Research Article

A Strategic Analysis of National Electricity Generation Alternatives: A Perspective from the Future

Adi Wolfson[1*], Ofira Ayalon[2], Alon Tal[3]

[1]Green Processes Center, Department of Chemical Engineering, Sami Shamoon College of Engineering, Basel/Bialik Sts., Beer-Sheva 8410001, Israel

[2]Department of Natural Resources and Environmental Management, University of Haifa, Israel and Samuel Neaman institute, Technion

[3]Department of Public Policy, Tel Aviv University, Tel Aviv 69978, Israel

[*]**Corresponding Author:** Adi Wolfson, Green Processes Center, Department of Chemical Engineering, Sami Shamoon College of Engineering, Basel/Bialik Sts., Beer-Sheva 8410001, Israel, E-mail: adiw@sce.ac.il

Received: 27 August 2020; **Accepted:** 02 September 2020; **Published:** 11 September 2020

Citation: Adi Wolfson, Ofira Ayalon, Alon Tal. A Strategic Analysis of National Electricity Generation Alternatives: A Perspective from the Future. Journal of Environmental Science and Public Health 4 (2020): 282-295.

Abstract

Climate change and energy policies raise complex issues about intergenerational justice. We conducted a (SWOT) analysis with the objective of evaluating the Israeli strategy for development and prioritization of natural gas (NG) versus renewable energy (RE) options, focusing on the impacts on current and future generations. Unlike the traditional SWOT evaluation, our analysis proceeds in two stages where the strengths, weaknesses, opportunities and threats to the current generation are characterized and then a parallel evaluation made for future generations. The severity of the anticipated climate emergency affects many of the components within the parallel SWOT assessments, with several current strengths becoming weaknesses and opportunities transformed into threats for future generations. In analyzing the results, we show the dominant role that inter-generational justice should play in determining a local optimal, energy strategy. While NG holds impressive advantages in the short-term, once long-term considerations and the impact on future generations are considered, NG's inferiority as a centerpiece of future energy strategy becomes apparent. These dynamics are particularly germane in the case of Israel, which, in recent years,

has begun to develop its copious off-shore reserves of NG in the Mediterranean Sea.

Keywords: Natural gas; Renewable energy; SWOT

1. Introduction

Because energy infrastructure is expensive and sunken cost dynamics preclude nimble transformations, decisions made today about optimal energy sources have profound effects for the future. Some greenhouse gases, like carbon dioxide (CO_2) persist in the atmosphere for centuries. But even gases, like methane (CH_4), whose atmospheric lifetime is only measured in decades, continue to contribute to the thermal expansion of the oceans for hundreds of years [1]. Beyond the immediate economic and environmental questions associated with prioritizing different electricity sources, energy policies pose profound ethical issues involving intergenerational justice. The prolonged warming effect of today's emissions means that present energy strategies will have a significant effect on future generations.

Israel's objective environmental conditions are unique, frequently producing management conundrums that constitute extreme examples of natural resource challenges faced by most countries around the world. Although its economic performance places it solidly in the OECD, Israel has many of the demographic and social characteristics of developing countries. Geographically diminutive and located almost entirely in the drylands, historically the country has responded to its idiosyncratic, natural resource challenges with innovative solutions - in areas ranging from effluent recycling and desalination to dryland forestry and drip irrigation. Historically, the country's leadership has generally sought to adopt policies that prioritize long-term investments in infrastructures involving a modicum of sacrifice, for the well-being of future generations.

Israel's energy dynamics are also exceptional. Surrounded by neighbors that are either unfriendly or who have very modest electricity infrastructures, the country is essentially an energy island. In order to conserve electricity, during the 1970s Israel was something of a pioneer in the field of solar energy (SE), developing the world's first regulatory requirement for passive solar water heater installation on new buildings (up to eight stories). The regulation spawned a modest commercial industry [2]. But this inclination proved ephemeral and economic forces of the time soon left Israel fully dependent on conventional energy sources. With a burgeoning economy, Israel's energy demands rapidly increased: not only is the country's population expanding quickly at an annual pace of ~2% [3], but due to its particular circumstances, electricity, production rate grows even faster [4]. For instance, the country's water supply is increasingly reliant on sea water desalination. Desalination plants are already responsible for 0.4% of the world's electricity consumption [5]. Providing a reliable water supply for Israelis living in arid and semi-arid conditions, however, is far more energy intensive, requiring 10% of the country's generated electricity, roughly half of which goes to power several major seawater desalination plants [6].

The discovery and development of extensive natural gas (NG) fields in Israel's Mediterranean exclusive economic zone constitutes a turning point in the country's energy and climate-change policies [7]. It also creates dilemmas that highlight some of the critical sustainability decisions that nations must make as they look to the future.

After decades of dependence on imports of coal and heavy fuels, NG reserves provide the country with a modicum of energy independence. NG also promises to produce lucrative economic dividends, with some of the associated profits to be invested in a special trust for the citizens of Israel. The transition from Israel's historic reliance on coal for electricity production to NG is already felt in improved ambient air quality. Furthermore, Israel's new energy abundance promises to be a geopolitical game changer. As much as 50% of the country's NG extracted is to be exported, largely to Egypt and Jordan [8]. In addition, a pipeline from Israel to Cyprus and Greece, continuing onto Italy and all Europe is already in the planning stages.

There are, however, conspicuous disadvantages associated with an energy strategy which relies primarily on NG. Chief among them is methane's relatively high "carbon footprint" and the high price of NG relative to SE. Doubling down on NG means massive investment in a new generation of fossil fuel generated electricity plants, pushing the development of renewable energy further away at a time when it needs to be prioritized. In view of the climate crisis and urgent efforts to reach a zero-carbon economy, if a more sustainable future is to be created, it makes sense to assess the energy management strategy and policies of Israel. We have done so by emphasizing the implications of today's decisions on future generations. The salient question today is not only whether it is prudent for a country to base its current economy and energy market almost entirely on NG, but whether it is morally or economically appropriate to do so given the long-term impacts?

We apply strategic *Strengths, Weaknesses, Opportunities, and Threats* (SWOT) analyses to assess the two competing energy pathways, using a two-stage process that focuses on the impacts faced by current and then by future generations. The SWOT framework emerged during the 1950s from the Harvard Business School [9] as an important tool in strategic management. Originally designed for application in the business world, this relatively simple procedure facilitates a systematic evaluation of a firm's *strengths* and *weaknesses* along with the *opportunities* or *threats* associated with making important decisions [10]. Among the advantages of a SWOT analysis is its ability to facilitate clear distinctions between external factors that are out of an organization's control (e.g., economic and political factors, new technologies, or competition) and internal factors where an institution can bring its specific capabilities, circumstances and values to bear.

The SWOT methodology has proven valuable in defining a broad range of development strategies [11]. In the context of sustainability, it has been applied to assess climate-change policy and energy related strategies for businesses [12], for national climate change programs [13] as well as energy policies [14] - and even to characterize the comparative advantages of different responses to global environmental challenges [15]. Yet, the implications of strategic decisions about developing NG resources and the associated opportunity costs resonate over an extremely long time horizon. The decision to invest in NG as the centerpiece of a national energy strategy locks a country into a particular infrastructure and economic commitments for decades, while contributing to an adverse climatic reality which future generations will face.

Accordingly, we apply a SWOT analysis to the many dilemmas associated with the development of Israel's NG resources and its optimal role in domestic electricity production. Rather than limit the evaluation to the immediate implications of different NG development alternatives, we expand the conventional SWOT analysis to include the impacts that present decisions will have on future generations. This approach can help current decision makers better analyze, anticipate and respond to climate-related data and design activities to ensure that considerations of intergenerational justice are fully integrated in the process.

2. SWOT Analysis

Sustainability is the capacity of ecosystems to bear the stress of economic and social processes while meeting not only the needs of the present generation, but also those of future ones [16]. The energy sector frequently drives social and economic development, but energy production also affects public health and global warming. Combating climate change requires a fundamental conversion in energy production and consumption patterns, with the ultimate goal of zero-carbon markets. NG is considered a lower-carbon and cleaner energy source than coal and oil [17]. Thus, a decade ago it was recognized as a transition fuel or "bridge" fuel to RE. Yet, as RE technologies grew increasingly more efficient, cheaper and more reliable [18], using NG as a transition fuel has become controversial [19, 20].

The state of Israel must decide about its energy policy and strategy, and specifically, about its future fuel mix as it seeks to ensure a stable, reliable and secure electricity supply. The discovery of significant NG reservoirs offshore Israel [21], led the government to choose it as the dominant fuel in the Israeli energy market for the next 30-50 years, despite the fact that Israel has more than 300 days of sunshine a year. Moreover, as part of the Paris climate agreement, the state of Israel has pledged to use 17% RE in 2030 [22], with the remainder to be produced by NG. Recently, Israel's Minister of Energy declared a new target of 25-30% RE at 2030, but this does not yet constitute a statutorily, binding target. The rationale behind the relatively low RE is linked to Israel's aforementioned status as an energy island, that cannot balance its electricity supply and rely on backup from neighboring countries. In addition, in assessing Israel's RE potential, SE emerges as the dominant alternative, notwithstanding its high land intensity and sensitivity to inconsistent weather conditions. At the same time, complementary energy storage technologies are not yet considered ready to be scaled up cost-effectively on a national level.

3. Current Generation Focused SWOT Analysis (CG-SWOT)

Based on these assumptions, we performed a SWOT analysis assessing alternative Israeli strategies for development of its energy sector focusing on electricity production and consumption. Accordingly, it is structured according to three categories: environmental, social and economic, whereby strengths and weaknesses involve domestic and short-term elements that positively or negatively impact a specific theme; elements that might be exploited as opportunities, or threats, are caused by external factors that affect a given theme, and that focus on non-local or longer-term impacts.

Table 1 illustrates the SWOT analysis of a NG dominant Israeli energy market, i.e. current generation CG-SWOT. It begins by identifying internal strengths and weaknesses. The main incentive for the development of the NG sector in Israel, and its primary strength, involves energy independence, which we classify as a social component. From an economic point of view, the government anticipates increasing the state's revenue, as well expanding the development of local industry and trade. But it also argues that the price of NG will be lower than that of SE combined with storage.

Another positive outcome from NG prioritization touted by the Israeli government involves reduction of air pollution from electricity production and the anticipated transition to transportation fueled by electricity and condensed NG (CNG). This environmental outcome, would, in turn, result in less morbidity and mortality, classified as a social outcome. Burning coal emits myriad conventional air pollutants, from sulfur dioxide (SO2) and nitrogen oxides (NOx), which exacerbate a range of respiratory illnesses, to particulate matter (PM), volatile organic compounds (VOCs) and heavy metals which contribute to respiratory illnesses, lung, ischemic heart disease and cancer, as well neurological and developmental damage in humans [23, 24]. Burning NG for energy, results in fewer emissions of nearly all types of air pollutants, producing negligible amounts of SO2 and heavy metals, and significantly lower levels of NOX, VOCs and PM. The amount of PM emissions from NG-fired power plants is about 6-55 times lower than that of coal-fired ones, depending on the source of the coal and the technology and efficiency of the power plant [25].

In addition, the government also argues that NG combustion emits less greenhouse gases (GHG) than burning coal. Recent studies suggest that a new, efficient, NG power plant emits 50-60% less CO_2 relative to a comparable new coal plant [26]. Yet, the overall magnitude of GHG reductions is debated when considering the entire life cycle of NG compared to coal due, inter alia, to reduced plant efficiency over time. Another environmental advantage with social implications is land usage -- which is lower for NG power than solar electricity. This aspect is especially germane in a small, dense country like Israel, rich in biodiversity and iconic religious/tourist sites that might be compromised if land is intensively used for renewable electricity production.

With respect to weaknesses, the dominant disadvantage that emerges is environmental. While CO_2 emissions during combustion of NG are reduced by 50%, methane, the main component of NG, is an aggressive GHG. The global warming potential of methane is 84 and 28 times higher than CO_2 over a 20-year and 100-year time horizon [27]. Taking into account all of the GHGs emissions across the full life cycle of NG, while considering leakage of NG during exploration, processing, transporting, storage and electricity production can potentially offset most climate benefits of replacing coal with NG. It may even increase GHG emissions beyond those of coal during malfunctions, as well as in routine operation [28, 29]. In addition, exploring and processing NG has other environmental disadvantages, such as increased risk of marine pollution due to malfunction. Finally, investment in energy infrastructure constitutes a zero-sum game, so that opting an NG power would probably supplant investment in RE.

The external opportunities and threats in the case of NG-based electricity market are related primarily to long-term and international effects. Opportunities are both social and economic, involving the export of NG to neighboring countries like Egypt and Jordan. Anticipated exports not only produce foreign currency, but also improve regional cooperation in an area of historical conflict. Plans also exist to lay an underwater pipeline to export NG from Israel to Cyprus, Greece and Italy as well as connect the grids of Israel, Greek and Cyprus via submarine power cable. Regarding threats, the spectrum ranges from terrorism and deliberate sabotage of supply to changes in prices along with loss of economic competitiveness. In addition, NG might face future costs due to an international or domestic carbon tax. The environmental theme focuses on the implications for climate mitigation, given NG's aforementioned carbon footprint and potential to increase global warming relative to RE.

4. A Future Generations Focused SWOT Analysis (FG-SWOT)

In contrast to the CG-SWOT that emphasizes internal, domestic and short-term aspects, the FG-SWOT analysis begins with relevant external, global and long-term aspects associated with the decision. Initially, challenges and consequences should be defined, starting with threats that yield opportunities. Then, the analysis should be narrowed to the country level by identifying connections to strengths and weaknesses.

Though it is difficult and even impossible to forecast precisely how decisions made by current generations will affect future generations, because of the acute or catastrophic ramifications associated with climate change, long term impacts must be characterized to the extent possible. According to IPPC reports [30] and scientists' warnings [31], the window of opportunity to act is almost closed. The need to better reflect the scientific consensus about the urgency and the magnitude of the anticipated "catastrophe for humanity", has led to a change in terminology and adoption of expressions like "global heating" and "climate emergency".

The FG-SWOT analysis, therefore, focuses on the imminent climate emergency, and its environmental, social and economic aspects. As the effects of global warming know no borders, and the Middle East is considered a climate change "hot spot" [32], current energy decisions will also affect the *strengths* and *weaknesses* for FG living in Israel. Finally, while CG-SWOT analyzes NG utilization relative to the use of coal, (i.e., based on performance during the past, 30 years ago) FG-SWOT looks to likely technological evolutions. Thus, it compares between a future where NG is dominant to one involving a reliance on RE over the coming 30 years.

The primary *threat* for future generations involves the *climate emergency* associated with projected global and local temperature increases, which is expected to become far more acute than the climate change which is assessed as merely a *threat* in CG-SWOT (Table 1). In practice, this means that climate changes, such as increases in temperature and frequency of extreme weather events, droughts, floods, desertification, etc., will now be expressed as internal *weaknesses*.

Anticipated climate changes will also be manifested in social *weaknesses*, such as increased outbreak of zoonotic diseases caused by invasive species, mass migration of refugees and violent conflict.

The *opportunities* in FG-SWOT reflect the potential ability to adapt to future changes in diverse areas: from energy, food and water security to resilience of building and infrastructures -- to the development of new technologies. Furthermore, Israel will be expected to take part in global efforts to achieve net-zero greenhouse gas emissions by the second half of this century. This constitutes an essential target for the long-term health of the planet. These find expression in the political cooperation and commitment appearing as being “part of the world”, in the opportunities listed in FG-SWOT.

Finally, moving from NG to SE further reduces GHG emissions. This means that while reduced emission of GHGs compared to coal appears as a strength (and higher GHG emissions relative to RE appears as a weakness in the CG-SWOT), lower emission of GHGs from RE compared to NG becomes a strength in the FG-SWOT. NG also further reduces air pollution and thus morbidity and mortality. This means that while reduced emissions of GHGs compared to coal lead to less morbidity and mortality and appears as a strength in CG-SWOT, lower emissions of GHGs from RE compared to NG lead to further reductions in morbidity and mortality, thus appearing as a strength in FG-SWOT. RE will also increase the country’s economic competitiveness as well as reduce aggregate costs from any future carbon taxes. Accordingly, while a high carbon tax appears as a threat in the CG-SWOT, low carbon taxes appear as a strength in the FG-SWOT. At the same time, loss of economic competitiveness appears as a threat in CG-SWOT, while economic competitiveness appears as an opportunity under FG-SWOT.

Finally, moving Israel’s electricity system to fuller reliance on SE will also allow the end-user, i.e., electricity *consumer*, to become concomitantly an electricity *producer*, with many residents assuming the role of *prosumers*. This allows individuals to more actively participate in the energy market, improving economic and behavioral motivation for diffuse mitigation investments [33, 34]. (Prosumer potential appears as a strength in the FG-SWOT.) An energy strategy dominated by renewables will also allow the electricity system to operate in a more local, rational and efficient way. It can also serve to make consumers more responsible and create community-wide cooperation. Furthermore, it facilitates decentralization of the electricity system, which has security benefits in a country which faces intermittent violent interludes. Lastly, switching to RE will also increase employment opportunities (a strength in FG-SWOT).

Internal (direct)		**External (indirect)**	
Current generation **NG compare to coal**	**Future generations** **Solar compare to NG**	**Current generation** **NG compare to coal**	**Future generations** **Solar compare to NG**
Strengths		**Opportunities**	
Social: -Greater energy independence compared to coal and diesel (domestic source) -Less human morbidity and mortality **Economic:** -Increased state revenue and local economic development -Non-intermittency as energy source (no need for energy storage system) -Increase in decentralized nature of energy system -Reduced non-provisioning costs **Environmental:** -Reduced conventional air pollution from electricity production and transportation compared to coal and diesel -Reduced land requirements relative to solar and wind installations -Increased biodiversity potential due to reduced encroachment on habitat -Reduced emission of GHG compared to coal	**Social:** -Reduced human morbidity and mortality -Potential for prosumer engagement -Greater employment potential -Participation of community climate change mitigation **Economic:** -Reduced carbon tax **Environmental:** -Lowered emission of GHG -Reduced conventional air pollution from electricity production and transportation	**Social:** -Increased geopolitical cooperation and influence -Reduced reliance on energy imports -Decentralization creates potential for development of smart grids -Increase of electric transportation and Condensed NG vehicle fleet **Economic:** -Improved balance of trade -Sovereign wealth fund (SWF)-public revenues to be utilized for the future: Use the money to support the needy now. **Environmental:** - Reduced global warming compared to coal	**Social:** -Greater integration into the global community **Economic:** -Increased economic competitiveness due to lower local energy costs (than countries with renewables) **Environmental:** -Easier to adapt to climate change
Weaknesses		**Threats**	
Social: -Supplants investment in renewables -Finite quantities available (non-renewable) -More centralized than renewables **Economic:** -Vulnerability associated with energy delivery limited to two pipelines **Environmental:** -Higher GHG emission from electricity production and	**Social:** -Higher carbon footprint -contributes to mass migration of refugees and increased violence and conflicts -Greater vulnerability to invasive species and zoonotic disease outbreaks. **Environmental:** -Increase in temperature, sea level rise and extreme weather event s -Increased risk to marine	**Social:** -Terrorism and sabotage of gas platforms **Economic:** -Vulnerability to price fluctuations of energy market - Loss of economic competitiveness due to higher local energy costs (than countries with renewables) -Increase in economic gaps (economic benefits concentrated in the hands of a small minority)	**Environmental:** -Climate change becomes climate emergency

transportation compared to renewables. -Higher conventional air pollution compared to renewables -Increased risk of marine pollution due to malfunction of gas production off-shore -In case of malfunctioning, levels of pollution and emissions are high	pollution	-High carbon tax **Environmental:** -Increased climate changes compared to renewables	

Table 1: SWOT analysis of electricity production in Israel till 2050.

5. SWOT Implementation

The last part of the comparison between CG-SWOT and FG-SWOT includes five scenarios for electricity production in 2050:

(1a) 70% NG and 30% SE, whereas GHG emissions of NG are equal to coal;

(1b) 70% NG and 30% SE, whereas GHG emissions of NG is 30% less than coal;

(2a) 50% NG and 50% SE, whereas GHG emissions of NG are equal to coal;

(2b) 50% NG and 50% SE, whereas GHG emissions of NG are 30% less than coal;

3) 100% SE.

6. Environmental Outcomes: GHG Emissions

Israel's net GHG emissions are modest, and for the foreseeable future, the influence of its carbon footprint on a global scale is assumed to remain negligible [35]. Nonetheless, though Israelis make up only 0.11% of the total world population [36], their GHG emissions are 0.22% of overall global emissions [37]. As part of its obligation under the Paris agreement, Israel pledged to reduce its GHG per capita emission from 9.2 tons in 2016 to 7.7 tons in 2030. This means that the country's present target produces higher emissions per capita than most European countries (e.g., France or Italy). It also means that even if emissions per capita are further reduced, due to rapid demographic growth, the overall emissions of the country are expected to increase.

The main sources of GHG emissions in Israel are from electricity production (~55%) and transportation (~20%). The remainder come from industry, agriculture, construction and solid waste / wastewater decomposition [38]. As previously mentioned, a 50% reduction of GHG emissions, by switching from coal to NG is a very optimistic scenario, due to leakage of methane. Accordingly, a scenario of 30% reduction was assumed. Moreover, as other studies report, the total emissions of GHG with NG-based electricity production are equal and may even exceed those of coal. Hence, a scenario of 0% reduction was also tested. Furthermore, switching to RE, especially SE with storage, will dramatically lower emissions per kWh electricity produced, ca.1000 g CO_2e/kWh, ~700 g/kWh and ~40 g/kWh for coal, NG and RE, respectively, based on overall life cycle [39], i.e., a 96% reduction.

In 2019 Israel's population of 8.9 million people generated 72 TWh of electricity (~67% from NG and the rest from coal). A continued annual population growth of 2% and 3.2% increase in electricity production during the next 30 years [40], will yield 15 million people and 186 TWh in 2050. Thus, a target of 50% SE for electricity for all uses, including transportation, in 2050, can be expected to cut the overall emissions of the electricity sector in Israel, compared to a fuel mix of 70% NG and 30% solar energy by 26%.

Furthermore, assuming that the corresponding emissions from electricity (including transporting) will remain unchanged at 75%, and that the fuel for energy in industry will be primarily NG, this yields total emissions of 124 million tons and per capita emission of 14.6 tons for scenario with 177 million tons and 20.8 ton per capita for scenario 1b (Table 2). A target of 50% SE for electricity for all uses, however, yields 92 million tons and 10.8 tons per capita for scenario 2a and 129 million tons and 15.2 tons per capita for scenario 2b. Finally, a target of 100% SE for electricity for all uses yields 7.4 million tons and 1.2 tons per capita for scenario 3. Yet, 100% SE requires backup. We assumed availability of increasingly inexpensive batteries and pumped energy as a more sustainable energy backup. If NG is used as backup, additional emission should be calculated accordingly.

7. Social Outcomes: Mortality and Jobs

As previously stated, fuel combustion at power plants leads to the emission of various air pollutants. The higher SO_2, NOx, and PM emissions caused by coal-fired electricity, result in five times greater premature mortality than NG [41]. According to the World Health Organization, fine pm (particulates a diameter of 2.5 µm or less, PM2.5) emissions are also major contributor to premature mortality [42]. In the year 2015, 250 people per million inhabitants died from illness associated with PM2.5 [43]. Transitioning from coal to NG in power plants reduces the PM emissions by 70%, but emissions from solar energy are zero. Thus a transition to a higher NG rate in the energy mix reduces premature deaths, but RE eliminates them entirely.

The current policy, that seeks to base Israel's electricity market primarily on NG-fired power plants and combined heat and power systems, will define the country's energy strategy for the next 30 years. The following parameters are critical for decisions with such long- term implications:

- The population in Israel is expected to double during in the next 32 years.
- Most of the population will live in dense cities, where air pollution exposures are highest [44].
- NG-based power plants are built close to population concentrations
- Electrification (in the energy and transportation sectors) will contribute significantly to growing demand for electricity but will also produce low cost opportunities for SE storage.

As the reference study about mortality from air pollution in Israel was conducted in 2015, we used this year as the basis for our calculations. Electricity production in Israel in 2015 was 65.4 TWh based on 55% share for NG, 2.5% share for RE and the remainder fueled by coal with coal. In 2050 production should reach 186 TWh. Switching from coal to NG will reduce emissions of PM2.5 by 70%. Consequently, we assume that it will also produce a decrease of 70% in mortality and morbidity. Accordingly, 643 deaths per year can be anticipated for scenarios 1a and 2a and 900 mortalities per year for scenarios 1b and 2b (Table 2). Switching to 100% RE, however, will reduce most mortality and morbidity from PM2.5, yielding 0 deaths per year for scenario 3. At the same time, 100% renewable systems will not entirely eliminate mortality, as there are upstream impacts of manufacturing and installation, which should be taken into account. Another important social aspect involves the relatively minor opportunities for creating employment offered by expanded conventional electricity generation versus RE. This leads to an estimated multiplier of 4.5 for renewable energy employment relative to fossil fuel industry employment [45].

8. Economic Outcomes: Electricity Costs and Carbon Taxes

The so-called profit of CG from development and use of NG, is anticipated to become a burden on FG: as the world moves toward RE and prices for renewable technologies continue to drop, Israel will be forced to use NG for many years without being able to export it.

Estimates of the economic cost caused by an additional ton of GHG emission, classified as the "social cost of carbon" (SCC), remain highly uncertain. A recent study estimated a SCC of $31 per ton of CO_2 in 2015 with a steady 3% rise over the next 35 years, becoming an $87 cost by 2050 [46]. This means that moving from scenario 1a to 2a, while using an emission factor of 700 g/kWh for NG, will yield a reduction in SCC from $0.044/kWh to $0.032/kWh while moving from scenario 1b to 2b will yield a reduction in SCC from $0.062/kWh to $0.045/kWh. Furthermore, scenario 3 will yield a SCC of $0.003/kWh. If SCC is internalized within the electricity bill, an average household in Israel, with monthly electricity consumption of 600 kWh, will pay an additional monthly fee of: $26, $37, $19, $27 for scenarios 1a, 1b, 2a, 2b, respectively, while only $3 for scenario 3.

	Scenario 1a	**Scenario 1b**	**Scenario 2a**	**Scenario 2b**	**Scenario 3**
Environmental pillar:					
Overall annual emission of CO_2 in year 2050 (million tons)	124	177	92	129	7.2
Annual GHG emissions per capita in year 2050 (tons per capita)	14.6	20.8	10.8	15.2	1.2
Social pillar:					
mortality (people in year 2050)	643	900	643	900	0
Economic pillar:					
SCC ($/kWh) in year 2050	0.044	0.062	0.032	0.045	0.003

Table 2: Examples in three sustainability pillars.

9. Concluding Remarks

Decisions made today about optimal energy sources have profound effects on the future. Our analysis shows that basing electricity production primarily on NG, a strategy pursued in Israel during the past decade, will not only expose future generations to higher air pollution, with associated increases in morbidity and mortality, but will also jeopardize future generations' economic well-being and increase the severity of the climate related impacts they face. In all three categories assessed: environmental, social and economic, the *long-term* advantages of RE versus NG, which systematically considered the effects on the future, appear more dominant than under a more myopic analysis. Investing in infrastructure for decarbonized electricity and adopting a more rapid path towards renewable energy emerge as a far more compelling strategy when the benefits to future generations are integrated into present strategic decision-making. As the world considers the dilemmas associated with optimal investment in electricity infrastructure, it would be well to upgrade the commitment to future generations from an amorphous slogan to an integral component of energy policy making.

References

1. Zickfield K, Solomon S. Gilford D. Centuries of thermal sea-level rise due to anthropogenic emissions of short-lived greenhouse gases. PNAS 114 (2017): 657-662.
2. Bar Ilan Y, Pearlmutter D Tal, A. Building Green, Promoting Energy Efficiency in Israel. Haifa, Techion Press, Israel (2010).
3. World Bank, Population growth (annual %), World Bank Data Base (visited April 6, 2020).
4. Israel, Central Bureau of Statistics, Energy Balance (2020).
5. United Nations, The United Nations, World Water Development Report: Water and Energy. Report. Paris, UNESCO 25 (2014).
6. Tal A. Addressing desalination's carbon footprint: The Israeli experience. Water 10 (2018): 197-210.
7. Cohen E. Development of Israel's natural gas resources: Political, security, and economic dimensions. Resources Policy 57 (2018): 137-146.
8. Azran E. Israeli gas is great – for Egypt and Jordan, HaAretz – The Marker (2020).
9. Weihrich H. The SWOT matrix a tool for situational analysis. Long Range Planning 15 (1982): 54-66.
10. Ghazinoory S. Abdia M. Azadegan-Mehr M. SWOT methodology: A state-of-the-art review for the past, a framework for the future. J. of Business Economics and Management 12 (2011): 24-48.
11. Dutton J. Discerning threats and opportunities. Administrative Science Quarterly 33 (1988): 370-387.
12. Pesonen HL. Horn S. Evaluating the climate SWOT as a tool for defining climate strategies for business. J. of Cleaner Production 64 (2014): 562-571.
13. Fertel C. Bahn O. Waaub JP. Canadian energy and climate policies: A SWOT analysis in search of federal/provincial coherence. Energy Policy 63 (2013): 1139-1150.

14. Markovska N. Taseska V. Pop-Jordaniv J. SWOT analyses of the national energy sector for sustainable energy development. Energy 34 (2009): 752-756.
15. Nzunda EF. Mahuve TG. A SWOT analysis of mitigation of climate change through REDD. In: Leal Filho W. (Ed.) Experiences of climate change adaptation in Africa. Climate Change Management. Springer, Berlin, Heidelberg (2011): 20-216.
16. Our Common Future. Oxford: Oxford University Press (1987).
17. Burnham A, et al. Life-cycle greenhouse gas emissions of shale gas, natural gas, coal, and petroleum. Environmental science and technology 46 (2012): 619-627.
18. Ralon P, et al. Electricity storage and renewables: Costs and markets to 2030. International Renewable Energy Agency: Abu Dhabi, United Arab Emirates (2017).
19. McJeon H, et al., Limited impact on decadal-scale climate change from increased use of natural gas. Nature 514 (2014): 482-485.
20. Jackson RB, et al. Methane removal and atmospheric restoration. Nature Sustainability 2 (2019): 436-438.
21. Siddig K. Grethe H. No more gas from Egypt? Modeling offshore discoveries and import uncertainty of natural gas in Israel. Applied energy 136 (2014): 312-324.
22. http://www.energy-sea.gov.il/English-Site/Pages/Regulation/energy_economy_objectives_2030.pdf
23. Teyer K. Bauer C. Simons A. Human health impacts in the life cycle of future European electricity generation, Energy Policy 74 (2014): S31-S44.
24. Hendryx M. Zullig KJ. Luo J. Impacts of coal use on health. Annual Review of Public Health 41 (2020): 397-415.
25. Hyo-Jin K. Ju-Hee K. Seung-Hoon Y. Do people place more value on natural gas than coal for power generation to abate particulate matter emissions? Evidence from South Korea. Sustainability 10 (2018): 1740.
26. https://www.osti.gov/servlets/purl/1574764
27. https://www.ipcc.ch/site/assets/uploads/2018/02/WG1AR5_Chapter08_FINAL.pdf
28. Brandt AR, et al. Methane leaks from North American natural gas systems. Science 343 (2014): 733-735.
29. Alvarez RA, et al. Assessment of methane emissions from the US oil and gas supply chain. Science 361 (2018): 186-188.
30. IPCC AR5 Synthesis Report: Climate Change 2014 https://www.ipcc.ch/report/ar5/syr/
31. Ripple WJ, et al. World scientists' warning of a climate emergency. BioScience (2019).
32. Tabari H. Willems P. Seasonally varying footprint of climate change on precipitation in the Middle East. Nature, Sci Rep 8 (2018): 4435.
33. Zepter J. Lüth A. del Granado PC. Egging R. Prosumer integration in wholesale electricity markets: Synergies of peer-to-peer trade and residential storage. Energy and Buildings 184 (2019): 163-176.
34. Parag Y. Sovacool BK. Electricity market design for the prosumer era. Nature energy 1 (2016): 1-6.

35. Ayalon O, Lev-On M, Lev-On PP. Greenhouse gas emission mitigation plan for the State of Israel: Strategies, incentives and reporting. Climate Policy 15 (2015): 784-800.
36. https://www.worldometers.info/world-population/israel-population
37. https://web.archive.org/web/20160526230803/http://cait2.wri.org/
38. State of Israel. Israel's Third National Communication On Climate Change, Submitted to the United Nations Framework Convention on Climate Change (2018).
39. Report on State of Electricity Sector 2018-The Electricity Authority
40. https://www.nrel.gov/docs/fy13osti/56487.pdf
41. Jacobson MZ. Evaluation of coal and natural gas with carbon capture as proposed solutions to global warming. Air Pollution, and Energy Security, (2020).
42. http://www.euro.who.int/__data/assets/pdf_file/0006/189051/Health-effects-of-particulate-matter-final-Eng.pdf
43. Ginsberg GM. Kaliner E. Grotto I. Mortality, hospital days and expenditures attributable to ambient air pollution from particulate matter in Israel. Isr J. Health Policy Res., 5 (2016): 2-7.
44. Carozzi F. Sefi R. Dirty density: Air quality and the density of American cities. (2019).
45. Garrett-Peltier H. Green versus brown: Comparing the employment impacts of energy efficiency, renewable energy, and fossil fuels using an input-output model. Economic Modelling 61 (2017): 439-447.
46. Nordhaus, WD. Revisiting the social cost of carbon. Proceedings of the National Academy of Sciences 114 (2017): 1518-1523.