so far covers about 85% of GHGs in Israel that result from energy-related processes. In addition, the simulation does not take into account the health benefits to the economy that result from the reduction of regional air pollutants, which are highly correlated with GHG emissions. Moreover, the economic and social benefits from climate change mitigation are not incorporated in the analysis, as the mitigation results are dependent on the global decarbonization effort. Furthermore, the model does not take into account the effect of structural changes in the economic sectors on the composition of employment.

Nevertheless, the analysis allows us to derive several important conclusions. First, adopting targets to reduce GHG emissions by 2050 represents an exceptional opportunity for long-term strategic planning in Israel. Significant reductions in GHG emissions can be achieved by electrification of the economy while basing power generation on renewable energy sources. Achieving these goals involves investing, which, if implemented optimally, can contribute to achieving both emission reduction goals and economic growth. In particular, there is a synergy between adopting emission reduction targets and the need for considerable investment in infrastructure to achieve the Israeli economy's growth targets, given the expected demographic growth.

However, considerations of energy security must also be evaluated carefully. On the one hand, increased use of domestic renewable energy reduces the reliance on imported coal and oil. On the other hand, the main source of RE in Israel is solar energy, while hydroelectric and nuclear-based power generation are not feasible. Accordingly, to meet the goals of RE in power generation, demand management and storage of electricity, as well as wind and waste-to-energy, should be promoted.

The transport sector is responsible for more than two-thirds of Israel's fossil fuel energy consumption. In addition, Israel suffers from a decade-long underinvestment in transportation infrastructure. Given the urgency of solving road congestion and the continuing increase of new vehicles on our roads every year, which are driven by demographic and economic growth, we recommend rapid electrification of lighting and public ​​transport to be the government's most important budgetary commitment, requiring immediate implementation. Accordingly, we call for investment in electric and efficient public transportation. Infrastructure that allows transmission for electricity storage and supply can also contribute to solving the challenge of a high proportion of solar energy in power generation.

The construction sector also provides an opportunity to achieve decarbonization goals. The high rate of population and economic growth requires construction of about 100,000 new residential units per year. The government-sponsored “Buyer's Price Program” (Ministry of Finance, 2020) speeds up housing construction at lower-than-market-prices but avoids green building standards and energy efficiency considerations completely. Energy efficiency can be increased, both by designing residential dwellings and commercial, public, and industrial centers according to green building standards that reduce energy consumption and by connecting them with efficient electric public transportation. Those steps might lead to increasing up-front building costs in the short term, but they have been proven to be cost-efficient in the long run (Palatnik, Davidovitch, Ayalon, & Trop, 2018; Gabay, Meir, Schwartz, & Werzberger, 2014). The green standard must also be applied to construction as part of the renovation/evacuation/construction government programs that are planned to replace TAMA 38 for private and public buildings and offices. Another recommendation is to promote the “prosumers” (Mega, 2019) programs, wherein the end users provide their energy needs by solar panels or wind turbines and supply the surplus to the grid.

Industry is also responsible for a significant proportion of pollutant emissions. To make the most of Israel’s offshore NG reserves, the government subsidizes the investment in NG infrastructure for energy-intensive industries. The utilization of NG is indeed preferable in terms of pollution when compared to other fossil fuels. However, heavy investment in NG infrastructure might prevent the investment in electrification of industry that is required to meet the goals of decarbonization. In addition, the government is called upon to reconsider the industry development plans of oil refineries.

In addition, the manufacturing sector should prepare for the possibility of other countries adopting green regulations that would make it difficult to export products produced in Israel with polluting energy that could be produced elsewhere with renewable energy. The many investments, in Israel and in the world, that are needed to adopt energy-efficient and non-polluting technologies in the fields of transportation, construction, and others also create an opportunity for investment in technological innovation in industry.

A major incentive for energy efficiency and the transition to renewable energy among the various economic players is the relative price of the polluting energy. The carbon tax internalizes the negative externalities created by GHG emissions and therefore is found to be the best solution to mitigate GHG emissions, both globally and locally. Therefore, we recommend accompanying the policies proposed above with the adoption of a carbon tax, combined with the provision of subsidies for the use of non-polluting capital. Carbon tax levied on a budget-neutral basis does not increase the tax burden and may lead to a double dividend in terms of improved environmental and economic performances (Palatnik & Shechter, 2008).

**Acknowledgements**: The study was conducted as a part of the project “Sustainable economic development” led by the ministry of Environmental Protection and the Israel Democracy Institute, Israel. The authors thank Prof. Nathan Sussman, Mrs. Daphna Aviram-Nitzan, Dr. Gil Proector, Mr. Yuval Laster, Mr. Ron Kammara, and the Energy Research Program at IIASA for fruitful cooperation and valuable input.

**Appendix**

|  |  |
| --- | --- |
| **Data** | **Source** |
| Population growth | [Medium and high scenarios (CBS, 2017)](https://www.cbs.gov.il/he/mediarelease/doclib/2017/138/01_17_138t1.pdf) |
| GDP growth | [Medium (Argov & Tsur, 2019)](https://www.boi.org.il/en/Research/DiscussionPapers1/dp201904e.pdf); High (IEC, 2017) |
| Energy prices till 2030 | [World Bank 2019](http://pubdocs.worldbank.org/en/598821555973008624/CMO-April-2019-Forecasts.pdf) |
| Energy prices 2031–2050 | [EIA 2019](https://www.eia.gov/outlooks/aeo/) |
| Interest rate | Israeli National Economic Council (unpublished) |
| Energy taxes Israel | Ministry of Energy, Fuel Department (4/ 2019) |
| Coal power generation Israel | Ministry of Energy Chief Scientist |
| Storage costs Israel | Ministry of Energy Chief Scientist |
| NG Capital cost and OM cost | Ministry of Energy Chief Scientist |
| Coal Capital cost and OM cost | Ministry of Energy Chief Scientist |
| Solar Capital cost and OM cost | Ministry of Energy Chief Scientist |
| Technology efficiency | Ministry of Energy Chief Scientist |
| Power plants lifetime | Ministry of Energy Chief Scientist |
| NG reserves | [Adiri committee 2018](https://www.gov.il/BlobFolder/reports/periodic_examination/he/ng_dec_18.pdf) |
| NG export till 2050 | [Adiri committee 2018](https://www.gov.il/BlobFolder/reports/periodic_examination/he/ng_dec_18.pdf) |
| Historical data on energy balance, Israel | EIA, (IEA, 2019) and CBS |
| Elasticities of electricity demand | [BOI (Galo, 2017)](https://www.boi.org.il/he/Research/DocLib/dp201713h.pdf) |
| Emissions factors | Ministry of Environmental Protection |
| Carbon Tax | EPA (2015) |
| Electricity Transportation | Ministry of Energy |
| Renewable energy goals | Ministry of Energy Roadmap 2030 and PUA (2019) |

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1. Open model, data and documentation <https://message.iiasa.ac.at/en/stable/model/MESSAGE/model_core.html> [↑](#footnote-ref-1)