RENEWABLE ENERGY RESOURCES AND USE

Jordan is a front-runner in the region in terms of the speed and scale with which it has deployed renewable energy, especially in the power sector. Renewables accounted for over 13% of total electricity generated in 2019, up from a near-zero share in 2012. The growth has been made possible largely due to strong government commitment and action to diversify the primary energy mix.

The potential for renewable energy to contribute to Jordan's energy mix is much greater. The next phase of renewables growth in Jordan could focus on building the right enabling conditions for integrating higher shares of electricity from renewables in the power sector. Electricity also represents only 22% of final energy consumption as noted in the previous chapter. To diversify Jordan's energy mix, reduce reliance on imports and bring down energy costs, renewables in non-power end-use sectors – heating/cooling and transport – will absolutely need to be scaled up substantially from current levels.

This chapter discusses the renewable energy sector in Jordan, analysing the trends in deployment in the power, heating/cooling and transport sectors. It sets the stage for an in-depth discussion in the next chapter on policies and regulations – a key enabler for adoption and integration – and the investment landscape to identify gaps and challenges that need to be addressed to scale up renewable energy adoption.

3.1 Renewable energy resources

The presence of abundant resources is a crucial starting point for the development of renewable energy. It greatly influences the operational performance and financial viability of projects. Owing to its geographical position, Jordan's most abundantly available renewable energy resources are solar and wind, with potential also for bioenergy, hydropower and geothermal.

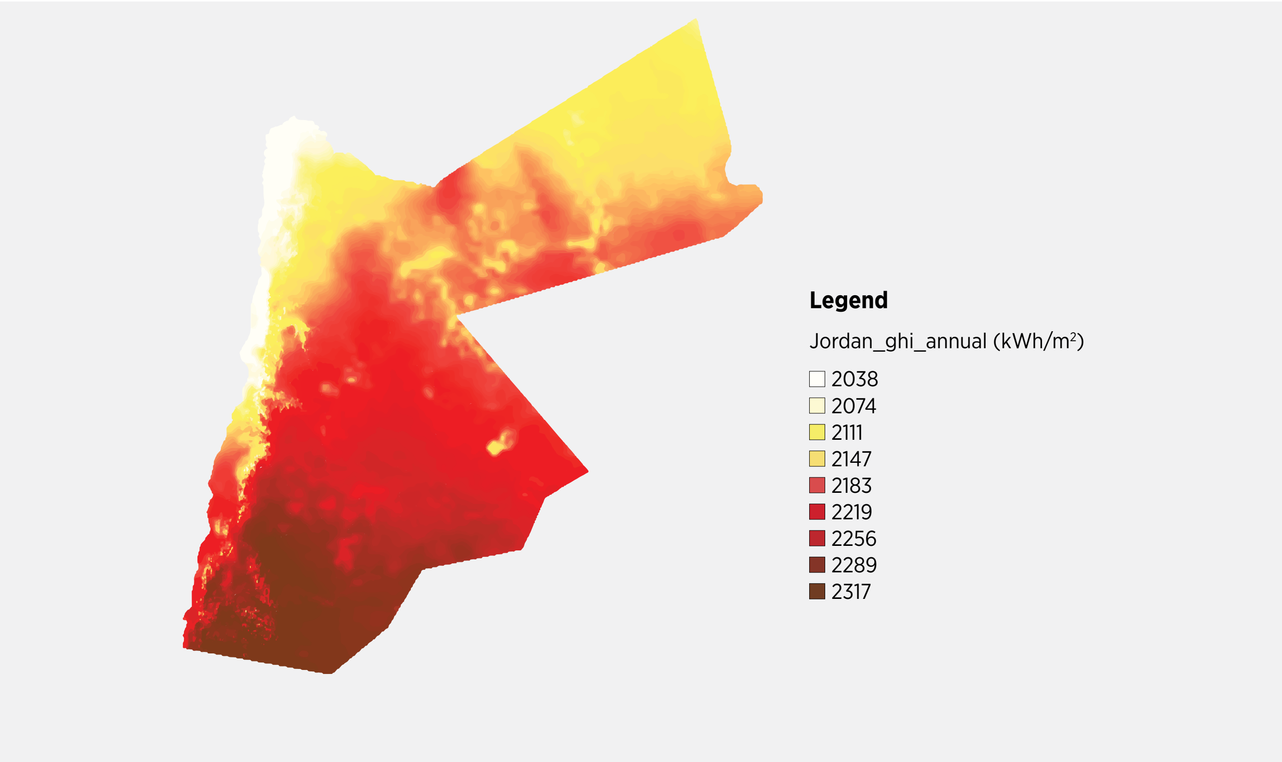
Solar

Average daily solar irradiation ranges between 4 and 7 kWh/square metre (m^2), with about 300 sunny days per year, which corresponds to an annual average solar irradiation of 1 400-2 300 kWh/m^2 (Figure 10). The favourable climate conditions have allowed Jordan to benefit from some of the most conducive solar sites at the regional and international levels. This is also reflected in the low cost of electricity generated from new projects.

Wind

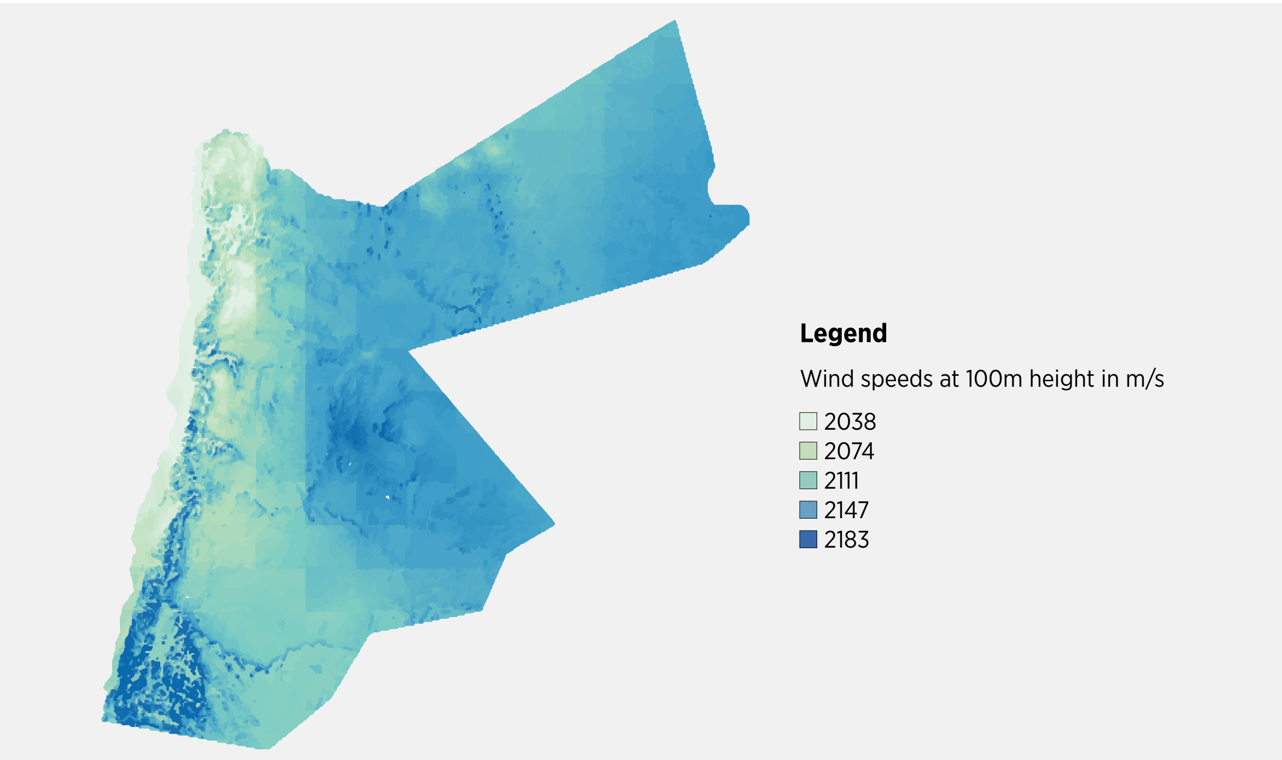
Jordan has significant wind energy resources to exploit for electricity generation. Average wind speeds are site-specific and generally range from 6 metre per second (m/s)to 8 m/s in good locations in the Kingdom (Marar, 2019) (Figure 11). According to a study carried out by the MEMR and the Royal Scientific Society, approximately 16% of the total country's land are suitable for wind power production, with a total technical potential of 3.6 GW (AlRahahleh, 2018).

Figure 10. Spatial distribution of global solar irradiation in kWh/m² resource maps for Jordan



Based on: IRENA Global Atlas, Solar PV Map Data: World Bank Group, 2018, Global Horizontal Irradiation kWh/m² World 1 km

Figure 11. Spatial distribution of wind irradiation in Jordan



Based on: IRENA Global Atlas, Wind Map Data: Technical University of Denmark Global Wind Atlas, Average Wind Speed 1 km at 100 m height

Bioenergy

Bioenergy resources in Jordan exist primarily in the form of municipal solid waste (MSW). The amount of municipal waste is rapidly growing as a result of the increasing population and represents an important resource. A pilot plant using MSW with a capacity of 3.5 MW has been operational since 2000. The Greater Amman Municipality plans to implement a biogas project by using the methane gas captured in the Ghabawi landfill, the main solid waste landfill in Amman. With the expansion of the landfill, the capacity is expected to reach 6 MW in 2020 and 7 MW in 2022. The opportunity to utilise biogas from waste for the transport sector also exists.

Animal waste also has potential for utilisation – albeit with a lower resource potential compared to municipal waste – on a smaller scale for heating/cooking purposes. More than 80% of total manure production, mainly from cattle, poultry and sheep, is concentrated in four northern governorates: Al Zarqa, Amman, Al-Mafraq and Irbid (Barilaro, 2019). Jift – a waste product from olive oil harvesting – is also available in Irbid and Al-Mafraq. It can be used either as fuel or feed. Estimates suggest that the total jift supply in these regions is around 19 000 MT annually (Mercy Corps, 2017).

Geothermal[7]

Jordan has several thermal water resources (springs and wells) spread along the Rift Valley, in addition to thermal wells in the central and eastern plateau. The geothermal gradient map of Jordan shows two distinct regions with high gradients up to 50°C/km (degrees Celsius per kilometre) – one in the immediate vicinity of the east Dead Sea escarpment and another near the border with Syria and Iraq. The former represents a locally available energy resource for heating along the eastern margin of the Dead Sea Rift, where temperatures range from 53-63°C, with many hotels and resorts in the vicinity.

Hydropower

Jordan's hydropower resources are currently limited to the King Talal Dam – the country's only hydropower plant – with 7 MW of installed power capacity. Aqaba Power Station has been equipped with hydropower turbines with 6 MW of total capacity using the available head of returning cooling sea water. The elevation difference between the Red Sea and the Dead Sea also provides a potential hydro resource of an estimated of 400-800 MW, which could be exploited via the proposed Red Sea Dead Sea Canal project. Meanwhile, to improve power system flexibility, MEMR has recently conducted feasibility tests on Jordan's existing dams and reservoirs with a view to establishing pumped storage hydro power projects (see Box 5).

3.2 Renewables in the power sector

Renewable energy in the power sector has existed since 1998, with the first wind energy farm of 1.125 MW operational at Hofa in northern Jordan. A strong impetus for the adoption of renewables for electricity generation came in 2012 with the introduction of the Renewable Energy and Energy Efficiency Law (13). Until 2014, the total installed capacity of renewables in the country's power sector stood at about 14 MW, comprising predominantly hydropower. Total renewables capacity had grown to about 500 MW in 2016 and to over 1.5 GW by early 2020 (Figure 10). Renewables now account for over a quarter of total installed power capacity in Jordan. This rapid growth has primarily been driven by capacity additions of onshore wind and solar PV technologies.

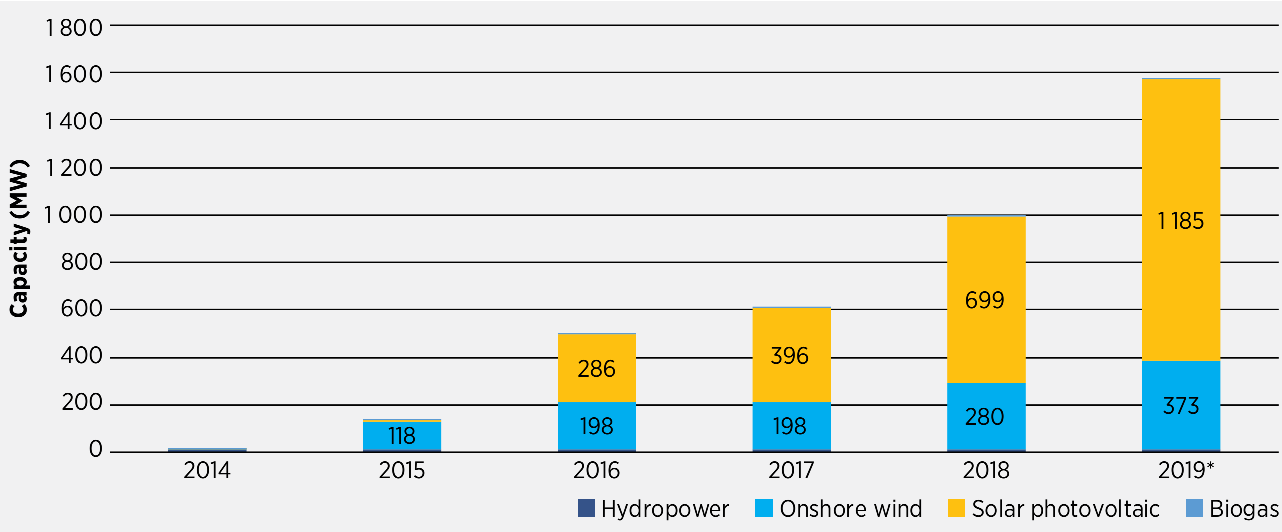
In 2015, the 117 MW Tafila wind project came online, followed by the 80 MW Ma'an wind project in 2016. In the same year, solar PV projects from the first round of direct offers comprising 200 MW of capacity were commissioned. In 2018, the second-round projects – along with the 103 MW Quweira plant – were commissioned, taking the total solar PV capacity up to nearly 700 MW. By the end of 2019, solar PV installed capacity had risen to about 1.2 GW and wind capacity hit 373 MW. Of the total solar and wind capacity installed, about 985 MW are connected to the transmission system, while about 573 MW are connected under the net metering and wheeling schemes (MEMR, 2020).[8]

As the capacity of renewables in the power sector has grown, so has generation. Total electricity generated from renewables reached 2 187 GWh in 2018, accounting for about 11% of all generation. Solar PV represented well over half (65%) of all electricity generated from renewables, followed by onshore wind (32%), hydropower (3%) and biogas (0.3%) (Figure 11).

7 Based on Saudi and Swarieh (2015).

8 Based on MEMR presentation (January 2020).

Figure 12. **Renewable energy capacity, by source (2014-2019)**

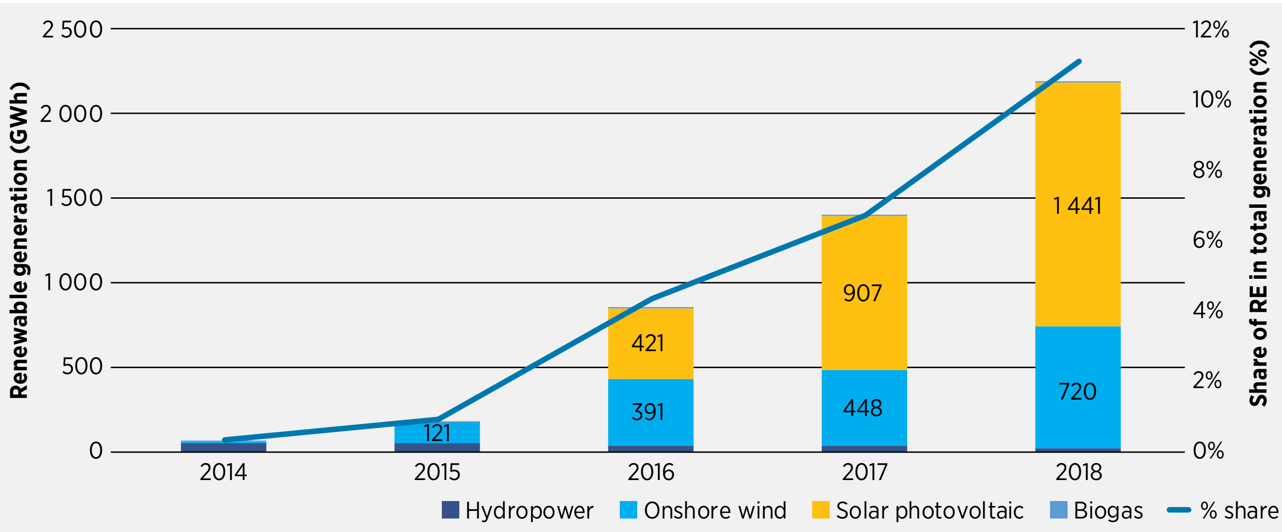


* Reported as of January 2020.

Note: Hydropower and biogas generation capacity remained the same throughout the reporting period at 12 MW and 3.5 MW, respectively.

Source: NEPCO (2019a); MEMR(2019b)

Figure 13. **Renewable energy generation, by source (2014-2018)**



Based on: Data from NEPCO and MEMR

Note: In 2018, hydropower generation amounted to 23 GWh, while biogas supplied 3 GWh.

Table 3. **Solar PV and wind project status (as of January 2020)**

Energy source	Under construction	Operational
Utility- scale wind	247 MW	373 MW
Utility-scale solar (direct proposal)	250 MW	612 MW
Wheeling solar projects	-	222 MW
Distributed solar PV net metering projects	-	351 MW

The pipeline for **utility-scale renewable energy projects** is composed primarily of solar PV and wind. About 250 MW of solar PV and 247 MW of wind projects are currently under construction (not including net metering and wheeling projects).[9] Besides stand-alone utility-scale renewable energy projects, multi-fuel IPPs are also integrating solar PV projects into the fuel mix to reduce conventional fuel use during peak-load hours. AES Jordan's 250 MW IPP project was commissioned in 2014 and was originally designed to be tri-fuel using heavy fuel oil, light fuel oil and natural gas. However, 46 MW of solar PV is anticipated to be connected to the existing plant to reduce engine use and associated fuels during peak solar generation and to cut emissions (Wartsila, n.d.).

Targeted policy support through **net metering and wheeling** projects (discussed in depth in Chapter 4) has provided further impetus for investments in renewable energy solutions for self-consumption projects. More than 15 300 applications have been approved so far by distribution companies (Jordan Times, 2020b). Under the Fils Al Reef initiative, over 2 000 solar PV systems of 2 kW size are also being installed in households that are under national support and that have electricity consumption of under 200 units.

Figure 13 shows that electricity generation from renewables has grown rapidly over the past four years, reaching around 11% of total supply mix from a negligible starting point. With nearly 500 MW of utility-scale solar PV and wind projects under construction and due to come online by 2021, as well as already approved net metering and wheeling projects, the share of renewable electricity is estimated to continue to rise.

Jordan has so far managed to integrate the rapidly growing share of electricity generated from renewables through various measures including the development of a dedicated transmission grid infrastructure to evacuate power from resource-rich regions to load centres and the reinforcement of existing grid networks (Bellini, 2018). The Green Corridor Project, presently under development, is one such example (Box 1). The Kingdom has also been a pioneer in the MENA region in the development of grid-scale energy storage projects. In February 2019, commercial operations of the expanded 23 MW/12.6 MWh solar PV plus storage project began in the Al-Mafraq region. This is the first utility-scale solar and storage combined project in the MENA region. It demonstrates the value of storage to support integration by smoothing out variability and allowing load-shifting. MEMR had also announced a 30 MW/60 MWh project in Ma'an for which proposals have been received (MESIA, 2019). Qualified bidders were announced in January 2020; however, in April 2020 it was confirmed to have been cancelled (Colthorpe, 2020).

Raising the share of renewables beyond the current pipeline of projects has raised grid integration concerns. A Cabinet Resolution dated 9 January 2019 was issued to suspend granting approvals for renewable energy projects exceeding 1 MW until the MEMR has studied the ability of the grid to absorb additional power and included appropriate integration measures into its long-term strategy (EDAMA, 2019a). Raising the share of renewables in the electricity generation mix will require efforts to stimulate demand, as well as integration measures such as storage, electrification of end-uses and demand-side management. These will be discussed in greater detail in Chapter 4.

Box 1. Transmission grid development to facilitate renewable energy integration

To facilitate the integration of utility-scale solar PV and wind, measures are being taken to support the development of adequate transmission infrastructure. A Green Corridor project is underway that includes the construction of a new substation in Ma'an (400/132) kilovolt (kV), and the expansion of the Qatrana and the airport substations (132/33) kV in addition to constructing the necessary transmission lines for connecting these substations.

Source: NEPCO (2018)

9 Based on MEMR presentation (January 2020).

Off-grid renewable energy solutions are also being deployed for the provision of electricity services in villages, border points, telecommunication stations, desert camps and rural communities in Jordan. Although the national electrification rate is close to 100%, a number of households located in remote areas are unconnected to or under-served by the grid. For those areas, off-grid solutions are deemed suitable and economical to deliver basic electricity services.

Distributed renewable energy solutions are also increasingly being adopted across sectors such as agriculture and water. Under the European Union (EU)-funded Renewable Energy and Energy Efficiency II Programme, 214 solar pumps were installed in the Jordan Valley and 106 in the Highlands. The project was developed by the National Energy Research Centre and the Ministry of Environment. The energy costs of large water conveyance projects, such as the Red Sea Dead Sea project, can be prohibitively high. The Ministry of Water and Irrigation has taken steps to tap into low-cost renewable energy, reducing its electricity costs.

3.3 Renewables in heating/cooling and transport

Renewable energy use for heating/cooling applications has been limited compared to that of the power sector. The market for renewable energy heating in Jordan is based mostly on solar water heaters dating back to the 1970s. The solar water heater industry is well developed, catering to domestic, industrial and commercial applications. The domestic sector dominates, with solar meeting hot water requirements for residential use. Other applications include those for swimming pools, hospitals, hotels, universities, schools and sports facilities, as well as for space heating. In industry, solar heating solutions deliver process heat and pre-heating systems (e.g., in dairy) (CRES, 2008).

In 2016, the total number of solar water heaters reached 3 500 systems with the installed capacity of water collectors reaching nearly 880 Megawatt-thermal (MWth)) (IEA-SHC, 2019). This number almost tripled, reaching 16 000 installed solar water heaters by the end of 2018 with at least 24 000 systems now in place (JREEEF, 2020). The market for solar water heaters grew organically for several decades and was catalysed with the launch of dedicated financing programmes. The JREEEF financing programme for the installation of over 22 000 solar water heaters was completed in 2019 with the next phase being rolled out in partnership with commercial banks (discussed further in Chapter 4) (Jordan Times, 2019b).

Despite the progress, solar water heater penetration in Jordan is lower compared to countries such as Lebanon and State of Palestine on a per 1 000 inhabitants' basis with similar resource potential (Weiss and Spörk-Dür, 2020). The solar thermal program in the 2007-2020 energy strategy set a target to increase household penetration from 15% to 25% by 2015, but the target has not been met (Abu-Dayyeh, 2015). This has primarily been a result of a lack of enforcement of regulations that came into effect in 2013 which made it solar water heaters installation mandatory for households, apartments and offices above a specific area.

Besides solar water heaters, concentrated solar heat (CSH) applications for the provision of process heat in industries has been piloted. In 2015, a CSH Fresnel collector pilot was installed in Sahab. It had a thermal capacity of 223 kWh and provided process steam at 160 degrees with suitable applications for drying and sterilisation processes in the pharmaceuticals industry (Solar Concentra, 2017). JTI (Jordan), the largest cigarette manufacturer in Jordan, has installed a solar steam generation unit which covers 85% of the annual steam consumption and 30% of cooling and heating needs. It saves over 2.8 GWh of LPG energy consumption and 1.6 GWh of electricity per year (JTI, 2018).

In February 2020, the Solar Heating Arab Mark and Certification Initiative (SHAMCI) mark and certification for solar thermal systems was endorsed. SHAMCI is the first Arab certification scheme providing a regional industrial and regulatory compliance for policy makers, industry and end-consumers (RCREEE, 2020).

Geothermal-based heating and cooling solutions have also been piloted. The American University of Madaba, about 50 km south of Amman, has deployed two geothermal systems to meet the cooling load of 1 680 kW and heating load of 1 350 kW of two buildings. It is estimated to reduce CO_2 emissions by 223 tonnes annually, a 47% reduction compared to conventional chiller/LPG boiler (Laylin, 2012).

The transport sector accounts for nearly half of all energy consumed in Jordan. Direct renewables use in transport is very limited. Jordan inaugurated its first solar-powered charging station for electric cars as early as 2012 at El Hassan Science City. Incentives have been offered for the adoption of hybrid and electric vehicles although these are not coupled with renewable power for charging. Jordan has experienced a surge in the adoption of electric vehicles, from around 9 000 in 2016 to 18 000 in 2018 with a compounded annual growth rate of up to 34% by 2025 (Friedrich-Ebert-Stiftung, 2019).

The Greater Amman Municipality (GAM) has set up 120 charging stations (five utilising solar to cover part of the consumption) and is working on installing fast charging stations. GAM has also worked with taxi operators and provided incentives (e.g., fee exemptions, use of public charging infrastructure) to reach 30% of fleet size with electric vehicles.

Besides electrification, renewable energy potential for fuelling transport through biogas generated with municipal waste and liquid biofuels also exists. Given the excess power generation scenario in Jordan, energy carriers, such as hydrogen, may also be relevant as they can create new electricity demand while also facilitating storage and integration in industry and transport sectors.

3.4. Conclusion

Jordan has abundant domestic renewable energy resources, in particular for solar and wind. Developing these resources supports all four pillars of the Master Strategy for the Energy Sector 2020-2030: to secure a sustainable future energy supply, diversify the national energy mix and increase the share of local resources, reduce dependence on external energy resources, and enhance environmental protection.

Backed by strong government action, the renewable energy sector has seen rapid growth since 2012, especially in the power sector. Renewables' share in total installed power capacity grew from under 1% in 2012 to 20% by the end of 2019. Concurrently, of total electricity generated in Jordan, renewables' share has risen rapidly to over 13% during the same timeframe (MEMR, 2020).

Sustaining continued growth of renewables in the power sector will call for a stronger look at a portfolio of short-, medium- and long-term integration solutions as the share of renewables in the electricity mix grows. Under the present conditions in the power sector, the future growth of renewables is contingent upon the growth of electricity demand, which has been slow in recent years and is further compounded by the Covid-19 crisis. Demand stimulation requires cross-sector policy making and strategies aimed at demand stimulation and electrification of end-uses.

Non-electricity end-use sectors comprise over 60% of final energy consumption and, therefore, reducing reliance on imported fuels will inevitably require much greater adoption of renewables-based heating and transport. Mature renewable energy applications, such as solar water heating systems, as well as new solutions, such as CSH for industrial applications and electric vehicles, are already present in the market.

The next chapter tackles emerging issues facing the further expansion of the renewable energy sector in Jordan and the measures available to address the current barriers and accelerate progress towards much higher shares of renewables in the primary energy mix.

Al-Rajif wind plant 86 MW 1
Photograph: MEMR

RENEWABLE ENERGY POLICIES AND INVESTMENT: CURRENT LANDSCAPE AND EMERGING ISSUES

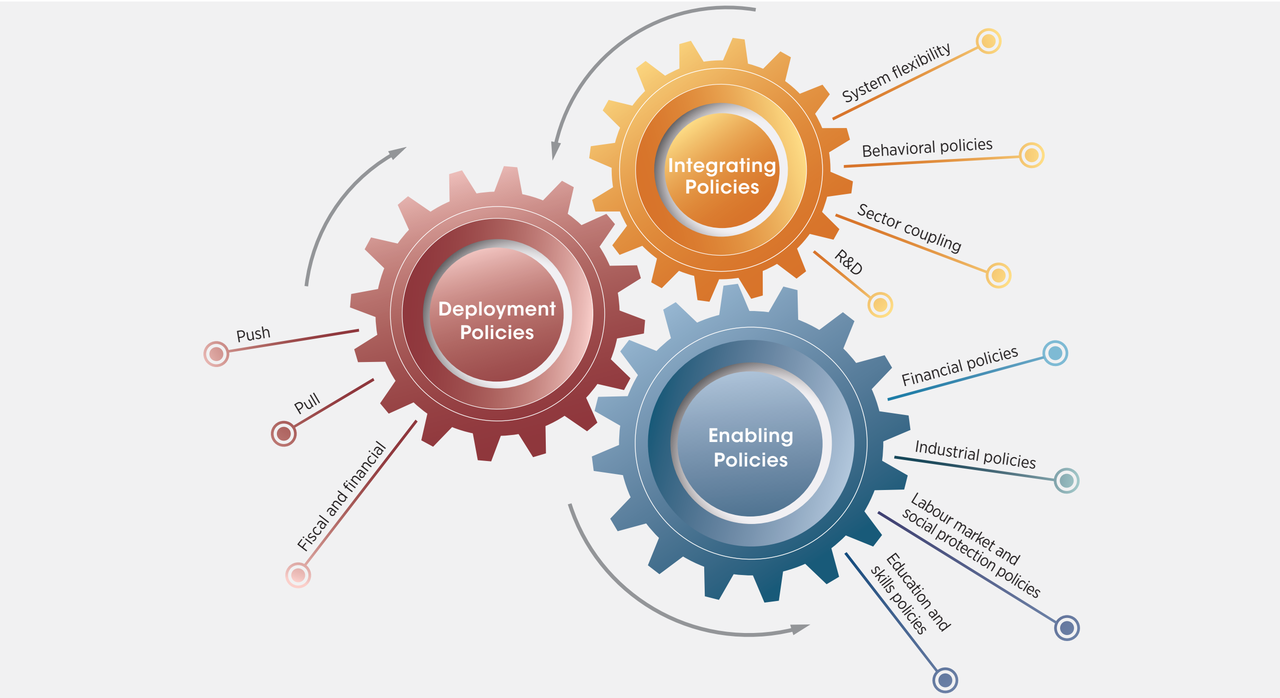
As seen in the previous chapters, Jordan has made remarkable progress over a short span of time in deploying renewable energy, especially in the power sector. A robust deployment policy has played a crucial role in driving the development of utility-scale and distributed renewables capacity, as well as selected applications across end-use sectors (e.g., solar water heaters). This chapter will discuss the policies and investment frameworks that will be instrumental for achieving a much deeper penetration of renewables in Jordan's energy mix. It will analyse the present landscape, identify the emerging issues and challenges, and highlight the pressing issues that require action.

4.1 Adapting the policy and regulatory environment for future renewables growth

The policy and regulatory landscape strongly influence the appeal of the renewable energy sector to attract investments and scale up deployment. Country experience has shown that to harness the full potential of renewables and reach majority shares of renewables in the electricity and energy mix, deployment policies alone are not sufficient. A wider policy mix is needed, as illustrated in Figure 14, that also includes policies for integration of renewables in the energy system and for supporting long-term sector development and maximising local benefits.

This holistic view of the policy and regulatory environment is particularly crucial in the context of Jordan, which is on track to reach a relatively high share of renewables in the electricity mix and whose future growth will rely strongly on demand growth and implementation of a wide range of integration measures across the energy sector. This chapter will first discuss planning and target setting, followed by a detailed assessment of the policy mix in Jordan needed to achieve a much deeper penetration of renewables in the coming decades.

Figure 14. **Policy mix to reach substantially higher shares of renewable energy**



Source: IRENA, IEA and REN21 (2018)

Plans and target

The Jordan National Energy Strategy 2007-2020 set an objective of reaching 7% of renewable energy contribution in the primary energy mix by 2015 and 10% by 2020. As part of the updated 2015-2025 Master Strategy for Energy Sector, the target was updated to 20% of renewables share in the electricity generation mix by 2025. To advance the implementation of the 2015-2025 strategy, the government of Jordan, with the technical assistance of the EU, undertook the task of developing the National Renewable Energy Action Plan (NREAP) for the period 2018-2023. However, the NREAP was not adopted in light of the recent update to the National Energy Strategy for 2020-2030.

The National Energy Strategy for 2020-2030 was developed and released in June 2020. The strategy provides long-term clarity on the evolution of the energy sector and includes an updated target that renewables will make up 31% the total installed power generation capacity by 2030. This involves setting a vision for improving flexibility of the electricity system (e.g., through storage), demand stimulation and harnessing synergies with energy efficiency (MEMR, 2019a).

The updated National Energy Strategy would pave the way for a NREAP, which would provide greater insights on the vision for the renewable energy sector to 2030 and the mechanisms for reaching the set targets. Through follow-on regulations, end-user sector targets can be further disaggregated (e.g., specific to industry, households, public buildings) for effective policy making, monitoring and enforcement. The data and information base guiding planning and target-setting also needs to be strengthened, especially for industry. By law, the Department of Statistics is authorised to gather data, and sector-specific efforts are needed to standardise and gather energy end-use data. In the specific case of industry, for instance, the Chamber of Industry and MEMR would be the key stakeholders to conduct a nationwide effort such as this.

The successful design and implementation of the policy mix illustrated in Figure 14 rests on a cross-sector and multi-institutional approach. For instance, the effective integration of variable renewables in the power sector, as will be elaborated upon in Chapter 4, Section 1, "Policies and regulations to maximise benefits", requires cross-sector policies for the electrification of end-use sectors such as transport. The National Energy Strategy must incorporate the cross-sector interlinkages (e.g., electrification of transport, water, agriculture), consider emerging technologies (e.g., storage, electric vehicles and other decentralised applications) and provide the optimum roadmap to reach higher shares of renewable energy in the primary energy mix.

Box 2. Bylaws and instructions for the implementation of the Renewable Energy and Energy Efficiency Law No. 13 of 2012

Several bylaws, instructions and directives have been issued to support the implementation of the Renewable Energy and Energy Efficiency Law No. 13 of 2012. These address different aspects of renewable energy development, including conditions and procedures for developing, connecting and remunerating projects of different scales and applications. Some important bylaws and instructions issued are:[10]

1. Bylaw No. 50 of 2015 and its amendment in 2016 sets the conditions and procedures of the renewable energy direct proposal submission and connection to the grid.
2. Instructions for costs of connecting renewable energy sources to the distribution system in the cases of competitive bidding and direct proposals related to the Article 9/B of the Renewable Energy and Energy Efficiency Law.
3. Instructions governing the sale of electrical energy generated from renewable energy systems related to the Article 10/B of the Renewable Energy and Energy Efficiency Law (net metering system).
4. Instructions governing electricity wheeling for energy generated from renewable energy sources, for consumption purposes and not for sale to others (electricity wheeling) and for wheeling charges (costs of the electricity wheeling).
5. The instructions issued based on Article 2 of Renewable Energy and Energy Efficiency Law 13/2012 for the reference pricelist record for the calculation of electrical energy purchase prices from renewable energy sources.
6. Bylaw No. 49/2015 concerns the establishment of the Jordan Renewable Energy and Energy Efficiency Fund, which aims to provide funding for the preparation of projects and programmes for the purpose of exploiting, implementing and developing renewable energy sources.
7. Bylaw No. 10 of 2013, amended in 2015, 2017 and 2018, concerns tax exemptions for renewable energy and energy efficiency systems and equipment. A list of imported and locally manufactured equipment is attached to the bylaw.
8. Intermittent Renewable Resources Distribution Connection Code at Medium Voltage: MEMR has set the rules and designed a contract for projects interconnecting renewable energy with the transmission network.
9. Guidelines for interconnection of renewable energy sources on distribution and transmission grids as well as on electric meters for net metering apply to both distribution and transmission grids.

10 In addition to those listed, several other important bylaws and instructions were issued, including the mandatory Environmental Impact Assessment by the Ministry of Environment; Mandatory Licensing of companies working in RE by EMRC; Mandatory Licensing of Solar companies working in construction by the Jordan Construction Contractors Association; Optional Certification of Design and Supervision Engineers working in Solar PV by the Jordan Engineers Association; and the Mandatory Zoning check by Greater Amman Municipality and the municipalities.

Policies and regulations for deployment

The policy and regulatory landscape for renewable energy in Jordan is composed mainly of laws whose implementation is undertaken through a series of supporting bylaws, instructions and directives. The Electricity Law No. 64 of 2002 lays down general rules for generation, transmission and distribution activities. There is no specific Heat Law that guides the utilisation and retailing of heat. The Renewable Energy and Energy Efficiency Law No. 13 of 2012 and its amendments form the backbone of the policy landscape for renewable energy and energy efficiency in Jordan (Box 2).

The policy and regulatory framework for renewables deployment in the power sector is among the most advanced and elaborate in the MENA region. Renewable energy projects are mainly developed through three routes: direct proposal submission (build-own-operate projects offered through competitive bidding), government-owned (offered as engineering, procurement and construction [EPC] contracts for the private sector) and self-consumption (wheeling and net metering projects). Off-grid projects, including those for solar water pumping, are also being pursued. Each of these will be discussed in depth in this section, followed by the policy and regulatory landscape for renewables deployment in heating/cooling and transport end-use sectors.