Chapter 7

Israel's Energy Security, Nationally Determined Contribution to the Fight Against Global Warming, and Emissions Outlook[1]

- International agreements on reducing greenhouse gas emissions were reached at the United Nations Climate Change Conference (COP26), which took place toward the end of 2021 in Glasgow, Scotland. Most of the countries, including Israel, presented their national targets for a substantial reduction in emissions in the intermediate and long terms. There is some doubt as to whether the agreements reached are sufficient in order to put the world on a trajectory toward net zero emissions or to limit global warming to the target set in the Paris Agreement in 2015.[2]
- While many developed countries are still building, developing, and planning coal-fired power plants, which are a particularly polluting source of energy, Israel is expected to discontinue its use of coal when its last coal-fired power plant is closed in 2026.
- Simulations we carried out of emissions show that Israel will have difficulty meeting the climate targets it has set for itself. The scenarios are based on existing technology.
- The gap between the emission reduction targets and the ability to achieve them with existing technology is not unique to Israel. Therefore, the international reaction to Israel's slow progress toward the targets will likely be muted.
- A significant expansion of solar energy in the supply of electricity in Israel will require investment in energy storage options and the maintenance of power stations based on natural gas, which will be able to answer demand in the case of extreme weather conditions.
- The accelerated reduction in electricity production capacity based on fossil fuels in the absence of stable alternatives may impair Israel's energy security, as demonstrated by recent events in Europe.
- In view of the developments at the Glasgow Conference of Parties, which have implications for the rate of reduction in greenhouse gas emissions, the risks of continued global warming have increased. There is therefore a greater need to adapt to the new situation. The most relevant risk for Israel is to the economic and healthcare systems. Although the risk to our region is low relative to other countries according to IPCC reports, the increase in overall risk is expected to affect us as well.

[1] With thanks to Professor Lior Elbaz (Chemistry Department, Bar-Ilan University), Hagit Ben Hamo (Ministry of Energy), Shahar Dolev (Ministry of Energy), Lior Haimovitch (National Economic Council), Sharon Hazor (Ministry of Energy), Professor Asher Tisher (Tel Aviv University), Gina Cohen, Yuval Laster (Ministry of the Environment), Yonatan Miller (Foreign Ministry), Shani Mandel Laufer (Ministry of Finance), Dr. Gil Proctor (Ministry of the Environment), Eitan Parnes (Association of Green Energy Companies in Israel), Professor Noga Kronfeld Shor (Chief Scientist, Ministry of the Environment), Dr. Ohad Karni (Ministry of the Environment), Tamar Raviv (Ministry of the Environment), Professor Nir Shaviv (Rokach Institute for Physics, the Hebrew University), and Gal Tamir (Ministry of the Environment).

[2] For a similar position on the chance of achieving carbon neutrality and its connection to the coal industry, see the view of the head of the International Energy Agency: https://www.ft.com/content/1b203a3e-efdf-49b8-8fa9-72f9ec963501

Although the Paris Agreement is flexible and is tolerant of the possibility of noncompliance, it has an influence on public awareness. Since it was signed it has been the driver for policy activity that is moving the global economy toward carbon neutrality.

This chapter presents a macroeconomic analysis of the main risks related to the climate crisis and the energy transition that it will require. The first section of the chapter describes the policy issues; defines the terminology, such as carbon neutrality, energy security, and energy transition; and illustrates them by means of data on greenhouse gas emissions, the distribution of the main emission sources, and the breakdown of energy production. An examination of the trend in emissions by country shows a large gap between the targets specified in the Paris Agreement in 2015 and the current level of emissions. The experience of various countries in recent years demonstrates the need to advance the transition between energy sources in a controlled manner in order to preserve energy security and the stability of energy production during the course of the process and upon its completion.

The second section, which surveys the developments at the Glasgow 26th Conference of Parties (United Nations Climate Change Conference, herein: COP26), points to the possibility that future reductions in emissions will be slower than expected, and adaptation to this new situation, in which the atmospheric concentration of greenhouse gases will be higher than at present, is therefore important. This increases the chance of global warming beyond current forecasts. This adaptation process includes preparedness for the realization of climate risks, and will require a larger allocation of public resources (Box 7.1).

The third section looks at the gap between the emission targets submitted by the Israeli government to the COP26 and its current plans for reducing emissions. Israel's situation is like that of all other countries: Carbon neutrality is dependent on technology that is not currently commercial. Early investment in energy infrastructure in Israel can prepare the energy system for assimilating such technologies as they develop.

1. THE TENSION BETWEEN ENERGY SECURITY AND ENERGY TRANSITION

In 2015, 192 nations signed the Paris Agreement, which represented a milestone for the environmental agenda on climate. The goal of the agreement was to strike a balance between the emissions of greenhouse gases from anthropogenic sources[3] and the absorption of greenhouse gases by the land and oceans, thus achieving a situation known as carbon neutrality or zero net emissions.[4,5] Although the agreement itself is flexible and takes into account the possibility of its targets not being met, it has an influence on public awareness. Since it was signed, it has motivated the actions

[3] Apart from environmental damage to the climate caused by greenhouse gas emissions into the air, man damages the environment through his effect on land and water.

[4] Article 4.1, Paris Agreement: "a balance between anthropogenic emissions by sources and removals by sinks of greenhouse gas in the second half of this century."

[5] For the use of these terms, see European Commission: "A European Green Deal: Striving to be the first climate-neutral continent."

of countries that are navigating the world economy toward carbon neutrality.[6] The countries that signed the Paris Agreement committed themselves to revising the emission reduction targets and to report—once every five years—on their contribution to the fight against global warming through the reduction of greenhouse gas emissions.[7] The importance of the COP26 meeting in Glasgow was that it was a milestone on the way to 2023, when, a "stocktaking" will be carried out in accordance with the Paris Agreement in order to assess the emission levels of the agreement's parties.[8]

In order to achieve carbon neutrality, anthropogenic greenhouse gas emissions need to be reduced to a level that equals the total greenhouse gasses absorbed on land and in the oceans.[9] Total global greenhouse gas emissions (in terms of carbon dioxide, which is the most common greenhouse gas) reached an annual level of 49 gigatons (gt) in 2018 (see Table 7.1)[10], while the ocean and land biospheres absorbed 11 gt and 12 gt, respectively. In order to reach carbon neutrality, emissions must be reduced by 26 gt.[11]

Energy production is the largest source of emissions, and is responsible for 76 percent of the global total. In particular, the burning of coal and oil account for 33 percent and 27 percent of global emissions, respectively (Table 7.1).[12] Currently, the commercial sources of clean energy production are water, wind, solar, and nuclear. Other technologies for dealing with greenhouse gas emissions, such as carbon capture and storage, waste treatment, and preventing emissions from chemical processes, are still not commercial. In view of energy production's large share in emissions, together with the fact that eliminating emissions from the energy sector is more technologically feasible than in the case of other sources, the main efforts to reduce global emissions are focusing on the energy sector, making that the main topic of discussion in this chapter.

Energy transitions, which have occurred a number of times in history, involve a replacement of energy sources. The current one involves the replacement of energy sources that lead to the emission of greenhouse gases, particularly fossil fuels, with clean energy sources. In contrast to past energy transitions, the current one is not a

[6] As an expression of its commitment to the agreement, the American government under President Obama signed it without the agreement of Congress. At a later stage, this allowed the Trump administration to withdraw from it. For further details see J. Dorney (2017). "Defining the Paris Agreement: A Study of Executive Power and Political Commitments", Carbon & Climate Law Review, 11(3): 234–242.

[7] Article 4.9, Paris Agreement: "communicate a nationally determined contribution every five years."

[8] Article 14.2, Paris Agreement: "Agreement shall undertake its first global stocktake in 2023 and every five years thereafter."

[9] For a similar description by the EU, see European Parliament (Oct 2019). "What is carbon neutrality and how can it be achieved by 2050?"

[10] The COVID-19 pandemic reduced economic activity and therefore energy use and greenhouse gas emissions. Since the subject of the discussion is carbon neutrality and the mitigation of global warming, which are long-term goals, the COVID-19 years are not representative.

[11] Absorption is also expected to decline as emissions are reduced, which means that the targets must be even more ambitious. This only strengthens the result of the analysis below.

[12] The correct identification of primary sources requires identifying the sources of emissions rather than the final products. Thus, for example, most of the emissions from agriculture are the result of using fuels and coolant gasses, and it is therefore the practice to attribute them to the energy sector and the chemicals sector rather than to agriculture.

Table 7.1:
Balance of global greenhouse gas emissions, 2018

Emission			Absorption		
	GT CO2 Equivalence	Percent of total		GT CO2 Equivalence	Percent of total
Energy	37	76%	Oceans	11	22%
Carbon	16	33%	Terrestrial biosphere	12	25%
Oil	13	27%	**Total absorption**	**23**	**47%**
Natural gas	8	16%			
Other energy	1	1%			
Waste	2	3%			
Agriculture	6	12%			
Industrial use	3	6%			
Other	1	3%	**Reduction target**	**26**	**53%**
Total emissions	**49**	**100%**		**49**	

SOURCE: Climate Watch, Global Carbon Project, and IEA.

result of market forces, but rather political forces that generally reflect pressure to internalize external costs and therefore to impose constraints on market forces. Since the externalities are international in scope, the pressure on domestic government policy in the management of the electricity sector originates from the international arena.

Energy security allows households, businesses, and governments to efficiently plan their consumption and investment. "Uninterrupted availability of energy sources at affordable prices" avoids the costs of production disruption and capital adjustment.[13] Energy consumption differs from the consumption of other goods and services with respect to its necessity: A failure in the energy system will deal a critical blow to economic activity and well-being that is far greater than energy's share of GDP (which is about 7 percent). For this reason, the public sector in various countries regulates the energy system and serves as a supplier who is more resilient to business cycles than the free market. Arguments showing the importance of energy security have also recently arisen from the climate agenda. They present the importance of

[13] The definition of energy security according to IEA, 2019.

this public good in adapting to the new situation, in which temperatures will be higher than previously.[14]

Transitioning the energy system to carbon neutrality requires the replacement of primary energy sources. This necessary condition for carbon neutrality has the greatest potential for achieving emission reductions. At the same time, if it is carried out too rapidly—without an appropriate balance between the energy sources that are eliminated and added and without modifying the transmission system to the changes in the mix of production—it will harm energy security. An expression of the tension between energy security and energy transition can be seen in the recent disruptions in the German energy system. Germany implemented the substitution of fossil fuels and nuclear energy too hastily, which became clear in recent years. It also did not make the necessary modifications to the transmission and backup networks, which are connected to the electricity systems of other countries. As a result it suffered from disruptions in the supply of electricity and from skyrocketing energy prices.[15] Although the current crisis in Germany reflects a combination of demand factors and supply factors, a report by McKinsey & Company in 2019 already pointed to the risks involved in replacing the energy sources in Germany if it is done too quickly and without overall planning for the long term.[16] The current events in Ukraine are demonstrating the danger implicit in a nondiversified mix of energy sources. In order to expand the arsenal of responses to achieve energy security while reducing emissions, the EU recently decided to classify some of the natural gas technologies that are combined with carbon capture and some of the nuclear technologies as green energy sources.[17] Even before that, the Israeli Ministry of Energy published a recommendation, as part of the Roadmap for the Energy Sector 2050, to examine the possibility of producing electricity from nuclear energy as a way to decarbonize the energy system while maintaining energy security.[18] This tension between the climate agenda and the need to provide energy security is a major policy question facing world governments. The

[14] The last report of the International Panel on Climate Change (IPCC) devoted a special chapter to energy. For further details, see IPCC 2022: Climate Change 2022: Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [H.-O. Pörtner, D.C. Roberts, M. Tignor, E.S. Poloczanska, K. Mintenbeck, A. Alegría, M. Craig, S. Langsdorf, S. Löschke, V. Möller, A. Okem, and B. Rama (eds.)]. Cambridge University Press. In Press.

[15] This crisis developed only recently and there are therefore only preliminary reports in this context, such as Yana Popkostova (2022),"Europe's Energy Crisis Conundrum: Origins, Impact, and Way Forward."

[16] See Pflugmann et al (2019), "Germany's Energy Transition at a Crossroads", McKinsey & Company.

[17] It should be emphasized that this does not apply to every natural gas technology, bur only ones that include carbon capture at certain rates, which are currently not in widespread commercial use. For further details, see European Commission (2022). "EU Taxonomy: Commission Begins Expert Consultations on Complementary Delegated Act Covering Certain Nuclear and Gas Activities."

[18] See Ministry of Energy (April 2021), "Roadmap to a Low-Carbon Energy Sector by 2050", p. 16. [in Hebrew]

Israel's greenhouse gas emissions are negligible in terms of their effect on global warming. Its commitment to reducing emissions is important primarily as an expression of participation in the global community and in the international effort.

presidents of the US and the EU recently released a joint declaration that emphasizes the importance that their governments attribute to these two issues.[19]

Israel's greenhouse gas emissions are negligible in terms of their impact on the climate and global warming (accounting for only 0.2 percent of global emissions). Its commitment to reduce emissions is therefore important primarily as an expression of membership in the global community and participation in the international effort, as well as to avoid the risk of possible action by the international community against countries and carbon-emitting companies that don't meet international standards. For Israel, meeting climate targets is a particularly challenging task, for a number of reasons[20]: 1) it has a particularly high rate of population growth relative to other developed countries; 2) its per capita emissions at the starting point were not higher than in other developed countries[21]; 3) Israel is an "electrical island" since it has no possibility, at this stage, of relying on other electricity systems[22]; 4) the technologies that are available for the zero-emission production of energy in Israel are limited to solar and nuclear, yet there are various constraints that hinder their adoption.[23] Israel's limited territory makes it challenging to rely on large scale solar energy and will require creative solutions, such as double use of land or the widespread installation of solar panels on roofs.[24]

The replacement of the primary energy sources with zero-emission sources is a necessary condition for carbon neutrality, and it has the greatest potential for contributing to emission reduction. At the same time, if it is carried out too quickly it will harm energy security.

The shift to zero-emission energy sources is expected to progress in three stages, each of which involves the abandonment of a fossil fuel: 1. a shift from coal to natural gas (electricity); 2. a shift from oil to natural gas (transportation); and 3. a shift from natural gas to zero-emission sources. Figure 7.1 presents the distribution of primary emission sources for the group of countries that we will be analyzing, in terms of the potential contribution of each fossil fuel to the reduction in greenhouse gas emission. The countries appearing in the graph are responsible for about 70 percent of global greenhouse gas emissions.

[19] See Joint Statement by President Biden and President von der Leyen on US-EU Cooperation on Energy Security.

[20] The Paris Agreement relates explicitly to its implementation according to the special circumstances and needs of each country. See the Paris Agreement, paragraph 2.2.

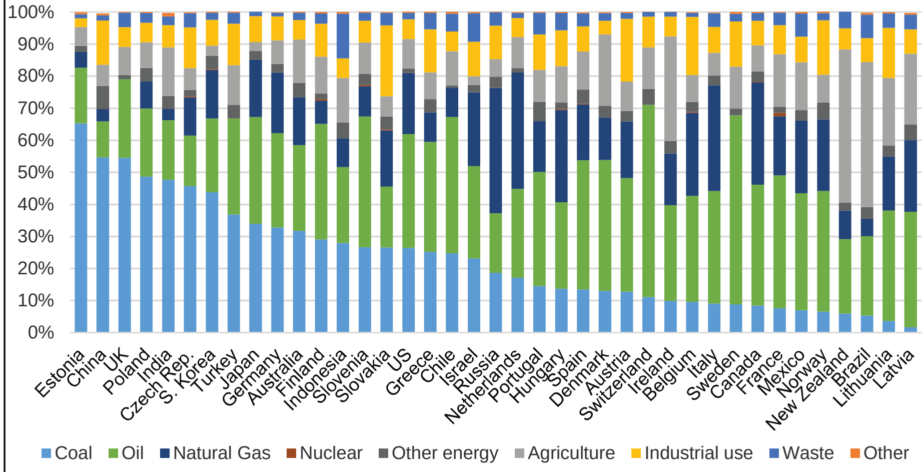
[21] In 2019, the average in Israel was 9.4 tons per capita per year while the average for the OECD countries was 10.1. For a discussion of the link between per capita emission levels and changes in emissions, see below.

[22] Although an agreement for trade in electricity was recently signed with Jordan, it does not connect Israel to the Jordanian electricity system but only to an independent facility on the Kingdom's territory. Although Israel is an electric island, it is not considered to be an energy island, since its energy system includes oil, natural gas, and more. Furthermore, Israel's natural gas network is connected to the networks of Egypt and Jordan.

[23] In Europe, for example, the main zero-emission sources of energy are water, wind, and nuclear.

[24] For a discussion of the land issue, see 1. Ministry of the Environment (2020), "Evaluation of Solar Production in Urban Areas in Israel"; 2. Ministry of Energy (April 2021). "Roadmap to a Low-Carbon Energy Sector by 2050", p. 69 and onward and p. 136; and 3. Electricity Authority (2020), "Increasing the 2030 Targets for Electricity Production Using Renewable Energy". [in Hebrew]

Figure 7.1
Distribution of Greenhouse Gasses by Initial Source, OCED Countries and 5 Largest Emitters, 2018 (percentage of total emissions)



* The five non-OECD countries in the list are China, India, Russia, Brazil, and Indonesia. The countries in the sample are responsible for about 70 percent of tall global emissions. Costa Rica was not included due to a lack of data.
SOURCE: World Bank Global Carbon Project; BP Statistical Review of World Energy, 2021; and ClimateWatch data.

The first stage involves phasing out coal and replacing it with natural gas, a source of energy with low emission and pollution levels.[25] Coal is the most significant source of emissions not just because of its widespread usage but because it has the highest rate of emissions per unit of energy.[26] The initiative to reduce the use of coal was therefore the flagship of COP26, and it is expected to be the main target of the next climate conference (which will take place in Sharm el-Sheikh in 2023).[27] The graph shows that coal is still the most significant source of emissions in developing countries such as China and India, as well as in developed countries like the United Kingdom, Germany, Japan, and Australia.[28] At COP26, a target was set for phasing down the use of coal (rather than the initial goal of phasing it out), which is expected to take a long period of time. Notably, while many developed countries are still building, developing, and planning coal-burning power plants, Israel is expected to completely phase out the use of coal with the closing of its last coal-burning power plant in 2026.

Coal is the most important primary source of greenhouse gas emissions, due to its prevalence and because it has a high level of emissions per unit of energy. Therefore, the initiative to reduce the use of coal was the flagship of the COP26 meeting, and is expected to continue being an important target at the next climate conference in Sharm el-Sheikh in 2023.

The shift from oil to natural gas involves converting the transportation industry to zero-emission vehicles.[29] The challenges include changing household behavior and

[25] For each unit of energy, natural gas emits 43 percent less than coal.
[26] Coal emits 100 TTJ (tons of carbon dioxide per terajoule), followed by oil (75 TTJ) and natural gas (57 TTJ).
[27] In the developing countries, the energy transition involves the replacement of wood, coal, cow manure, and crop waste, which are burned within homes, with sources such as coal, natural gas and oil, which are burnt in generators.
[28] More than 50 percent of China' emissions are from coal. China is also the largest consumer of coal (54 percent of global consumption), followed by India (12 percent), the US (6 percent) and Japan (3 percent).
[29] Per unit of energy, the emissions from natural gas are 38 percent less than from oil.

investment alongside public sector investment in infrastructure and the establishment of the necessary regulation and legislation.[30] Zero-emission vehicles are dependent on the availability of storage technologies, particularly lithium or hydrogen batteries, whose price has dropped significantly in recent years. It should be emphasized that these technologies require different infrastructures, and the choice of their mix therefore has implications for the investment needed. Due to the cost structure of these types of technology, lithium batteries are more appropriate for small private vehicles, while hydrogen is appropriate for larger vehicles such as buses and trucks. With the shift from coal to natural gas for electricity production in Israel in recent years, transportation's share of greenhouse gas emissions has risen. The largest government intervention in this context is its investment in the infrastructure needed for zero-emission vehicles and public transportation. This is in parallel to the implementation of the UK Initiative, which Israel signed at the COP26 meeting and according to which Israel will work toward the goal that all new private vehicles will be zero-emission by 2035.[31] Israel has gone even farther in this context than the agreement it signed at COP26. Government Decision 171 states that as early as 2030, the new vehicle emissions will be limited to 5 percent of what they were in 2020 for a similar vehicle.[32]

Israel has already initiated the replacement of natural gas with zero-emission technologies, and the proportion of zero-emission renewable energy in supply reached more than 9 percent in 2021.[33] The establishment of a renewable energy sector in the economy is a major achievement of the public sector in Israel in recent years, following many years in which this industry did not manage to take root.

Figure 7.2 describes the breakdown of zero-emission energy sources worldwide in 2020, where the most common types are water (30 percent of zero-emission energy on average) and wind (20 percent). Neither are particularly relevant for Israel. The other zero-emission sources of energy are nuclear (22 percent) and solar, whose weight in total zero-emission production of energy is relatively low (11 percent). Israel is unique from this standpoint, since solar energy accounts for 96 percent of its total zero-emission energy. The low weight of solar energy technology in other countries is primarily explained by the fact that this technology, particularly photovoltaic technology became commercial only in recent years.[34] Furthermore, it is a nondispatchable energy source, since the energy it produces has to be used when it is produced, such that the production of the energy must be synchronized with its

[30] For a detailed analysis of the emissions from the transportation sector in Israel see Lior Gallo and Yossi Margoninski (2021), "Reducing the Climate Footprint of the Transportation Industry in Israel," Bank of Israel, Selected Research and Policy Analysis Notes, 51. [in Hebrew]

[31] UK Department for Business, Energy & Industrial Strategy (Dec 2021). "COP26 declaration on accelerating the transition to 100% zero emission cars and vans."

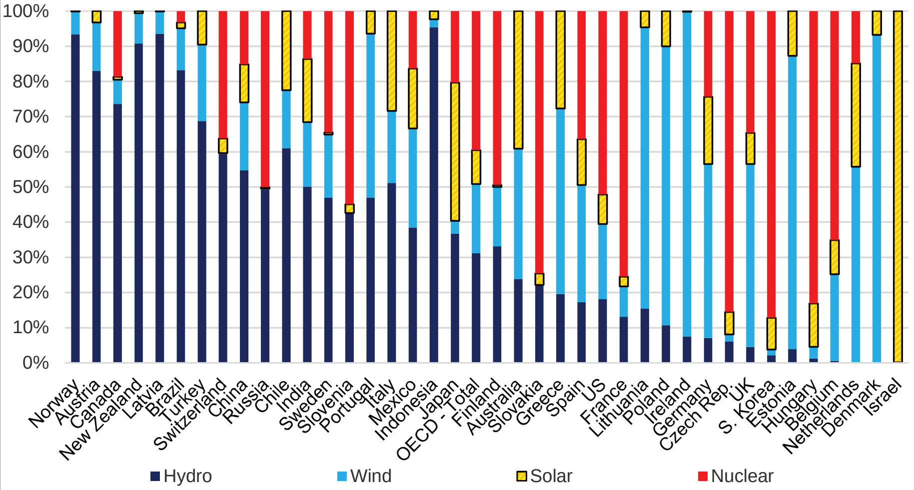
[32] See Prime Minister's Office (2021), "Shift to a Low-Carbon Economy". [in Hebrew]

[33] We are not counting biomass as zero-emission energy since its emission coefficient, i.e. emission per unit of energy, is similar to that of oil.

[34] See Lior Gallo and Yehuda Porath (2017), "The Development of the Electricity Market in Israel: Toward a Sustainable Electricity Market", Bank of Israel, Recent Economic Developments¸143.

consumption. Alternatively, solutions are needed for its storage, which will increase its cost and which are available only to a limited extent. This is the most serious barrier to substituting these types of energy for others, and it is expected to be removed in the future with the development of storage technologies. Box 7.2 discusses the issue of storage in lithium batteries or by means of hydrogen. The discussion concludes that lithium batteries are currently a more economically feasible method of storage than hydrogen for the electricity system.[35]

Figure 7.2
Energy Consumption from Zero-Emission Sources by Primary Source, OECD Countries and 5 Largest Emitters, 2020 (percentage of total emission-free energy)



* The five non-OECD countries in the list are China, India, Russia, Brazil, and Indonesia. The countries in the sample are responsible for about 70 percent of total global emissions. Costa Rica was not included due to a lack of data.
SOURCE: BP Statistical Review of World Energy, 2021.

a. The state of emissions, commitments, and performance

A significant portion of greenhouse gas emissions worldwide are concentrated in a few large countries. Figure 7.3 presents total emissions and its per capita level for countries in the sample. As stated, these countries account for 70 percent of total emissions.[36]

China, India, Russia, Indonesia, and Australia, which are responsible for about 40 percent of total emissions have rejected the climate targets, namely carbon neutrality in

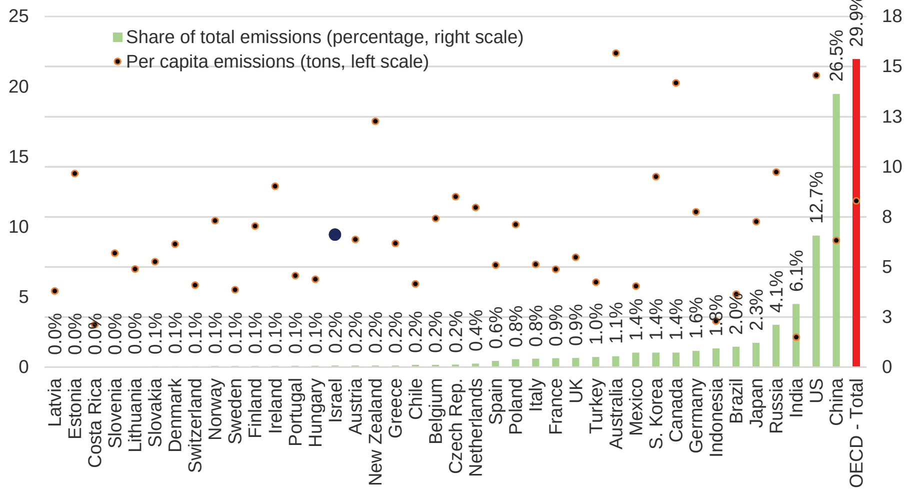
China, India, Russia, Indonesia, and Australia, which are responsible for about 40% of total emissions, rejected the climate target at Glasgow and have facilitated the future development of energy production by means of coal in their countries.

[35] For large vehicles, such as buses and trucks, the use of hydrogen is becoming more economically feasible.

[36] China alone is responsible for 14 GT, which constitutes 27 percent of total emissions. The US is the second largest source (13 percent). US emissions are also higher in per capita terms, second only to Australia. The next countries in line are India (6 percent) and Russia (4 percent).

2050, and have thus enabled their coal-fired energy production to grow in the future.[37] Similar developments are expected in several of the developing countries, which are at an earlier stage of the energy transition, and energy consumption—and with it emissions in the developing world—are therefore expected to grow significantly in coming years.

Figure 7.3
Greenhouse Gas Emissions, OECD Countries and 5 Largest Emitters, 2019
(tons of CO_2)

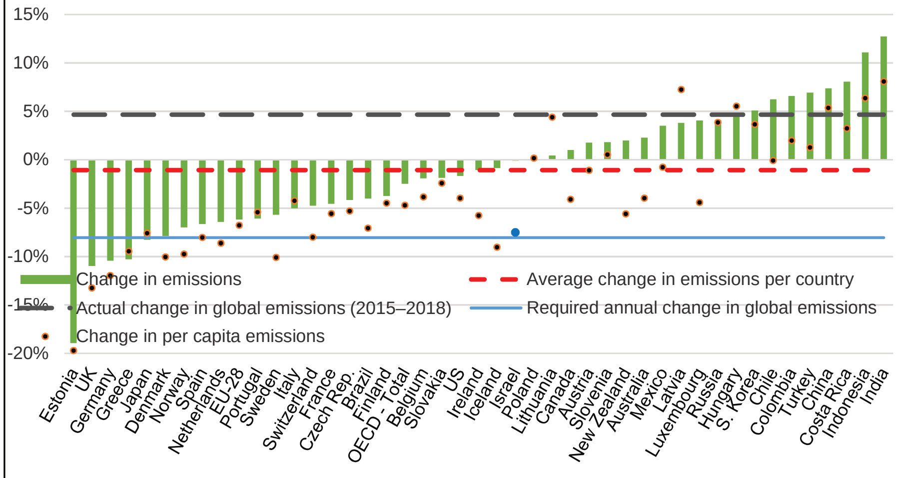


* The five non-OECD countries in the list are China, India, Russia, Brazil, and Indonesia. The countries in the sample are responsible for about 70 percent of total global emissions. Data for Brazil, Costa Rica, Mexico, and South Korea are as of 2018.
SOURCE: Climate Action Tracker, World Bank, OECD, and EGR 2021.

The next challenge on the climate agenda that Israel will face after COP26 is the "stocktaking" that will take place in 2023, in which each country's emission reduction will be measured relative to other countries. Figure 7.4 presents the current stocktake, i.e. the change in total emissions by country between 2015 and 2019. The average decline in the surveyed countries during this period is 1 percent, and it is represented by the red dotted line. However, the average decline ignores the size of the country, and thus gives the same weight, for example, to China and Israel. The weighted average of the change in emissions, which is equivalent to the reduction in total emissions, presents a more pessimistic picture, in which total emissions rose by 5 percent during this period, which is represented in the graph by the dotted black line. In order to illustrate the distance between the targets and the actual situation, the blue line at

[37] See the link in Footnote 2. In addition to the countries mentioned there, India, Indonesia, and Australia did not sign the agreement. The life expectancy of a coal-fired power plant is between 35 and 40 years. A commitment to carbon neutrality in 2050 implies a reduction of 5 to 10 years in the life of a power plant, which translates into a lower present discounted value and therefore less ability to finance it. As a result, the some countries' commitment to carbon neutrality in 2060 is essentially a declaration of "business as usual" for the time being.

Figure 7.4
Emission Performance: Change in Greenhouse Gas Emissions between 2015 and 2019, OECD Countries and 5 Largest Emitters (percent)



* The five non-OECD countries in the list are China, India, Russia, Brazil, and Indonesia. The countries in the sample are responsible for about 70 percent of total global emissions. Data for Brazil, Costa Rica, Mexico, and South Korea are as of 2018.
SOURCE: Climate Action Tracker, World Bank, OECD, and EGR 2021.

the level of 8 percent represents the level of reduction that would have been needed during this period in order to reach neutrality in 2050.

The data also show that a number of countries, apart from those that have openly rejected the climate targets, have increased their greenhouse gas emissions during the sample period. Israel is located at the center of the graph, with a small change in total emissions. In addition to the total emissions metric, the graph presents the index of change in the level of per capita emissions. On this metric, Israel's achievements are not high with respect to other countries, since it takes into account the rapid growth in Israel's population relative to other developed countries, most of which have reduced their emissions.

As mentioned above, the climate targets are particularly challenging to the Israeli economy, partly because the level of per capita emissions in Israel is not high relative to the developed countries and because Israel's rate of population growth is high relative to other countries. Figures 7.5a and 7.5b show the relationship between actual reductions and these two factors. The upper graph (7.5a) shows the relationship between them and per capita emissions in 2015. The graph shows two groups of countries: the larger one includes the majority of countries in the sample, while the second includes several countries in which per capita emissions are relatively high (the US, Canada, New Zealand, and Australia). The graph shows the negative relationship between the level of per capita emissions in 2015 and the change in emission performance in the group that includes the majority of countries. Countries with a high level of per capita emissions managed to reduce them more than countries with a low level. This empirical result is explained by the fact that countries with a high level of per capita emissions have more possibilities for reducing it in the early stages of the process (at

Figure 7.5a
Change in Greenhouse Gas Emissions (2015–2019), and Per Capita Emissions (2015)
(percent)

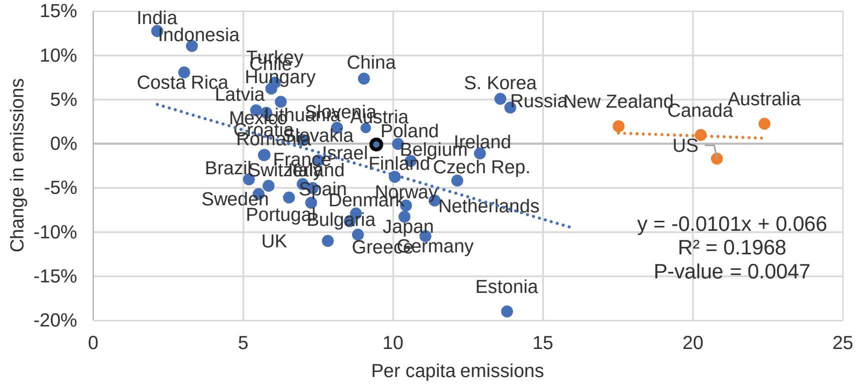
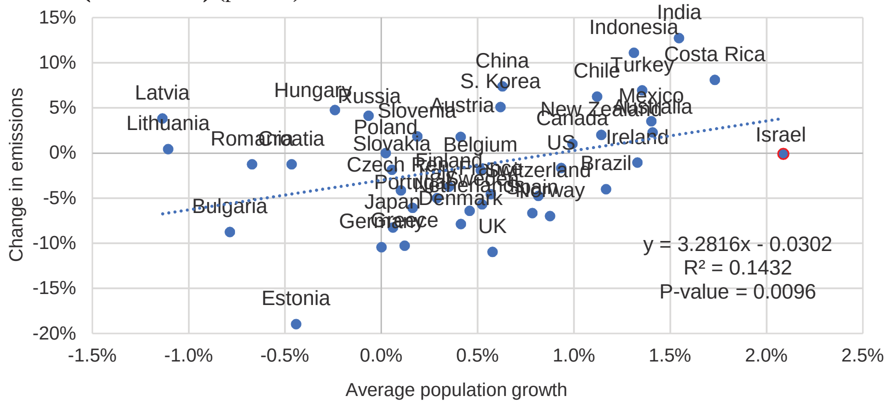


Figure 7.5b
Change in Greenhouse Gas Emissions (2015–2019), and Average Annual Population Growth (1995–2015) (percent)



SOURCE: Climate Action Tracker, World Bank, OECD, and EGR 2021.

the end of which the countries are meant to arrive at "carbon neutrality"). The lower graph presents the relationship between the reduction in emissions and the size of the population, which reveals a positive correlation between population growth and emissions growth. The graph also shows that even though population growth in Israel is higher than the other countries in the sample, its emissions did not increase, placing the country below the trend line. In conclusion, Israel is located near the two trend lines, implying that if one takes into account the circumstances of the Israeli economy, its performance in reducing emissions is in line with the global trend, i.e. somewhat higher emissions than the trend when looking at the level of per capita emissions and somewhat lower than the trend when looking at population growth.

b. The potential effects of decisions made at the Glasgow Conference on Israeli policy

Israel's climate policy involves fiscal policy decisions that have long-term implications. Thus, for example, the investment in energy infrastructure can be routed to channels that provide a short-term solution or infrastructure that will facilitate a solution in the long term when new technologies are developed, and also to infrastructure that provides solutions for reducing emissions or for adaptation, which are sometimes opposed to one another.[38] The decisions on the timing of government investments and their mix depend partly on the intensity and timing of the emission reduction process worldwide, including the rules that will be adopted by the international community.

Since at this stage, weaning off coal is the most critical challenge on the climate agenda, the COP26 initiatives were directed at the phase-out of this fossil fuel. This includes the summit of leaders whose goal was to advance the decarbonization of the global economy within another 30 years[39], the financial initiative to halt the financing of the development and investment in the coal industry for the production of energy, and the energy initiative to halt the development and subsidization of coal-fired power plants. It was agreed at the conference, that the phase-out of energy production from coal would be replaced by a phase-down. The phase-out was meant to halt the development and support of energy production from coal, which is expected to occur in Israel in 2026. Instead, it was decided, in accordance with the aforementioned change in the international forum, to make do with a partial reduction in the support of this industry, primarily by reducing inefficient subsidies, though not all of the subsidies. Although a number of worthwhile policy targets were agreed on at COP26 apart from the main climate initiative—particularly agreement on the importance of halting the destruction of the rain forests, the initiative to limit the emissions of methane gas and the agreement of various bodies to relate to the matter from a financial perspective—their impact is small relative to reducing the use of coal.[40,41]

One of the achievements of COP26 is an agreement on a universal mechanism for trade in emissions, which will include countries that currently are not part of that trade. In this framework, countries that have not met reduction targets will be able to pay countries that have reduced their emissions beyond their targets, and thereby accrue credit for the surplus reduction.

One of the achievements of COP26 is an agreement on a universal market mechanism for trade in emissions, which will include countries that currently are not part of that trade. In this setup, countries that have not met their emission reduction targets will be able to pay countries that have reduced emissions beyond their targets, and thereby accrue credit for the surplus reduction. This formalizes the mechanisms for the future assessment of progress toward meeting the Paris Agreement targets. This market mechanism will allow Israel, and other countries, to weigh the cost and benefit of not reaching the targets and reacting by way of a formal mechanism, with the option of increasing emissions by making payments to other countries that are

[38] See, for example, the Noga Company (February 2022). "The Electricity Sector in Israel", as part of the special committee for the Citizens of Israel Fund.

[39] See footnote 36.

[40] For a similar position to that presented here on the chances for carbon neutrality and the connection to the coal industry, see the statement by the head of the IEA.

[41] For further details on the achievements at the conferences, see United Nations: "COP26. Together for our Planet."

reducing their emissions. This removes a significant portion of the uncertainty with respect to political developments and the possibility of international sanctions in the future.

2. ISRAEL'S EMISSIONS OUTLOOK AND INTERNATIONAL COMMITMENTS

This section presents Israel's international commitments relative to the emission outlook scenarios that are described below. We will differentiate between Israel's commitments on the basis of formal declarations of future emission levels and the effect of policy tools including directives, regulation, and fiscal policy tools (taxation or government expenditure) on emissions. In other words, the emissions outlook does not assume that the goals will be achieved, but rather examines the likelihood they will be, based on past emission trends and the effect of the various policy tools. The various scenarios correspond to the various policy tools. We concentrate on policy tools related to energy rather than the possibility of reducing emissions by means of policy tools applied to waste, industrial processes, or agriculture. The forecast assumes that the emissions from these sources will grow according to past trends.

The results of the simulations indicate that there is no scenario based on the policy tools—among those that we examined—in which Israel meets the emission reduction targets and, as a result, the climate targets it has set itself. The policy tools that we examined indeed lead to considerable structural changes, which constitute an important part of the transition to a low-carbon economy, and these changes have an impact on the rate of growth in emissions in the short term. However, in the long term trends with an exponential growth rate, such as population and GDP, have a greater impact

Table 7.2:
Israel's Nationally Determined Contribution (NDC) for reducing emissions

(Israel's emission level and its emission reduction obligations)

	Actual emissions			Targets			
	2015	2019	2019	2030		2050	
	MtCO2e*	MtCO2e	Change since 2015	MtCO2e	Change since 2015	MtCO2e	Change since 2015
			Emissions / General targets				
Total	**79**	**79**	**0%**	**58**	**-27%**	**12**	**-85%**
			Emissions / Sectoral targets				
Electricity	37.6	32.6	-13%	26.3	-30%	5.6	-85%
Transportation	17.6	18.7	6%	18.2	3%	0.7	-96%
Manufacturing	12	12.4	3%	8.4	-30%	5.3	-56%
Waste	5.5	5.6	1%	2.9	-47%	0.4	-93%
Other	6.3	9.7	54%	6.3	0%	6.3	0%
Total sources	**79**	**79**	**0%**	**62.1**	**-21%**	**18.3**	**-77%**

* MtCO2e - Million tons of CO_2 equivalent.

SOURCE: Government decision 171 and Central Bureau of Statistics.

on emissions. Therefore, in order for Israel to meet its commitments, additional policy measures will be needed in coming years, in addition to the use of technologies, some of which do not currently exist or are not currently economically feasible.

The Israeli commitment to COP26 has two main targets: a 27 percent reduction in total annual greenhouse gas emissions by 2030 relative to 2015, and an 85 percent reduction in total annual emissions by 2050 relative to 2015.

a. Israel's Nationally Determined Contribution

Israel's Nationally Determined Contribution (NDC), which was submitted to the UN following Israel's Government Decision 171 from July 25th, 2021 ("Transition to a Low-Carbon Economy"), is summarized in Table 7.2.[42,43] This decision made substantial changes in Israel's commitments by transforming them from commitments in per capita terms to commitments in absolute terms. The Israeli commitment has two general targets: total annual emissions of greenhouse gasses will be reduced by 27 percent by 2030 relative to their level in 2015 (from 70 to 58 megatons) and total annual emissions will be reduced by 85 percent by 2052 relative to their level in 2015. Accordingly, the annual level of emissions in 2050 will be about 12 megatons.[44] In addition to these general targets, Israel has committed itself to sectoral targets. The Table reveals a disparity between the general target and the total of the sectoral targets[45], and this will have to be dealt with in the future, perhaps by means of a further revision of the commitments.

b. The emissions outlook

This section describes the assumptions and outcomes of Israel's greenhouse gas emissions outlook. As mentioned, this outlook is based on the emissions of every primary source on the basis of past trends, including the effects of policy tools. The "business as usual" scenario's forecast is presented in Figure 7.6. The relevant dates of the commitments and goals described above are presented as vertical lines for the years 2015, 2021, 2023, 2030, and 2050. The black line describes the maximum amount of emissions that Israel is permitted to emit according to its NDC. We emphasize that the linear trend line is a working assumption for purposes of illustration and is not part of the commitments. As a result of the transition from a target in per capita emissions terms to one in terms of an absolute reduction in emissions starting in 2020, the black line has a downward slope.

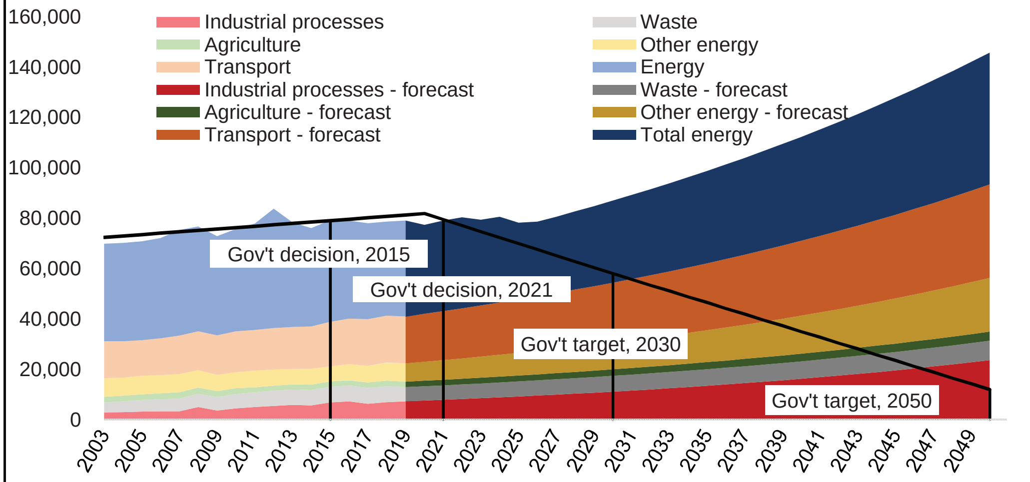
[42] See Prime Minister's Office (July 2021): "Transition to a Low-Carbon Economy". For paper submitted to the Climate Conference, see "Israel's Intended Nationally Determined Contribution (INDC)". Submission to the ADP.

[43] The Prime Minister and the Minister of Energy have announced even more ambitious targets than those submitted to the Climate Conference. See Prime Minister's Office (October 2021). "Prime Minister Bennett and Minister of Energy Elharar have agreed to establish a national target of zero greenhouse gas emissions by 2050." [Hebrew]

[44] See Prime Minister's Office (July 2021). "Transition to a Low-Carbon Economy." [in Hebrew]

[45] Apparently because the sectoral targets did not take emissions due to agriculture into account.

Figure 7.6
Israeli Government Decisions and Emissions Outlook by Source (10 percent renewable scenario, data for 2003–2019, tons of CO_2)



SOURCE: Central Bureau of Statistics, and OECD data.

The data for total emissions, up to 2019, are divided according to the primary emission sources. The emission from "total energy" is divided into three components: production of energy (47 percent of total greenhouse gas emissions in 2018), which is primarily electricity production, transportation (24 percent), and other energy (9 percent).[46] Other emission sources include industrial processes (9 percent)[47], waste (8 percent)[48], and agriculture (3 percent).[49] The emission data after 2019 are based on the emission forecast. Apart from the policy tools in the energy sector, which are described below, all of the forecasts in the "business as usual" model are based on past trends.[50]

The rate of growth in electricity production is 2.7 percent per year.[51] The mix of energy in the "business as usual" scenario assumes that 10 percent of electricity is produced by solar power, which is close to the current situation, and that this will continue until 2050. The only policy intervention that is taken into account in the "business as usual" scenario is the timing of the phase-out of coal and the transition to natural gas in 2026. The results of the scenario indicate that under these assumptions,

[46] "Other energy" primarily includes the burning of fuels such as LPG, kerosene, and wood.
[47] Primarily hydrofluorocarbons that are used in air conditioners.
[48] In other words, organic waste processes.
[49] Its emissions stem from waste processes, chemical processes, and animal waste.
[50] In particular, other transportation emissions increase at an annual rate of 3.5 percent, other energy emissions increase at a rate of 3.5 percent, those of industrial processes at a rate of 3.8 percent, those from waste at a rate of 1 percent, and those from agriculture at a rate of 1.7 percent.
[51] L. Gallo (2017). "A Long-Term Forecast of Electricity Demand in Israel", Bank of Israel Research Department, Discussion Papers Series 2017.13. Since 2017, a number of revisions have also been made to Israel's GDP growth forecast, but they do not have a substantial impact on the result of the forecast for electricity demand.

Israel will not meet its target in 2023 when the "stocktaking" takes place, or the targets for 2030 or 2050.

We now examine the impact of a number of proposed energy policy measures on the emissions outlook. The results of the simulation of the various scenarios are presented in Table 7.3. The first line presents the total maximum emissions permitted to Israel on the basis of its NDC in the relevant years. The second line presents the emission targets from electricity production, the third line presents the quantity of emissions expected in the "business as usual" scenario as described above, and the fourth line presents the emissions from electricity production in the "business as usual" scenario.

Following that, the table presents a scenario that we will refer to as the "30 70 scenario" in which the mix of fuels is based on the Ministry of Energy plan for 2030, which is presented in Figure 7.7. The energy mix reflects the phase-out of coal and the energy transition in Israel, with the end of coal burning by 2026 and the continued implementation of the third phase of the energy transformation (from natural gas to clean energy). We emphasize that a significant portion of the reduction in emissions in Israel in recent years was the result of the transition from coal to natural gas, and this

Table 7.3:
Emissions outlook under various fuel mix scenarios in the production of electricity

(MtCO2e)

	2023	2030	2040	2050
Targets - NDC				
Emission level	75	58	35	12
Emissions from electricity production	34	26	16	6
Business-as-usual scenario				
Emission level	79	87	112	146
Emissions from electricity production	34	33	41	52
30 percent renewable and 70 percent natural gas by 2030				
Emission level	77	80	103	134
Change in the emission level relative to the business-as-usual scenario	-2	-7	-9	-12
Emissions from electricity production	32	25	32	41
100 percent renewable by 2050				
Emission level	76	76	85	93
Change in the emission level relative to the business-as-usual scenario	-3	-11	-27	-52
Emissions from electricity production	31	22	14	0

SOURCE: Based on Bank of Israel calculations.

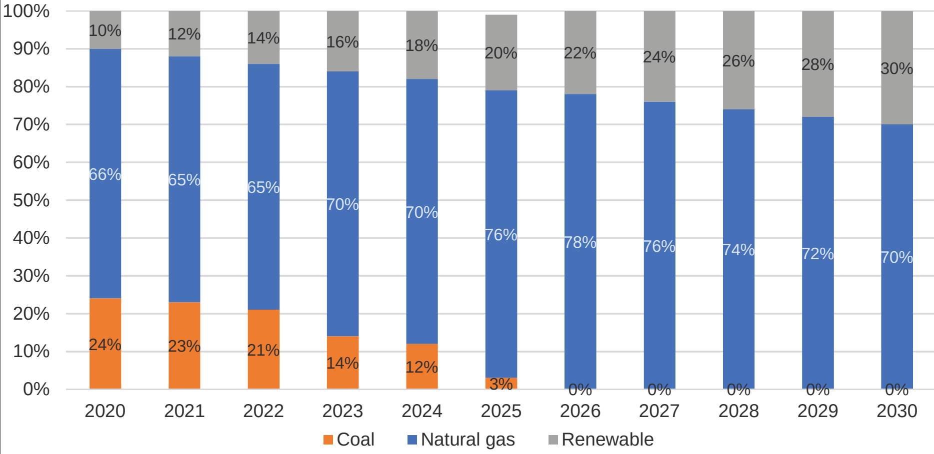
decline will exhaust its potential once the transition has been completed. In the "30 70 scenario", the weight of clean energy will gradually increase from 7 percent in 2019 to 30 percent in 2030 and will remain at that level thereafter. As part of this scenario, the rest of the electricity will be supplied by means of natural gas, at a rate of 70 percent, and without any other fuels, such as coal or fuel oil. According to the assumptions of

In the long term, trends with an exponential growth rate, such as population and GDP, have a greater impact on emissions, emissions continue to rise, and Israel does not manage to comply with the general targets under any scenario. Nonetheless, it may be possible for it to comply with the sectoral target for the electricity sector.

this scenario, Israel is expected to meet the target set for the electricity sector but not the overall target.

The last scenario presents a hypothetical situation in which the weight of zero emission energy in the mix of fuels continues to rise linearly from its present level to a level at which all electricity is produced by solar energy in 2050. According to this scenario, solar energy will account for 40 percent of total electricity production in 2030, and indeed, Table 7.3 shows that this scenario reduces emissions more than the "30 70" scenario. In this scenario, Israel meets the sectoral target for the electricity sector, but meeting the general target will require major steps in other areas as well. The Ministry of Energy has prepared a roadmap for a low-carbon electricity sector by 2050 with the goal of reducing carbon emissions from the electricity sector by 85 percent by that year.[52] This plan has two trajectories. In the first, all of the emission reduction is achieved through the use of solar energy, accounting for up to 87 percent of the fuel mix, and in the other a "natural" growth rate is assumed for solar energy, which reaches 54 percent in 2050, with the rest of the emission reduction achieved by means of technologies that are not yet commercial or are not currently in use in Israel, such as gas turbines with carbon capture, connecting to the electricity networks of neighboring countries in order purchase electricity from renewable sources, offshore wind turbines, etc. According to the plan, the actual trajectory will be somewhere between these two extreme scenarios. Furthermore and according to the Prime

Figure 7.7
Israel's Future Mix of Fuels for Electricity Production, 2020–2030



SOURCE: Development of the Natural Gas Sector - Special Committee for Supervising the Fund for Managing State Revenues for the Natural Gas and Oil Levy, Ministry of Energy.

Minister's commitment at COP26 to net zero carbon emissions by 2050, a number of future technologies were identified that will be able to achieve net zero emissions in Israel, such as long-term storage and pyrolysis of methane. The processes described in

[52] See Ministry of Energy (April 2021). "Roadmap to a Low-Carbon Energy Sector by 2050".

the scenarios may be reinforced by the imposition of a carbon tax, as recommended by the Bank of Israel. According to a box appearing in the Bank of Israel Annual Report for 2019, an increase of one percent in the price of electricity as the result of a tax will reduce the demand for electricity by about 0.3 percent, which will bring the economy closer to its goals.

Another examination introduced an additional policy measure into the previous scenarios, namely the transition from oil to natural gas. Following the UK Initiative, the assumptions were that all new vehicles in Israel would be electric from 2035 onward; the level of emissions related to a zero-emission vehicle is measured on the basis of the fuel mix used in producing transportation-related energy; the rate of growth in the number of vehicles is according to the growth in the population (1.7 percent)[53]; ten percent of vehicles are new; the annual scrapping rate of vehicles is 5 percent; and zero-emission private vehicles grow linearly as a share of total new vehicles from their present level to 100 percent in 2035. The change in the level of emissions as a result of this process is marginal and therefore not presented here.

3. CONCLUSIONS AND POLICY RECOMMENDATIONS

This chapter analyzes the growing tension in recent years between the need to provide energy security and the global trend to promote carbon neutrality in the energy sector. Decarbonization of the energy system (electricity, transportation, and "other energy", which together account for 76 percent of greenhouse gas emissions) is a necessary condition for achieving carbon neutrality, namely to reduce global greenhouse gas emissions by at least 53 percent, and solutions to the emission of greenhouse gasses from the energy sector are more feasible than solutions for the rest of the sources. For this reason, the analysis in this chapter has concentrated on the energy sector and has ignored other sources of emissions (waste, chemical processes, and agriculture). It was found that as long as carbon capture technologies are not commercial, the only way to achieve decarbonization of the energy system is to replace primary sources of energy from fossil fuels with zero-emission energy, such as renewable and nuclear energy sources.

International experience in recent years points to the importance of synchronization and correct planning of the production and transmission systems during the transition to renewable energy. This process includes government preparation of the energy market, infrastructure and relevant regulation for the development of renewable energy industries, and ensuring redundancy and backup. The accelerated development of storage technologies is expected to facilitate the responses to these challenges. These measures are also needed from the perspective of adaptation since they reinforce the

[53] The number of vehicles in Israel grew at an annual rate of 5 percent. If this trend continues, the number of vehicles on Israel's roads is expected to quadruple by 2050. Since this scenario is not sustainable, we chose a more moderate scenario. Of course, this means that the emissions presented in the scenarios here are downward biased and it can be reasonably assumed that they will be higher.

In view of the risks in relying exclusively on solar energy, we concur with professional bodies who recommend cautiously considering the production of electricity using nuclear technology. This has not been done so far, for reasons unique to Israel, even though nuclear power is common in many countries and developing in others, even in the Middle East.

technical and institutional abilities of the energy system in Israel. Therefore, renewable technologies are still the most feasible solution for achieving carbon neutrality in Israel. The renewable energy industry can be advanced by means of support for its ability to compete. This can be done by pricing in fossil fuel externalities (for example by imposing a carbon tax) and investment in electricity system infrastructure.[54]

At the same time, and in view of the risks in relying exclusively on solar energy, we concur with the opinion of professional bodies who recommend cautiously considering the production of electricity using nuclear technology. This has not been done in Israel so far, for reasons that are unique to the country, even though nuclear power is common in many countries and developing in others, even in the Middle East.[55,56] Nuclear energy is currently the most technologically and commercially available source that can achieve the two policy goals of energy security and carbon neutrality. As long as nuclear energy is not on the agenda in Israel, the feasibility of carbon neutrality is dependent on future technologies that do not yet exist or are not yet commercially available and on policy measures that have not yet been specified and attempted in Israel. Meeting Israel's commitment to the international community is therefore dependent on future technological developments. It is important that the consideration process should be as transparent as possible to the energy markets, since the government's policy trajectory is important to their ability to plan for the long term. As an example of the importance of long-term planning, the Bank of Israel has previously recommended the promotion of a masterplan for the energy sector in Israel, and indeed there has been progress in this direction.[57] Technological developments in recent years hint at the possibility that a nuclear technology will be developed that is more commercially feasible than previous technologies and will allow countries that are not signatories to the Non-Proliferation Treaty to produce nuclear energy with the development of small reactors.[58]

The developments at COP26 have a number of implications for Israel. First, it appears that the chances of global success in meeting the global warming limitation targets established in the Paris Agreement have diminished. Therefore, adaptation to the new situation has become more important. Box 7.1 briefly describes the issue of adaptation, the assessment of physical risk to Israel, and the main policy tools to mount a response. Second, the lack of broad international commitment to emission reduction targets increases the risk that the drop in demand for fossil fuels in countries

[54] For a full description of the national plan, which also relates to emissions that are not from the energy system, see Ministry of the Environment (October 2021), "National Implementation Plan for Dealing with the Climate Crisis 2022–26." [in Hebrew].

[55] See Ministry of Energy (April 2021), "A Roadmap to a Low-Carbon Energy Sector by 2050,", p 16. [in Hebrew].

[56] S. Griffiths (2017). "A Review and Assessment of Energy Policy in the Middle East and North Africa Region." Energy Policy, 102: 249–269.

[57] See "The Worldwide War on Global Warming and its Implications for Israel," Bank of Israel *Annual Report 2019, Selected Studies*.

[58] Jacopo Buongiorno, Ben Carmichael, Bradley Dunkin, John Parsons, and Dirk Smit (2021). "Can Nuclear Batteries Be Economically Competitive in Large Markets?" Energies 14(14): 4385.

that intend to meet the climate targets will be partly offset by the rise in use of these fuels in countries that are not committed to the targets, due a drop in their prices.[59] Moreover, among countries that do meet the climate targets, there is the possibility that lower investment in fossil fuel energy will lead to energy crises that would lead to a policy reversal. Third, since a considerable proportion of countries—including superpowers such as Russia and China as well as developed countries such as Australia—have officially rejected the climate target, the likelihood that the imports from countries with high emissions will be taxed may have decreased. Whatever the case, the developments illustrate the dynamic of the international political system and the rapid turns of events that occur within it. An example is the agreement among countries, after years of difficult negotiations, on a reform of international taxation, including the distribution of certain tax receipts among the countries. For further details, see Box 6.3 in Chapter 6 of this Report.

The events of recent years in Europe in general and Germany in particular illustrate the importance of synchronizing the reduction in use of existing energy sources with the introduction of renewable energy and the assurance of energy supply. The tension between the energy transition and the climate agenda on the one hand and energy security on the other is an important policy question facing governments all over the world. As part of the widening responses to this dilemma, the EU has recently classified nuclear energy and natural gas technologies that include carbon capture and storage as green technologies.[60] The presidents of both the US and the EU referred to this tension in their recent joint declaration.[61]

The aforementioned difficulties in the process of transitioning to renewable energy technologies do not constitute a valid argument against preparing the energy markets, energy infrastructure, and relevant regulation for assimilation in the Israeli energy system. This is partly in view of the progress being made in storage technology, which is expected to alter the situation in the future. The preparation of infrastructure that will be suitable for these technologies is also important for the adaptation to the new reality, since it strengthens the system's resilience and technical and institutional capabilities. Therefore, and despite the aforementioned challenges, adopting these measures is still the most pragmatic policy in order to achieve carbon neutrality in Israel.

With respect to the policy measures to deal with the market, and in view of similar recommendations by the international organizations, it is recommended that the competitive status of the renewable energy industries be reinforced relative to the industries based on fossil fuels, which can be accomplished by carbon pricing.[62] In

[59] This assessment is consistent with that of the World Economic Forum: "The Global Risk Report", World Economic Forum, 2022.

[60] See European Commission (2022), "EU Taxonomy Commission Begins Expert Consultations on Complementary Delegated Act Covering Certain Nuclear and Gas Activities".

[61] See The White House (2022). "Joint Statement by President Biden and President von der Leyen on US-EU Cooperation on Energy Security".

[62] See International Monetary Fund (2019): "Fiscal Monitor: How to Mitigate Climate Change".

view of the small size of the Israeli economy, a carbon tax is more feasible than other policy measures since it is more efficient and its excess burden is the smallest.[63] A carbon tax will assist in achieving a balanced transition to renewable energy by allowing the market—which is where the relevant knowledge is located—rather than the bureaucracy to choose the best-suited technology. Government Decision 286 applies that principle.[64] The directive issued by the Ministry of Finance following this decision is now being discussed in the Finance Committee.[65,66] Since this measure will increase the price of electricity, it is important that it be accompanied by supplementary policies to minimize the effect on sensitive populations, though without harming the incentives for emission reduction.

The development of the renewable energy industry, which is essential to the progress of both emission reduction and the process of adaptation, requires a developed infrastructure in the electricity sector. To this end, investment should be accelerated in connecting potential production sites in the South to consumption concentrations in Jerusalem and the Center. This investment is also essential to the structural change that is occurring in the electricity sector, with the transition from centralized to decentralized production. In addition, acceleration in the development of infrastructure is needed to reinforce the resilience of the system, in view of the need to adapt to a situation in which the level of risk is higher than it is today. A stronger electricity infrastructure will prevent instability in the event of natural disaster or extreme weather conditions. Investment in the electricity infrastructure is also needed for the transition from oil to natural gas and the parallel transition in the transportation sector from internal combustion engines to zero-emission vehicles, which will add to the load of the electricity system. These will also increase both demand and traffic to a considerable extent, a situation that also requires an appropriate electricity infrastructure.

Given the current trends in emissions, the existing technologies, and the proposed policy measures, Israel's ability to meet its NDC, particularly in relation to 2023 (the year of the "stocktaking"), is in doubt. However, Israel is not facing this challenge alone. Other countries are also expected to face major challenges in meeting the targets. Israel can also take credit for a number of achievements, as described above. In view of this situation, and alongside the problems that have emerged in achieving an international consensus on the emission reduction targets, if decarbonization efforts in Israel progress slower than dictated by the targets, it may be accepted with understanding by the partners in the process.

[63] The document published by the IMF (ibid.) presents an in-depth discussion of the advantages and disadvantages of the various policy measures for advancing emission reduction and points to the economic benefit of introducing a high and broadly applied carbon tax. (The example in the IMF document is a tax of 75 dollars per ton of carbon.)

[64] For further details, see Yossi Margoninsky and Lior Gallo (2020), "The Worldwide War On Global Warming and its Implications for Israel", Bank of Israel Annual Report 2019 Selected Studies.

[65] See Prime Minister's Office (2021). "Pricing of Greenhouse Gas Emissions".

[66] See the announcement by the Knesset Finance Committee on this subject: https:// main.knesset.gov.il/News/PressReleases/Pages/press07122021L.aspx

BOX 7.1: ADAPTATION AND RISK ASSESSMENT IN ISRAEL[1]

This box briefly presents the issue of adaptation to global warming and sheds light on the main risks created by global warming for the Israeli economy. The issue of adaptation to the effects of global warming does not often appear in international public discourse because the benefits from adaptation are on the national level. Accordingly, COP26 called on the countries of the world to accelerate their implementation of the relevant measures on the local, i.e. national, level.[2]

This box is based on the reports of the Intergovernmental Panel on Climate Change (IPCC) on the issue of adaptation, and makes use of the basic definitions and results that are relevant to Israel.[3] The risk assessment in the IPCC reports is organized according to climatic regions rather than according to country, and the most recent report (published in February 2022 and referred to as AR6) therefore includes a chapter on the Middle East. This calls for a specific risk assessment for Israel. It is worth emphasizing that the basic scenario presented in AR6 does not take into account the assessment presented above, which implies that according to the agreements reached at COP26 the likelihood of a higher level of emissions has increased. The findings of AR6 described here may therefore underestimate the risk.

One of the main conclusions in AR6 is that the forecasts made in previous years underestimated the expected harm in each global warming scenario. This is partly due to the greater effects of climate change so far, new information that has accumulated, and the faster than expected increase in temperatures, based on measurement.

Climate change leads to an increase in temperature and in the frequency and intensity of extreme climatic events. Thus, it endangers physical systems, terrestrial and oceanic ecological systems, and human systems. The potential effect of climate change in each of these systems differs across geographic regions and is highly dependent on the level of local infrastructure. The IPCC classifies the degree of certainty attributed to each of the risks according to five levels, from lowest to highest. The highest level of certainty is attached to risks to the physical system, such as storms, floods, rising water levels, droughts, heat waves and land erosion.[4] The potential damage arising from the realization of these risks is expected to be even greater in the developing countries for two reasons. First, physical disasters are more likely in central and southern Africa, in South America and in East Asia, including India and China. Second,

[1] Special thanks to Professor Noga Kornfeld Shor, Tamar Raviv, and the staff of the Ministry of the Environment for their significant contribution to this box.

[2] Decision -/CP.26: "urges Parties to further integrate adaptation into local, national, and regional planning."

[3] The previous AR5 report: C,B, Field & V.R. Barros (eds.) (2014). "Climate Change 2014–Impacts, Adaptation and Vulnerability: Regional Aspects. Cambridge University Press; The current AR6 report: https://www.ipcc.ch/report/sixth-assessment-report-working-group-ii/

[4] J.A. Patz, D. Campbell-Lendrum , T. Holloway, and J.A. Foley (2005). "Impact of Regional Climate Change on Human Health", Nature, 438(7066): 310–317; C. Mora, B. Dousset, I.R. Caldwell, , F.E. Powell, R.C. Geronimo, C.R. Bielecki, and C. Trauernicht (2017). "Global Risk of Deadly Heat", Nature Climate Change, 7(7): 501–506; R. Basu and J.M. Samet, (2002). "Relation Between Elevated Ambient Temperature and Mortality: A Review of the Epidemiologic Evidence", Epidemiologic Reviews, 24(2): 190–202; R.S. Kovats and S. Hajat (2008). "Heat Stress and Public Health: A Critical Review", Annual Review of Public Health, 29: 41–55.

the level of physical infrastructure (energy, water, healthcare, transportation, and communication) in the countries of these regions is less developed and therefore more sensitive to risk.[5]

Apart from the physical risk, there are risks to the terrestrial and marine ecological systems. These risks include significantly higher frequency and intensity of fires, drying up of rivers, loss of biological diversity and extinction of species, desertification, damage to coastal cliffs, the spread of zoonotic disease, and more. With respect to the Middle East, the IPCC report describes a variety of adverse effects, including an increase in the frequency and intensity of extreme heat waves, which are expected to cause an increase in mortality rates, particularly among sensitive populations[6], an increase in the frequency and intensity of fires, an increase in the concentration of dangerous airborne particles (2.5 ppm) as a result of the desertification process, and an increase in the incidence and intensity of life-threatening storms.[7]

The knowledge regarding the effect of global warming on the risks to the human system is highly limited since this is a particularly complicated subject with a high level of uncertainty. Furthermore, such knowledge requires a local and high-resolution assessment more so than the risks to other systems. There is currently no risk assessment that focuses on Israel, which is also stated in the report published by the Climate Change Preparedness Administration.[8] Such an assessment is needed in view of Israel's unique characteristics, due to which it faces different risks than other countries in the region. For example, since Israel is a crowded country with rapid population growth, its consumption of resources (primarily water, food, energy, and land) is also growing rapidly. Many of its infrastructures, including desalinization and energy, and its cities are located along the coast, where they are exposed to the risks of flooding and a rise in the sea level. Although Israel's infrastructure is at the level of a developed country—unlike that of other countries in the region—without a detailed mapping of the risks and preparations to deal with them, the bottlenecks in investment and planning are liable to endanger the entire system.

An example of a physical risk that is relevant to the region is damage to water sources, including their drying up. For decades, Israel has developed the most advanced desalination capabilities, which currently supply most of the water for household use. However, it should be remembered that the desalination process is energy-intensive, and predicting Israel's future water demand must therefore also include an energy calculation. Desalinization also does not meet the need for water in agriculture, and the drying up trend will therefore also affect this sector in the future.

Another possibly risk that may be relevant for Israel relates to human systems and national and regional security. Physical events are liable to have a significant effect on other countries in the region, which may intensify conflicts with neighboring countries or lead to climate migration from affected countries.[9] A different risk in the context of human systems is related to the healthcare system. The COVID-19 pandemic, which led to loss of life and reduced well-being, is providing a stress test in real time and has

[5] W.N. Adger, S. Huq, K. Brown, D. Conway, and M. Hulme (2003). "Adaptation to Climate Change in the Developing World." *Progress in Development Studies*, 3(3): 179–195.

[6] See Chapter 9 in AR6.

[7] See Chapter 6 in AR6.

[8] See "The State of Israel's Climate Change Preparedness"– reports of the Administration. [in Hebrew].

[9] "Climate and Security in the Middle East and North Africa", Congressional Research Services, 2022. The IPCC report describes the connection between heat events and the level of violence in conflicts, particularly in the Middle East (Chapter 7).

motivated the healthcare system in Israel to adapt itself in order to respond to the crisis. It is important to preserve the knowledge accumulated during the pandemic for use in similar events in the future.

In view of the Israeli economy's exposure to climate risks, there is a lack of information on the risks and expected effects on population sectors, assets, infrastructures, and economic activity. Therefore, it is important to make progress in assessing the national situation, with the goal of mapping and assessing the potential risks to Israel in detail and presenting directions for the development of possible responses. This should be done as soon as possible, since preparations for some of these potential risks will require a long period of time. It is important that such an analysis begin with a scientific evaluation that will present the implications of the physical risks of climate change to the region. On that basis, a scientific analysis of each aspect of the economy should be carried out, alongside an analysis of the financial and planning implications.

BOX 7.2: AN ECONOMIC COMPARISON OF THE MAIN ENERGY STORAGE TECHNOLOGIES

- The use of solar or wind energy to account for a significant proportion of electricity production will increase the need for energy storage capability. In order to calculate the required energy storage capacity, it will be necessary to also take into account the fluctuations in daily production due to changing weather conditions.
- In a comparison between two storage technologies—lithium batteries and hydrogen—storage using hydrogen is shown to be more expensive. However, according to current estimates, its relative price is expected to drop.
- The adverse environmental effects of storage using lithium batteries is greater than in the case of hydrogen.

The use of renewable energy is an important tool for reducing greenhouse gas emissions in many countries, including Israel, based on the targets they have adopted for themselves. In 2021, renewable energy accounted for about 7 percent[1] of total electricity production. Ninety-five percent[2] of that by solar energy. A comparison of the distribution of renewable energy consumption to the distribution of its hourly production reveals an only partial correspondence between the peak hours of production and the peak hours of usage. Since the production of solar energy depends on the sun, a transition to renewable energy on a large scale will require a solution for the storage of excess energy during the day, so that it can then be used at night. Numerous technological improvements and growing climatic awareness have brought about a sharp increase in demand for various storage methods in private and public markets. This box concentrates on two storage methods that are gaining momentum: lithium-ion batteries (chemical storage) and hydrogen (storage in fuels).

1 Calculations by the Bank of Israel on the basis of Israel Electric Company data.
2 Central Bureau of Statistics data.

Lithium-ion batteries are an electrochemical energy storage method in which lithium ions travel from a negative to a positive electrode and vice-versa. The main advantages of this method are high energy density, a high number of charge/discharge cycles, and low degradation of capacity during the cycles. Furthermore, the battery can be charged and discharged directly without any need for intermediate processes as in other storage methods. A significant breakthrough led Sony to start marketing this technology in 1991, and its use has grown continuously since then. Technological improvements have reduced the cost of this technology by about 98 percent over the ensuing three decades. By way of comparison, the total global battery market was estimated at about $3–5 billion[3] in 2000, and the price of storing one kilowatt-hour of electricity was estimated at about $2,200. The current market is estimated at about $41 billion[4], and the price of storing one kilowatt-hour is estimated at about $140.

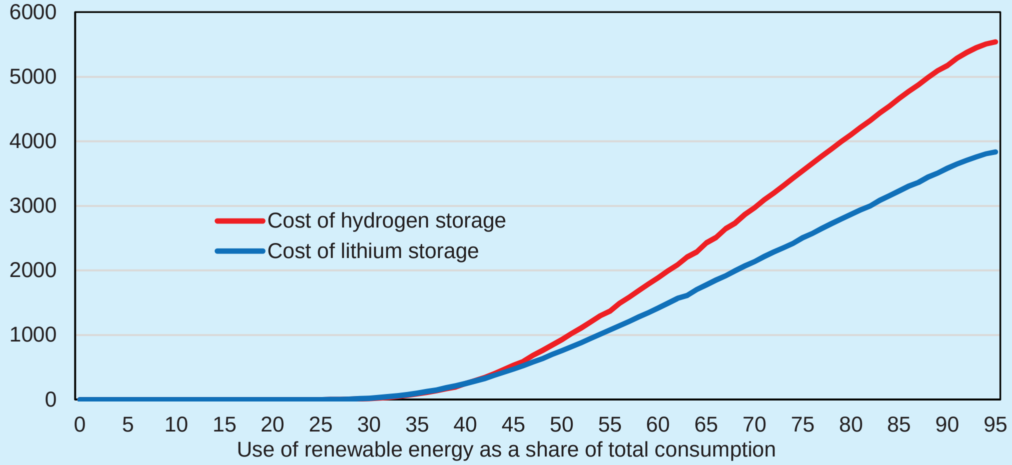
Hydrogen production can be accomplished in several ways, each of which differs in pollution level and cost. The cleanest way to produce hydrogen, and the one we will focus on, is "green" hydrogen produced from water. In this method, hydrogen is produced using electricity based on renewable energy. The process uses electrolysis (electrical separation), where water molecules are separated into hydrogen and oxygen. The separated hydrogen can be converted back into electricity by means of various fuel cell technologies. The global use of hydrogen is estimated at about 330 toe (tons of oil equivalent)[5] and total hydrogen sales in 2018 were estimated at about $115 billion. However, about 95 percent of production is from polluting technologies rather than renewable energy.[6]

To make an economic comparison between various energy sources, a standard unit of measurement is required, one that takes into account variations in their characteristics (method of operation, lifecycle, supply capability, etc.). The literature commonly uses "Levelized cost of energy/storage", which is defined as the total financial investment in an energy source per unit of energy produced.[7]

Israel's total daily electricity consumption in 2021 was about 207,000 megawatt-hours. Based on the hourly distribution of consumption, a simulation was carried out for each storage method, in which the storage costs were calculated alongside the increase in production capacity of renewable energy as dependent on the percentage of its use in total annual consumption. These simulations indicate that the comparison of storage methods starts to become relevant when the use of renewable energy exceeds 23 percent of total consumption, and that storage on an economically significant scale is required starting from approximately 40 percent (Figure 1).[8] According to the simulations, another important parameter is the gap between the scenarios concerning the total renewable energy that will need to be produced when storage is necessary. This gap is due to the waste in the process—the loss of energy involved in converting electricity to hydrogen and back again during use. The quantities of renewable energy needed are also an indication of the resources required to create the production infrastructure.[9] With existing technology,

[3] C. Pillot, March 2017.
[4] The market grew linearly from 2000 to 2016, and the industry has doubled in size since then.
[5] IRENA, September 2018.
[6] IRENA, September 2019.
[7] $LCOS = \frac{\text{Total lifetime cost of storage}}{\text{Total lifetime output}}, LCOE = \frac{\text{Total lifetime cost of production}}{\text{Total lifetime output}}$
[8] Considering the high daily variation in renewable energy production capacity due to weather conditions, the effective threshold is lower and is also dependent on the level of redundancy in other energy sources.
[9] The creation of the infrastructure includes both the means of producing renewable energy and its transmission.

Figure 1
Annual Cost of Storage as Dependent on Percent of Usage of Renewable Energy, 2021
($ million)



SOURCE: Based on Ministry of Energy, Lazard, Bloomberg, Israel Electric Company, and Central Bureau of Statistics.

the loss of energy is estimated at between 55 and 75 percent of the energy invested in the hydrogen. This means that in order to use 1 kilowatt hour that has been stored during the daytime, about 2.5 kilowatt hours must be produced. In contrast, to the loss of energy with a lithium ion battery is estimated at only 5–15 percent.[10] However, it is expected that hydrogen technology will advance and that the gap in the scenarios will narrow.[11]

Table 1 presents a cost comparison of storage scenarios between hydrogen and lithium ion batteries, in a scenario in which renewable energy accounts for about 50 percent of annual energy consumption at its 2021 level.[12] Furthermore, the comparison assumes only intraday storage, where the storage of renewable energy produced during the daytime will need to also provide a substitute for demand in the nighttime.[13] The analysis shows that overall—assuming current technologies and costs—energy storage using lithium ion batteries is economically more feasible than hydrogen in the abovementioned scenarios. The cost of storage by means of hydrogen is estimated at about $930 million annually, while the cost of using batteries is about $757 million. This result primarily reflects the fact that storage technology by means of hydrogen is less efficient and therefore requires the building of additional production capacity and the

[10] The analyses below use efficiency of use (energy that is utilized as a share of energy invested) at a level of 40 percent for hydrogen and 85 percent for lithium, since these are the most commonly used values in the literature, especially that of the IEA. See the entry in World Energy Council, 2020 and IEA, June 2019.

[11] Depending on a number of variables, such as the rate of technological progress in lithium ion batteries, the supply of raw lithium and of the various metals involved in battery production, and improvement in the efficiency of hydrogen technology at a faster rate than lithium ion technology.

[12] As the demand for electricity increases, the need for storage will become relevant at a lower proportion of renewable energy within total use.

[13] In this analysis, we did not examine long-term storage scenarios, even though they are certainly possible.

production of more renewable energy during the daytime, which leads to greater use of renewable energy and therefore less storage than with the use of lithium.[14] Nonetheless, the waste of energy has a dominant effect, making the use of hydrogen more expensive.

Another difference is that in the case of lithium ion batteries, the storage means are also the product itself, while hydrogen production and storage are separate stages. There are various ways to store hydrogen, such as compression into containers, storage in designated underground caves, conversion into

Table 1:
Cost comparison of renewable energy storage for identical quantity for 50 percent of total consumption in 2021 terms

(energy unit in TWh)

	Hydrogen scenario	Battery scenario
Total annual electricity consumption, 2021	74	
Total annual electricity consumption from renewable energy	37	
Total annual electricity production from renewable energy[a]	44	38
Total annual renewable energy designated for storage[b]	12	7.3
Efficiency of storage means[c]	40%	85%
Total annual electricyt consumption from storage means[d]	4.8	6.2
Total equivalized storage (dollar per MWh)[e]	194	122
Total annual storage cost (NIS million)[f]	931	757

[a] Electricity consumption from renewable energy equals total electricity production from renewable energy minus energy that is lost during storage.
[b] Electricity production allocated to means of storage, gross.
[c] Efficiency means total utilized energy (output) divided by total stored energy (input).
[d] Quantity of energy used to produce electricity from stored energy.
[e] Assuming that the equivalized costs of both means of storage are fixed (not dependent on the quantity produced) - from Lazard and Bloomberg estimates. Includes the cost of producing energy that is lost during storage.
[f] The cost is a multiple of the quantity of energy consumed from storage and the normalized cost of storage.
SOURCE: Based on Bloomberg and Lazard.

liquid, and absorption into other chemical substances, such as ammonia. In this analysis, it is assumed that containers are used to store the hydrogen in the form of compressed gas.[15] The cost of storing hydrogen in this manner is estimated at about 19 cents per kilogram.[16]

Despite the economic advantage of batteries in the above scenarios, there are predictions that by 2050 the cost of producing hydrogen will drop drastically—to about $50 per megawatt hour—thanks to

[14] This is because in both situations, total demand by consumers is the same, as is the case for production from fossil fuels. Thus, for example, storing electricity using hydrogen requires greater renewable energy production capacity, but since these sources are also available during the daytime, the use of fossil fuel can be reduced during the daytime and increased during the nighttime. This reduces the need to consume stored energy from renewable sources during the nighttime.

[15] The compression solution was chosen in this analysis since it is relatively common, technologically straightforward, and designed for short-term storage. However, there are underground caves where hydrogen could be stored. The solution of absorption in other chemicals is common primarily as part of hydrogen storage during transportation from one location to another.

[16] For further details, see Bloomberg's Hydrogen Economy Outlook.

technological improvements and the large amounts invested in hydrogen R&D.[17] The situation is more complicated for batteries. Thus, although there are also predictions that their price will fall as a result of technological progress (though at a slower pace than for hydrogen), batteries are produced partly from lithium, which is quarried and has a limited quantity. It is therefore difficult to rule out the possibility that without a major technological breakthrough, together with an increase in global demand[18], prices will in fact rise. In the context of the environment, it is important to mention that production of lithium ion batteries creates pollution, and as of today, the recycling of batteries is not worthwhile for producers and is being done on a relatively small scale. This means that a significant portion of these batteries currently end up in landfill and constitute an additional source of pollution.[19] This issue will require a solution in the future, by means of a policy that will lead to the internalization of landfill costs and make it worthwhile to recycle the batteries.[20]

This box has presented separate scenarios for the two storage methods, but the optimal solution may necessitate a combination of the two. This is particularly the case in view of the current advantages of batteries for intraday storage alongside the ability of hydrogen to also store energy for longer time periods.

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[17] Bloomberg's Hydrogen Economy Outlook.
[18] Partly as a result of growth in the storage of green energy and in the number of zero-emission vehicles.
[19] The calculations do not include this cost.
[20] For further details, see "Reducing the Climate Footprint of the Transportation Industry in Israel," by Yossi Margoninsky and Lior Gallo, in Selected Research and Policy Analysis Notes, Bank of Israel Research Department, October 2021.