ARTICLE

Israel's Renewable Energy Strategy: A Review of its Stated Goals, Current Status, and Future Prospects

Sujata ASHWARYA *

Abstract

Israel's commitment to renewable energy development stems from a desire to reduce its reliance on imported fossil fuels while also meeting environmental goals. The Israeli government has aided the development and expansion of the renewable energy sector through a series of favorable regulatory decisions. Solar energy has established itself as the primary driver of the country's renewable energy development. Wind energy development, on the other hand, is hampered by a slew of political and administrative squabbles, and biomass technology, which is not considered profitable due to its inability to generate grid-level electricity, is investment-constrained. While wind and biomass renewable technologies would benefit overall renewable energy development, they currently offer only marginal growth opportunities. As intermittent renewable energy sources become more common in the electric grid, Israel's expanding hydropower capacity will help to maintain grid stability and reliability by stepping in during unplanned outages. The country's 2030 goal is to phase out coal, oil and diesel, and renewable energy will be critical to achieving that goal. Solar photovoltaic tariffs have dropped significantly in recent years, putting this energy resource in direct competition with natural gas, which Israel has in abundance due to its Eastern Mediterranean reserves. Although renewables do not threaten the dominance of natural gas in the electricity market, Israel's goal of 30 percent renewable energy in the country's energy mix by 2030, achieved through increased capacity addition across technologies, will help the country meet its climate change mitigation goals.

Keywords

Israel, renewable energy, fossil fuels, hydropower, smart meter.

* Associate Professor, Centre for West Asian Studies, Jamia Millia Islamia, New Delhi, India.
E-mail: scheema@jmi.ac.in. ORCID: 0000-0001-6700-619X.

Received on: 05.05.2021
Accepted on: 11.10.2021

Introduction

Israel's energy system is extremely vulnerable, as the country is an electricity "island" with no interconnections to the grids of its neighbors—a result of its unique history in the conflict-ridden region. Approximately one-third of its electricity generation is currently derived from imported coal, and the transportation sector is entirely reliant on imported crude oil. Coal and oil imports account for a sizable 63 percent of Israel's total primary energy supply (TPES). Although natural gas from indigenous fields—discovered in 1999–2000 in Israeli economic waters in the Eastern Mediterranean and in significant quantities ten years later—has become the country's "fuel of choice" for power generation, significantly improving its energy security, reliance on imported fossil fuels entails economic and security risks associated with the need to maintain energy supplies. These risks, however, can be significantly mitigated by integrating renewable energy into Israel's energy system, given the country's substantial solar, wind and hydropower resources. While the government authorized the incorporation of renewable energy into Israel's energy supply chain in 2002 by inviting independent power producers (IPPs) to construct and operate solar energy facilities, renewable energy's share of total electricity generation has remained relatively low.[1] In addition, the country's renewable energy portfolio is not particularly diverse, with solar energy accounting for the lion's share of supply.

Despite a 17 percent year-on-year increase in 2018–2019, Israel's solar energy penetration rate remains among the lowest in the world, especially when compared to OECD countries, particularly Europe, which receive significantly less sunlight. Despite having one of the highest irradiance rates in the world and an abundance of sunlight throughout the year,[2] a number of factors have slowed Israel's development of solar energy and other renewable energy sources. The most significant barriers have been bureaucratic red tape, onerous regulations and difficulty in acquiring land for renewable energy farms. For years, Israeli inventors have been developing cutting-edge solar energy technologies, but due to the difficulty of bringing their inventions to market in Israel, they have primarily exported their expertise.

Despite these obstacles, non-fossil fuel electricity generation gained traction after the Israeli government enacted a regulatory mandate in 2011 requiring the optimization of renewable energy in power generation through grid-connected quotas for each renewable energy technology. A slew of financial incentives, including feed-in tariffs (FIT), the elimination of taxes on residential solar and wind energy generation and the net-metering system, have all contributed to the growth and diversification of Israel's renewable energy market.[3] When the Public Utilities Authority (PUA) for Electricity (colloquially called the Electricity Authority) launched a solar tendering round in 2017, it ushered in a new era of market-driven renewable development by removing the red tape associated with licensing, eliminating long lines and mountains of paperwork for renewable energy entrepreneurs.[4]

In addition, the Israeli government has funded renewable energy research in order to advance the field's development. In 2019, the Office of Chief Scientists of the Ministry of Industry, Trade and Labor allocated $1.45 billion USD, equivalent to 5 billion Israeli New Shekel (NIS), to clean technology research and development projects, including renewable energy.[5] The 2018 electricity market reforms, which separated the electricity generation and transmission segments of the public utility Israel Electric Corporation (IEC), significantly increased opportunities for local and international IPPs to build and operate renewable energy plants. By 2025, private electricity generation facilities are expected to account for 60 percent of Israel's total capacity.[6]

This article examines the various renewable energy technologies currently in use in Israel, as well as the government's efforts to accelerate their development in light of the Paris Climate Agreement's quantitative pledges to improve air quality and reduce emissions. It contends that in the coming years, the solar energy sector will be the primary driver of Israel's renewable energy expansion, owing to governmental support, the presence of excellent natural solar resources, declining technology costs and political and administrative disputes over wind energy development. Hydroelectricity, for which Israel has set a separate development quota, will serve as a backup source to compensate for the intermittent nature of renewable energy sources, which are increasingly being integrated into the country's power grid.

Hydroelectricity, for which Israel has set a separate development quota, will serve as a backup source to compensate for the intermittent nature of renewable energy sources, which are increasingly being integrated into the country's power grid.

Renewable Portfolio Standard: Evolution and Implementation

Israel is proud of its renewable energy pioneering history. Following the country's establishment in 1948, Prime Minister David Ben Gurion made the visionary decision to establish an Israel Research Council to promote research and development that would apply scientific knowledge to the task of developing a new nation with almost no natural resources. In the Research Council's Physics and Engineering division, Harry Tabor, a British scientist hired by Ben-Gurion, developed the Tabor Selective Surface—thermal panels capable of absorbing and storing solar energy. Tabor then incorporated this technology into the water boiler, yielding what many Israelis affectionately refer to as a "dude shemesh" or sun boiler: solar-heated water tanks that have been a fixture on Israeli rooftops since the 1960s.

By 1967, 50,000 sun boiler systems were being sold each year,[7] and this technology was widely adopted locally following a 1980 law requiring the installation of solar water heating systems on all new residential buildings up to 27 meters in height.[8] With this national building code in place, Israel achieved

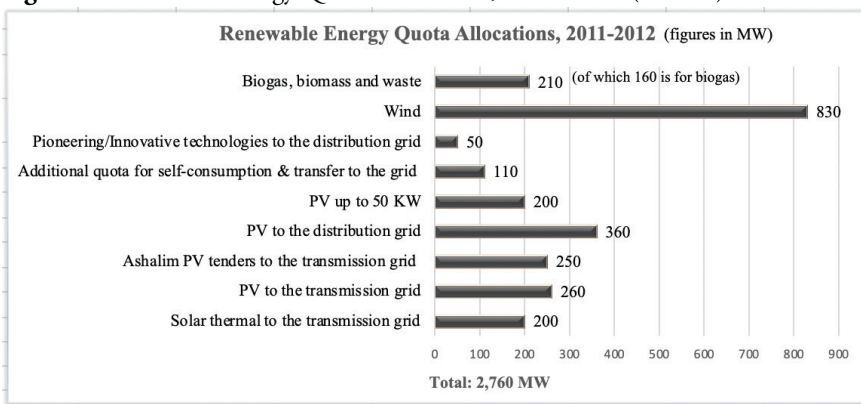
one of the highest penetration rates of solar water heaters in the world, contributing to a 3 percent reduction in electricity consumption over time. Israel is now the world leader in solar water heating systems, with 85 percent of households heating their water using rooftop solar collectors.[9] However, from 1948 until the early twentieth century, there was a strong bias in Israeli policymaking circles in favor of fossil fuels, which were viewed as a more reliable source of energy. There were few takers in the energy ministry for a proposal to implement renewable energy technology on a national scale.

Nonetheless, Israel's 1992 accession to the United Nations Framework Convention on Climate Change sparked internal debate about climate change mitigation, prompting the IEC to integrate natural gas into electricity generation and the energy ministry to consider using renewable energy to clean up the country's power grid. This shift in thinking resulted in the development of a Renewable Portfolio Standard (RPS). The RPS is a collection of regulatory provisions aimed at increasing the use of non-fossil fuel alternatives for electricity generation through the allocation of developmental quotas for each type of renewable technology. Its objective is to diversify a country's energy sources, reduce reliance on expensive fossil fuel imports, promote domestic energy research and reduce polluting emissions. The RPS establishes progressive targets or requires utilities to sell a certain percentage of electricity generated by renewable sources.[10] Global advancements in renewable energy generation are fueled by national commitments to renewable energy.

The first step in the evolution of the RPS in Israel was taken in November 2002, when Government Decision (henceforth, Decision) 2664 mandated the integration of renewable energy into the electricity sector with a minimum 2 percent share by 2007 (above domestic solar water heaters) increasing to 5 percent by 2016.[11] In accordance with Decision 2664, the government implemented policy measures, such as a tariff review and renewable energy technology quotas, to encourage businesses to invest in renewable energy projects. The construction of two large privately-funded solar power plants with a combined capacity of 250 megawatts (MW)[12] near Kibbutz Ashalim in the Negev Desert was approved by Decision 3338 in March 2008.[13] Simultaneously, the government introduced tax benefits for solar photovoltaic (PV) facilities.

In January 2009, Decision 4450 revised the 2002 renewable energy targets to 5 percent and 10 percent by 2014 and 2020, respectively, and included a quantitative target of 1,550MW and 2,760MW. Notably, the Ministry of National Infrastructure was tasked with the responsibility of promoting renewable energy projects as national infrastructure projects. Decision 3484, issued in July 2011, precisely defined grid-connected quotas for solar, wind, biogas and biomass technologies.[14] Solar energy, including residential PV and wind energy, received significantly higher quotas (Figure 1). These quotas were to be distributed by the Electricity Authority, the body in charge of enforcing RPS decisions.

Figure 1: Renewable Energy Quota Allocations, 2011–2012 (in MW)



Source: Author; Government Resolution No. 3484, July 17, 2011; A. Fakhouri & A. Kuperman, "Backup of Renewable Energy for an Electrical Island: Case Study of Israeli Electricity System—Current Status," *The Scientific World Journal* (Hindawi), 2014, p. 4.

In 2008, the Electricity Authority introduced the FIT as a financial incentive to advance Israel's renewable energy sector, and established the tariff rates that the IEC must pay to IPPs or domestic rooftop solar power producers.[15] Israel's solar generation capacity increased steadily and significantly from 2008 to 2012 (Table 1), when the FIT was phased out. Furthermore, as the Decision 3484 empowered the Electricity Authority to conduct a tariff review in order to meet renewable energy targets, it implemented a "net metering scheme" in January 2013. This was intended to encourage self-consumption by domestic producers who had solar panels installed on their roofs.[16] Under net-metering, the IEC would purchase excess energy generated on rooftops by home energy producers. According to the current provisions, whatever mechanism is used for the sale of renewable electricity by entrepreneurs and home users, the tariff will always be determined by the Electricity Authority.[17]

In the run-up to the Paris Climate Conference in November 2015, the Israeli government set a long-term national target of 17 percent clean energy generation by 2030 and a shorter-term target of 13 percent by 2025 to achieve net zero emissions.

In the run-up to the Paris Climate Conference in November 2015, the Israeli government set a long-term national target of 17 percent clean energy generation by 2030 and a shorter-term target of 13 percent by 2025 to achieve net zero emissions. Both of these targets were lofty, given that renewable energy accounted for only 2 percent of Israel's electricity generation at the time. Former Energy Minister Yuval Steinitz announced a new, higher target of 30 percent share by 2030 in February 2020, with an interim target of 17–20 percent

by 2025.[18] The elimination of imported coal from Israel's energy mix and total self-sufficiency in electricity generation would occur concurrently. Notably, Israel's decision to raise the renewable energy target coincided with a 362MW increase in solar power capacity, indicating growing confidence in renewable energy development. The year 2020 saw the highest growth in solar power in the previous 15 years, with installed capacity nearly doubling (Table 1).

Table 1: Installed Capacity and Electricity Generation for Solar PV and Solar Thermal in Israel (2005-2020)

Year	Photovoltaic				Solar Thermal			
	Installed Capacity (MW)		Electricity Generation (GWh)		Installed Capacity (MW)		Electricity Generation (GWh)	
	Net Additions	Cumulative	Net Additions	Cumulative	Net Additions	Cumulative	Net Additions	Cumulative
2020	1,040.0	2,230	-	-	(-6.1)	242.0	435.7	447.7
2019	120.0	1,190	1,023	2,597	242	248.1	-	11.3
2018	101.0	1,070	63	1,574	0	6.1	-	11.3
2017	103.0	969	-15	1,511	0	6.1	-	11. 3
2016	100.3	866	365	1,525	0	6.1	-	11. 3
2015	95.8	766	320	1,160	0	6.1	-	11. 3
2014	250.0	670	346	840	0	6.1	-	11. 3
2013	183.3	420	92	494	0	6.1	-	11. 3
2012	47.0	237	80	402	0	6.1	-	11. 3
2011	119.8	190	204	322	0	6.1	-	11. 3
2010	45.4	70	77	119	0	6.1	-	11. 3
2009	21.5	25	37	42	0	6.1	0.2	11. 3
2008	1.2	3	2	5	0	6.1	-	11.1
2007	0.5	2	1	3	0	-	-	-
2006	0.3	1	1	2	0	-	-	-
2005	-	1	-	2	0	-	-	-

Source: International Renewable Energy Agency, September 2021.

Solar PV: Introduction of Competitive Tendering

As of 2017, it was becoming increasingly clear that there was a mismatch between the allotted quotas and their utilization. In light of this discrepancy, Israel's energy ministry decided to launch a new incentive plan for the deployment of 1,600MW of PV capacity over the next three years. The new scheme, designed to support all types of PV facilities—including ground-mounted units, large roofs, reservoirs and

small roofs—included a call for tenders and the reinstatement of the FIT.[19] Small rooftop PV installations that did not compete in tenders could send power to the grid at a fixed rate under the FIT scheme. PV projects with a maximum capacity of 15KW were eligible for net metering or FIT for a period of 20–25 years.[20]

While the new scheme retained net metering for installations up to 5MW, the minimum capacity for a single tender was set at 50MW. A tender participant could either sell all electricity to the grid at the winning tariff or to other consumers connected to the same solar roof.[21] Another tendering process awarded the right to build 168MW of solar PV capacity in the Negev desert to three local companies in July 2020 as part of the 300MW scheme launched earlier that year.[22] These projects, which are expected to be completed by 2022, will allow Israel to meet its interim target of 17–20 percent renewables in electricity generation.[23]

By eliminating the bureaucratic regulatory burden that had long been a significant issue for developers, the transition from quota-based FITs to competitive auctions increased predictability in solar PV development.[24] Developers/entrepreneurs of renewable energy can now simply seize the opportunity by offering the best price. The Electricity Authority created open bids to encourage competition, which would eventually lead to lower electricity prices, benefiting consumers if not the profit margins of renewable developers.

In the midst of the COVID-19 pandemic-related losses, the Israeli government's "stimulus package" for economic recovery calls for the addition of 2GW of solar capacity, which will require a total of $7.1 billion in private investment.

In the midst of the COVID-19 pandemic-related losses, the Israeli government's "stimulus package" for economic recovery calls for the addition of 2GW of solar capacity, which will require a total of $7.1 billion in private investment. This capacity addition, backed by the government to the tune of $145 million USD (NIS 500 million) in state guarantees,[25] will complement the 15GW of solar energy required in the coming years to bring renewable energy to 30 percent of total electricity generation by 2030.[26]

Over 80 percent of Israel's electricity generated during peak hours will come from renewable energy sources, primarily solar, with the remainder coming from indigenously produced natural gas. Renewables would

meet 100 percent of demand during certain hours, and surplus energy would be stored in batteries.[27] Simultaneously, coal, which currently accounts for 30 percent of the country's electricity generation, would be phased out by 2025.[28] IPP-led investments in renewable generation facilities include the development of energy storage options and grid modernization. The IEC has also unveiled a complementary plan to double transmission capacity from the Negev, which is home to some of Israel's largest solar farms, to the central, more populated areas.

As the share of natural gas produced from Israel's Eastern Mediterranean reserves in electricity generation increases and coal-fired units are phased out, renewables promise increased self-sufficiency for Israel's isolated grid. The cost of solar energy generation continues to decline, and the price is approaching 20 agorot (5.8 cents) per kWh (kilowatt-hour),[29] the reported price at which the IEC will purchase power for 23 years from the winner of the July 2020 solar PV quota awards.[30] In June 2019, EDF Renewables Israel set a record low price of 8.68 agorot (3 cents) per kWh for Ashalim's fourth solar PV energy plant, a significant reduction from the 40 agorot (12 cents) per kWh of Ashalim's first solar thermal plant, which has been operational since December 2017.[31] When compared to natural gas, which costs nearly 7.5 cents per kWh,[32] PV solar appears to be Israel's cheapest energy source, achieving grid parity and kicking Israel's transition to clean energy into high gear.

Given Israel's promotion of rooftop solar panels as a means of increasing the share of renewable energy consumption in a small country, this capacity is increasing by leaps and bound; in 2020 alone, solar PV capacity increased by 87 percent (Table 1). Rooftop generation is a true democratization of electricity generation, and it is emerging as the driving force behind the greening of Israel's power grid.

Wind Energy Generation: A Perilous Endeavor

Wind energy development in Israel has been the slowest of all renewable energy technologies, despite its enormous potential in the country's hilly and mountainous terrain. In 2009, the Electricity Authority approved the FIT for small-scale wind turbines and established a quota of 30MW (domestic consumers up to 15kW and commercial turbines up to 50KW). It allocated 800MW for installation by 2020 and approved the FIT for medium and large wind turbines in 2011.[33] However, the government reduced the wind energy quota by 90MW in October 2014 via Decision 2117, claiming that the sharp decline in solar tariffs increased the cost of wind energy, and thereby transfer-

ring approximately 110MW to the solar PV industry.[34]

Wind energy development in Israel has been the slowest of all renewable energy technologies, despite its enormous potential in the country's hilly and mountainous terrain.

Only a few of Israel's 23 proposed wind energy projects have received all of the necessary approvals, and only two wind farms have been connected to the power grid. This is due to the high cost of wind energy generation and opposition from a variety of groups, including environmental activists and the military. Since the early 1990s, Israel has operated a 6MW wind farm in Tel Asania on the Golan Heights,[35] though it is currently in need of repowering. There are currently conditional approvals for wind projects in Golan, specifically the Emek HaBacha (102MW) and Emek Haruchot (169MW) projects, as well as the Ruach Bereshit (130MW) project in the Lower Galilee region.[36] An added 152MW wind project in the northern Golan Heights is also in the works as a critical national infrastructure project.[37]

Emek HaBacha is the most advanced wind project in Israel, with completion scheduled for the end of 2021. Under a 20-year power purchase agreement, the IEC will purchase electricity from the Emek HaBacha project at a rate of 35.81 agorot (Shekel 0.3581) per kWh.[38] This price is instructive because it is lower than that of previously sanctioned projects, but still significantly higher than that of solar PV. In 2014, the Electricity Authority approved a purchase rate of 48.5 agorot (Shekel 0.4851) per kWh for the proposed wind farms in Ramat Sirin (9MW) and Ma'ale Gilboa (11.9MW).[39] In any case, these two projects remain dormant due to a lack of approval from authorities who have cited potential harm to bird and bat populations as well as interference with Israel Air Force operations.[40] Hence, cost is not the only impediment to wind energy development in Israel, as evidenced by the country's low installed capacity of 27MW.[41]

Opposition to Wind Energy

In comparison to solar PV and concentrated solar power, wind energy development has been hampered by strong domestic opposition. Wind turbines, according to environmentalists, harm rare birds nesting in Golan, where wind assessments are optimal for the establishment of wind farms.[42] Environmental-legal challenges brought against wind farm developers have slowed the development of wind energy projects. However, one positive result has been that developers have been forced to take extra precautions with their tasks, such as installing special night radar to reduce bird deaths.[43]

The Israeli Ministry of Defense has long been a formidable impediment to wind energy development, citing operational, radar and other critical system disruptions. Following the rejection of the Sirin project by the National Infra-

structure Committee in January 2020, the Israeli ministries of energy, defense, and finance signed a framework agreement to jointly fund NIS 250 million ($72 million USD) for the development of new technology required for wind turbine operation without interfering with military or air force operations.[44] The agreement removes one of the major obstacles to large-scale projects in the Golan Heights.

Wind turbines have also met with strong opposition in Golan from both Arab Druze farmers and Jewish settlers, who fear the proposed installations will endanger human health and the region's fragile biodiversity. Druze farmers are concerned about a number of other issues as well. The planned renewable energy projects in Golan, according to al-Marsad, are a manifestation of Israel's efforts to strengthen its occupation of this Syrian territory. Al-Marsad notes in a forceful report, *Windfall*, that Israel has prioritized the production of natural resource industries in the occupied territories, owing to the fact that these industries are "physically embedded in the land."[45] Israel's creation of "facts on the ground," the authors argue, also explains its efforts to mine oil in the Golan Heights since 2013 from a geologically complex shale play.

According to the report, Israel is looking for a new way to bolster its hold on the Golan Heights by expanding wind energy development there. Many Druze farmers in Golan villages who leased their land to Israeli developer Energix for wind farms claim they were misled by "exaggerations, misleading information, and lies about the perceived benefits."[46] They claim that they signed the lease contracts out of desperation after being unable to sell their produce due to Syria's civil war and seeing their incomes dwindle. Energix's compensation offer appeared reasonable in these circumstances; however, it turned out to be significantly less than the amount offered to Jewish settlers and granted the company unqualified rights. Hundreds of Druze Agricultural Cooperatives and individuals have protested Energix's proposed wind energy development. However, the inspector appointed by the Israeli National Planning and Building Council (for national infrastructure) to investigate the Druze's complaint has rejected all of their objections.[47] Despite community opposition, Israeli companies plan to build 45 wind turbines on 600 hectares of Druze farmland.[48]

Hydropower Expansion as a Back-Up for New Renewables

Hydroelectricity is a tried-and-true, low-cost renewable energy source. The Israeli Energy Ministry has allocated 800MW of pumped hydro-storage capacity for national deployment. Israel lacked hydroelectric generation until July 2020, when the 300MW Gilboa Pumped Storage Hydropower (PSH) in the North began operations.[49] Another PSH project in the works is the 344MW Kokhav Hayarden PSH project in Israel's Northeast.[50] A third project, to build a 156MW PSH facility in Northern Israel, was granted a conditional license in June 2020.[51] Notably, Israel's PHS plants are located in Northern

Israel near Lake Tiberias, the country's primary source of fresh surface water.

In light of Israel's water scarcity, the country's hydroelectric projects are PHS systems that require the construction of two reservoirs separated by a steep gradient and connected via a network of tunnels. Water is allowed to fall from the upper reservoir onto the turbine blades, turning them and generating electricity. After that, water is channeled to collect in the lower reservoir. When the grid is overloaded with power (typically at night or during periods of low demand), the turbines reverse direction to recharge the upper reservoir. Because a PHS project does not qualify as 'new renewable energy source' under the current governmental regulations, the IEC must purchase electricity from it under a 20-year fixed dispatch agreement rather than through the feed-in tariff.

Benefits of Hydroelectricity to Israel

PSH plants are critical components of grid management and control. They can provide electricity to the national grid in less than two minutes and meet peak demand, ensuring grid stability. Moreover, PSH plants eliminate the need for more expensive and environmentally harmful conventional power plants. The upper and lower reservoirs in a PSH plant act as potential energy stores that can be used when needed to ensure the reliability of an electricity system. Hydroelectric generation can meet a significant portion of the grid's variable electricity load as Israel's grid incorporates an increasing amount of renewable energy.

In the event of a power outage, hydroelectricity would allow the IEC to respond quickly and effectively. PSH plants can store energy for extended periods of time, making them an important tool for managing, controlling and streamlining the power system. They are also extremely valuable because they reduce Israel's reliance on imported fossil fuels, improving the country's energy security.

Biogas and Renewable Municipal Waste: A New Frontier

Biogas technology is a technique for producing fuel gas from organic matter such as animal manure, agricultural waste, municipal waste, green plants, sewage, agro-industry and food waste. Biogas is a low-energy fuel because it contains between 50–75 percent methane, as opposed to natural gas, which contains between 80–90 percent methane. Biogas is an excellent energy source for stoves, heaters, lamps, refrigerators and internal combustion engines. The use of a generator to convert biogas to electricity is a well-established technology. Power generation plants using biogas have a significant advantage over solar and wind facilities in that they provide a consistent, non-weather-dependent

source of energy. The production of biogas and renewable municipal waste energy also contributes to environmental cleanliness, sanitation, hygiene and groundwater protection. In Israel, where agricultural emissions account for 2.8 percent of total greenhouse gas emissions (2.26 million tons), biogas production could help maximize resource efficiency.[52]

The Electricity Authority established a FIT for biogas plants with a maximum capacity of 160MW in 2011. Nonetheless, in 2014, a ministerial decision allocated 60MW of the biogas quota to solar PV due to growing interest. As of 2020, Israel had 29.3MW of installed renewable energy capacity for biogas and municipal waste out of a total of 100MW quota allocated in 2011 (Table 2). Despite significant progress, biogas projects have been slow to gain traction as biogas cannot supply grid-level electricity, making it less profitable than wind or solar. While biogas will never be able to completely replace conventional fuels, it does have significant emission-reduction potential, which alone should qualify it for increased government support.

Israel is currently building the world's most advanced and environmentally friendly waste-to-energy facility in the Ma'ale Adumim settlement near Jerusalem.[53] This facility would be the first in a series of environmentally friendly alternatives to Israel's landfills, and it is one of several infrastructure projects being promoted by the government as part of the larger 2030 Infrastructure Program, which includes transportation, water, energy and environmental protection. It will help to significantly reduce the national landfill disposal rate from 80 percent to 26 percent.[54]

Despite significant progress, biogas projects have been slow to gain traction as biogas cannot supply grid-level electricity, making it less profitable than wind or solar.

Table 2: Energy from Biogas and Renewable Municipal Waste since the Introduction of Quota and FIT

Year	Biogas		Renewable Municipal Waste	
	Installed Capacity (MW)	Electricity Generation (GWh)	Installed Capacity (MW)	Electricity Generation (GWh)
	Cumulative	Cumulative	Cumulative	Cumulative
2020	26.0	-	-	-
2019	25.0	81.3	3.2	-
2018	25.0	162.7	3.2	-
2017	25.0	162.7	3.2	8
2016	25.0	162.7	3.2	8
2015	25.03	162.7	3.2	8
2014	13.8	89.6	3.2	8
2013	10.9	71.1	3.2	8
2012	6.9	45.1	3.2	8
2011	6.9	45.1	3.2	8

Source: IRENA, September 2021.

Biogas as a Tool for Promoting Peace

Portable bio-gas generators known as 'digesters,' made in Israel, are increasingly being used to generate clean energy for Palestinian villages in remote, off-grid areas of the West Bank.[55] Around 40 digesters have been installed in Al-Awja, a Palestinian village in the Jordan Valley, as part of a European Union-funded pilot project to promote Israeli-Palestinian cooperation through Tel Aviv's Peres Center for Peace and Innovation.[56] In addition, researchers affiliated with the Arava Environmental Studies Institute (AEIS) in the Negev have provided organic waste digesters to Susya, a rural village in Hebron, in collaboration with the Israeli NGO Villages Group. In this location, bio-digesters generate electricity and fertilizer for Palestinian farmers.[57]

A number of bio-digesters have also been installed in Bedouin communities in Israel and Jordan as part of a joint effort between the Middle East Regional Cooperation Program, a USAID-funded research grant program, and AEIS.[58] By utilizing livestock manure that would otherwise accumulate on their land, cause disease and pollute the environment, the biogas equipment now provides low-cost cooking gas to these rural communities.[59] These digesters are portable and can be easily relocated if the Bedouin community so desires.

Smart Grid and Renewable Energy Integration

In Israel, electricity is distributed centrally from power plants that use fossil fuels, allowing the IEC to maintain control over supply and demand. The transition to renewable energy and decentralized electricity generation in Israel will necessitate a shift in grid structure. The increased emphasis on rooftop and backyard solar generation results in bidirectional electricity flow, necessitating efficient management of thousands of producers with varying outputs. In this decentralized production scenario, any endpoint on the grid can act as both a producer and a consumer of green electricity.[60] The 'smart grid' comes into play here.

A smart grid is an upgraded electricity distribution system that makes use of two-way, automated communication technology to collect and analyze real-time data. It enables producers and consumers to make real-time energy purchasing, sales and storage decisions—similar to mobile phone usage packages. As an integral part of the smart grid, smart meters benefit both producers and consumers. While they enable electric utilities to forecast demand in real time, they also provide consumers with real-time information about their electricity usage. Utility companies can reduce operating and management costs by understanding consumption patterns, while consumers can tailor their electricity usage more precisely to their needs, saving both energy and money.

Israel's Smart Grid and Smart Meter Rollout

As part of the IEC's smart grid efforts, the company bid to replace the existing DMS (distribution management system) with an Advanced System (ADMS).[61] In March 2019, the state-owned electricity supplier signed a contract with GE for ADMS; its implementation began in December 2019 with completion scheduled for mid-2021.[62] The IEC's three-stage smart metering initiative is thus currently underway.[63]

The project's first phase, finished in 2014, included the installation of approximately 4,400 smart meters in Binyamina, Givat Ada and the Caesarea Industrial Zone in Northwestern Israel. In February 2017, the IEC awarded Erikson Israel Company a contract to supply smart meters for installation over the next three years as part of the project's second phase. Over 30,000 meters have been installed across the country, allowing the IEC to conduct a practical cost-benefit/tariff analysis of a full transition to smart meters.[64]

The IEC, which constructs, maintains and operates electricity transmission and distribution networks, plans to invest approximately $1 billion in grid modernization to meet the requirements of the 2018 electricity market reforms law.

The final phase will see a nationwide rollout of 2.6 million smart meter units beginning in 2021, ensuring that every meter in Israel will be a smart meter within a few years.[65] The IEC, which constructs, maintains and operates electricity transmission and distribution networks, plans to invest approximately $1 billion in grid modernization to meet the requirements of the 2018 electricity market reforms law. For example, given the more than doubling of Israel's solar energy capacity over the last five years (Table 1), which has been driven by solar power plants in the Negev, the IEC is building a massive Eshkol Negev power transmission line that is expected to be completed in 2023.[66]

Religious Opposition to Smart Meters

Implementing smart grid measures has sparked a number of public concerns, some of which are universal and some of which are unique to Israel. Some people are concerned that the detailed data collected on electricity consumption by smart meters constitutes an unprecedented invasion of their privacy. This is a recurring source of concern for this constituency. Others, including Binyamina residents, have expressed concern about the health risks associated with smart meter radiation. The IEC has responded that home meters would transmit data via a power cable to a regional data box, which would then transmit it via a cellular network to the company's computers, avoiding unnecessary radiation exposure.[67] The religious debate over the use of meters on the Sabbath is a uniquely Israeli issue. The observant Jewish community has already adopted a large number of automated electrical appliances to avoid violating the religious prohibition against using electricity on the Sabbath. There is no reason to believe that a solution to this smart meter problem cannot be found.[68]

Conclusion

The Israeli Ministry of Energy is adamant about eliminating coal, gasoline and diesel from electricity generation and transportation by 2030, and promoting the use of renewable energy and less carbon-intensive natural gas from indigenous fields. Solar PV generation has reached grid parity and has the potential to displace natural gas, which has been critical in Israel's power generation and industrial operations for more than a decade. Along with the liberalization of the electricity market, the renewable energy sector, particularly solar energy, is being vigorously promoted through policy measures. While there is currently no legislation mandating rooftop solar installation as part of the building code, it is clear that such measures could result in increased solar energy penetration. With renewables supplying an increasing amount of electricity, grid fluctuations caused by their intermittent nature present a challenge that must be managed carefully. In the event of a power outage, Israel's PSH can easily inject the necessary electricity into the country's grid, thus providing the country with unprecedented energy security.

Several concerns have been raised about Israel's burgeoning solar market, including whether the country's preference for abundant natural gas will lessen the urgency of renewable energy development. The IEC plans to replace coal-fired power plants in Hadera and Ashkelon with natural gas turbines, and the government is investing in gas infrastructure in the hopes that gas will continue to meet the majority of energy demand in the coming years. It is illogical to propose that Israel's energy system change and eliminate indigenous natural gas, which has provided the country with relative energy independence. Nonetheless, solar PV plants that have begun generating electricity at a significantly lower cost have called into question the cost-effectiveness of natural gas use in the power sector. In view of the imperatives of climate change mitigation and the country's need for a continuous and sustainable source of energy, it is safe to say that while natural gas will remain critical to Israel's energy system for the foreseeable future, renewable energy will contribute to increased electricity generation in the coming years.

Endnotes

1 According to the *BP Statistical Review of World Energy 2021*, renewable energy accounted for 3.3 percent of power generation in 2019 and 5.7 percent in 2020.

2 Annual incident solar irradiance is approximately 2000 kWh per square meter (sqm) at approximately 30 degrees North latitude, which equates to an average of 5.5 kWh per sqm radiative energy per day, indicating a very high intensity.

3 *The Israeli Net Metering Scheme: Lessons Learned*, Israel: Public Utilities Authority (PUA) Electricity, September 29, 2014, p. 2.

4 *Electricity Market Report for 2017*, Israel: Ministry of Energy, 2017, p. 63.

5 "Alternative Energy/Cleantech," *Nefesh B'Nefesh*, 2019, https://www.nbn.org.il/aliyahpedia/employment-israel/professions-index-employment-israel/hi-tech/alternative-energy/.

6 "Overview of the Israeli Electricity Market 2020," *LNRG Technology*, August 30, 2020, https://www.lnrg.technology/2020/08/30/overview-of-the-israeli-electricity-market-2020/.

7 Alon Tal, "Will we Always Have Paris? Israel's Tepid Climate Change Strategy," *Israel Journal of Foreign* Affairs, Vol. 10, No. 3 (September 2016), p. 411.

8 "Renewable Energy Planning and Policy—An Overview: Lawmakers Pass First Solar Energy Legislation," *Ministry of Environmental Protection*, February 19, 2017, https://www.sviva.gov.il/English/env_topics/climatechange/renewable-energy/Pages/Renewable-Energy-Planning-And-Policy.aspx.

9 K. Hudon et al., *Low-Cost Solar Water Heating Research and Development Roadmap*, Denver, Colorado: National Renewable Energy Laboratory, US Department of Energy, Office of Energy Efficiency & Renewable Energy, 2012, p. 23.

10 "Renewable Energy Standards," *Solar Energy Industries Association*, 2020, https://www.seia.org/initiatives/renewable-energy-standards; "Renewable Portfolio Standards," *National Renewable Energy Laboratory*, https://www.nrel.gov/state-local-tribal/basics-portfolio-standards.html.

11 *Decision Number 2664: Electricity Generation Policy—Renewable Energy* (in Hebrew), 2002.

12 A megawatt is a unit for measuring power, equivalent to one million watts.

13 "Financing has been Completed in a BOT Tender for the Planning, Construction and Operation of the Thermal Power Plant in Ashalim," *Ministry of Energy*, June 25, 2014, https://www.gov.il/he/Departments/news/ashalim_energy_station.

14 "Government Resolution No. 3484," *Government of Israel*, July 17, 2011, https://www.gov.il/he/Departments/policies/2011_des3484.

15 A FIT is a long-term contract between a government public utility and a small-scale renewable energy producer. It guarantees an over-the-counter price for each electrical unit injected into the grid by a producer. *The Israeli Renewable Energy Market and Regulation: Current Status Report*, Israel: PUA Electricity, June 1, 2013, p. 1; Arnulf Jäger-Waldau, *PV Status Report 2019*, Luxembourg: Publications Office of the European Union, 2019, pp. 1–85, https://ec.europa.eu/jrc/sites/jrcsh/files/kjna29938enn_1.pdf.

16 Net metering is a tax credit that allows homeowners and businesses with solar PV systems to export their net surplus to the grid. In exchange, 'credits' can be redeemed for a reduction in the user's electricity bill or for use at night or at other times of the year (for example, during the winter months) when electricity consumption exceeds output and more electricity is drawn from the grid. See "Israel Net-Metering Regulation Framework," *International Energy Agency*, August 25, 2017, https://www.iea.org/policies/6381-israel-net-metering-regulation-framework.

17 *The Israeli Net Metering Scheme*, p. 1.

18 Gwen Ackerman & Filipe Pacheco, "Renewable Energy Push Boosts Bets on Wind, Solar in Israel," *Bloomberg Quint*, August 26, 2020, https://www.bloombergquint.com/technology/renewable-energy-push-boosts-israel-investor-bets-on-wind-solar.

19 "Policy Principles—Additional Quota Required to Meet Government Targets for Electricity Generation from Renewable Energy by 2020," *Ministry of Energy*, November 26, 2017, https://www.gov.il/he/Departments/policies/renewable_energy_2020.

20 Veselina Petrova, "Israel Unveils Plans for 1st Solar Tenders, 1.6-GW Goal—Report," *Renewables Now*, November 27, 2017, https://renewablesnow.com/news/israel-unveils-plans-for-1st-solar-tenders-16-gw-goal-report-592435/.

21 Emiliano Bellini, "Israel Issues 1.6 GW Scheme for Rooftop Solar," *PV Magazine*, March 29, 2018, https://www.pv-magazine.com/2018/03/29/israel-issues-1-6-gw-scheme-for-rooftop-solar/.

22 José R. Martín, "Israel Seeks Developers for 300MW Solar Project in Negev Desert," *PV Tech*, January 24, 2020, https://www.pv-tech.org/news/israel-seeks-developers-for-300mw-solar-project-in-negev-desert.

23 Vaselina Petrova, "Pre-qualification Round in 300-MW Israeli Solar Tender Gets 27 Bids," *Renewables Now*, June 24, 2020, https://renewablesnow.com/news/pre-qualification-round-in-300-mw-israeli-solar-tender-gets-27-bids-703840/.

24 *Electricity Market Report for 2017*, Israel: PUA Electricity, 2017, pp. 66–67, https://www.gov.il/BlobFolder/generalpage/dochmeshek/he/Files_doch_meshek_hashmal_doch_meshek_2017_eng.pdf.

25 Emiliano Bellini, "Israel's Plan to Recover from Covid-19 Crisis Includes 2 GW of New Solar," *PV Magazine*, April 29, 2020, https://www.pv-magazine.com/2020/04/29/israels-plan-to-recover-from-covid-19-crisis-includes-2-gw-of-new-solar/.

26 Anu Bhambhani, "Israel Wants over 15 GW Solar By 2030," *Taiyang News*, June 3, 2020, http://taiyangnews.info/markets/israel-wants-over-15-gw-solar-by-2030/.

27 Amiram Barakat, "Israel's Renewable Energy Target: 30% by 2030," *Globes*, June 2, 2020, https://en.globes.co.il/en/article-israels-renewable-energy-target-30-by-2030-1001330943.

28 "Review of Developments in the Natural Gas Economy" (in Hebrew), *Ministry of Energy*, March 22, 2020, p. 11. https://www.gov.il/he/Departments/publications/reports/ng_2019.

29 A kilowatt-hour is a measure of electrical energy equivalent to a power consumption of one thousand watts for one hour.

30 Yoram Gabison, "An Energy Revolution for Israel: Solar Power to be Cheaper than Fossil Fuel," *Haaretz*, July 15, 2020, https://www.haaretz.com/israel-news/business/.premium-an-energy-revolution-for-israel-solar-power-to-be-cheaper-than-fossil-fuel-1.8994782.

31 Sue Surkes, "EDF Renewables Wins Tender to Build Solar Plant, Sets New Low in Prices," *The Times of Israel*, December 5, 2019, https://www.timesofisrael.com/edf-renewables-wins-tender-to-build-solar-plant-sets-new-low-in-prices/.

32 Lior Gutman, "Electricity from Solar Power has Become so Cheap, No Other Sources can even Compete," *CTECH (Calcalist)*, September 7, 2020, https://www.calcalistech.com/ctech/articles/0,7340,L-3848585,00.html; "Israel: EDF Renewables Wins a Call for Tenders for the Construction of a Solar Power Plant," *i24News*, December 8, 2019, https://www.i24news.tv/fr/actu/israel/1575654251-israel-edf-renouvelables-remporte-un-appel-d-offres-pour-la-construction-d-une-centrale-solaire%C2%A0%C2%A0.

33 "Market Overview—Renewables," *Green Energy Association of Israel*, *202*0, http://www.greenrg.org.il/he-il/english.htm#:~:text=Small%2Dscale%20wind%20turbine%20FIT,introducing%20a%20quota%20of%20800MW; Heather O'Brian, "Israel Plans Two-tier Wind Tariff," *WindPower Monthly*, February 1, 2011, https://www.windpowermonthly.com/article/1052519/israel-plans-two-tier-feed-in-tariff.

34 "Government Resolution 2117: Implementation of Government Targets for Electricity Generation from Renewable Sources—A Discussion of Appeals against the Decision of the Ministerial Committee on the Promotion, Development and Implementation of Renewable Energy," *Government of Israel*, October 22, 2014, https://www.gov.il/he/Departments/policies/2014_govdec2117; Ivan Shumkov, "Israel Revises Quotas to Open Space for 520MW of Additional PV," *Renewables Now*, October 23, 2014, https://renewablesnow.com/news/israel-revises-quotas-to-open-space-for-520-mw-of-additional-pv-444560/.

35 The Golan Heights (commonly known as Golan) is a 1,800-square-kilometer rocky plateau on the border between Israel and Syria in Southwestern Syria. Israel occupied the Golan Heights, the West Bank, East Jerusalem and the Gaza Strip during the June 1967 Arab-Israeli War. Following the establishment of an armistice line, the region came under Israeli military control. Syria attempted but failed to reclaim the Golan Heights during the 1973 War. Both countries signed an armistice in 1974; since then, a UN observer force has been stationed along the ceasefire line. Israel permanently occupied the Golan Heights and East Jerusalem in 1981, a move that has not been recognized by the international community.

36 Jan Dodd, "Israel's Plans to Tap into Wind Power Take Shape," *WindPower Monthly*, January 30, 2015, https://www.windpowermonthly.com/article/1331651/analysis-israels-plans-tap-wind-power-shape.

37 "Periodic Report for 2017," *Energix Group*, 2017, p. 44, https://www.energix-group.com/uploads/1543916097.pdf.

38 Yoram Gabison, "Largest Wind Energy Project in Israel Commences: Will Bring in NIS 105 Million Per Year," *The Marker* (in Hebrew), June 10, 2018, https://www.themarker.com/markets/1.6159248.

39 Aviram Barakat, "Electricity Regulator Accused of Smothering Wind Energy," *Globes*, June 30, 2014, https://en.globes.co.il/en/article-electricity-regulator-accused-of-smothering-wind-energy-1000950342.

40 Zafirt Rinat, "State Panel Rejects Wind Turbine Project in Israel's Lower Galilee," *Haaretz*, October 2, 2019, https://www.haaretz.com/israel-news/.premium-state-panel-rejects-wind-turbine-project-in-israel-s-lower-galilee-1.7924543.

41 "Onshore Wind Energy," in *Renewable Energy Statistics 2021*, New York: IRENA, 2021.

42 Andrew Lee, "Bird Campaigners Bid to Halt Israel's Largest Wind Farm," *Recharge*, February 11, 2019, https://www.rechargenews.com/wind/bird-campaigners-bid-to-halt-israels-largest-wind-farm/2-1-540367.

43 Rinat, Zafrir, "Wind Turbines in Israel Kill Many More Birds, Bats than Expected," *Haaretz*, December 20, 2017, https://www.haaretz.com/israel-news/wind-turbines-in-israel-kill-many-more-birds-bats-than-expected-1.5629170.

44 Eytan Halon, "Israel Green Lights Hundreds of Wind Turbines in North," *Jerusalem Post*, January 1, 2020, https://www.jpost.com/israel-news/israel-green-lights-hundreds-of-wind-turbines-in-northern-israel-612757.

45 Aaron Southlea & D. Nazeh Brik, *Windfall: The Exploitation of Wind Energy in the Occupied Syrian Golan*, Majdal Shams, Golan Heights: Al-Marshad Arab Human Rights Centre in Golan Heights, January 2019, p. 8.

46 Ibid, p. 18.

47 Al-Haq et al., "Occupied Syrian Golan Wind Turbine Project Poses Existential Threat to Indigenous Syrian Population," *Business and Human Rights Resource Centre*, https://www.business-humanrights.org/en/latest-news/occupied-syrian-golan-wind-turbine-project-poses-existential-threat-to-indigenous-syrian-population/.

48 Hazem Sabbagh, "People of Golan Reiterate Rejection of Israeli Occupation's Plans to Wind Turbines on their Land," *Sana News Agency*, May 18, 2020, http://sana.sy/en/?p=191964.

49 "Israel's 300-MW Mount Gilboa Pumped Storage Begins Operating," *World Energy*, May 8, 2020, https://www.world-energy.org/article/9080.html.

50 "GE Renewable Energy Books $100+MM Deal for Hydro Pumped Storage Project in Israel," *General Electric*, August 8, 2017, https://www.ge.com/news/press-releases/ge-renewable-energy-books-100mm-deal-hydro-pumped-storage-project-israel.

51 Max Hall, "Israel Prepares 800MW of Pumped Hydro Storage," *PV Magazine*, June 24, 2020, https://www.pv-magazine.com/2020/06/24/israel-prepares-800-mw-of-pumped-hydro-storage/.

52 Aimee Teplitskiy, "The Start-up that Turns Cow Patties into Clean Energy," *Israel21c*, August 4, 2019, https://www.israel21c.org/the-startup-that-turns-cow-patties-into-clean-energy/.

53 The international community considers all settlements built by Israel in territories occupied by it during the 1967 Arab-Israeli war to be illegal.

54 Etan Yalon, "Israel to Construct First Waste-to-energy Power Plant," *Jerusalem Post*, October 15, 2019, https://www.jpost.com/israel-news/israel-to-construct-first-waste-to-energy-power-plant-604380.

55 Robert Hackwill, "Palestinian Engineer Develops Affordable Gas Generator Powered by Waste," *Euronews*, December 1, 2015, https://www.euronews.com/2015/12/01/palestinian-engineer-develops-affordable-gas-generator-powered-by-waste.

56 Ori Lewis & Elana Ringler, "Israeli Biogas Digesters Energize Isolated Palestinian Village," *Reuters*, August 24, 2015, https://www.reuters.com/article/us-israel-palestinians-biofuels/israeli-biogas-digesters-energize-isolated-palestinian-village-idUSKCN0QT0RB20150824.

57 "Organic Waste Recycling & Biogas Production," *Arava Institute for Environmental Studies (AIES)*, https://arava.org/arava-research-centers/center-for-renewable-energy/organic-waste-recycling-biogas-production/.

58 Ibid.

59 Ibid.

60 Kirsi Kotilainen & Ulla A. Saari, "Policy Influence on Consumers' Evolution into Prosumers: Empirical Findings from an Exploratory Survey in Europe," *Sustainability*, Vol. 10, No. 186 (2018), p. 1.

61 DMS is an information technology system for utilities that collects, organizes, displays and analyzes data on a real-time electrical distribution system, enabling operators to plan and operate complex electricity distribution-related operations. It optimizes grid efficiency, prevents overload, and optimizes power flows. Apart from DMS operations, ADMS as a software platform enables the integration of renewable energy into the grid. Due to the fact that a large amount of cumulative power is injected into the grid's distribution section at various times (via decentralized renewable generation), ADMS includes functions that forecast load, prevent interruption and automatically restore shutdown. This way, the distribution network's performance can be optimized. *Utilities Find Success Using NREL's ADMS Test Bed for Grid Modernization*, Office of Energy Efficiency and Renewable Energy, US Department of Energy, March 2020, pp. 1–2; "Distribution Management System," *Open EI*, 2012, https://openei.org/wiki/Definition:Distribution_Management_System.

62 "Israel Electric Corporation Ltd. Electricity Generation, Transmission, Distribution, and Supply," *BDI Code*, 2018, https://www.bdicode.co.il/en/company/israel-electric-corporation-ltd-en/.

63 *Financial Reports*, Israel Electric Corporation Ltd, December 31, 2016, p. 77.

64 "Ericsson Israel Won a Procurement Tender for Supplying Smart Meters in the Electricity Network," *Tashtiot*, February 12, 2017, http://www.tashtiot.co.il.

65 "Smart Meters," *Tnuda*, January 23, 2018, https://www.tnuda.org.il/en/policy-and-legislation/smart-meters.

66 Amiram Barkat, "5% of Israel's Electricity Now Produced from Solar Energy," *Globes*, November 6, 2019, https://en.globes.co.il/en/article-5-of-israels-electricity-now-produced-from-solar-energy-1001306287.

67 Nati Yefet, "Erickson Israel Will Supply 200,000 Smart Meters to the IEC," *Globes*, February 2, 2017, https://www.globes.co.il/news/article.aspx?did=1001176544.

68 Lucy Michaels & Yael Parag, "Motivations and Barriers to Integrating 'Prosuming' Services into the Future Decentralized Electricity Grid: Findings from Israel," *Energy Research & Social Science*, Vol. 21 (November 2016), p. 71.