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Clean Energy Technology Assessment Methodology Pilot Study

Morocco

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INTERNATIONAL ENERGY AGENCY

The International Energy Agency (IEA), an autonomous agency, was established in November 1974. Its primary mandate was – and is – two-fold: to promote energy security amongst its member countries through collective response to physical disruptions in oil supply, and provide authoritative research and analysis on ways to ensure reliable, affordable and clean energy for its 29 member countries and beyond. The IEA carries out a comprehensive programme of energy co-operation among its member countries, each of which is obliged to hold oil stocks equivalent to 90 days of its net imports. The Agency's aims include the following objectives:

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- Promote sustainable energy policies that spur economic growth and environmental protection in a global context – particularly in terms of reducing greenhouse-gas emissions that contribute to climate change.
- Improve transparency of international markets through collection and analysis of energy data.
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Foreword

This report presents the results of a pilot study, testing the International Energy Agency (IEA) Clean Energy Technology Assessment Methodology (CETAM) in Morocco.

The IEA is at the forefront of clean energy – the Agency is modernising by increasing activities in clean-energy technology and innovation, while strengthening ties with emerging economies and assisting them towards a cleaner future. Most recently in June 2016, the IEA became a new home for the Clean Energy Ministerial, a multinational forum on accelerating the global transition to clean energy.

The benefits of increasing the deployment of clean energy technologies range from reducing climate change to strengthening energy security and increasing economic productivity. However, increasing the uptake of clean energy technologies requires a strong enabling environment, including supportive policies and stable sources of finance. Equally important are tools for policy makers and investors to assess markets for clean energy technologies, empowering them to make informed decisions on technology policies and investments. To this end, the IEA has developed CETAM as a tool for decision makers to assess and monitor clean energy technology markets in the Early Transition Countries (ETCs)[1] and Southern and Eastern Mediterranean (SEMED)[2] region, as well as in other developing and emerging economies. Alongside this report, two other pilot studies were conducted in Belarus and Kazakhstan, published separately.

Morocco, which is highly dependent on energy imports, has in the past decade taken determined steps to tap into its significant renewable energy resources. In 2009, the government adopted a national energy strategy, setting clear targets for wind, solar and hydropower. It was one of the first countries in the Middle East and North Africa to scrap most energy subsidies while at the same time adopting energy efficiency measures to reduce consumption. However, a wider deployment of energy efficiency technologies across all sectors of the economy is needed if Morocco is to reduce its reliance on energy imports.

In addition to its sizeable renewable energy resources, the Kingdom of Morocco benefits from a supportive regulatory and institutional framework thanks to recent legislative reforms, a process that was ongoing as this report went to press. These factors have helped it attract finance from international development banks and foreign investors. The IEA considers that Morocco's impressive record in the deployment of renewable energy technologies and its coherent energy policy should serve as a model for the rest of the SEMED region. It is therefore fitting that the Moroccan city of Marrakech will be hosting the COP22 climate summit in November 2016.

I hope this study will encourage more countries to apply CETAM so that decision makers can gain a clearer picture of the untapped renewable energy and energy efficiency potential and use this knowledge to accelerate the deployment of clean energy technologies for sustainable development.

Mr. Paul Simons

Deputy Executive Director

International Energy Agency

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[1] Under FINTECC (Finance and Technology Transfer Centre for Climate Change), the ETCs are: Armenia, Azerbaijan, Belarus, Georgia, Kyrgyz Republic, Moldova, Mongolia, Tajikistan, Turkmenistan and Uzbekistan. The IEA-European Bank for Reconstruction and Development (EBRD) collaboration also considers Kazakhstan as a reference country within this grouping.

[2] For the EBRD, and for the purposes of the IEA-EBRD collaboration, SEMED refers to: Egypt, Jordan, Morocco and Tunisia.

Table of contents

List of Figures

List of tables

List of boxes

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The IEA preparation of this Partner Country Series paper was conducted under the auspices of a collaboration with the Finance and Technology Transfer Centre for Climate Change (FINTECC) of the European Bank for Reconstruction and Development (EBRD). Launched in 2013, EBRD FINTECC, funded by the Global Environment Facility (GEF), is designed to support climate technology transfer in the ETCs and in the SEMED region through a combination of policy dialogue activities, technical assistance and EBRD financing blended with incentives. This IEA–EBRD collaboration is aimed at addressing the information gap related to the market penetration of climate technologies[3] in the ETC and SEMED regions.

The GEF is a partnership for international co-operation where 183 countries work together with international institutions, civil society organisations and the private sector, to address global environmental issues. Since its establishment in 1991, the GEF has provided USD 13.5 billion in grants and leveraged USD 65 billion in co-financing for 3 900 projects in more than 165 developing countries.

The IEA wishes to convey its sincere thanks to the EBRD for their financial support to the project via the FINTECC programme supported by the GEF, and via the EBRD Special Shareholders Fund.

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[3] In the framework of FINTECC, “climate technologies” concern technologies that can assist climate change mitigation and/or climate change adaptation. The IEA collaboration with the EBRD focuses on energy efficiency and renewable energy technologies (“EE&RET”). In parallel, the EBRD is collaborating with the Food and Agriculture Organization (FAO) on climate technologies with a focus on the agrifood and water sectors.

Executive summary

Morocco has enjoyed strong economic growth in recent years as the country transitions from a predominantly agricultural-based economy to one with a greater proportion of manufacturing and services. In parallel to this transformation, energy use has also risen, increasing Morocco's already high reliance on imported fossil fuels. This poses significant challenges from an energy security, fiscal, and environmental perspective.

It is in this context that the Moroccan government has implemented a comprehensive plan to increase the share of renewable energy in the energy mix and significantly improve energy efficiency. Targets have been set for increasing the share of electricity generating-capacity from renewables (42% by 2020 and 52% by 2030) as well as targets for decreasing energy consumption by 12% by 2020 and 15% by 2030 through energy efficiency improvements.

As a country with plentiful renewable resources and a strong desire to increase energy efficiency, Morocco provided an interesting pilot country for the International Energy Agency (IEA) to test the Clean Energy Technology Assessment Methodology (CETAM). CETAM is designed to provide clear, transparent information about clean energy technology markets and to assist countries and investors to identify the most promising clean energy technologies for policy support and investment, as well as to establish metrics for tracking their deployment over time. Below is the summary of outcomes of the study for renewable energy technologies (RETs) and energy efficiency technologies (EETs) in Morocco.

RETs

Morocco has an abundance of renewable energy resources including excellent wind and solar regimes. The majority of Morocco's hydro resources have been exploited although some undeveloped resources remain. Preliminary estimates of biomass resources indicate bioenergy could be feasible for some applications, but more detailed resource assessments are needed. Other renewable energy resources that are yet to be fully assessed, but which may have promise in the future, include offshore wind, marine resources and geothermal.

Solar, wind and hydropower have been designated as the priority technologies in Morocco's renewable energy plan. Analysis undertaken in this study supports the decision to prioritise these technologies for electricity generation given resources, technology maturity, costs and market opportunities driven by increasing electricity demand.

In addition to renewable electricity generation technologies, this analysis suggests that solar heat technologies could supply heat for the industrial, residential, and commercial and public services sectors. Among other benefits, solar heat technologies could reduce the use of traditional biomass and butane as well as the fiscal impact of the generous subsidies granted to butane, which currently represent a significant cost to the government. Other promising technologies that emerged from the study are bioenergy technology options, including biofuels for transport and biomass for heat, although further work is needed to define the resource potential and costs.

Steps 2 and 3 of the pilot study show that the penetration of RETs in Morocco is increasing rapidly, with wind now comprising 5% of electricity generation and installed capacity of 780 megawatts (MW). Excluding traditional biomass, hydro is the largest renewable energy source with 1 780 MW of installed capacity. Morocco currently has 180 MW of concentrated solar power (CSP) capacity and small amounts of solar photovoltaics (PV), yet in the next five years total solar capacity is set to expand significantly, with a target of 2 000 MW of installed solar capacity by 2020. The same targets exist for wind and hydro. Of the three, hydro is the most likely to be achieved by 2020 since existing hydro installed capacity means Morocco is already close to reaching 2 000 MW of capacity, whereas achieving the wind and solar targets will require significant new deployment over the next five years.

Morocco's recent successes with renewable energy deployment, achieving some of the world's lowest bid prices for wind and solar CSP, reflect not only its excellent resources but also the fact that it has established an enabling environment conducive to renewables deployment. Future success in reaching its ambitious deployment targets may depend on whether the regulatory framework is supportive of private developers on whom the government is relying to play a key role in deploying renewable energy technologies to 2030. Deployment of small-scale renewable energy technologies would be assisted by continuing to roll back fossil fuel subsidies, of which Morocco's progress to date should be commended.

EETs

Analysis of Moroccan energy consumption for this pilot study suggests that energy use is growing and may increase across virtually all sectors of the economy in line with continued economic growth and improvements in the standard of living. The largest energy-consuming sector is transport, and transport energy consumption is likely to grow in the near future although significant energy efficiency opportunities exist. Industrial subsectors with likely energy efficiency opportunities include sugar production, paper and pulp, textiles, and metals production. In the residential sector as well as in the commercial and public services sector, significant reductions in energy consumption could be achieved by switching from butane to a more energy-efficient fuel for cooking such as electricity.

Traditional biomass (wood) also continues to be used in significant amounts in the commercial and public services sector and in the residential sector for heat production. As with butane use, wood use in these sectors could be reduced by increasing the uptake of equipment and appliances that can generate heat more efficiently using electricity or renewable sources of heat (such as solar hot water heaters).

A key outcome from Step 1 of this study, "Prioritisation of renewable energy technologies", is the identification of a range of best-practice priority EETs for deployment in the transport, residential, industrial, and commercial and public services sectors. Analysis undertaken at this Step shows that the estimated market penetration of EETs in priority sectors is currently likely to be low, with most EETs falling below 25% market penetration, meaning significant deployment opportunities exist.

Steps 2 and 3 of the energy efficiency section of this report focus on passenger vehicles and low-rolling resistance tyres, to demonstrate how metrics and monitoring systems could be established to track the deployment of EETs. While Morocco's current data collection system allows for a relatively good level of monitoring, increasing the frequency of data collection and clearly delineating responsibility for maintaining energy efficiency indicators would help improve Morocco's ability to track EET and policy impacts.

Introduction

Project overview

RETs and EETs, referred to from this point on as "clean energy technologies",[4] have many benefits, which have been well documented. Clean energy technologies are important for improving energy access, energy security and economic productivity, and have a host of other co-benefits. With the majority of greenhouse gas emissions generated by energy, shifting to renewable, low-carbon energy sources and using energy efficiently is vital to mitigating anthropogenic climate change.

Despite these benefits, in some regions deployment has been slow, even where there are plentiful renewable energy resources and energy efficiency opportunities. Such is the case in certain Southern and Eastern Mediterranean[5] (SEMED) countries and Early Transition Countries[6] (ETCs) of the Black Sea–Caspian region. While there are myriad reasons for the relatively low deployment of clean energy technologies in these countries, broadly speaking, analysis has shown that policies to directly support clean energy technologies, and the wider "enabling environment" in which these policies operate, are under-developed (IEA, 2015a).

While there is a general understanding that clean energy technology deployment in these regions has been low, there tends to be a lack of detailed information about exactly which technologies have been deployed in which sectors and whether the market conditions are such that uptake could be increased. This presents a potential barrier to implementing effective policies and increasing public and private finance; it is difficult to make targeted policy and investment decisions without detailed information on the existing market penetration of clean energy technologies and the potential for increased deployment.

To help fill the information gaps described above, the European Bank for Recon European Bank for Reconstruction and Development has partnered with the IEA to deliver a project under the EBRD's FINTECC. Launched in 2013, FINTECC, funded by the Global Environment Facility, is designed to support climate technology[7] transfer in the ETCs and SEMED countries through a combination of policy dialogue activities, technical assistance, and EBRD financing blended with incentives.

Under the IEA–EBRD project, there are two main work streams:

1) **Policy dialogue for needs assessment**: to review and establish the necessary policy instruments to support market penetration of climate technologies. The primary output of this work stream was the IEA Insights Series paper, "Enabling renewable energy and energy efficiency technologies: Opportunities in Eastern Europe, Caucus, Central Asia, Southern and Eastern Mediterranean" (IEA, 2015a).

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[4] For the purposes of this paper, "clean energy technologies" refers to RETs and demand-side EETs. It excludes analysis of other technologies that can be used to reduce carbon emissions on the supply side, such as nuclear energy or carbon capture and storage, and technologies to increase the energy efficiency of energy production, transmission and distribution.

[5] For the European Bank for Reconstruction and Development, and for the purposes of the IEA-EBRD collaboration, SEMED refers to: Egypt, Jordan, Morocco and Tunisia.

[6] Under FINTECC (Finance and Technology Transfer Centre for Climate Change), the ETCs are: Armenia, Azerbaijan, Belarus, Georgia, Kyrgyz Republic, Moldova, Mongolia, Tajikistan, Turkmenistan and Uzbekistan. The IEA-European Bank for Reconstruction and Development (EBRD) collaboration also considers Kazakhstan as a reference country within this grouping.

[7] In the framework of FINTECC, "climate technologies" concern technologies that can assist climate change mitigation and/or climate change adaptation. The IEA collaboration with the EBRD focuses on EETs and RETs, referred to collectively as "clean energy technologies" (see footnote 4 above). In parallel, the EBRD is collaborating with the Food and Agriculture Organization on climate technologies with a focus on the agrifood and water sector.

2) **Methodology for market assessment and monitoring:** to assess and monitor the market conditions for clean energy technologies. The first output of this work stream was the IEA Insights Series paper, "The Clean Energy Technology Assessment Methodology: A methodology for assessing renewable energy and energy efficiency technology markets" (IEA, 2016a). The second major output of this work stream is a series of three pilot studies in three different countries to test the methodology, of which the results of one pilot study are presented here.

Structure of this report

The remainder of this report is structured as follows. The rest of the introductory section provides a brief overview of the IEA CETAM before outlining the purpose of the three pilot studies. In the following chapters, the results of the Morocco pilot study are presented, which include:

- a general overview of the country, including key elements of its existing energy profile
- results of the pilot study for RETs
- results of the pilot study for EETs.

Finally, some closing remarks are provided at the end of the paper, summarising key findings from the pilot studies that could inform future applications of CETAM.

CETAM

CETAM is designed to provide clear, transparent information about clean energy technology markets in the SEMED and ETC regions. Its goal is to assist the EBRD and others identify the most promising technologies for policy support and investment. It is based on previous IEA work on indicators and technology assessments and builds on other evaluation frameworks as appropriate. The methodology takes into account potential challenges related to data availability and consistency within the ETC and SEMED regions.

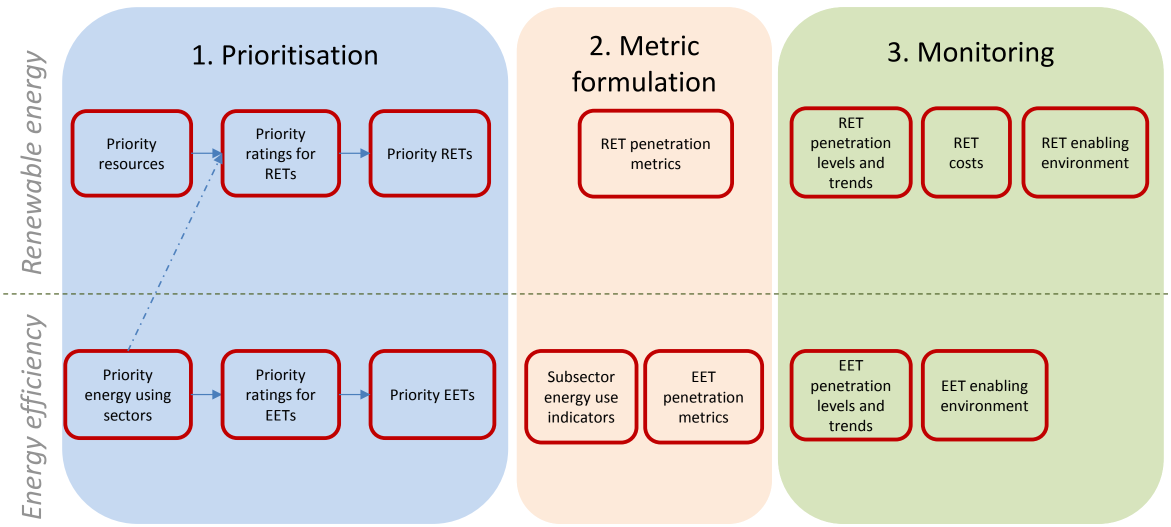
The primary users of CETAM will be the EBRD, which intends to use it as one input to inform assessments of RETs and EETs investment opportunities in the SEMED and ETC regions, and policy makers in the two regions, who could use it to track progress toward achieving clean energy technology deployment targets and inform policy formulation.

The methodology focuses on the energy supply, and industrial, buildings, and transport demand sectors and is complemented by work being carried out by the Food and Agriculture Organization (FAO) in conjunction with EBRD on the regionally important agro-industry sector. The methodology's outputs include:

- an assessment of priority clean energy technologies
- metrics for measuring the market penetration and impact of the above technologies on energy supply and demand
- a high-level qualitative assessment of the enabling environment for priority clean energy technologies.

Key steps and outputs at each step are described in Figure 1 below.

Figure 1 • Key steps and outputs of the methodology



A full explanation of the methodology can be found in the IEA Insights paper, *The Clean Energy Technology Assessment Methodology: A methodology for assessing renewable energy and energy efficiency technology markets* (IEA, 2016a).

The pilot studies

CETAM has been developed in consultation with representatives from ETCs and the SEMED region[8] to help ensure it is applicable in the two regions. To further test the methodology's regional applicability, pilot studies were carried out to test the methodology in Belarus, Kazakhstan and Morocco. The aims of the pilot studies are to:

- Test the methodology in the field to ensure it is applicable to the two regions and gather information to inform the final design of the methodology.
- Provide the EBRD and the three pilot countries with useful assessments of clean energy technology penetration and market conditions, which could inform future policy design and investments.

These countries were selected as pilot countries based on discussions with the EBRD and representatives from the countries themselves. Key factors contributing to their selection included a strong interest in deploying renewable energy and energy efficiency technologies and the relatively good availability of data in the countries.

Data availability was of particular importance given the short timeframe available for conducting the pilot studies and the IEA team acknowledges that data availability in the pilot countries may not be representative of the region as a whole. In a real world application, undertaking all steps of the methodology may require several months, if not longer, depending on the availability of information and data.

An in-depth report published by the IEA in 2014 provided valuable background for this pilot study. Additional data were collected for the purposes of this report in 2015 and 2016 with the help of the Ministry of Energy, Mines, Water and Environment (MEMEE) and a number of

[8] On 16 June 2015, the IEA held workshops on the draft methodology in Istanbul with representatives from ETCs and SEMED countries. Feedback from these workshops has been considered during the methodology's development.

agencies responsible for overseeing and implementing Morocco's national energy strategy. The IEA team conducted three missions to Morocco to meet with relevant stakeholders and gather necessary data. In addition, throughout 2015-16, data and information were shared electronically, facilitating the successful implementation of the pilot studies within an accelerated timeframe.

While information on RET penetration is generally comparatively easy to obtain in most countries, EET penetration is very difficult to gauge, as there are a diverse range of EETs spread across a large number of end-use sectors. To overcome this challenge, the IEA provided pilot country counterparts with lists of "best practice" EETs for each subsector, and asked in-country experts to prioritise these technologies and estimate their market penetration, using CETAM's EET prioritisation screening tool. The results are found at Annex A of this report.

The reader should note that for EETs, only Step 1 of CETAM (prioritisation) has been applied in full under this pilot study. Steps 2 and 3 are applied to *one* priority technology, as a means of demonstrating these steps of CETAM. In the case of Morocco, these steps were applied to low rolling resistance tyres. This decision was made for pragmatic reasons: the time required for analysing the penetration, market conditions, and establishing metrics and monitoring systems for all priority EETs within even one subsector would require resources well beyond the scope of this study.

Country overview

The Kingdom of Morocco (hereafter "Morocco") lies in northwest Africa, with a coastline on both the Mediterranean and the North Atlantic. The capital is Rabat. The largest city, Casablanca, has a population of nearly 4 million. Other major cities are: Agadir and Kenitra, on the Atlantic coast; Tangier, Tétouan, Nador, Oujda and Fes in the north; and Marrakech in the interior. The landscape is dominated by the Atlas Mountains, which separate the coastal plain from the much drier interior.

Provisional data show that Morocco's gross domestic product (GDP) reached close to USD 103 billion in 2015 and the country could achieve economic growth in excess of 4.5% in 2016 (IMF, 2016). The services sector accounts for just over half of GDP. Agriculture represents roughly 15% of GDP and employs just over 40% of the population, with other key sectors being manufacturing, mining, and construction (Mansour and Castel, 2014). The reliance on agriculture and tourism as significant revenue earners exposes the economy to the vagaries of weather and geopolitical developments. As a result, the Moroccan government has stepped up an economic reform programme that was launched in 2011 to modernise the agriculture sector, improve housing, and institute pro-market policies to attract foreign investment. Because of its geographic advantage as a gateway to Europe and the rest of the African continent, Morocco is working to expand its industrial, manufacturing and transport sectors to serve its two key markets.

Despite Morocco's economic progress, the country suffers from high unemployment, poverty, and illiteracy, particularly in rural areas. According to the International Monetary Fund (IMF) (2016), youth unemployment remained high at 20% in 2015, with overall unemployment estimated at 9.5%. The IMF also considers that, subject to continued reform, growth is expected to accelerate again in the medium term, although it points to downside influences such as geopolitical risks in the Middle East and activity in the euro area, which it believes could affect tourism, exports, foreign direct investment and remittances.

Because Morocco relies on imports for nearly 95%[9] of its energy requirements, the removal of subsidies on most energy products in 2014 helped the government achieve fiscal stability and reduce debt. This heavy reliance on imports of oil, gas and coal prompted a drive by the government, with strong backing from King Mohammed VI, to switch to renewable energy sources and begin an energy efficiency drive to meet higher demand in a restructured economy. It has set itself very ambitious renewable energy and energy efficiency targets. It has plans for 42% of installed electricity generation capacity to be from renewable sources by 2020 and is in the process of drafting plans to increase the share of installed electricity generation capacity from renewables to 52% by 2030, mainly from solar, wind and hydropower.

The government has been assisted by strong foreign investment, as well as by concessional financing from international development agencies such as the European Investment Bank, the African Development Bank and national agencies, particularly in the United States and Europe.

Morocco signed a bilateral free trade agreement with the United States in 2006 and an advanced status agreement with the European Union in 2008. Morocco's co-operation with the Organisation for Economic Co-operation and Development (OECD) goes back at least ten years. Morocco has subscribed to a number of OECD international instruments, such as the Declaration on International Investment and Multinational Enterprises (2009) and the Declaration on Transparency in Business and International Finance (2012). In 2015, The OECD and the Kingdom

[9] 94.5% in 2014 according to the Ministry of Energy, Mines, Water and Environment (MEMEE).

of Morocco signed a memorandum of understanding on a two-year Country Programme, which will support Morocco's reform agenda.

MEMEE and the IEA signed a memorandum of understanding on co-operating in the field of energy policy in 2007, which resulted in publication of an in-depth report on Morocco's energy sector in 2014 (IEA, 2014a).

Energy profile

Energy supply

Total primary energy supply (TPES) in Morocco was 18.9 million tonnes of oil-equivalent (Mtoe) in 2014. Energy supply has grown considerably during the past decade, increasing by a total of 5 Mtoe (about 60%) since 2004.

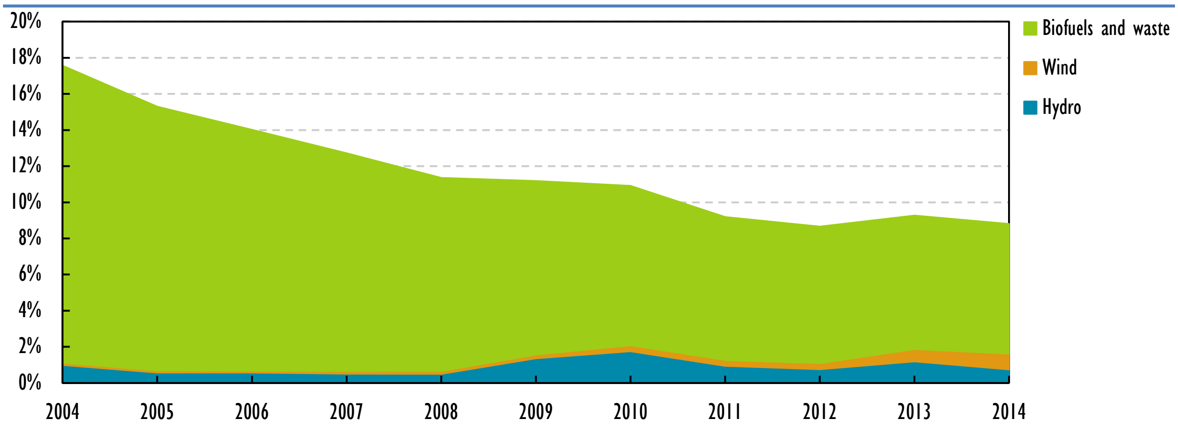
Morocco's energy mix in 2014 was dominated by oil, which represented 61.9% of TPES (a fall from 66.7% the previous year). Coal accounted for a further 21.3%, followed by biofuels and waste (7.2%), natural gas (5.3), electricity net imports (2.7%) and, to a small extent, hydropower (0.7%) and wind (0.9%).

Renewable energy in Morocco accounted for nearly 1.8 Mtoe in 2013, 9.4% of TPES (Figure 2). The share of renewables in TPES over the last two decades varied between 8% and 12%, mainly because of volatility in annual rainfall.

While the supply of biofuels and waste had been increasing historically, since 2004 it has been decreasing, and for the last two years has supplied between 7-7.5% of TPES (Figure 2).

Biofuels – the main source of renewable energy in Morocco – dropped from 16% of TPES in 2004 to 7.2% in 2014.

Figure 2 • Percentage of TPES sourced from renewable fuels, 2004-14, Morocco



Source: IEA (forthcoming), *Energy Balances of Non-OECD Countries*, www.iea.org/statistics/.

Hydropower ranged from just below 1% of TPES in 2004 to 1.75% in 2010, accounting for 0.74% in 2014. Wind power was initiated in 2000 and had increased thirtyfold by 2014.

In 2014 electricity generation from renewables was 3 561 gigawatt hours (GWh), representing 12% of total generation – a decrease from 15% of total generation in 2013. This was mainly due to a decrease in hydro generation. Wind power generation increased by nearly 30% in 2014, up to 1 924 GWh from 1 481 GWh in 2013. As a result, in 2014, wind represented 6.7% of total generation. Other sources of renewable energy were still negligible, but analysis in this chapter shows that this is expected to change rapidly. During the decade 2004-14, the share of hydropower in domestic electricity production was 8% on average.

Energy demand

The transport sector and residential sector are the largest consumers of energy in Morocco, together accounting for nearly 60% of total final consumption (TFC). Transport accounted for 34% in 2014, and residential use for 25%.

The industry sector represents 21% of TFC, with agriculture accounting for 7%. Total energy demand increased by 36% from 2004 to 2014, with demand in transport growing 56%.

Energy intensity in Morocco, measured as TPES compared to GDP at purchasing power parity (PPP), was 0.08 tonnes of oil-equivalent per USD 1 000 GDP PPP in 2014. This is relatively low compared to most IEA countries and is still below the IEA average.

Energy-related carbon dioxide emissions

Emissions of carbon dioxide (CO_2) from combustion fuels amounted to 53.1 million tonnes ($MtCO_2$) in 2014 and have grown without interruption in the past three decades. CO_2 emissions have increased by 80% since 2000, in parallel with a similar increase in energy consumption.

Oil consumption remains the main source of fuel combustion CO_2 emissions in Morocco, accounting for 65.4% of total emissions, followed by coal (30.1%) and natural gas (4.4%). However, the strongest increase in emissions came from natural gas, as a consequence of significant consumption growth (nearly 20 times greater in 2014 compared with 2004). Over the same period, emissions from oil increased by 45%, while emissions from coal increased by 31%.

As host to the first climate change summit after the landmark 21st Conference of the Parties (COP) agreement in Paris in late 2015, Morocco has been keen to highlight its actions to reduce CO_2 emissions. It plans to reduce greenhouse gas (GHG) emissions by 13% unconditionally and by 35% conditionally by 2030, according to the Intended Nationally Determined Contribution (INDC) submitted by Rabat ahead of COP21. The high end of the range is conditional on “gaining access to new sources of finance and enhanced support, compared to that received over the past years, within the context of a new legally-binding agreement under the auspices of the UNFCCC [United Nations Framework Convention on Climate Change]”.

Energy policy framework

In 2009, Morocco launched a National Energy Strategy to support the energy sector as a whole by transitioning towards low-carbon energy sources and reducing the country’s energy dependence. The main goals of the National Energy Strategy are to ensure the security of supply and availability of energy, as well as generalised access to energy at reasonable prices, and demand restraint with a heavy focus on energy efficiency as a pillar of the new energy policy. In presenting the strategy to parliament, King Mohammed singled out industry, housing and transport as the three key areas for deployment of new energy technologies. A key enabler of the switch to renewable energy that is currently underway has been deregulation of the electricity sector. Among the key objectives of the strategy is diversification of energy sources, although coal remains the main component of the electricity mix at least to 2020, before its share declines by 2030.

The strategy sees renewable energy displacing fossil fuels by roughly 2.6 Mtoe per year and the creation of 25 000 jobs. The strategic priorities in the action plan are to:

- Build an optimised electricity mix around reliable and competitive technologies. Coal is the main production base, being the most easily available technological option, offering the most stable prices and a relatively inexpensive price per kilowatt hour (kWh). Deployment of natural gas and liquefied natural gas (LNG) imports are contingent on their long-term accessibility and availability as well as technical feasibility and competitiveness.
- Conduct a feasibility study for deployment of nuclear power and the possibility of direct combustion of shale gas for power generation, as and when the technology is available.

- Step up domestic petroleum exploration projects.
- Explore new technologies adapted to deployment of biomass and locate sites favourable for development of geothermal energy.
- Further develop wind, solar (both CSP and solar PV), and hydroelectric power capacity, the latter through optimisation of existing plants and boosting storage capacity. Biomass will also make up a small part of the energy mix by 2030. The 2020 target is to increase hydropower capacity to 2 000 MW and develop 2 000 MW of wind power and 2 000 MW of solar power.
- Establish a comprehensive energy efficiency programme, which will include, amongst other measures: a national public awareness campaign; new building codes; creation of “green cities”; encouragement of co-generation in industrial processes; replacing obsolete equipment in manufacturing; rejuvenating the car fleet and improving traffic movement through better signalling; and developing and modernising public transport.

At a regional level, the following are among priorities in the integrated energy strategy:

- extension of electricity interconnections with Spain and Algeria
- securing electricity swap deals through arbitrage opportunities
- becoming a hub for the transit of gas from Africa to Europe
- integration into the Mediterranean solar plan.

Other measures to be adopted include the restructuring of the energy department to steer the new policy and regulate the transformation of the energy system; reorganisation of the electricity sector and creation of an independent regulator; implementation of competitive and transparent pricing for oil products while protecting lower-income families; and encouraging investment by operators and investors by ensuring a stable fiscal environment that guarantees their rights and obligations.

At the end of 2015, the King issued a royal decree expanding the responsibility of the Moroccan Agency for Solar Energy (MASEN) to cover all renewable energy and not only solar.

Political and economic stability combined with a coherent energy programme have allowed Morocco to benefit from low-cost financing from international institutions as well as from friendly Arab states. Saudi Arabia and the United Arab Emirates (UAE) are the two main contributors to the Moroccan Energy Development Fund.

Results of the pilot study for renewable energy technologies

Step 1: Prioritisation of renewable energy technologies

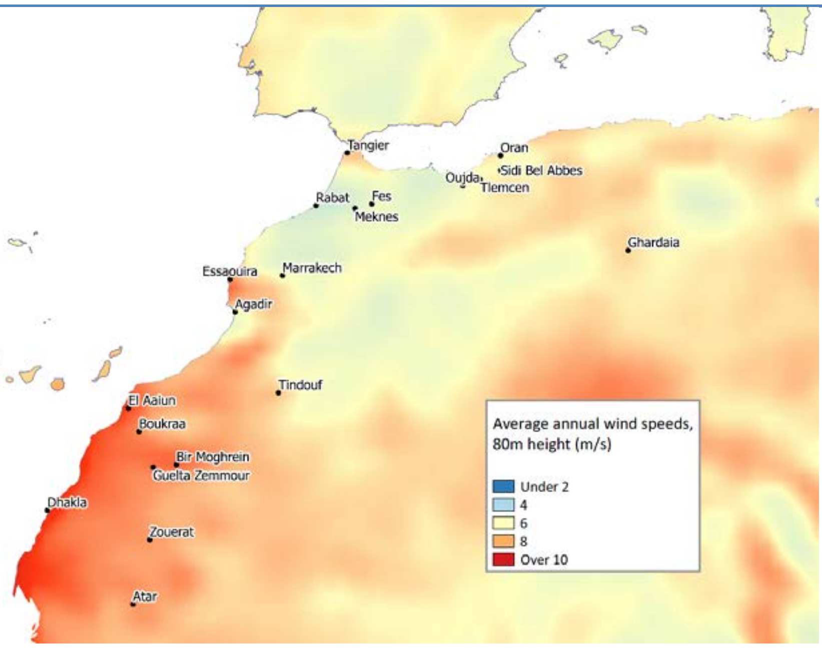
1.1 Renewable resources

Several renewable resource mapping exercises have been undertaken in Morocco to inform the Moroccan National Energy Strategy. The Agency for Renewable Energy and Energy Efficiency (ADEREE) is tasked with identifying and evaluating the potential for renewable energy and energy efficiency in Morocco. It has mapped solar irradiance, wind speeds and direction, and has undertaken a national biomass resource assessment.

Wind

Figure 3 shows a wind map of Northwest Africa, which indicates that at a hub height of 80 metres (m), wind speeds in the provinces of Guelmim-Oued Noun, Laâyoune-Saguia Al Hamra, and Dakhla-Oued Ed Dahab are regularly above seven metres per second (m/s). According to MEMEE, at a hub height of 40 m, wind speeds vary from 9.5 m/s to 11 m/s at Essaouira, Tangier and Tétouan and 7.5-9.5 m/s at Tarfaya, Dakhla, Taza and Laâyoune (MEMEE, 2011). This means that the wind resource in Morocco is very good and should allow high utilisation factors for wind turbines, so reducing generation costs. ADEREE estimates that the "exploitable potential" wind resources have a capacity of around 25 000 MW. Offshore wind resources are yet to be fully quantified.

Figure 3 • Wind resource map



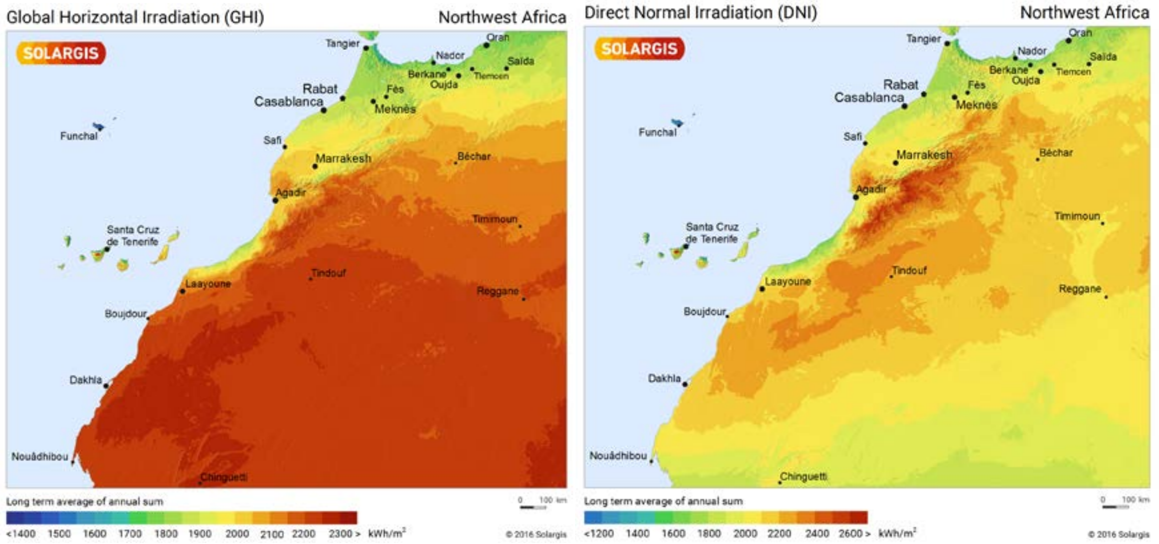
Notes: NCAR Global Climate Four-Dimensional Data Assimilation (CFDDA) hourly 40 km reanalysis; this map is without prejudice to the status of or sovereignty over any territory, to the delimitation of international frontiers and boundaries, and to the name of any territory, city or area.

Source: Rife et al. (2014), *NCAR Global Climate Four-Dimensional Data Assimilation (CFDDA) Hourly 40 km Reanalysis*.

Solar

Morocco has excellent solar resources, especially in the south, where irradiation levels reach over 2 200 kilowatt hours per square metre (kWh/m^2) for global horizontal irradiance (GHI), and up to 2 600 kWh/m^2 of direct normal irradiance (DNI) annually (Figure 4). Such levels indicate high technical and economic potential for technologies such as CSP and solar PV to produce affordable electricity, as well as being favourable for solar thermal heat production for use in buildings and industry.

Figure 4 • Solar resource maps (GHI, left; DNI, right)



Notes: This map is without prejudice to the status of or sovereignty over any territory, to the delimitation of international frontiers and boundaries, and to the name of any territory, city or area.

Source: Maps provided by Solargis.

Biomass

According to ADEREE, biomass represents a "significant untapped energy resource", with key sources of biomass being from municipal waste and the agricultural and agribusiness sectors (ADEREE, 2016a). A national biomass assessment has been published (ADEREE, 2011), which estimates the country's biomass resources in 2010 and projections for 2020. The IEA understands this study presents figures that are largely extrapolated from two studies of specific regions by GIZ (the German Federal Enterprise for International Co-operation). As a detailed, countrywide resource assessment is yet to be conducted, these figures should therefore be considered with caution. That said, they provide a preliminary estimate of possible biomass resources in Morocco. The results of this assessment are summarised in Figure 5.

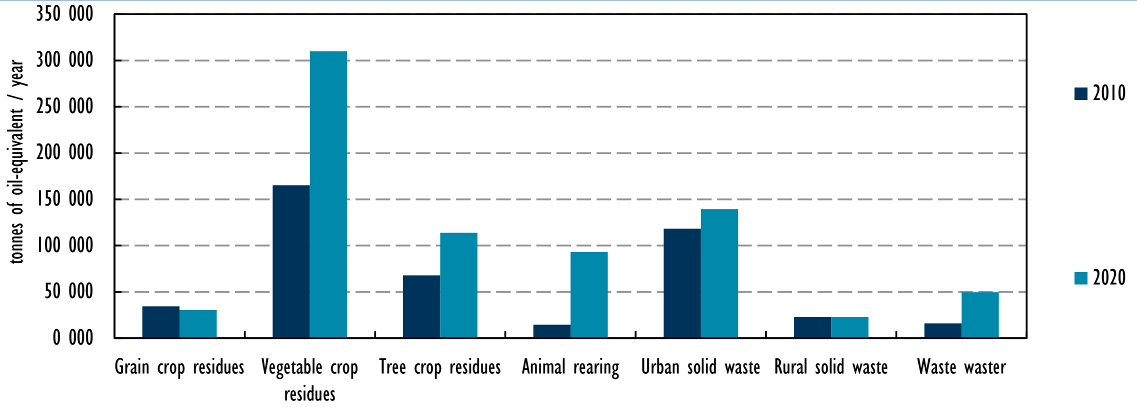
The national biomass assessment shows key biomass resources in agriculture and solid waste, with significant growth anticipated between 2010 and 2020 in annual biomass sourced from vegetable crop residues (87%), animal rearing (534%) and waste water (212%).

The total estimate for 2020 of around 0.6 Mtoe would be some 3.2% of national TPES of 18.9 Mtoe. However, not all the material is likely to be available sustainably or economically.

Given these uncertainties, it would be worth building on the existing work to check both the availability and the likely costs of the various feedstocks, and to investigate the potential for niche applications that could be cost effective and which might provide other benefits (e.g. improved environmental performance associated with waste management and disposal).

The IEA understands a project led by the European Union (EU) is currently underway to improve the quantification of biomass resources in Morocco.

Figure 5 • Estimated annual biomass resources in 2010 and 2020



Source: ADEREE (2011), *Potentiel National en Biomasse-Energie* [*National Potential of Biomass Energy*].

Geothermal

Morocco is yet to conduct a detailed assessment of its geothermal resources. However, a recent study (Barkaoui et al., 2015) indicates that resources are to be found in the northeast of the country and at boreholes in the Berkane and Oujda areas. An average geothermal gradient of more than 120°C per kilometre (km) has been recorded at depths greater than 300 m. This suggests the potential for applications beyond the existing limited uses of geothermal energy, which have been restricted to bathing and agriculture.

Hydro

Morocco has exploited many of its large-scale hydro resources, but others still remain undeveloped. According to the 2011 National Energy Strategy, some 987 MW of available hydro capacity could be feasibly developed, including around 200 sites for small-scale projects (MEMEE, 2011). The Ministry of Energy has authorised the development of around 100 MW of small-scale capacity to date.

In the past, water shortages have been a problem for existing hydro capacity and with rainfall declining 40% since the 1960s, the prospects for a significant increase in large-scale hydro generation are unlikely to improve given expected climate change impacts on Morocco. According to MEMEE, 85% of Morocco's land area receives less than 300 millimetres of rain per year (MEMEE, 2011).

Ocean/wave power

With 1 835 km of coastline, Morocco may demonstrate strong potential for wave power. Situated on the Atlantic, the country could enjoy similar conditions to Portugal, where the world's first commercial-scale wave power pilot project was built in 2008. No resource assessments have been conducted to date, although ADEREE is set to commence a study to map marine power resources in 2017.

Summary of resources

Morocco's National Energy Strategy identifies three priority renewable resources: solar, wind and hydro. Biomass is also listed as a secondary resource. Given the country's excellent wind and solar resources, this appears to be a sensible prioritisation, and opportunities may exist for biomass to make a useful (if minor) contribution to energy supply while bringing in additional benefits, for example improved waste management practices or rural economic development. The IEA suggests that a more detailed assessment of each of the potential resources be undertaken, using consistent criteria, to establish the long-term practical and economic potential of the full suite of renewable resources that are available.

1.2 Likely costs of produced energy

CETAM includes a procedure for estimating the likely costs of each of the main generating technologies, based on an analysis of global capital costs and typical operating parameters (IEA, 2016a). These capital costs can then be adapted to prevailing local financing conditions, reflecting the typical cost of finance expressed as the weighted average cost of capital (WACC), and the likely local resource availability. See IEA (2016a) for more details of this procedure and the underlying assumptions.

In Morocco underlying financing conditions are affected by the country's international credit rating. It is therefore anticipated that the underlying cost of capital is moderate (around 10%). However, Morocco has been highly successful in engaging with international developers and lenders and, through its own development bank, helping to secure finance for renewables projects at low rates (around 3.1% [CPI, 2012]).

Analysis of the available resource data suggests the classifications shown in Table 1, which are then compatible with the likely benchmark generating costs.

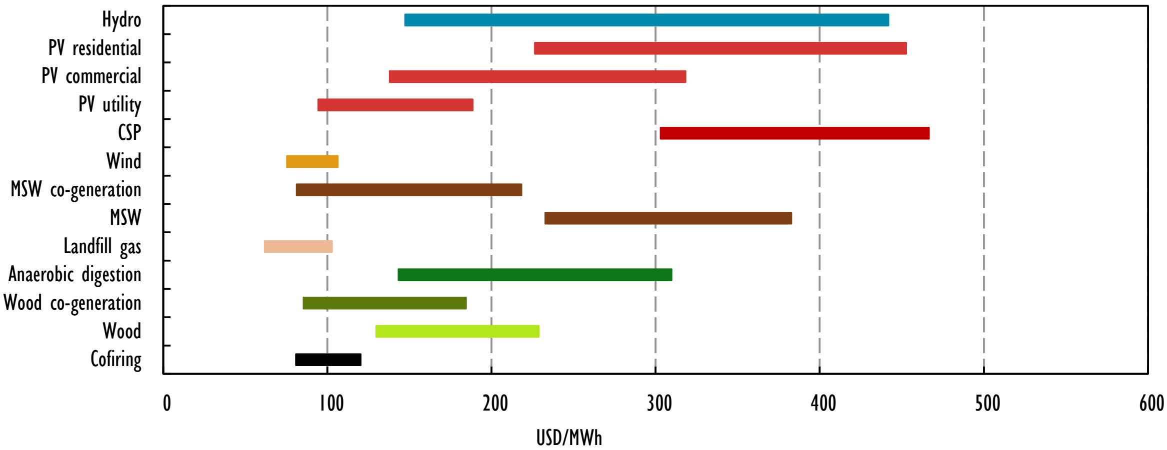
Table 1 • Likely cost range for renewable energy generation, Morocco

	Comment	Ranking	Likely range of costs USD/MWh	
Wood and agricultural residues	Constrained wood supplies	Poor to medium	Electricity only Co-generation	130-229 73-155
MSW	Poorly regulated waste management sector so currently no incentive to generate energy from MSW.	Poor	Electricity only Co-generation	233-383 81-218
Landfill gas		Good	62-103	
Anaerobic digestion	Poorly regulated waste management sector so currently no incentive to generate energy by anaerobic digestion.	Poor	Electricity only	143-310
Wind	Some areas of excellent wind resources	Excellent	41-58	
Solar PV	Some areas of very high solar resources	Excellent	Utility Commercial Residential	50-100 73-169 120-241
CSP	Excellent resource in some areas	Excellent	Utility	172-264
Hydro	Remaining sites constrained and possible water shortages	Poor		111-332

Notes: The ranges presented are based on IEA estimates of the levelised cost of electricity (LCOE) across multiple generating technologies. Co-generation refers to the combined production of heat and power; MSW = municipal solid waste; MWh = megawatt hour; renewable technologies for which resource assessments are unavailable or underdeveloped (for example marine and geothermal) are not represented.

The range of likely generating costs is shown in Figure 6.

Figure 6 • Indicative renewable energy generation costs, Morocco



Notes: Renewable technologies for which resource assessments are unavailable or underdeveloped (for example marine and geothermal) are not represented.

Source: IEA analysis.

1.3 Technology maturity and ambition

This section examines the main technologies available to exploit Morocco's renewable resources. It briefly examines the global maturity of each technology and whether Morocco has expressed ambitions to deploy them.

Large-scale solar thermal

Large-scale solar thermal is in the early stages of commercial deployment, with a global capacity of some 5.7 gigawatts (GW) in 2015 (compared with 219 GW of solar PV) (IEA, 2015b). This implies that is has considerable scope for further technical learning, with the potential cost reductions still to be achieved being relatively higher than for solar PV.

Despite this relative immaturity, Morocco has been one of the leading countries globally in its deployment of the technology. According to MASEN, the choice to pursue solar thermal for Morocco's large-scale solar projects was based on its ability to store thermal energy for generating electricity during the evenings,[10] a decision the IEA has advocated in the past (IEA, 2014a). Therefore, despite the cost advantages from ongoing falls in the price of PV panels, Morocco has elected to prioritise thermal technologies for its initial large-scale solar plants. The 160 MW Noor I and 200 MW Noor II projects both use parabolic trough technology. The 150 MW Noor III will use CSP tower technology. Of the two technologies, parabolic trough is more mature with only a small number of CSP tower projects having been built worldwide.

Morocco hopes to develop local manufacturing industries alongside the use of solar thermal energy, and the Research Institute for Solar Energy and New Energies (IRESEN) has begun testing a locally manufactured solar Fresnel technology that it hopes will be used to produce heat for steam in industrial applications.

Solar thermal (solar water heaters)

Small-scale solar thermal technologies (solar water heaters [SWHs]) are widely deployed in countries with a climate similar to that in Morocco and are a mature technology.

[10] IEA conversation with MASEN officials on 24 November 2015.

Given its favourable solar resources, Morocco has high ambitions for deploying SWHs, and the PROMASOL programme (2002-10) helped to develop a local SWH assembly industry. There are now some forty companies assembling or importing SWHs in Morocco as well as a standards and labelling programme (Allali, 2011).

Large-scale solar PV

Solar PV is now a very mature technology worldwide. Despite Morocco's initial decision to prioritise CSP for development, significant declines in PV system prices have also made this technology increasingly economically attractive for utility-scale applications.[11] To this end, a number of plans to develop selected solar sites for utility-scale PV have been recently announced, with over 1 GW in various stages of development.

Large-scale solar PV is at an immature stage of development in Morocco, with the first plants still to be commissioned. However, at the recently completed Green Energy Park (Figure 7), a research facility in Ben Guerir, IRESEN is testing the performance of different solar PV technologies under Moroccan weather conditions with the aim of producing research to accelerate both thermal and PV deployment.

Figure 7 • IRESEN Clean Energy Park, where research on solar thermal and PV technologies is being conducted to accelerate deployment in Morocco

Small-scale solar PV

Although small-scale solar PV is mature globally,[12] it is not widespread in Moroccan cities. However, deployment has been higher in off-grid applications in rural areas, due to the Global Rural Electrification Project (PERG), which resulted in the installation of some 150 000 small PV systems (from 50 W to 200 W) coupled with battery storage (totalling around 10 MW installed capacity).

The government has expressed interest in encouraging the deployment of small-scale PV systems in urban areas through reforms to the legal framework to allow grid connection of smaller-scale generation.

Onshore wind

Onshore wind is a mature technology globally and Morocco has now been deploying wind for some 15 years. Morocco has ambitious plans to deploy wind and, alongside this, to develop a local manufacturing industry for wind turbine parts. Already, Moroccan manufacturers produce

[11] For the purposes of this study, large-scale PV refers to utility-scale PV installations, defined as being above 1 MW of capacity.

[12] For the purposes of this study, small-scale PV refers to any PV system not classified as large-scale (over 1 MW) but typically refers to much smaller systems installed on commercial and residential buildings or in off-grid applications.

wind turbine towers and in the lead-up to winning a bid to develop 850 MW of wind capacity in Morocco, Siemens announced it will begin producing wind turbine blades at a factory in Tangier, the first in Morocco.

Offshore wind

Morocco is yet to deploy any offshore wind projects and globally the technology is still at the early commercial stage. Although Morocco may have significant offshore wind resources, it currently has no strong ambition to develop these resources, which is justifiable given the breadth and quality of its onshore wind power resources. Besides this, offshore wind costs currently range between USD 200 and USD 265 per MWh globally (IEA, 2015b).

Bioenergy for power, heat and fuel

Bioenergy power and heat plants are mature technologies, but have not been deployed in Morocco to date. According to ADEREE, analysis indicates that bioenergy power plant costs in Morocco are around double the price of coal plants.

The government has expressed an ambition to encourage the use of biofuels (particularly biogas) as a replacement for traditional biomass (wood, charcoal, etc.) in small-scale applications. ADEREE undertook a pilot project with GIZ in the Souss-Massa region to replace the use of traditional fuels (particularly wood) with biogas in hammams and public showers.

Marine power

Marine power is an immature technology globally and has not been deployed in Morocco. Morocco has not expressed any ambition to deploy marine power

1.4 Strategic priorities

According to MEMEE, future primary energy demand could reach 26 Mtoe in 2020 and 43 Mtoe in 2030 (with a range between 36.6 and 54.5 Mtoe). This rapid increase in demand makes energy security a key strategic priority for the government in the coming decades.

Given that Morocco imports some 95% of its energy supply (MEMEE, 2015a), it has a strong strategic motivation to source more of its energy supply from indigenous sources for both energy security and financial reasons. Morocco spends a significant sum on energy imports annually and in 2014 spent 92.88 billion Moroccan Dirhams (MAD) (around USD 10 billion) net (after exports). While oil prices are currently low, there is still a strong impetus to decrease Morocco's dependence on imported fuels, to shield itself from price volatility in the oil market. Morocco currently imports all of its refined product needs, as opposed to crude oil, following the lengthy closure of the Samir refinery due to unpaid debt. In early 2016 a court ordered that the refinery, which has capacity to process just under 300 000 barrels per day of crude oil, be placed in receivership.

In addition to the significant cost of imported energy, the Moroccan budget also faces costs from the subsidies it offers for butane fuel. Reducing consumption of butane through substitution by renewable energy would have a significant positive impact on the national budget.

In addition to imported oil products, in 2013 Morocco also imported some 0.48 Mtoe of electricity (around 15%) from Spain. While there may be strategic reasons for Morocco to supply its own electricity, it should be noted that Spanish electricity is currently priced very competitively due to an oversupply of electrical capacity relative to demand since the 2008 financial crisis. Improved connections to Spain and to other Mediterranean countries could play an important role in enabling higher shares of variable renewable electricity to be generated within Morocco, allowing exports at times of surplus and imports to make up for periods of high demand or lower production.

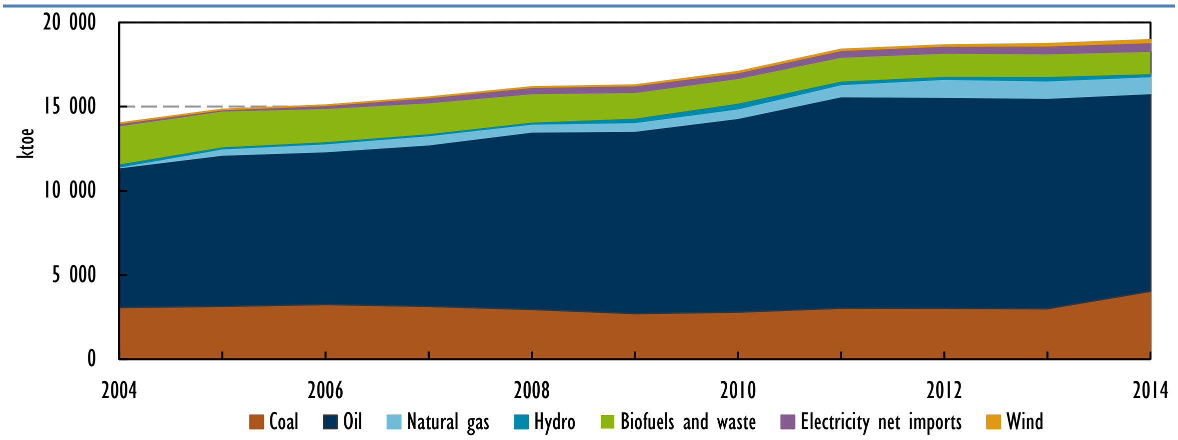
Plans also exist to strengthen the connection between the southern and northern shores of the Mediterranean Sea, and Morocco is actively examining the possibility of exporting electricity to Europe and the Middle East. Morocco is seen as a pivotal player in the future realisation of this project, due to its strategic location and increasingly liberalised electricity market (IEA, 2014a).

Despite its developing country status, Morocco has also taken a global leadership position on climate change mitigation. It plans to reduce GHG emissions by 13% unconditionally and by 35% conditionally by 2030, according to its INDC submitted ahead of COP21. In 2016, Morocco will host COP22.

Finally, water conservation is another strategic driver affecting technology selection. Technologies that use water in abundance for energy production and cooling (such as hydro and coal-fired power plants) may compete with other water uses. With climate change set to exacerbate water scarcity due to decreased rainfall (Niang et al., 2014, p. 1210), energy technologies that can minimise the use of water will be a priority for Morocco.

1.5 Market opportunities

Figure 8 • TPES, Morocco, 2004-14



Note: ktoe = thousand tonnes of oil-equivalent.

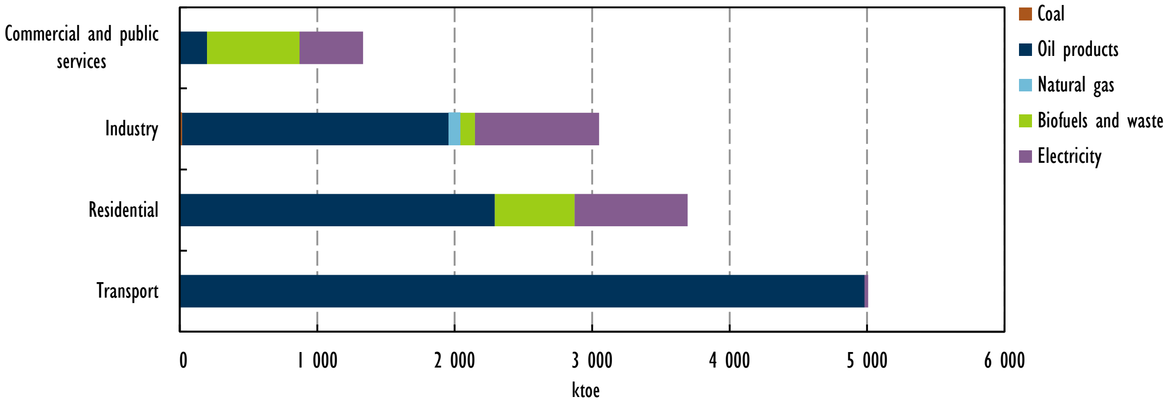
Source: IEA (forthcoming), *Energy Balances of Non-OECD Countries*, www.iea.org/statistics/.

Historically, Morocco has been heavily dependent on fossil fuels for its energy needs, particularly oil products (Figure 8). In the ten-year period between 2004 and 2014, the reliance on fossil fuels has continued as the supply of oil increased by 41% while biofuels and waste decreased at the same rate. Since 2004, the supply of natural gas in Morocco has surged, increasing from 51 Mtoe to 1 006 Mtoe per year. Coal supply increased by 31% over the same period. However, over the same period, there has also been a significant increase in electricity imports and electricity from wind power, with electricity net imports increasing three-fold and wind power generation increasing output more than eight-fold.

According to IEA total final energy consumption statistics for Morocco, transport consumes the most energy (34%), followed by residential sector (25%) and the industrial sector (21%).

Figure 9 shows TFC by fuel and end-use sector. In most sectors, the dominant fuel is currently oil products (10 613 ktoe consumed in 2014). While transport consumes the most oil products, industry, agriculture and forestry, and the residential sector also consume significant amounts. Second to oil products is electricity (2 477 ktoe consumed in 2013).

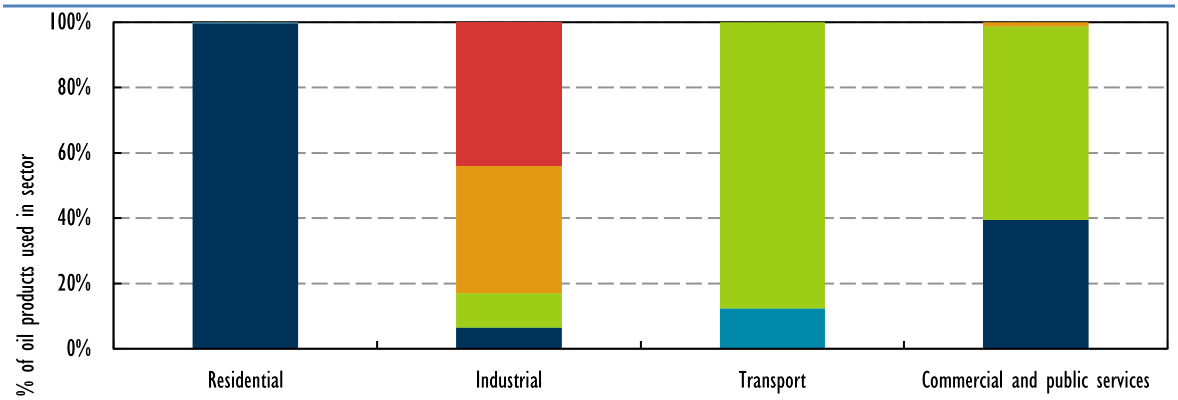
Figure 9 • TFC by end-use sector and fuel, Morocco, 2014



Source: IEA (forthcoming), *Energy Balances of Non-OECD Countries*, www.iea.org/statistics/.

Opportunities for substituting oil products with renewables will, to a certain extent, be determined by the type of oil product consumed by each sector, which varies considerably (Figure 10). For example, in the residential sector, LPG (butane and propane) is the main type of oil product used, whereas the transport sector primarily consumes diesel. The industrial sector uses a range of oil products, but primarily fuel oil and petroleum coke, which reflects the cement industry's use of petroleum coke in its kilns. Indeed 99% of the petroleum coke consumed by the industrial sector is used in the production of non-metallic minerals.

Figure 10 • Type of oil products consumed by sector, Morocco, 2014



Source: IEA (forthcoming), *Energy Balances of Non-OECD Countries*, www.iea.org/statistics/.

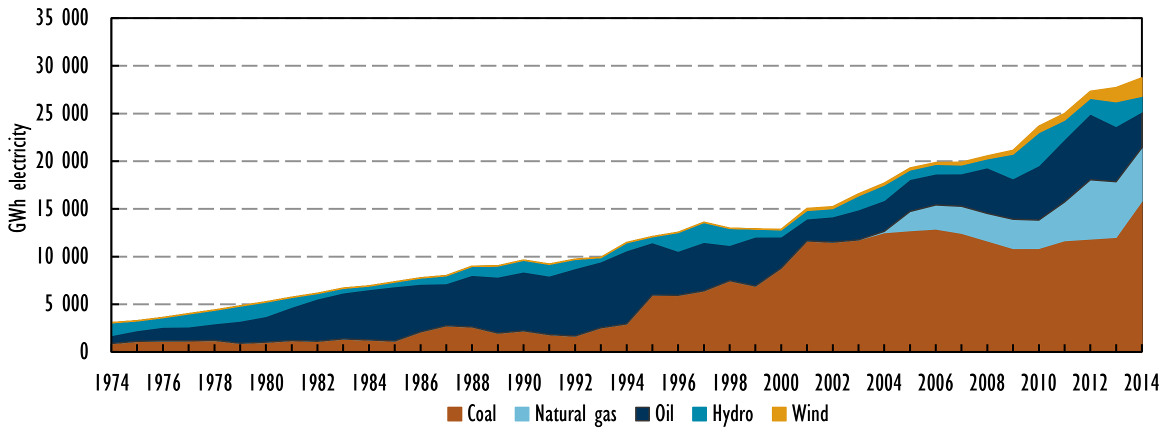
Analysis of energy consumption statistics for the energy efficiency section of this report (refer to Section 1.1.2) indicates that in the industrial sector, on a per-unit of production basis, sugar production and paper and cardboard production are the most energy-intensive industries. Both use significant amounts of steam, raising the possibility of using renewable heat from solar thermal and biomass. However, it should be noted that the majority of Morocco's sugar industry uses sugar beet rather than cane as a feedstock, providing only limited opportunities for using bagasse as a fuel because waste products from beet sugar processing are too water-dense and are currently processed into animal feed.

Increasing the penetration of renewable heat in end-use sectors depends in large part on the temperature requirements of the heat demand and which technologies can technically and cost-effectively meet them. Heat demand in the residential and commercial sectors is mostly for low-temperature applications such as domestic hot water and, depending from the location, space heating and therefore can be generated by technologies such as solar thermal collectors or ground-source heat pumps coupled with renewable electricity, instead of the current use of LPG. These technologies are also suitable for industries with low-grade process heat requirements, such as in the food-processing or textiles sectors.

Furthermore, industries with biodegradable waste streams, such as the paper pulp and printing industries or food and tobacco industries, can use these residues as a source of fuel for low-temperature heat demand. For certain fuels, substitution by renewable energy is straightforward – for example, LPG in the residential and commercial sector is primarily for cooking and water heating, applications that can be replaced with renewable heat (e.g. from solar) or electricity. With Morocco's high DNI levels, concentrating solar technologies could deliver the higher-temperature heat demand, as is typically needed by energy-intensive industries.

In other cases, it may be harder to completely substitute existing fuels with renewables. For example, substituting renewables for petroleum coke in industrial applications will only be possible with a technology that makes available a source of combustible renewable fuel with a calorific value high enough to generate sufficient heat at the temperatures needed for process heat. Looking at the electricity fuel mix in detail (Figure 11), the vast majority of Morocco's electricity is, and has historically been, generated from fossil fuels, with coal comprising 55% of generation, gas 19%, and a further 13 % of generation from oil products in 2014. The oil products used for electricity generation mean that Morocco's reliance on oil products is even greater than reflected in Figure 9, although it should be noted that the share of generation from oil products declined by nearly 8 percentage points between 2013 and 2014.

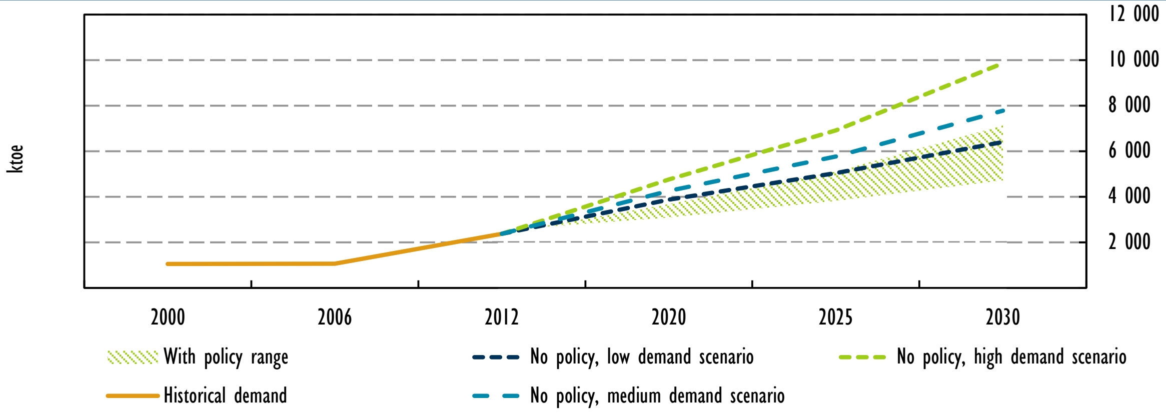
Figure 11 • Electricity generation by fuel, Morocco, 1974-2014



Source: IEA (forthcoming), *Energy Balances of Non-OECD Countries*, www.iea.org/statistics/.

The Moroccan government expects electricity demand to increase on average by 6% per year between 2014 and 2025. Based on these estimates, the government's latest projection is that an additional 16 590 MW of capacity will be needed between 2015 and 2030. However, the government has previously modelled other scenarios (Figure 12), including a high demand scenario, which sees demand increasing at a higher rate (7-7.5% per year to 2030). Other studies (Trieb et al., 2015) also project that long-term electricity demand could be significantly higher than the government's modelling.

Figure 12 • Projections of electricity demand, Morocco



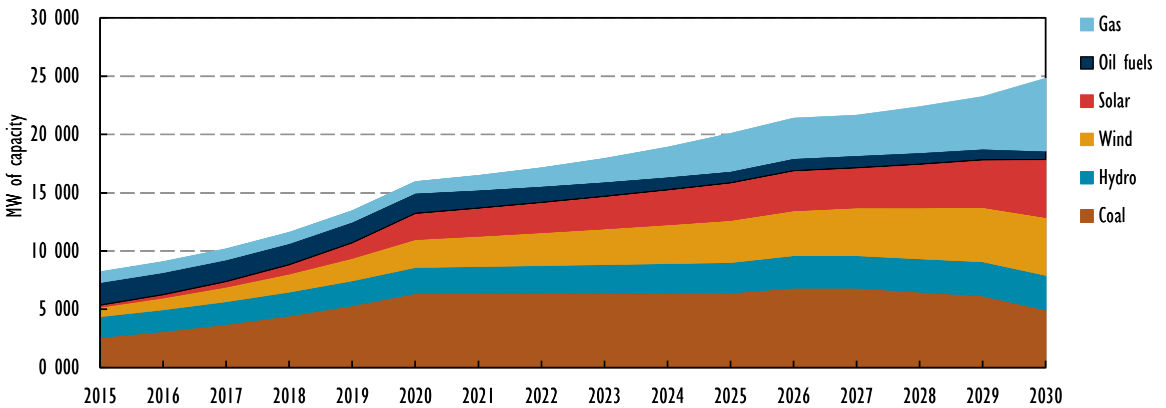
Notes: The "No policy, low demand scenario" represents a scenario in which there are no policy interventions to increase energy efficiency and the economy grows at the historical average rate; the "No policy, medium demand scenario" represents a scenario in which there are no policy interventions to increase energy efficiency and the economy grows at a medium rate; the "No policy, high demand scenario" represents a scenario in which there are no policy interventions to increase energy efficiency and the economy grows at a high rate; the "with policy range" represents the range of electricity demand if the government introduces energy efficiency policies and under and range of different economic growth scenarios.

Source: MEMEE (2015a), *Stratégie Energétique Nationale: Enjeux, Perspectives et Réalisations* [*National Energy Strategy: Issues, Perspectives and Results*].

According to Moroccan government projections, electricity generation from all fuels – except oil products – will increase to meet the official forecast growth in demand (Figure 13). Gas is projected to play a major role in the electricity mix, with Morocco planning to import 5 billion cubic metres (bcm) of LNG per year via a new LNG importing terminal, which will supply 2 400 MW of new combined-cycle gas turbines (CCGT).

The Moroccan government sees a significant opportunity for renewable energy sources to meet increased demand. Solar and wind capacity are projected to grow significantly to 2030. Installed wind capacity is projected to increase by over 500% between 2015 and 2030, while solar installed capacity is projected to increase by nearly 3 000% over the same period. By 2030, the share of renewable electricity capacity is projected to be 52%, comprised of 20% solar, 20% wind and 12% hydro. While hydro capacity is expected to increase in real terms, it declines as a percentage of total capacity (Figure 14).

Figure 13 • Projected installed electricity capacity by fuel, Morocco, 2015-30

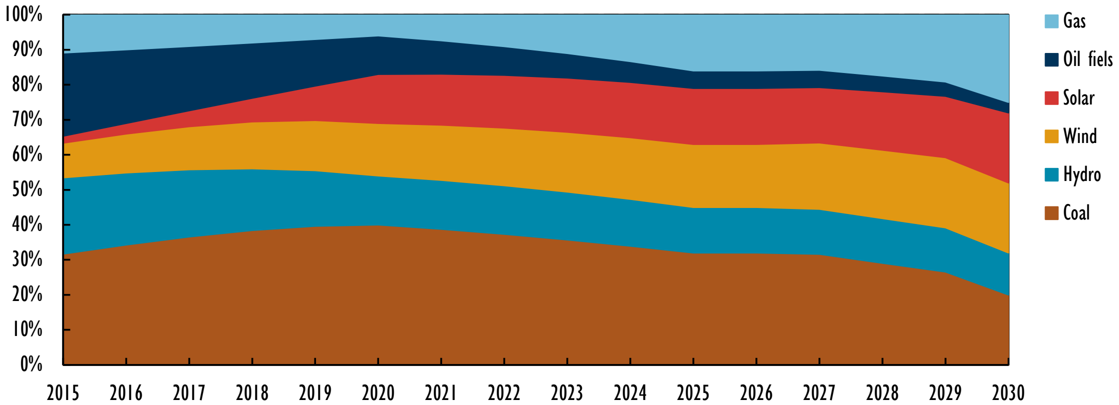


Source: MEMEE estimates and IEA assumptions[13]

[13] In 2015, 2020, 2025 and 2030, installed capacity by fuel is derived from information provided by MEMEE on the share that each fuel will supply of total installed capacity in those years (also supplied by MEMEE). To derive capacity in the years between, average annual growth rates have been applied to estimate capacity.

According to discussions with the National Agency for Electricity and Water (ONEE), the forecast increase in gas (including the 2 400 MW CCGT), hydro (including 450 MW of pumped storage) and coal capacity will provide dispatchable power to balance the intermittency of renewable electricity generators. Other measures to secure a stable supply of electricity include additional interconnections with Spain, Portugal, Algeria and Mauritania.

Figure 14 • Projected installed electricity capacity by share of fuel, Morocco, 2015-30



Source: MEMEE estimates and IEA assumptions[13]

Conclusions on market opportunities

- Growth in electricity use means opportunities exist for all electricity-producing renewable energy technologies to grow, particularly wind, which is an especially low-cost source of electricity in Morocco.
- Given the excellent renewable resources in Morocco (particularly from wind and solar), the projected contribution from renewables to electricity supply could potentially be increased. It is recommended that Morocco undertakes an assessment of 1) the likely availability and costs of an expanded contribution from wind and solar, 2) the issues associated with developing a flexible electricity system capable of providing reliable supply and making full use of flexible non-renewable generation, and 3) opportunities for importing and exporting power, demand-side management and storage.
- Growth in transport energy use provides an opportunity to supply the transport sector with renewable energy (biofuels and electricity). However, an assessment of potential feedstock from residues and wastes, and also for sustainable production of crops specifically for biofuels production, is needed before biofuels can be considered for this sector.
- Heat for industrial uses could be supplied through solar or biomass. Other heating needs at various temperature levels in industry and services could be met with non-concentrating solar thermal collectors for low temperatures (washing, etc.) or with different levels of concentration depending on the temperature levels (or steam pressure) required. As noted in the energy efficiency section of this report, the textiles, agri-food (particularly sugar), and paper and printing industries in particular are likely to offer interesting market niches for solar technologies – all of which could be procured from local manufacturers – thereby reducing their consumption of oil, diesel, natural gas or coal. Opportunities for solar heat may also be present for residential and commercial sector water heating, which would reduce the use of traditional biomass and butane, as well as the fiscal impact of the generous subsidies granted to butane.

1.6 Summary of priority renewable energy technologies

The information above indicates that Morocco has large and diverse renewable energy resources, strong strategic drivers, and significant market opportunities for deploying renewable energy technologies. The results of the evaluation of each of the main criteria are summarised in Table 2 below. In line with the methodology (IEA, 2016a), and on the basis of the evaluation of the individual criteria, the options are classified under four headings:

- **Ready for deployment:** options for which there is a good resource, the technology is fully commercialised internationally, the cost of energy production is attractive and there is a good fit with strategic priorities.
- **Some potential:** options for which there is a promising resource and which could, in principle, help meet strategic needs, but for which other factors are less positive. In these cases the appropriate option may be to carry out feasibility studies and pilot projects so as to test the technologies under local conditions.
- **Needing further evaluation:** resources and technologies for which there is a lack of information on the local resource characteristics and so on the likely costs. Further work to improve the information base is indicated.
- **Low priority:** options for which there is a poor resource base, high costs, poor strategic fit or where there are few market opportunities.

Table 2 • Renewable energy technology prioritisation decision matrix, Morocco

	Resources	Strategic drivers	Market opportunities	Maturity	Likely cost	Priority score
Rooftop PV	★★★★	★★	★★★	★★★★	★★	Ready for deployment
Large-scale solar PV	★★★★	★★★	★★★	★★★★	★★	Ready for deployment
Large-scale solar thermal	★★★★	★★★	★★★	★★★	★★	Ready for deployment
SWHs	★★★★	★★★	★★★	★★★★	★★★	Ready for deployment
Wind (onshore)	★★★★	★★★	★★★	★★★★	★★★	Ready for deployment
Wind (offshore)	★★★	★★★	★★★	★★	★	Low priority
Bioenergy power plants	★★	★★★	★★★	★★★★	★★	Needing further evaluation
Bioenergy heat plants	★★	★	★★	★★★★	★★	Needing further evaluation
Biofuels	★★	★★★	★★	★★★★	★★	Needing further evaluation
Hydro	★★	★★★	★★	★★★★	★★★	Some potential

Notes: Star ratings are out of 4 stars, with one representing a low score and four representing an exceptionally good score; ★ = poor; ★★ = fair; ★★★ = good; ★★★★= excellent; for the likely cost rating, the greater the number of stars, the lower the likely cost; technology maturity represents the global level of maturity; for a more detailed discussion of what each of these criteria means, please refer to (IEA, 2016a).

Solar, wind and hydropower technologies have been designated as the priority technologies in Morocco's renewable energy strategy. Analysis undertaken for the prioritisation step of this study suggests that Morocco could potentially examine bioenergy technology options, particularly biofuels. The production of biofuels that can directly substitute for oil products could bring multiple benefits, as oil products are by far the largest source of energy consumed in Morocco across most end-use sectors. However, further work is needed to define the resource potential and costs.

Special attention should also be given to SWHs, which score highly on the prioritisation decision matrix above. There are strong strategic drivers for deploying SWHs, particularly in the household and commercial sectors where they have the potential to replace butane and wood in water heating applications. Reducing butane consumption would have significant benefits: ADEREE has estimated that for every MAD 1 spent on SWHs, the Moroccan government could save MAD 5 in avoided butane subsidies.

Step 2: Indicators, current penetration and costs

2.1 Indicators and current levels of market penetration

The Moroccan government has determined that its renewable energy targets will be set in capacity (megawatts). The official targets are for renewables to provide 42% of installed electricity generating capacity by 2020 and 52% of installed capacity by 2030. To be consistent with these targets, the appropriate metric for measuring technology deployment is also megawatts of capacity.

The current deployment levels for renewable energy technologies in Morocco are shown in Table 3.

Table 3 • Current priority renewable electricity technology deployment levels, Morocco

	Small-scale PV	Large-scale PV	CSP (parabolic trough)	Onshore wind	Hydro	Bioenergy power generation
Current capacity	10 MW**	8 MW	180 MW	788 MW	1 780 MW	n/a
2020 target	40 MW	2 000 MW (large-scale solar target)		2 000 MW	2 000 MW	200 MW
2025 target	n/a	3 000 MW (large-scale solar target)		3 000 MW	3 000 MW	n/a
2030 target*	80 MW	TBC		TBC	TBC	400 MW

* = The 2030 targets are being revised in line with the new target of 52% of installed capacity to be sourced from renewable energy by 2030. The Moroccan government had not presented an exact MW target for each technology type at the time of writing.

** = Estimate based on 150 000 households being equipped with individual (isolated) solar kits with a capacity of 50, 75 or 200 watts (W) under the PERG programme.

Notes: n/a = not applicable; TBC = to be confirmed.

Sources: MEMEE (2011), *Stratégie Energétique Nationale: Horizon 2030* [*National Energy Strategy: Horizon 2030*]; MEMEE (2015a), *Stratégie Energétique Nationale: Enjeux, Perspectives et Réalisations* [*National Energy Strategy: Issues, Perspectives and Results*].

Table 4 • Electricity generation, Morocco, 2015

	Generation (GWh)	Share of generation (%)	Total renewable share %
Hydro	1 858.30	5.42	
Wind	1 735.20	5.06	10.5% (Hydro, Wind, Solar)
Solar	5.70	0.02	
Thermal	22 557.10	65.82	
Gas	2 490.80	7.27	
Net imports	4 973.50	14.51	
Private projects	644.40	1.88	
Other	8.30	0.02	

Notes: The category "private projects" may also include renewable energy generation.

Source: MEMEE data provided to the IEA.

Given the differing levels of availability (prospective full-load hours) for each of the principal electricity-producing technologies, it is also valuable to consider and monitor the meaning of these shares of capacity in terms of electricity generated (in GWh) in absolute terms and as a fraction of total electricity generated. The latest generation figures available are shown in Table 4.

Table 5 • Current priority renewable heat technology deployment levels in Morocco

	SWH	Biogas for heat
Current capacity	455 000- 640 000m^2	3 850 m^3**
2020 target	1 700 000m^2	n/a
2030 target	3 000 000m^2	n/a

* = This range is estimated. The lower bounds are based on deployment rates from 2001-11, excluding the impact of the PROMASOL programme. The upper bounds are based on recent import data suggesting an average annual increase in sales of 13-14%.

** = Based on 55% of the 350 digesters deployed being active and assuming an average capacity of 20 m^3 per digester (Beraich, Bakasse and Arouch, 2014).

Notes: kW/m^2 = kilowatt per square metre; m^2 = square metre; m^3 = cubic metre.

Sources: Ettaik (2012), *Solar Water Heaters in Morocco*, www.shamci.net/wp-content/uploads/2013/09/Morocco_ArSol_country-report.pdf; OME (2012), *Solar Thermal in the Mediterranean Region: Market Assessment Report*, www.b2match.eu/system/stworkshop2013/files/Market_Assessment_Report_II.pdf?1357834276.

In early 2016, the renewable energy generation fleet mainly comprised 22 hydropower plants with a total capacity of 1 780 MW, 788 MW of wind farms and 180 MW of solar thermal plant (Table 3), made up of the 20 MW Ain Beni Mathar plant and the 160 MW Noor I plant at Ouarzazate.

Anaerobic digesters to create biogas from agricultural residues, manure and other sources of biomass were introduced into Morocco in the early 1980s. More than 350 digesters have been introduced in rural areas, although some 45% of existing digesters are not in operation (Beraich, Bakasse and Arouch, 2014). Their estimated capacity is represented in Table 5. Table 5 also shows current SWH capacity and deployment targets for 2020 and 2030.[14]

2.2 Indicators and current levels of cost and remuneration

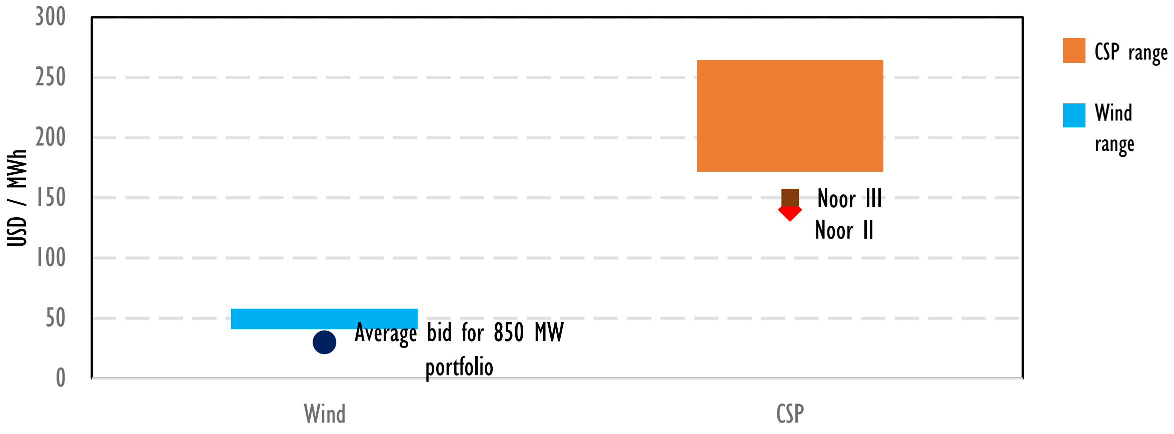
At this step in the methodology, energy generation costs for a range of technologies (both renewable and non-renewable) are compared by calculating the levelised cost of energy (LCOE) (refer to IEA, 2016a). This requires a detailed understanding of all sources of finance, finance costs, available remuneration (through feed-in tariffs or power purchase agreements [PPAs]), as well as capital costs and operating expenses (amongst other information). Detailed and accurate information was not easily obtainable for this pilot study; however, other studies have produced estimates of the LCOE for selected projects (for example, see CPI, 2012 and 2013).

Although not an accurate reflection of true generation costs, bid prices provide an indication of costs.[15] The most recent bids indicate that large-scale Moroccan solar prices are tracking below the expected cost range indicated in Step 1 (Figure 16).

[14] For solar heating the collector surface area is often used as a proxy measure of generation capacity.

[15] There are significant differences between bid prices and LCOE. Bids may not reflect the true cost of generating energy, as they are affected by a range of factors including the developer's perception of project risk over the lifetime of the project. Bid prices will also be influenced by the costs of establishing a presence in a country, of understanding local conditions and developing the necessary supply chain and then of the assessment of the longer-term size and sustainability of the market opportunity.

Figure 15 • Selected bid prices for wind and CSP compared to benchmark cost ranges



Notes: Prices adjusted to 2015 prices using IMF GDP deflators for Morocco; note that IMF staff estimates are used for the index; OANDA average annual exchange rate for 2015 used to convert from MAD to USD (www.oanda.com/currency/average) (MAD 1 = USD 0.10195 [2015]).

Sources: le360 (2015), "Solaire: La baisse des coûts profite à MASEN" ["Solar: The decline in costs enjoyed by MASEN"], http://fr.le360.ma/economie/solaire-la-baisse-des-couts-profite-a-masen-49303; Reuters (2014), "Saudi ACWA, Spain's Abengoa bid lowest on Moroccan solar plants – sources", http://uk.reuters.com/article/morocco-power-solar-idUKL5N0T300020141113, Conversations with ONEE, 8 March 2016.

Morocco does not currently have a feed in tariff. Instead, under the model used for major projects, MASEN (for solar) or ONEE (for wind and hydro) establish long-term PPAs with project developers, providing a stable source of remuneration, often backed by international sources of finance.

Morocco's PPA model has been successful in attracting developers of large-scale wind and solar projects, even for technologies that are comparatively high cost due to their relative market immaturity, such as solar CSP. MASEN's approach to providing remuneration for less-mature technologies has been to act as a broker between project developers and the grid operator, signing a PPA with both and effectively leveraging sources of domestic and international finance (explained in Box 1).

While large-scale projects have successfully been financed through the PPA model, incentives for medium- and small-scale projects are currently not available, which may be a barrier to deployment in some cases. For example, SWHs have comparatively high capital costs and so the lack of financial support makes them cost prohibitive in comparison to competing technologies (butane water heaters), which enjoy subsidies. This is discussed further in Section 3.4.

Step 3: Technology penetration and cost monitoring

3.1 Monitoring renewable energy technology penetration over time

Morocco has established installed-capacity targets for solar, wind and hydro deployment, and therefore these are the primary benchmarks against which technology deployment will be measured.

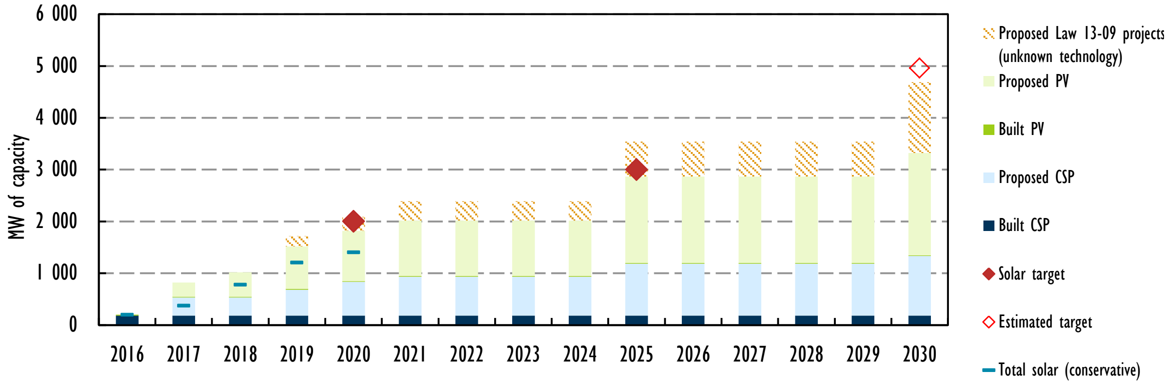
For large-scale technologies, a "bottom-up" approach was selected to monitor deployment levels and assess progress against national targets. Large-scale projects have been classified according to a four-tiered rating system:

1. Announced: Where the intention exists to develop a site and initial scoping studies have been conducted to estimate the potential capacity.

2. Planning: Where a process to select project developers has commenced. Requests for qualification or tender are carried out and a developer is selected. Project finance is secured.
3. Under construction: Construction of infrastructure at the site is under way.
4. Commissioned: Project is completed and is generating energy.

Using information on projects (most of which is publicly available), it is then possible to chart the projected deployment of large-scale renewables for solar, wind and hydro, and to track how deployment levels compare against national targets. This is shown in Figures 16, 17 and 18 below.

Figure 16 • Projected large-scale solar energy penetration to 2030 under best-case scenario, Morocco



Source: IEA analysis based on MEMEE (2016), *Evolution des Energies Renouvables a l'Horizon 2030* [*The Evolution of Renewable Energy to the Horizon of 2030*].

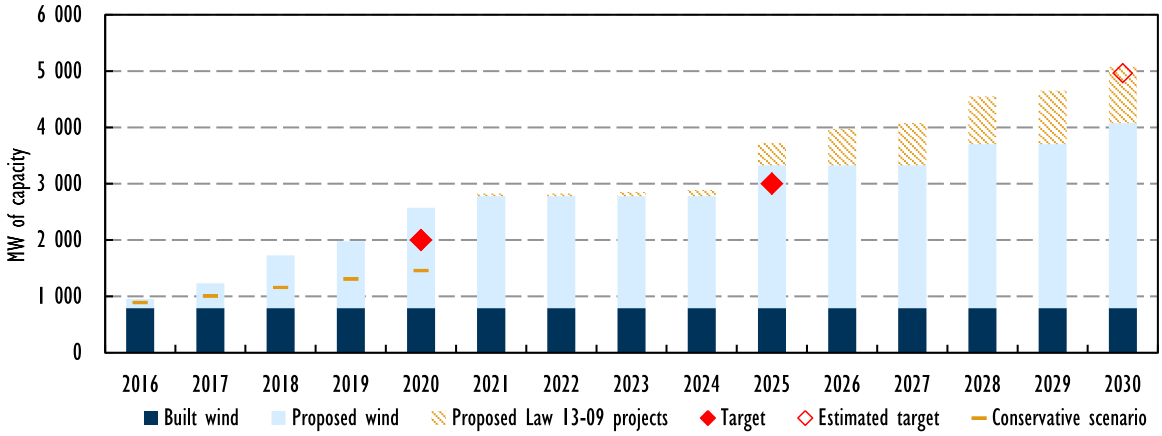
Figure 16 shows that, based on government estimates of planned construction timelines, Morocco is on track to deliver its 2 000 MW of large-scale solar by 2020. That said, reaching the target will require significant levels of deployment in the years between 2018 and 2020, particularly from private developers (utility-scale or distributed) under Law 13-09. The IEA understands that certain private developers have expressed concern about potential barriers to entry, particularly relating to securing grid access, and the fact that Morocco does not yet have an independent electricity market regulatory authority. This is being addressed (see "Enabling environment" section below), but delays in implementation may hold up deployment of private-sector driven projects, leading the IEA to anticipate that solar deployment levels may fall short of the 2020 target. A conservative estimate of future solar deployment to 2020, taking into account grid access issues for private developers and potential construction delays, is shown by the blue markers in Figure 16.

The existing 160 MW Noor I CSP plant at Ouarzazate will be augmented by two other large CSP projects, the 200 MW Noor II and 150 MW Noor III, which are currently under development and are scheduled to be commissioned in 2017. While Noor II is another solar trough-based plant, and will benefit from technology learning gained from Noor I, Noor III will be the first CSP tower project in Morocco, which may pose technical challenges.

PV penetration rises steadily from 2017, and in the period 2017-20 between 700 MW and 1000 MW of capacity may be added. Most of these large-scale PV projects are currently in the planning phase, with requests for proposals for several being considered in 2016.

From 2021 to 2030, solar PV penetration is expected to increase significantly, driven largely by government-owned projects to be implemented by MASEN and ONEE. The private sector is also expected to add some 1100 MW of capacity in that period under Law 13-09.

Figure 17 • Projected wind energy penetration to 2030 under best-case scenario, Morocco



Source: IEA analysis based on MEMEE (2016), *Evolution des Energies Renouvables a l'Horizon 2030* [*The Evolution of Renewable Energy to the Horizon of 2030*].

The government of Morocco foresees significant growth in wind capacity between now and 2020, with nearly 1800 MW expected to be added, which would result in Morocco exceeding its 2020 and 2025 targets (MEMEE, 2016). Adding this much capacity at such a rate would require a number of factors to be aligned, including: securing financing for all projects, particularly in politically sensitive regions; starting and completing construction within five years for most projects; and overcoming grid-integration issues for a significant amount of additional variable capacity in five years. Noting these factors, a less optimistic scenario than the "best-case" scenario is represented by the orange markers in Figure 17.

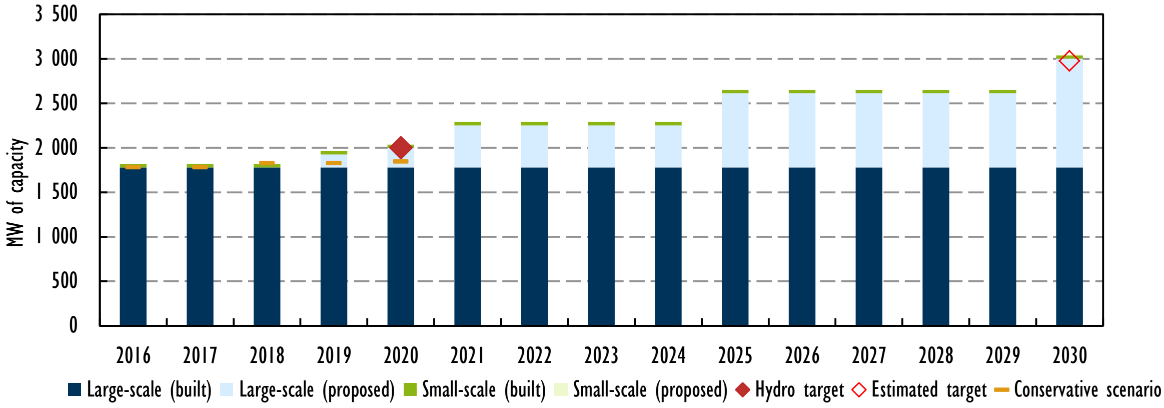
This new deployment is projected to begin in 2016 with 100 MW at the Akhfenir wind farm (expected to be commissioned in June) and partial completion of the 120 MW Jbel Sendoug–Khalidi wind farm, which the EBRD is supporting with a loan of EUR 126 million. The latter project is significant, as it is one of the first private renewable energy projects in the country to be developed under Law 13-09, which allows private producers to sell electricity directly to clients connected to the high-voltage and medium-voltage grid.

ONEE expects the first 150 MW tranche (Taza) of the 1 000 MW Integrated Wind Programme to be commissioned in 2017. Auctions for the remaining 850 MW took longer than analysts had expected, but a consortium comprising Enel Green Power and Nareva was selected in March 2016. This 850 MW is spread over five sites, which are expected to come online between 2017 and 2020, which represents a sizeable increase in capacity.

Between 2021 and 2030, a long list of projects is projected to come online, totalling 2 500 MW of capacity. Of this, 1 000 MW is projected to come from private developers under law 13-09, with 1 500 MW of state-led projects.

Hydropower capacity of 217 MW is set to be installed by 2020 at the major dams under construction. This includes 90 MW of capacity at M'Dez and a further 53 MW of expected projects under Law 13-09. Under Law 13-09, MEMEE (MEMEE, 2015a) has approved hydraulic micro-plants with a total capacity of 100 MW for development by the private sector (Figure 18). Under the conservative scenario (represented by the orange markers), project construction delays mean the 2020 target is not reached until after 2020.

Figure 18 • Projected hydro energy penetration to 2030 under best-case scenario, Morocco



Source: IEA analysis based on MEMEE (2016), *Evolution des Energies Renouvables a l'Horizon 2030* [*The Evolution of Renewable Energy to the Horizon of 2030*].

In addition to the capacity shown in Figure 18, a further 350 MW of pumped storage is projected to be added by 2020, through the addition of the Abdelmoumen project, for which a pre-qualification process was completed in late 2015. This project is designed to balance the variability of wind and solar PV generators.

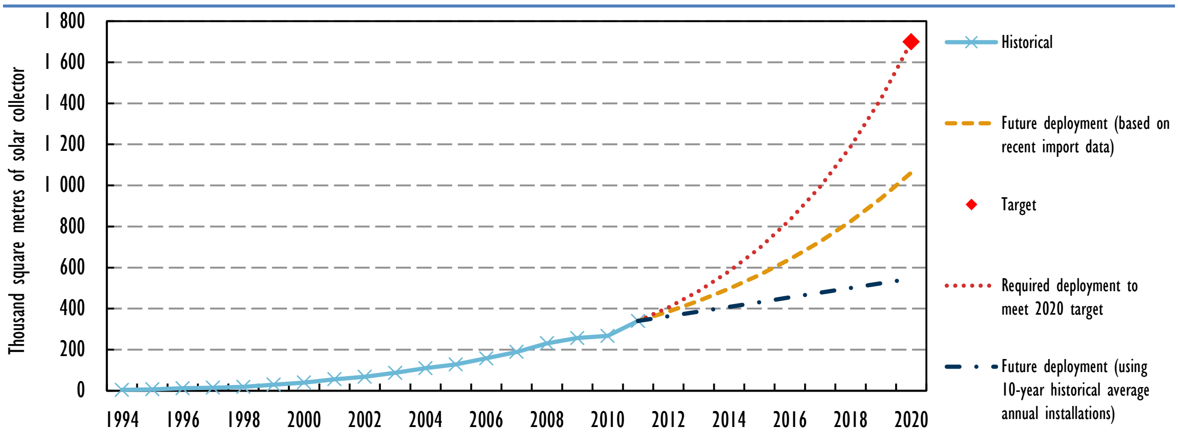
Morocco's 2030 target of renewables to account for 52% of installed capacity appears possible if the forecast project pipeline comes to fruition. However, the exact mix of technologies that will achieve that target is uncertain. In addition, the target may be easier or more difficult to achieve depending on the amount of capacity needed to satisfy demand. As shown in Figure 11, a range of views exists on future electricity demand, which will determine how much capacity Morocco will actually need in the future.

For small-scale technologies, a different approach is needed to track progress against targets, as less information is available as to when projects will be implemented. A more assiduous data collection process is required.

In Morocco's case, historical market penetration of SWHs has been assisted by support through the PROMASOL programme, which ADEREE estimates added an extra 8 000 m^2 per year during its operation (OME, 2012). Without support, penetration rates would have been lower – due to high costs in comparison to incumbent technologies for water heating (primarily butane, which receives heavy subsidies) – but not necessarily significantly lower, as the market had been expanding prior to PROMASOL.

Figure 19 shows that installations of SWHs will have to increase at an average annual rate of around 20% from 2011 levels until 2020 if the target is to be achieved. Based on recent SWH imports, ADEREE estimates that the recent *growth* rate of deployment has been around 13-14% per year. If this rate was to continue into the future, Morocco would fall short of the 2020 target (represented by the orange dotted line). A more conservative estimate is represented by the blue dashed line. This is based on a rough estimate of the rate of deployment in the ten years from 2001-11 (excluding the impact of the PROMASOL programme), which equates to only 23 000 m^2 of additional SWH collector area per year on average. If that trend continues, deployment is set to fall far short of the 2020 target. Whether an annual growth rate of 20% is achievable to 2020 will largely depend on the details of the Shemsi programme, currently being finalised by the government at the time of writing.

Figure 19 • Current deployment and required trajectory to meet SWH target, Morocco



Notes: The 10-year historical growth rate used for the projection of future deployment is based on the historical growth rate from the years 2001-11, removing the impact of the PROMASOL programme; projections are based off the year 2011 due to a lack of reliable data on more recent levels of SWH deployment

Sources: 2011 deployment figures from Ettaik (2012), *Solar Water Heaters in Morocco,* www.shamci.net/wp-content/uploads/2013/09/Morocco_ArSol_country-report.pdf; deployment from 1994-2010 from OME (2012), *Solar Thermal in the Mediterranean Region: Market Assessment Report,* www.b2match.eu/system/stworkshop2013/files/Market_Assessment_Report_II.pdf?1357834276.

3.2 Monitoring and benchmarking renewable energy technology costs

Obtaining the necessary information to compile an accurate time series of LCOE for various renewable and non-renewable generators in Morocco has not been possible during this study. It has, however, been possible to access public information on past and recent bid prices received for certain renewable energy technology projects.

Comparing projects based on bid prices or costs should be done carefully, as a range of factors affect the costs, including the quality of the resource at specific sites, learning over time, and differing requirements for storage, amongst others.

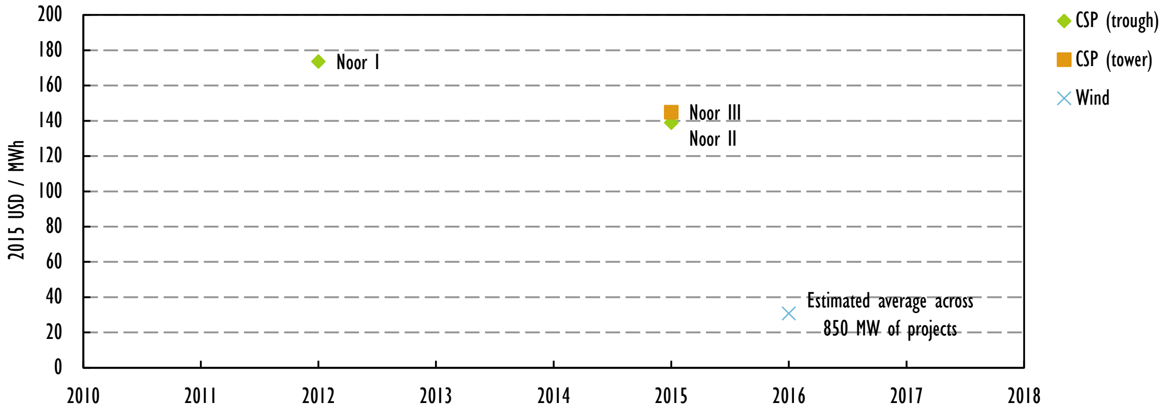
According to ONEE, wind costs were initially low in Morocco due to plentiful resources. Over time, they rose as the most economically attractive resources were exploited. Now, costs are falling again due to improvements from technology learning. As a result, in January 2016, ONEE reported that the latest bids for large-scale wind projects (850 MW over several sites) were between USD 25 and USD 35 per MWh (Figure 20). This is remarkable and puts the cost of Moroccan wind projects well below the "likely cost" range specified at Step 1.2 (Figure 15). Indeed Moroccan wind projects are now amongst the cheapest in the world.

Morocco's recently received bids for CSP of approximately USD 139/MWh for Noor II and USD 145/MWh for Noor III indicate that prices are falling from Noor I, which was over USD 173/MWh.[16] These prices are significantly below the global average of already commissioned plants, which is heavily influenced by the lower DNI resources in other parts of the world, for example in Spain, where half the global capacity is situated. They also reflect the low cost of capital achieved in Morocco due to a clever use of concessional financing (refer to Box 1). As other studies (CPI, 2012; CPI, 2013) have noted, without concessional financing, the cost of Moroccan CSP would be significantly higher.

[16] Prices adjusted to 2015 prices using IMF GDP deflators for Morocco. Note that IMF staff estimates are used for the index. OANDA average annual exchange rate for 2015 used to convert from MAD to USD (www.oanda.com/currency/average) (MAD 1 = USD 0.10195 [2015]).

The cost of PV installations has been falling rapidly (IEA, 2015b). The current global range is USD 100/MWh-USD 200/MWh, with the average weighted cost around USD 125/MWh for PV systems fully commissioned in 2015. The lowest recorded PPA was announced in the UAE for USD 30/MWh in early May 2016, for plants to be commissioned between 2018 and 2020, while other bids in the same auctions were below USD 45/MWh. Given Morocco's very good solar regime, utility-scale projects could be expected to yield electricity at below USD 60/MWh under favourable circumstances; it will be interesting to see the level of bids received when the first major solar PV projects are awarded later in 2016.

Figure 20 • Selected bid prices for CSP and wind, Morocco



Notes: Prices adjusted to 2015 prices using IMF GDP deflators for Morocco; note that IMF staff estimates are used for the index; OANDA average annual exchange rate for 2015 used to convert from MAD to USD (www.oanda.com/currency/average) (MAD 1 = USD 0.10195 [2015]).

Sources: le360 (2015), "Solaire: La baisse des coûts profite à MASEN" ["Solar: The decline in costs enjoyed by MASEN"], http://fr.le360.ma/economie/solaire-la-baisse-des-couts-profite-a-masen-49303; Reuters (2014), "Saudi ACWA, Spain's Abengoa bid lowest on Moroccan solar plants –sources", http://uk.reuters.com/article/morocco-power-solar-idUKL5N0T300020141113, Conversations with ONEE, 8 March 2016.

3.3 In-country monitoring systems

At the time of writing, the institutional framework for developing and monitoring renewable energy technologies was under review in Morocco. The results of the review may change the current monitoring framework, as it is expected that MASEN will have responsibility for the deployment and monitoring of *all* renewable energy technologies. Prior to the results of the review, it should be noted that a number of agencies currently monitor renewable energy technology deployment in Morocco and locating a centralised source of information on deployment can be difficult. ONEE, which to date has been responsible for deploying large-scale, state-supported renewable energy projects, is a primary source of data on renewable energy technology deployment, generation output, and costs. As the sole electricity buyer, ONEE has also had access to data on private projects deployed under Law 13-09. MASEN collects data on the large-scale solar projects under its purview, while it is currently unclear which agency collects data on the deployment of small-scale systems (rooftop PV, SWHs, etc.).

However, primarily MEMEE has overall responsibility for gathering information on renewable energy technology capacity and generation from all large-scale sources, in order to produce the guiding policies and strategies to reach Morocco's targets. MEMEE has been the source of publications showing forecast capacity requirements to meet Moroccan electricity demand (which were used to underpin Figures 13 and 14).

The IEA understands that no sophisticated modelling capacity is currently available to forecast expected demand in Morocco, nor the range of energy generation mix options that could meet that demand. Until this is improved, it will be very difficult to accurately plan for future renewables deployment.

As MASEN assumes responsibility for renewables deployment, it will be important that the agency collaborates with ONEE to establish a database of renewable energy technology capacity, generation and costs, to include historical data so that comparisons over time can be made.

Systems to monitor small-scale renewables deployment are underdeveloped, and it appears that no major efforts have been made to establish a system to track and monitor deployment, generation or costs. While these technologies have generally been concentrated in off-grid applications, as deployment in rural, grid-connected systems increases, it will be important to monitor their deployment, as experience in other countries suggests that collectively, these technologies can have major impacts on electricity demand from the grid.

3.4 Enabling environment for priority technologies

This section assesses briefly the enabling environment in Morocco for renewable energy technologies generally, rather than on a technology-by-technology basis. However, it makes reference to specific technologies where necessary.

Regulatory and institutional factors

Institutional framework

As noted above, Morocco's institutional framework for implementing clean energy technologies is under review. What follows is a discussion of the existing framework.

In 2009 Morocco established a new institutional framework to oversee the implementation of the country's renewable energy strategy. Each institution was designed to manage a particular step or steps in the technology deployment cycle (Figure 21). Starting at the research and development (R&D) stage, the Research Institute for Solar Energy and New Energies (IRESEN) is responsible for R&D of renewable energy and energy-efficient technologies. With EUR 50 million funding until 2020, IRESEN brings together researchers and the private sector to conduct studies and pilot projects of a range of renewable energy technologies, including solar thermal and PV, wind, and biomass. At its Green Energy Park, IRESEN tests renewable energy technologies in the field to assess performance under Moroccan climate conditions and to inform policy and deployment.

The Ministry of Energy, Mines, Water and the Environment (MEMEE) is the central ministry responsible for guiding Morocco's overall energy strategy, including renewable energy. MEMEE plays a co-ordinating role across all agencies and is also the main agency responsible for crafting renewable energy laws and the renewable energy strategy.

The Agency for Renewable Energy and Energy Efficiency (ADEREE) was established under the renewable energy law and is in charge of implementing the national renewable energy and energy efficiency plan. This includes drafting local renewable energy plans, managing the implementation of smaller-scale renewables projects and creating government programmes to encourage the uptake of distributed renewable energy technologies (for example, SWHs). Given that distributed renewable energy technologies affect energy demand, ADEREE also monitors their deployment as part of its management of energy efficiency indicators. ADEREE also produces renewable resource assessments for all the major renewable resources.

The State Investment Company (SIE) provides both small- and large-scale finance for renewable energy and energy efficiency projects. SIE has financed mini-PV plants, small hydro and around 100 MW for the Integrated Wind Energy Programme. SIE also owns 25% of shares in MASEN and to that end is involved in financing large-scale solar projects. Finally, SIE leverages its funds to mobilise private-sector and institutional sources of finance, both locally and internationally.

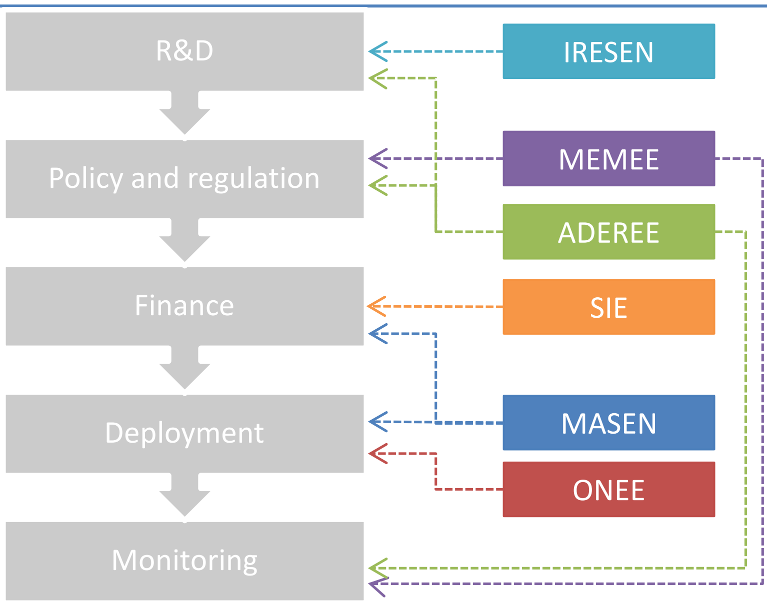
The National Agency for Electricity and Water (ONEE) is the result of the merger of ONE (electricity) and ONEP (drinking water), which became effective in April 2012 (Law 40-09). It is the (quasi) sole buyer of electricity in Morocco. As a public industrial and commercial establishment possessing legal personality and financial autonomy, it was invested with exclusive rights to production and transport. It also ensures the distribution of electricity to several Moroccan provinces, especially in rural areas. The main missions of the ONEE are to respond to the country's electrical energy needs, manage and develop the distribution grid, ensure the extension of rural electrification, manage overall electrical energy demand, and until recently, promote the development of renewable energy.

The Moroccan Agency for Solar Energy (MASEN) is a limited liability company with a board of directors and a supervisory board (Law 57-09). Its mission is to carry out a programme for developing a minimum of 2 000 MW capacity of integrated solar power generation projects. In December 2015, King Mohammad VI gave instructions to widen MASEN's role to include all renewables across the kingdom. The full implications are not yet known, nor is it clear whether this will be followed by consolidation given the number of agencies involved in the renewables sector.

The expanded mandate has been seen as recognition that MASEN's streamlined management structure is better suited to deliver renewables projects than state utility ONEE, whose monopoly has already been diluted by previous amendments to the law. It also reflects the King's personal commitment to the renewables programme. The latest change came following a meeting chaired by the Moroccan monarch on 27 December 2015 with all stakeholders in the sector, in Casablanca, where ONEE has its headquarters. Despite the impressive progress that Morocco has made in developing its renewables capacity, the King is understood to want swifter implementation of the programme.

MASEN has hitherto focused on development of the Ouarzazate CSP project and other solar projects, while ONEE had wider responsibility for the sector. In the new configuration, MASEN, which has developed an Africa-wide reputation for project delivery, is expected to have greater influence over projects across the sector, including wind and hydroelectricity.

Figure 21 • Morocco's renewable energy institutional framework



Policies and regulations

On 27 August 2015, the Moroccan government introduced four amendments to laws relating to renewable energy. These came into effect at the end of 2015. The amended laws 1) increase the amount of electricity that companies other than state monopoly ONEE are allowed to generate and transport through the national grid, 2) allow the sale to ONEE of any surplus electricity generated by renewables, and 3) raise the limit that private producers and generators can produce to supply their own needs.

Because of its high dependence on energy imports, Morocco devised an ambitious renewable energy strategy. It set a target of securing 42% electricity generation capacity from renewable sources by 2020 and to 52% by 2030. Significant legal reforms prior to the 2015 amendments included:

- Decree 1-06-15 of 2006, which obliges public institutions to employ competitive calls for tender in the award of projects. The law applies, for example, to municipalities that may wish to contract with wind farms or other sources of electricity from renewable energy.
- Law 16-08, voted in 2008, which raised the ceiling for self-generation by industrial sites from 10 MW to 50 MW. The law was conceived principally to support wind power, but applies equally to other technologies. It amends the 1963 Decree that created ONE and attributed to ONE a monopoly of production above 10 MW.
- Law 13-09, which promotes renewable energy development and provides a framework for developers and investors in clean energy projects. The new law does not put a limit on the installed capacity per project or per type of energy, and provides a legal framework for clean energy export.
- Law 16-09, which provides for the establishment of ADEREE.
- Law 57-09, which provides for the establishment of MASEN (the agency's mandate was significantly enhanced by royal decree at the end of 2015).
- Law 58-15, which was published in the official gazette in January 2016. The law authorises access to the national low-voltage distribution grid to renewables suppliers, but limits their contribution to 20% of annual electricity production. Furthermore, its concrete implementation remains dependent on the publication of detailed regulation.

A very clear regulatory framework is in place for *large-scale* projects, which creates conditions that are attractive to large-scale project developers and their financiers, with predictable income streams assured through long-term PPAs. This has been a critical factor in ensuring the current deployment of wind and solar at low cost. As Morocco seeks to broaden the base of its renewable energy developments – for example for medium-scale solar and wind projects and especially for commercial and residential-scale solar PV projects – it will need to put in place similar enabling regulations that allow and foster deployment.

It will also have to consider measures to promote solar water heating, which in principle should be a cost-effective option for industrial, commercial and residential heating needs. Such measures need to take into account the relatively highly subsidised nature of fossil fuel supply, which currently renders such options financially unattractive to consumers.

Key government programmes for renewables

ADEREE is responsible for programmes to increase the uptake of small-scale renewable systems. The PROMASOL programme (2002-10) had significant success, increasing the area of SWHs from 35 000 m^2 of solar thermal panels in 1998 to more than 350 000 m^2 today. The programme also helped increase the number of companies importing and/or locally assembling SWHs from about 5 to more than 40, and established an SWH manufacturing standards and labelling system.

Now the goal is to reach 1.7 million m^2 of installed SWH capacity by 2020, and 3 million m^2 by 2030. To achieve these goals, ADEREE has submitted a comprehensive plan to the government, known as the Shemsi programme. Details are forthcoming as to what the final version of the programme will look like if it is approved. However, it is understood to revolve around four axes: funding, labelling and certification, communication, and training and regulation. Estimates of potential energy savings from the programme are shown at Figure 44.

In order to improve agricultural yields and productivity while saving on water and energy, the national programme to promote solar pumping in irrigation water saving projects has been developed. This programme has a budget of MAD 400 million and foresees the development of 3 000 PV pumping systems with a total peak installed capacity of 15 MW. It would allow, among other things, savings on the butane gas subsidy by the Compensation Fund. These savings would cover the subsidy amount, which would be recovered at the end of three to five years. The grant provided for the solar pumping component will cover 50% of the installation cost, with a cap of EUR 7 000, providing the farmer installs drip irrigation.

Permitting process

Broadly speaking, Morocco has three types of project developer: the government (through ONEE or MASEN); large industrial entities that construct renewable energy projects to power industrial sites; and private developers, who create projects under Law 13-09. Government-operated projects are straightforward to develop. When ONEE or MASEN launch a tender for a renewable project, they select the site and secure site access prior to seeking bids from developers. As the national grid operator and sole buyer of electricity in Morocco, ONEE is able to guarantee access to the grid for such projects, without needing to undertake a lengthy approval process.

Large industrial developers are largely free to develop renewable energy projects on land they own, but must obtain approval from ONEE to connect to the grid. Two types of contract are required: a grid access contract and a grid connection contract.

Private developers of plants over 20 kilowatts (kW)[17] under Law 13-09 are required to secure land access themselves and obtain development permission from MEMEE through a two-step permitting process. Step one requires applicants to submit an administrative file with technical and financial information to obtain a temporary authorisation, known as a "Preliminary Statement". The developer will be required to renew the Preliminary Statement in cases where operation of the plant has not started within three years or where electricity production is suspended for more than two consecutive years.

Step two in the permitting process is to obtain final authorisation to begin generating electricity. Where the plant is between 20 kW and 2 MW, this is the final step in the process. Where the plant is equal to or greater than 2 MW,[18] ONEE is consulted on technical issues before final authorisation is granted. Once final authorisation is granted, it may be withdrawn if the plant is not used within one year, or if electricity production is suspended for more than two consecutive years. In addition to the process with MEMEE, developers must sign grid access and grid connection contracts with ONEE.

While the process outlined above seems straightforward, in practice the IEA understands that private renewable energy project developers have expressed some concern that grid access has been limited due to potential conflicts of interest stemming from the fact that ONEE is both a major project developer and controls the grid. While Law 58-15 ostensibly allows private developers to sell *surplus* electricity to the grid, this is capped at 20% of annual production and is

[17] Plants under 20 kW are not required to undertake a permitting process.

[18] For solar thermal plants, the threshold for consulting ONEE is 8 MW.

currently limited to those installations connected to the high- and very high-voltage grid, until the detailed regulation for low-voltage grid is published. Private developers seeking to connect to the medium- and low-voltage grids remain uncertain as to conditions they face.

Financial and market factors

Access to finance

A crucial part of the enabling environment in Morocco is the country's success in mobilising finance for renewable energy projects, particularly from international sources. This is particularly important given the comparatively high underlying rates for financing that many projects would face if they were financed by commercial lenders. Between 2011 and 2015, renewable energy was the largest recipient of greenfield foreign direct investment in Morocco, attracting close to USD 3 billion (Financial Times, 2016). Beyond the amount of finance mobilised, Morocco's success lies in the way that it has successfully managed multiple sources of finance to bring renewable energy projects to fruition, through an innovative institutional framework. Primarily through MASEN, a semi-government-owned entity, Morocco has secured a range of international and domestic sources of finance, which it has used to successfully reduce some of the financial risks for project developers, leading to very competitive bids for its first large-scale CSP project (Box 1).

Fuel subsidies

In 2014, Morocco undertook significant steps in a gradual process of reforms to reduce subsidies for certain fossil fuels. From 1 February 2014, subsidies for gasoline and industrial fuel oil were removed and from 1 June 2014 the same was applied to fuel oil for electricity generation. Butane and diesel oil continue to receive a partial subsidy, which creates barriers for the deployment of certain renewable energy technologies, most notably SWHs. According to Moroccan government sources, the payback period for an SWH when competing with subsidised butane is currently 21 years.[19]

In its INDC of June 2015, Morocco indicated that further fossil fuel subsidy reforms would form a key part of its climate change mitigation strategy (UNFCCC, 2015).

A reduction in fossil fuel subsidies over time will help to increase the attractiveness of renewables technologies, by reducing the cost difference with fossil fuels. This may have particular benefits for small-scale projects, such as SWHs, which currently cannot compete on price with subsidised butane.

Technical and infrastructure factors

One of the reasons for Morocco's success in rapidly deploying large-scale renewables is the way in which vital infrastructure is provided for renewable energy technology sites. Under the current model of large-scale solar development, the state (through MASEN) oversees the construction of infrastructure for project sites, including roads, water, hydrology, electricity, telecommunications, security, waste, lighting infrastructure and other services. This has many advantages for both parties. It allows developers to focus solely on the construction of generation infrastructure, reducing risks and costs. MASEN is able to develop a common model for delivering such "packages" of supporting infrastructure and, over time, becomes more efficient, reducing the time, risk and cost involved.

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[19] Conversations with Moroccan government officials, 24 November 2015.

Social factors

The National Energy Strategy notes that one potential constraint to renewable energy development is a "weak level of information and understanding of the general public" (MEMEE, 2011). These factors may affect public responses to renewable energy projects and should be considered carefully as part of social impact assessments prior to developing renewables sites.

Water management is a sensitive issue, particularly in rural areas dependent on agriculture. With 40% of the population employed by the agriculture sector, water stress has emerged as a concern for farmers worried that the water required for cooling turbines at the Ouarzazate CSP plant will reduce available resources for farming, particularly during times of drought. The launch of the first phase of the Ouarzazate CSP project coincided with a drought that will result in a poor agricultural season in 2016. However, a thorough analysis of the reservoir shows that water consumption needed to cool even a 500 MW CSP plant would have relatively little influence on dam water levels, from which 240 million m^3 are consumed each year for irrigation. This would hold even in the worst case of two consecutive years with minimum water input of 68 million m^3 instead of the average 420 million m^3 (Berraho, 2010).

While the water issue is likely to lead to public debate, it is unlikely to hamper development of solar and other renewable energy projects. The government has highlighted the new job opportunities that the renewable energy industry will generate, as well as the environmental benefits of less reliance on fossil fuels for power generation.

Environmental factors

A benefit of Morocco's geography is that settlements are all within relatively close proximity to areas with good renewable energy resources, and distances from renewable energy technology project sites to the grid are minimal. According to ONEE, most sites are less than 200 km from the grid, so costs for transmission and distribution infrastructure are not excessive.

As already discussed, a major barrier to the future deployment of hydropower infrastructure is water availability, and with future climate change this is likely to be exacerbated. The same is true for future expansion of the coal fleet (due to cooling requirements), which should create stronger drivers for non-water-intensive renewable energy technologies. That said, Morocco is actively working to shore up water resources by constructing retention basins and introducing drip irrigation, with a view to separating irrigation needs from energy needs to better satisfy demand.

Both IRESEN and MASEN are undertaking tests of solar performance in desert conditions to better understand how excessive dust build-up on PV panels and thermal reflectors may affect performance. In other contexts, such as Abu Dhabi, preventing the build-up of sand on solar thermal troughs has required regular maintenance and significant costs (Clean Technica, 2016).

Box 1 • Noor I: A case study of a public-private partnership financing renewables

The Noor I project provides a compelling case study in how a country can successfully bring the public and private sectors together and leverage both international and domestic finance for renewable energy projects.

As the first large-scale CSP plant built in Morocco, the 160 MW Noor I project had the potential to be a highly risky project for investors and project developers. Managing these risks required a new organisational and financial framework.

The project involved establishing a special purpose vehicle called the Solar Power Company (SPC), which would operate the plant on a "build, own, operate and transfer" basis. MASEN guaranteed SPC a revenue stream by signing a 25-year fixed-term PPA with it. MASEN also bought into SPC as an equity partner with the winning bidder, providing a clear signal to bidders that MASEN had a stake in SPC's future.

Box 1 • Noor I: A case study of a public-private partnership financing renewables (continued)

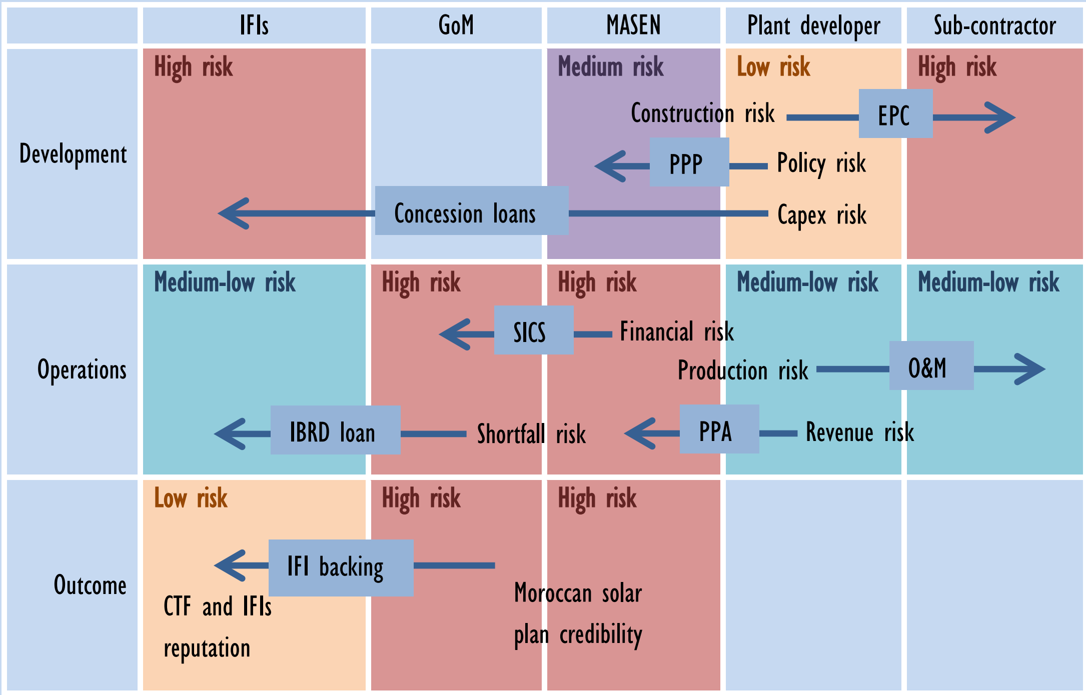
A second PPA was established between MASEN and ONEE, guaranteeing that the latter would purchase all electricity generated by Noor I at grid price. The Moroccan government would cover any differences between the price paid by ONEE and that offered by SPC. To reassure investors that the government could cover these costs, the Moroccan government also secured a USD 200 million World Bank loan.

To reduce capital costs and uncertainty about its availability, MASEN secured finance from a range of international sources, including the Clean Technology Fund, African Development Bank, World Bank, and European Investment Bank. It combined these products into a single financing package, which was offered at the development and bidding process. This shifted capital expenditure risks from project developers to the government and international financing institutions.

The effect was to significantly reduce the overall risk for plant developers, which encouraged them to bid competitively and offer a much lower rate than had been anticipated by the Moroccan government; the winning bid of MAD 0.163/kWh was 25% lower than forecast.

Analysis by the Climate Policy Institute (CPI, 2012; CPI, 2013) has shown that this public-private model was effective because it allocated risks to stakeholders who were best equipped to manage them: construction and operating risks were assigned to private developers, while political and policy risks rested within the public sphere.

Figure 22 • Dynamic risk matrix for the Noor I project



Notes: CTF = Clean Technology Fund; EPC = engineering, procurement and construction; GoM = government of Morocco; IBRD = International Bank for Reconstruction and Development; IFI = international financial institution; O&M = operation and maintenance; PPA = power purchasing agreement; PPP = public-private partnership; SICS = solar incremental cost support.

Sources: CPI (2012), *San Giorgio Group Case Study: Ouarzazate I CSP*; CPI (2013), *San Giorgio Group Case Study: Ouarzazate I CSP Update*.

Lessons learned from the pilot study

Data availability on renewable energy technologies

MEMEE co-ordinates the collection and compilation of energy supply data, including renewable energy data. MEMEE was the primary contact point during the pilot study and provided various useful data and information.

Some information is also available from ONEE. ONEE owns and operates several of Morocco's government-owned renewable energy plants and publishes fairly up-to-date information in French on its website about large-scale renewable energy projects for which it is responsible.

As the agency responsible for all renewable energy deployment, MASEN is emerging as a key source of data and information on deployment, electrical output and costs.

There would be benefits to having a clearly delineated agency responsible for the collection of data on all public and privately owned electricity plants, including information on technology, capacity, output and costs. Currently, MEMEE collects information on electricity plant capacity and output, but was unable to provide data on costs.

IEA experience in other countries is that the availability of transparent information on current renewable generation costs and their evolution over time is important both for domestic policy makers, and for attracting external investors and developers. In Morocco's case, where the conditions for renewable energy technology deployment are generally very good, there seems to be no reason why information on renewable generation costs should not be more easily available.

Recommendations on future users of the methodology in Morocco

Given that MASEN is likely to be given sole responsibility for implementing renewable energy technologies in Morocco, it is the logical agency for applying the methodology in future. MEMEE, as key agency for renewables policy, would also benefit from applying the methodology to assess the impacts of its policies. If ADEREE is assigned responsibility for small-scale renewables deployment after the review of institutional responsibilities, it could theoretically apply the methodology on a limited basis to assess small-scale priority technologies.

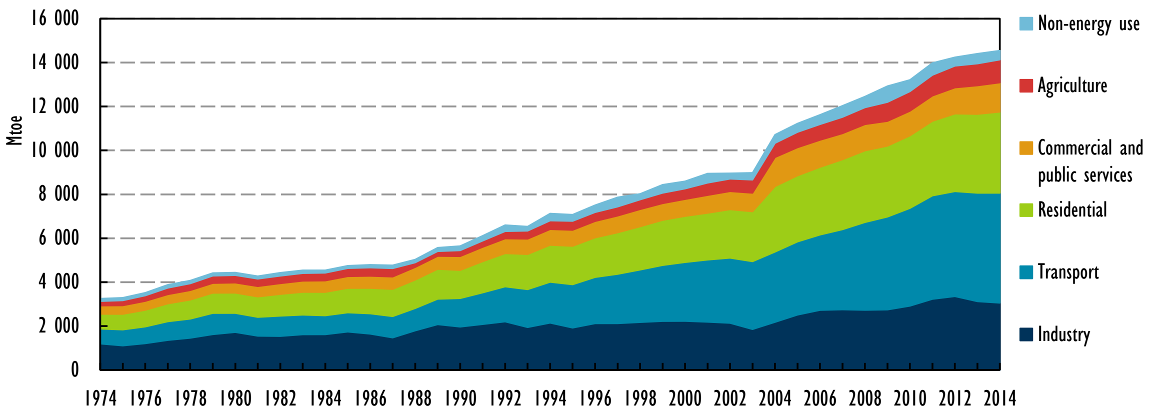
Results of the pilot study: Energy efficiency technologies

Step 1: Prioritisation

1.1 National energy end-use data analysis

According to the IEA total final energy consumption statistics for Morocco, transport consumes the most energy (34%), followed by residential (25%) and the industry sector (21%), (Figure 23). As the methodology is focused on the industrial, transport and buildings sectors, other sectors such as agriculture (12%) and non-energy use (4%) energy consumption are excluded from the analysis that follows.

Figure 23 • TFC, Morocco, 1974-2014



Source: IEA (forthcoming), *Energy Balances of Non-OECD Countries*, www.iea.org/statistics/.

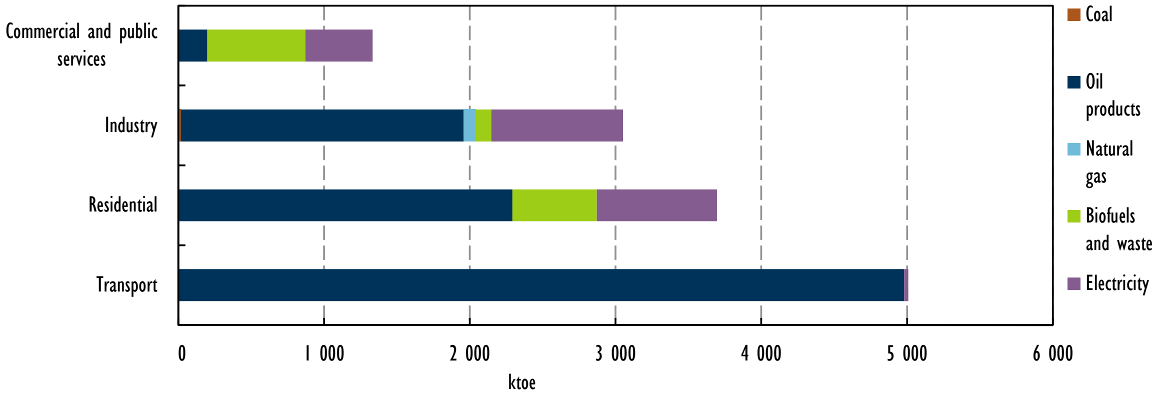
The broad historical trend over time has been a steady increase in Moroccan energy demand across all economic sectors (Figure 23). Demand has grown particularly quickly over the last decade, in line in with an increase in the pace of economic growth (Figure 40). Between 2004 and 2014, the greatest increase in energy consumption has been in the transport sector, which increased by 81% over the period, at an average annual growth rate of 5%. Most of this increase can be explained by significant growth of the vehicle fleet, the majority of which are diesel vehicles.

Energy consumption in the industry sector grew over the same period by more than 40%, increasing at an average rate of 5% a year although over the last two years, consumption has decreased.

The residential sector experienced approximately 24% growth in final energy consumption over the same period. According to a 2013 study by MEMEE, the majority of this increase in energy consumption can be attributed both to a strong penetration of household appliances (which have now become available to the vast majority of the population) and to the poor efficiency of the household appliances sold on the Moroccan market (MEMEE, 2013).

Final energy consumption in the commercial and public services sector increased only marginally over the decade 2004-14 but at an average annual growth rate of 5%. The 2013 MEMEE study, examining just the period 2004 to 2011, concluded that since the value-added of the sector did not increase at the same rate, there may be opportunities to improve energy efficiency in the commercial sector (MEMEE, 2013).

Figure 24 • TFC by end-use sector and fuel (excluding agriculture and non-energy use), Morocco, 2014



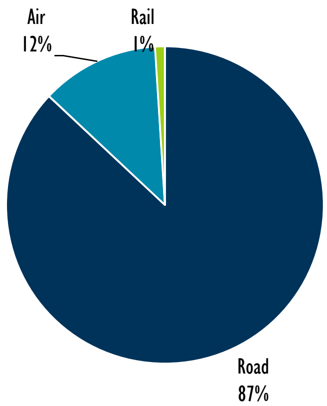
Source: IEA (forthcoming), *Energy Balances of Non-OECD Countries*, www.iea.org/statistics/.

Figure 24 shows total final energy consumption by fuel for the end-use sectors included for assessment. In the transport, industrial and residential sectors, the dominant fuel used is currently oil products. In the commercial and public service sector, consumption is more evenly distributed across fuels, with biofuels and waste comprising 50% of consumption and electricity comprising 35%.

1.1.1 Transport sector energy use

Examination of the transport sector shows that the vast majority of the energy used is consumed by road transport (87%) (Figure 25).

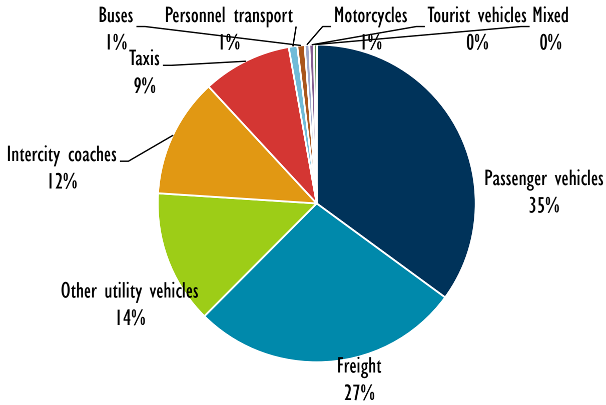
Figure 25 • Estimated transport energy use by mode, Morocco, 2014



Source: Data provided by DOCC and is estimated for the year 2014, based on data gathered from the 2011 transport sector energy consumption survey.

In the road transport sector, passenger vehicles, including taxis, consume the most energy (44%), followed by heavy-duty vehicles for freight (27%), with light-duty utility vehicles and intercity coaches consuming 14% and 12% respectively (Figure 25).

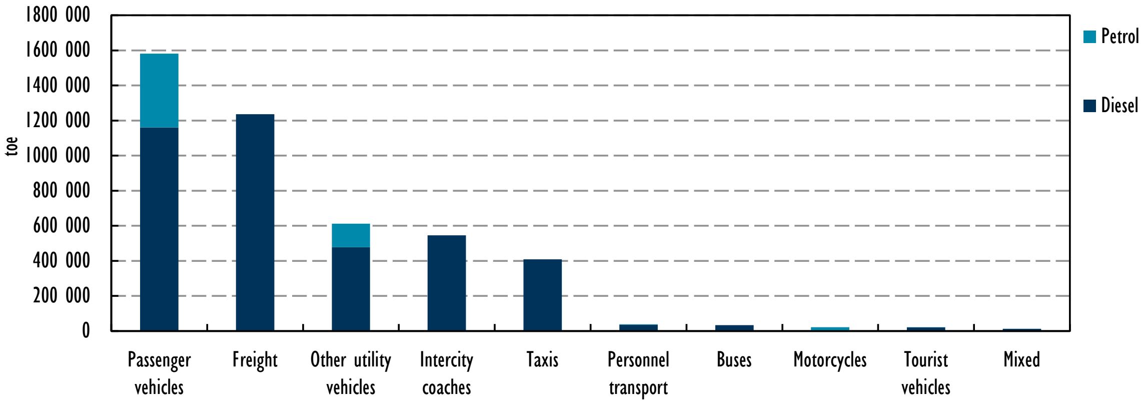
Figure 26 • Road vehicle energy consumption by vehicle type, Morocco, 2011



Source: Data provided by DOCC from the 2011 transport sector energy consumption survey.

In 2011, 87% of the fuel consumed by the road transport subsector was diesel, with petrol consumption in light vehicles and motorcycles accounting for around 13% (Figure 27). This is not surprising as during that time diesel subsidies were still in place and, in addition, most Moroccan passenger vehicles are imported from Europe, where incentives were geared towards producing diesel vehicles. Since this survey was taken, diesel subsidies have been removed, which may have had an impact on the passenger-vehicle segment.

Figure 27 • Road transport by vehicle type and fuel, Morocco, 2011

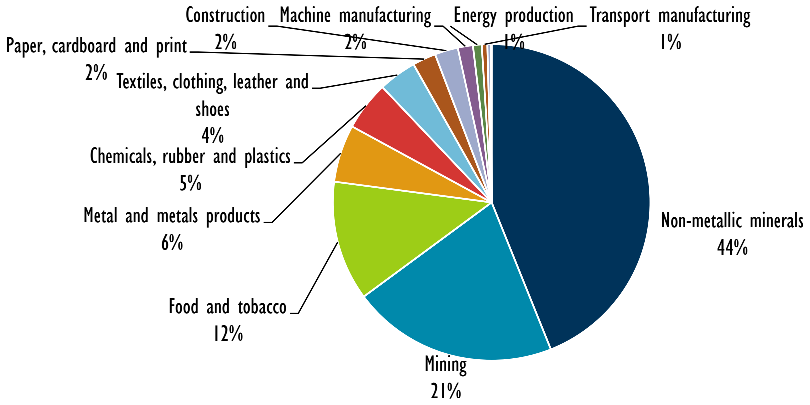


Source: Data provided by DOCC from the 2011 transport sector energy consumption survey.

Results from the 2011 transport energy consumption survey showed that the petrol passenger-vehicle segment of the Moroccan fleet consumed on average 6.7 litres per 100 km, while diesel passenger vehicles' fuel consumption was slightly less at 6.2 litres per 100 km. This compares with an average across the passenger-vehicle fleet in Europe in 2015 of around 5.1 litres per 100 km (ICCT, 2015). However, it should be noted that the fuel economy of Morocco's *new* passenger-vehicle fleet is rated quite well against 2015 European benchmarks (CEDARE, 2015). This is examined further in Section 1.2.2 below.

1.1.2 Industrial sector energy use

Figure 28 • Energy consumption of the industrial sector, Morocco, 2013



Note: "Other manufacturing" and "wood processing and wood products" both consume less than 1% of total industrial sector energy consumption so are excluded from this chart.

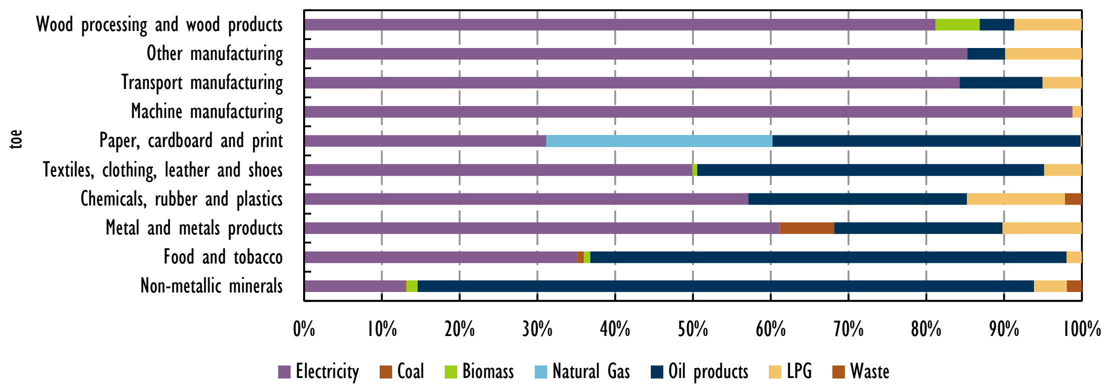
Source: Data provided by DOCC from the 2013 industrial sector energy consumption survey.

In the industrial sector, the largest energy-consuming subsector by a significant margin is non-metallic minerals manufacturing (43% in 2013), of which the cement industry alone was responsible for nearly 34%, mainly in the form of petroleum coke for clinker production (Figure 29). Cement production is concentrated into a small number of firms and facilities, which may increase the ease of implementing targeted interventions to improve energy efficiency. However, previous studies have pointed out that the Moroccan cement industry is already one of the most energy efficient in the region, so easy opportunities for improving energy efficiency may be harder to identify (Enerdata, 2014; Hmamouchi and Laabdaoui, 2012).

Examples of recent improvements to decrease cement industry energy intensity include:

- switch from heavy fuel oil and coal to petroleum coke
- improvement in the rate of additives in cement (cement/clinker ratio)
- use of waste and industrial by-products – fly ash, ash pyrrhotines, shredded tires, waste oil, etc.
- introduction of self-electricity generation from renewable energy (e.g. Lafarge's wind energy farm).

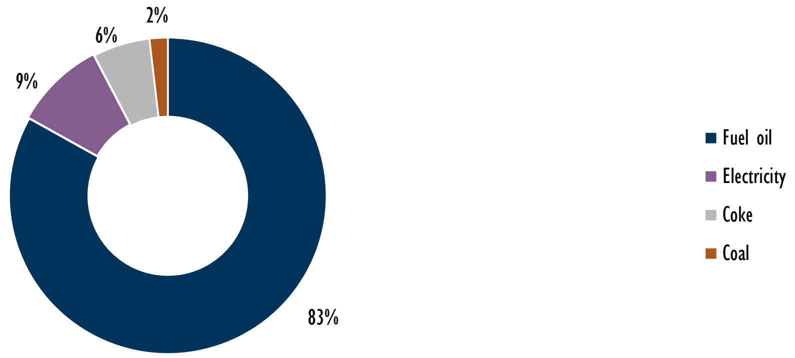
Figure 29 • Energy consumption of industrial manufacturing subsectors, Morocco, 2013



Source: Data provided by DOCC from the 2013 industrial sector energy consumption survey.

The second-highest consuming industrial subsector is food and tobacco processing (13%). Of this subsector, sugar production is by far the largest energy-consuming activity, accounting for 5.5% of industrial energy consumption, most of which is fuel oil for boilers (Figure 30). The Moroccan sugar industry is dominated by former state-owned company Cosumar, which operates seven facilities, two that use sugar cane as a feedstock and five that use locally grown sugar beet. While the cane-based production facilities could potentially replace fuel oil consumption with bagasse use, options for fuel alternatives are more limited for beet-based facilities, increasing the importance of focusing on energy efficiency.

Figure 30 • Energy consumption of the Moroccan sugar-processing industry, 2013



Note: Diesel and propane are also consumed in small amounts, not large enough to be represented on this chart.
Source: Data provided by DOCC from the 2013 industrial sector energy consumption survey.

Metal production (primarily iron and steel) and then chemical and petrochemical production are the third- and fourth-highest consuming subsectors. Chemical industry energy use in Morocco is dominated by the production of chemicals linked to Morocco's phosphate mining industry; 69% of Morocco's chemical industry comprises plants that process phosphate into fertilisers and other chemical products, such as phosphoric acid and sulphuric acid (MCINET, 2016). Rounding out the five highest-consuming subsectors is textiles, clothing and leather production.

According to a study published by the Moroccan government, based on 2013 survey data, the most energy-intensive manufacturing processes (measured as energy use per tonne of production) are sugar production and paper and cardboard (DOCC, 2015). Both subsector's production processes are heavily reliant on steam production, which may allow for energy efficiency opportunities in the form of improved steam management and heat recovery systems.

A further study examining the period 2000 to 2010 showed that energy intensity in the food and beverage processing, textiles, and primary metals subsectors was increasing. In the case of textiles, the estimated rate of increase in energy intensity was close to 10% per year (Enerdata, 2013).

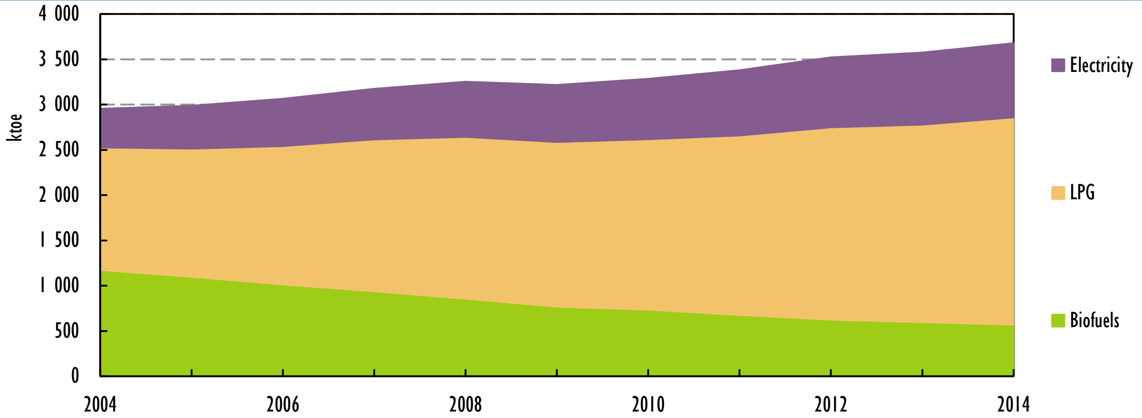
In 2011, an industrial energy audit programme began, which will be conducted every five years. The first audit results showed that approximately 360 of the 8 000 industrial entities audited account for some 70% of industrial energy consumption. This concentration of energy use in less than 5% of total facilities means that it may be possible to target a small number of individual facilities and achieve fairly large energy efficiency improvements.

1.1.3 Residential sector energy use

Residential energy consumption is dominated by LPG use (mainly butane), which comprised over 62% of residential TFC in 2014. Residential-sector LPG use increased over the decade 2004-14 by

69%. Electricity use has increased at an average rate of 7% per year, making it the fastest-growing residential fuel over the decade. In 2014, electricity comprised 22% of residential TFC. In 2014, a further 15% of demand was sourced from solid biofuels (wood), although residential sector biofuel use has been steadily declining over the past decade (Figure 31).

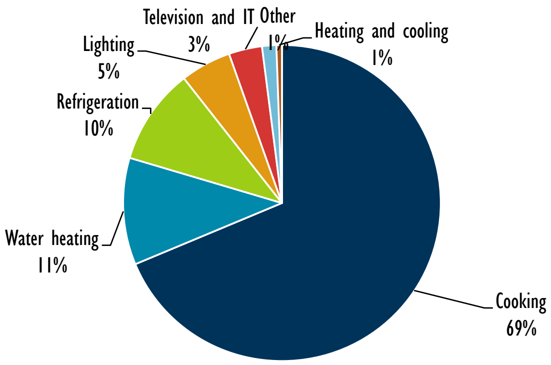
Figure 31 • Residential sector TFC by fuel, Morocco, 2004-14



Notes: Charcoal and non-specified oil products are also consumed in amounts too small to be represented on this chart.
Source: IEA (forthcoming), *Energy Balances of Non-OECD Countries*, www.iea.org/statistics/.

Figure 32 shows the results of a 2012 survey of residential sector end-uses. Cooking is responsible for nearly 70% of energy use in the residential sector. Of this, 72% is from butane and 25% from wood. Appliances (mainly refrigeration) and water heating are the next highest consuming end-uses. Energy for residential water heating is nearly 100% sourced from butane. Conversely, space heating and cooling is a relatively small proportion of residential consumption at just 1% in 2012. That said, recent studies have pointed out that demand for space cooling technologies (air conditioners) is growing quickly (Hmamouchi and Laabdaoui, 2012).

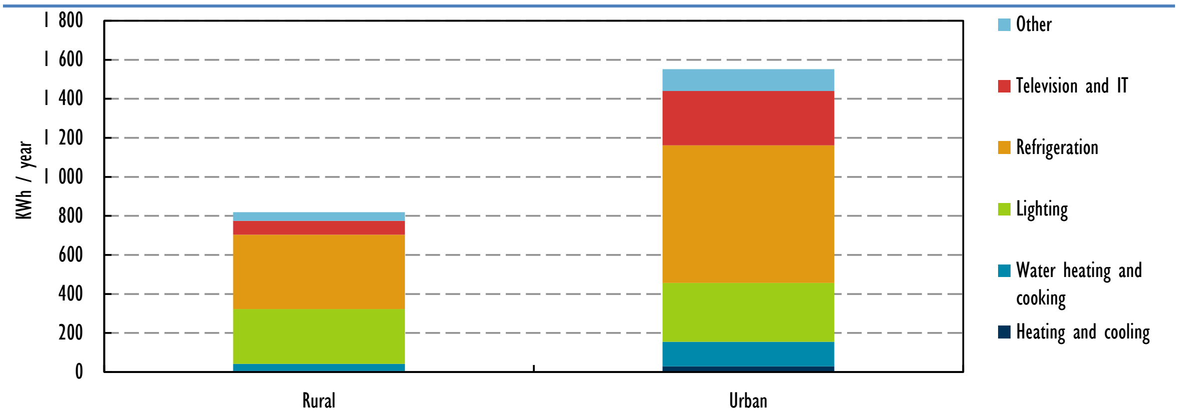
Figure 32 • Residential sector TFC, Morocco, 2012



Note: IT = information technology.
Source: Data provided by DOCC from the 2012 residential sector energy consumption survey.

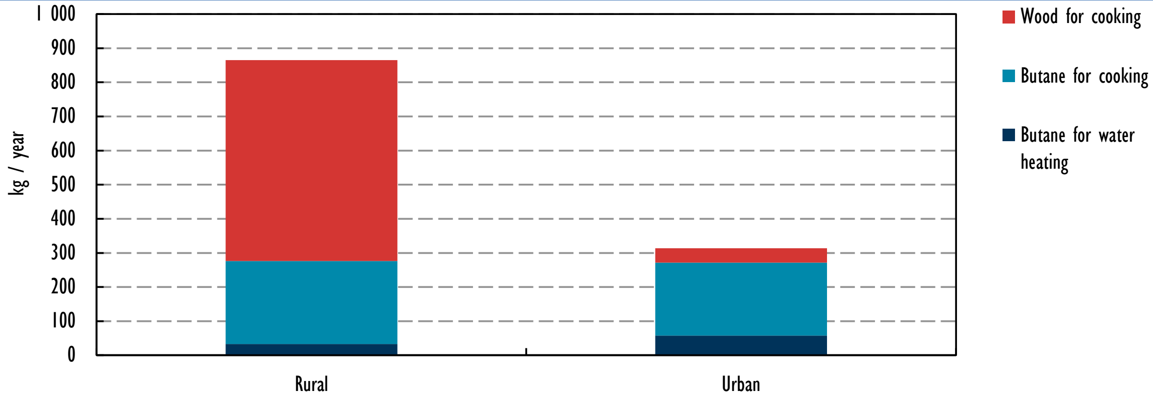
In the residential sector, significant differences in energy consumption exist between rural and urban energy users and between consumers in different income brackets. For example, while the average urban household uses more electricity for a range of uses than the average rural household (Figure 33), rural households use significantly more wood (Figure 34). This is not surprising as urban households tend to earn more than rural households on average, with 20% of urban households earning over MAD 7 700 per month compared to just 8% of rural households earning over MAD 7 100 per month. In addition, a greater number of households have no access to electricity in rural areas, leading to a higher reliance on combustible fuels for a variety of uses.

Figure 33 • Average per-household electricity consumption by end-use, rural and urban, Morocco, 2012



Source: Data provided by DOCC from the 2012 residential sector energy consumption survey.

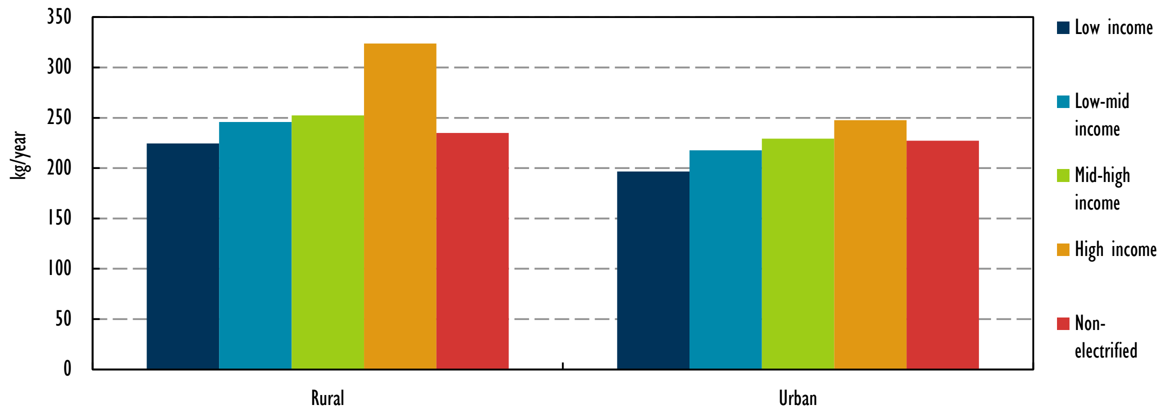
Figure 34 • Average per-household combustible fuel consumption by end use, rural and urban, Morocco, 2012



Notes: kg = kilogramme; in addition, a very small amount of charcoal is used for cooking and a small amount of butane is used for lighting and heating, which are not shown on this chart.

Source: Data provided by DOCC from the 2012 residential sector energy consumption survey.

Figure 35 • Average annual residential use of butane for cooking across all income brackets and household types, Morocco, 2012



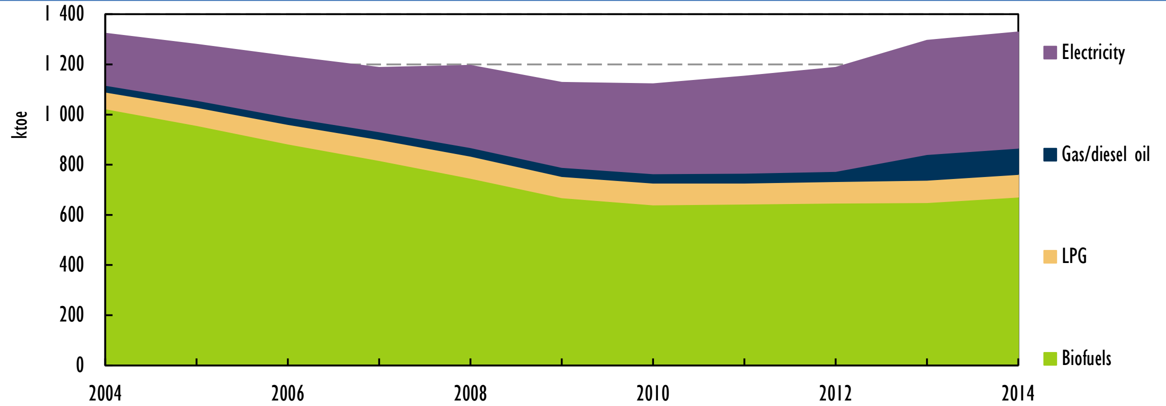
Source: Data provided by DOCC from the 2012 residential sector energy consumption survey.

One fuel that is used consistently throughout all Moroccan households is butane for cooking. Figure 35 shows that across both rural and urban areas, and regardless of income bracket, butane is a commonly used cooking fuel in Morocco, with most households using over 200 kg per year. A concerted effort to introduce more efficient cooking technologies in the residential sector that use fuels other than butane gas could therefore have significant impacts across the entire sector.

1.1.4 Commercial and public services sector energy use

The commercial and public services sector in Morocco is heavily dependent on wood consumption for energy, which represents 50% of the sector's consumption although consumption has decreased by around 34% over the decade 2004-14. The greatest increase in fuel use has been in diesel, which has increased almost threefold over the same period, at an average rate of 20% per year (Figure 36). In 2014, electricity use comprised 35% of this sector's TFC and over the previous decade, had increased 124% at a rate of 9% per year. LPG use also increased 36% over the same period, but at a slower rate of 3% per year on average.

Figure 36 • TFC of the commercial and public services sector, Morocco, 2004-14



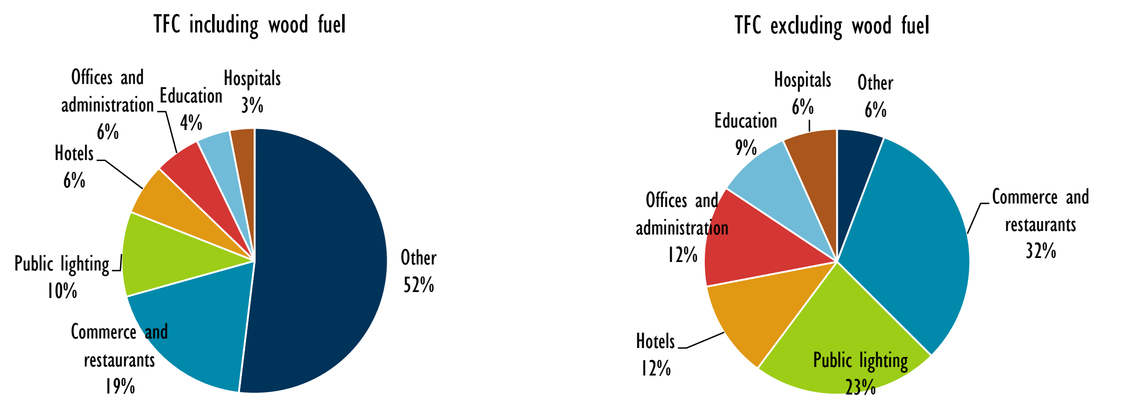
Notes: In addition to the fuels shown in Figure 37, negligible amounts of charcoal and fuel oil are consumed.
Source: IEA (forthcoming), *Energy Balances of Non-OECD Countries*, www.iea.org/statistics/.

The unusual dominance of wood use in the commercial and public services sector is worth interrogating in greater detail. Almost all (90%) of this wood is consumed in the "other" subsector (Figure 37, left-hand side). According to MEMEE, this is by and large associated with hammams (bathhouses), which use wood as a fuel to create steam. There are some 12 000 hammams in Morocco, each of which consumes an average of 800 kg to 1 tonne of wood per day.[20] Although wood is technically a renewable resource, the IEA understands that existing wood harvests may be unsustainable and direct combustion in commercial and public sector facilities may be having detrimental impacts on urban air quality. Therefore, reducing wood consumption in hammams and other commercial subsectors is a priority.

Subtracting wood from the tertiary sector energy balance gives a more nuanced view of the sector, allowing for the identification of other priority subsectors (Figure 37, right-hand side). Survey data from 2012 enables detailed analysis of end-uses by fuel in this sector. Starting with electricity (Figure 38), lighting as well as televisions and IT equipment are major end-uses across all subsectors. The largest electricity-consuming subsector is public lighting, with commerce and restaurants a close second.

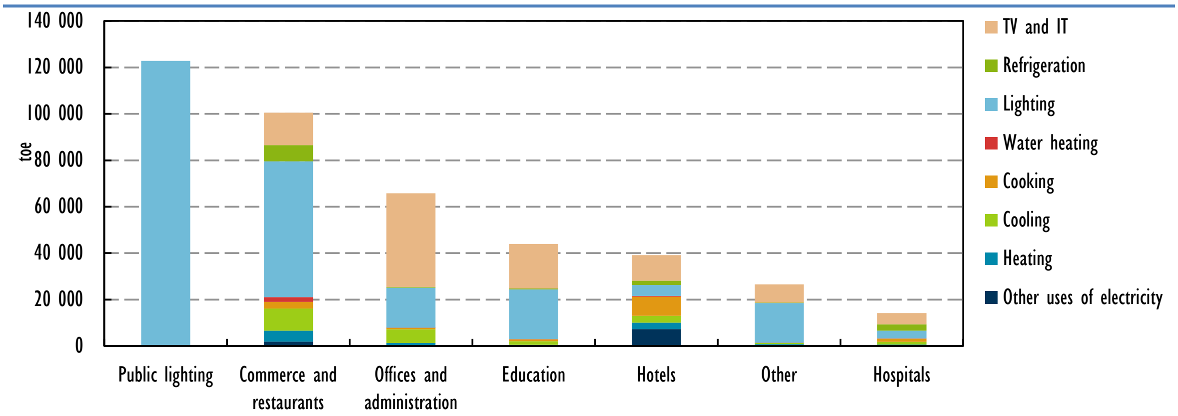
[20] Based on conversations with ADEREE.

Figure 37 • Energy consumption of the commercial and public services sector (2012), with wood consumption included (left) and excluded (right)



Source: Data provided by DOCC from the 2012 tertiary sector energy consumption survey.

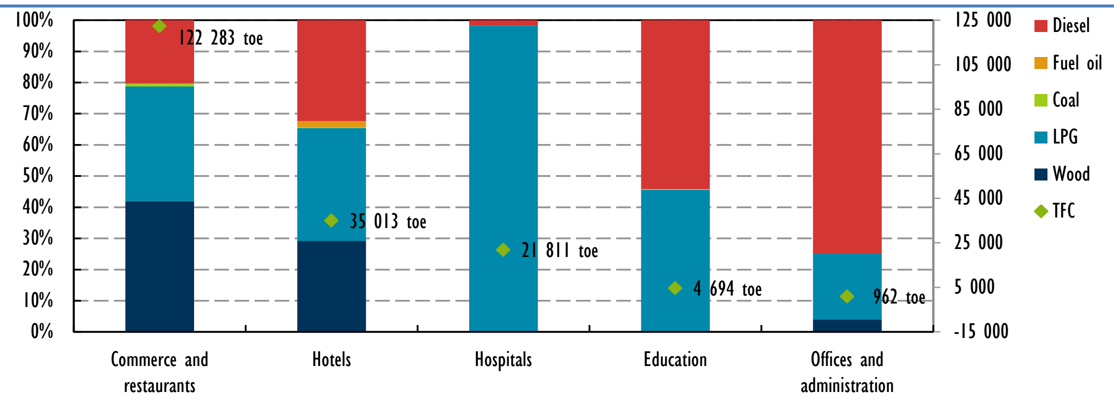
Figure 38 • Commercial and public services sector electricity end-uses, Morocco, 2012



Source: Data provided by DOCC from the 2012 tertiary sector energy consumption survey.

Turning to combustible fuels, including wood but excluding the "other" subsector (to remove the distorting effect of hammams on the data), Figure 39 shows that commerce and restaurants are the leading consumer of combustible fuels, and hotels second, with wood and butane consumed for cooking in both subsectors. Propane in the commercial sector is mainly for heating and cooking, while diesel is used for water heating and heating in some shops, restaurants and hotels.

Figure 39 • Commercial and public services sector combustible fuel use, excluding "other", Morocco, 2012



Source: Data provided by DOCC from the 2012 tertiary sector energy consumption survey.

1.2 Future energy use, drivers and policies

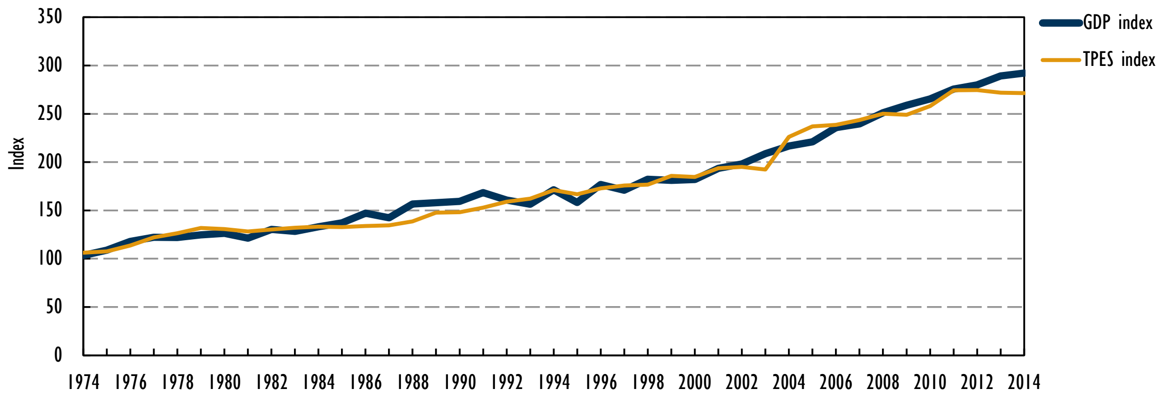
This section summarises a range of the key trends, drivers and policies that may affect future energy consumption in each of the major end-use sectors. Detailed modelling would be required for a deeper understanding of future trends in energy consumption and to examine how a range of drivers work simultaneously to influence energy demand.

1.2.1 Overall drivers

Economic growth

From a low base, Morocco's GDP per capita increased at an average of around 3.1% per year over the decade 2004-14 (Figure 40). Historically, economic growth has been viewed as a leading driver of energy use, as greater prosperity has tended to increase demand for energy services (mobility, heating and cooling, communications, etc.), leading to net increases in energy use.

Figure 40 • Index of GDP per capita and TPES per capita, Morocco, 1974-2014



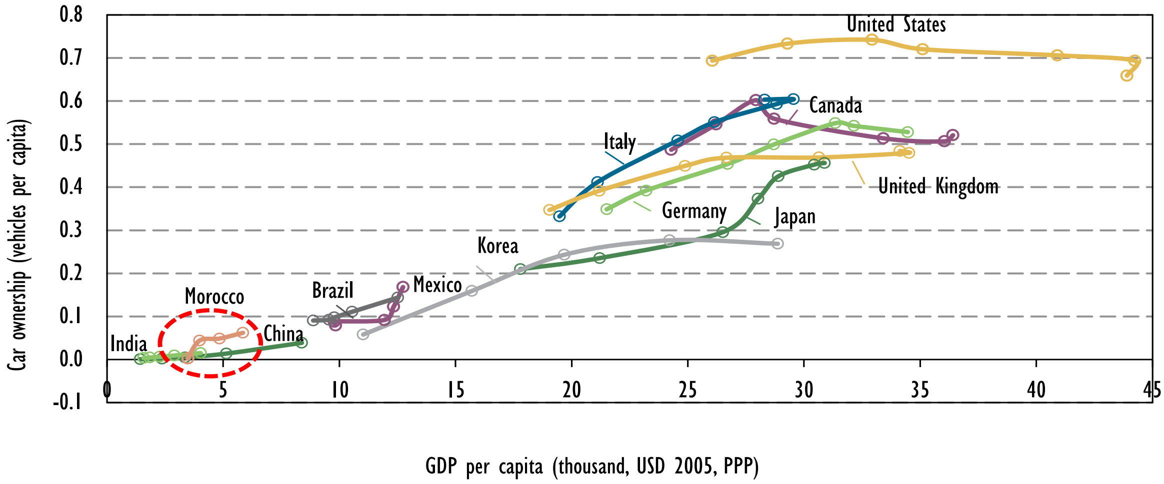
Source: IEA (2015c), *CO_2 Emissions from Fuel Combustion*, www.iea.org/statistics/.

However, the technology choices made by countries to meet rising demand for energy services will govern the extent to which energy demand and GDP are coupled or decoupled and, with the right technologies in place, developing countries such as Morocco may "leapfrog" energy-intensive phases of development, allowing them to decouple energy use and economic growth much faster than many developed countries achieved.

That said, the process of deploying highly efficient technologies will take time and, in the short term, it is still necessary to consider how economic growth *could* affect energy demand, particularly for the purposes of identifying sectors that may require interventions to spur deployment of energy efficiency technologies. Figure 40 shows a strong historical relationship between TPES per capita and GDP per capita in Morocco, indicating that energy supply and GDP in Morocco are yet to be decoupled and that energy intensity has remained fairly constant over time. This trend is likely to continue in the absence of technical energy efficiency improvements or a structural shift away from energy-intensive economic activities.

In the transport sector, vehicle ownership has generally increased with increases in GDP per capita (Figure 41). Over the period 2001-10, per capita passenger-vehicle ownership in Morocco has increased at an average rate of 4% per year, in line with rises in GDP per capita. As per capita GDP grows from what is still a low base, it is likely that demand for mobility – in the form of passenger vehicles and other forms of transport – will grow with it, leading to a net increase in energy use.

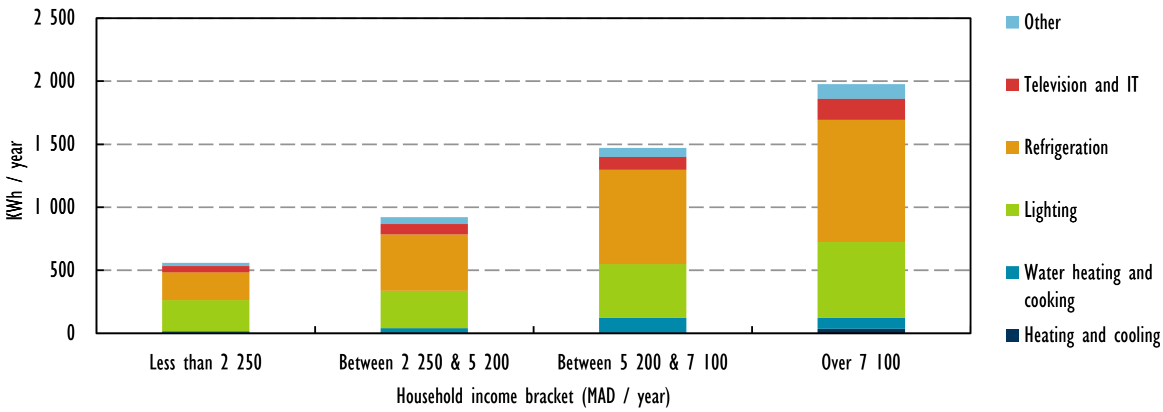
Figure 41 • Passenger vehicles and GDP per capita, Morocco, 1975-2010



Sources: IEA (2016b), *Mobility Model*, January 2016 version (database and simulation model), www.iea.org/etp/etpmodel/transport, and IEA (2015c), *CO_2 Emissions from Fuel Combustion*, www.iea.org/statistics/.

In the residential sector, IEA modelling of other developing economies suggests that increasing income tends to drive demand for larger, more comfortable buildings and more diverse energy end-uses (IEA, 2013). Unless super-efficient technologies are used, demand for increased energy services in households tends to lead to net increases in energy use. Data from Morocco's most recent household energy survey are consistent with this hypothesis, showing that households in the highest income bracket consume nearly four times more electricity for a wider number of uses than households in the lowest income bracket (Figure 42).

Figure 42 • Moroccan household electricity end-uses by income bracket, 2012



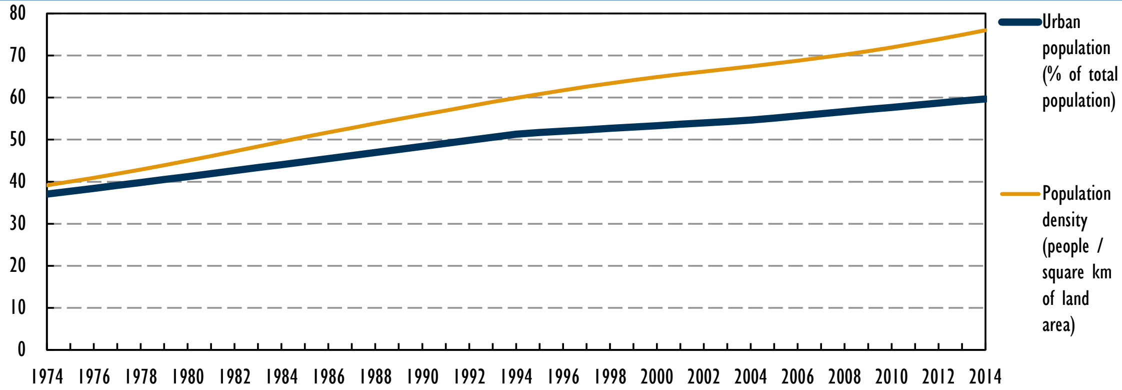
Source: Data provided by DOCC from the 2012 residential sector energy consumption survey.

Conversely, increases in wealth also permit energy users in all sectors to purchase more energy-efficient equipment, which sometimes has high up-front costs. For example, while cooking is currently a large user of total household and commercial energy (See Figures 32 and 39), this is mainly due to the use of inexpensive, inefficient fuels such as wood and subsidised butane, which, with rising incomes, could be replaced with more energy-efficient cooking technologies, such as electric and induction cooktops.

Urbanisation and population density

Over the four decades from 1974 to 2014, Morocco's urban population has increased from 37% to nearly 60% of the total (Figure 43). In the short term, urbanisation could be expected to increase residential sector electricity consumption and decrease wood use, because urban households in Morocco tend to use more electricity and less wood than rural households (Figures 33 and 34). In the long term, urban per capita energy use may decline in the residential sector, as increasing urban density may necessitate reductions in floor space per capita due to land and infrastructure constraints.

Figure 43 • Percentage of population living in urban areas and population density, Morocco, 1974-2014



Source: World Bank (2015), *World Development Indicators 2015*, http://data.worldbank.org/data-catalog/world-development-indicators.

The impact of increasing population density, particularly in urban areas, may also affect transport energy use. As population density increases, the necessity and economic viability of public transport systems increases, leading to a shift toward more energy-efficient forms of transport than fossil-fuel powered passenger vehicles. Traffic congestion is already a problem in Morocco's major cities and the government is working to encourage greater use of public transport.

National energy efficiency target

Morocco's national energy efficiency programme has an overall goal of reducing energy consumption by 12% by 2020 and 15% by 2030 against a "business-as-usual" scenario. Three sectors are targeted to achieve these savings: transport, industry and buildings. Unfortunately, detailed analysis as to exactly how and what proportion each of these sectors will contribute to achieving the targets appears to be lacking.

According to ADEREE, a new energy efficiency programme was being considered by the government at the time of writing, incorporating a comprehensive set of measures in all three sectors as well as cross-cutting measures targeting economy-wide energy efficiency improvements. A decision was due on the new energy efficiency programme by mid-2016.

Energy prices and subsidies

Fuel prices have a major impact on energy consumption patterns across all sectors. This is reflected clearly in Moroccan consumers' preferences for subsidised butane fuel across a range of sectors, and in the transport sector, which sees higher diesel use for passenger vehicles, a result of diesel enjoying lower prices than gasoline (MEMEE, 2015b). Electricity prices in Morocco are not cost reflective, meaning there is little incentive to increase the efficiency of electricity use. Rates for customers connected to the ONEE distribution grid are differentiated by voltage and consumer category. Household rates are incremental based on consumption and vary from MAD 0.901/kWh for a monthly consumption up to 100kWh, to MAD 1,542/kWh for users whose consumption exceeds 500kWh and that are subject to bi-hourly pricing aiming to reduce consumption during peak hours (depending on the season, from 17:00 or 18:00 to 22:00 or

23:00). Rates for industry and businesses are generally lower than residential rates and are also time sensitive.[21]

In 2014, Morocco undertook significant steps in a gradual process of reforms to reduce subsidies for certain fossil fuels. From 1 February 2014 subsidies for gasoline and industrial fuel oil were removed, and from 1 June 2014 the same was applied to fuel oil for electricity generation. Butane continues to receive a partial subsidy.[22] However, in its INDC of June 2015, Morocco indicated that further fossil fuel subsidy reforms would form a key part of its climate change mitigation strategy (UNFCCC, 2015).

Butane and electricity subsidy reform is likely to have significant impacts on energy consumption for most sectors of the economy, and the IEA has highlighted the importance of this measure to improving Morocco's energy efficiency in the recent past (IEA, 2014a). That said, the phase-out of subsidies will have to be managed carefully to avoid adverse impacts for sections of the population whose livelihoods depend on subsidised fuel.

1.2.2 Transport sector

Vehicle taxes and customs duty

In Morocco, vehicles are subject to a range of taxes upon their first registration in Morocco (MEF, 2014). These taxes are determined by the horsepower of the vehicle and are as follows:

- a fee of MAD 50 (approximately EUR 4.5) per unit horsepower
- a fee determined by the horsepower of the vehicle as shown in Table 6.

For example, a seven horsepower vehicle would be subject to horsepower taxes of 7 x MAD 50 (MAD 4 000) and MAD 2 500, making a total of MAD 6 500.

Table 6 • Horsepower tax regime for vehicles

Vehicle category (taxable horsepower)	<8	8-10	11-14	>15
Amount of tax	MAD 2 500	MAD 4 500	MAD 10 000	MAD 20 000

Source: MEF (2014), *Note Circulaire No. 722: Relative aux Dispositions, Fiscales, de la Loi de Finances, No. 103-13 pour l'Annee Budgetaire 2014* [Circular No. 722: Provisions Concerning Tax of the Finance Law, No. 103-13 for the Fiscal Year 2014], www.finances.gov.ma/Docs/2014/DGI/nc_%20722_lf_2014.pdf.

Table 7 • Tax on the value of the vehicle

Vehicle value (MAD)	Tax
400 000 – 600 000	5%
600 001 – 800 000	10%
800 001 – 1 000 000	15%
>1 000 000	20%

Source: MEF (2014), *Note Circulaire No. 722: Relative aux Dispositions, Fiscales, de la Loi de Finances, No. 103-13 pour l'Annee Budgetaire 2014* [Circular No. 722: Provisions Concerning Tax of the Finance Law, No. 103-13 for the Fiscal Year 2014], www.finances.gov.ma/Docs/2014/DGI/nc_%20722_lf_2014.pdf.

A "vehicle value tax" is applicable in addition to these duties when submitting a request for first vehicle registration (made on or after 1 January 2014) and is determined according to the vehicle value as shown in Table 7.

[21] Electricity rates are subject to periodic review and regulation changes. The ONEE website provides updates and detailed information http://www.one.org.ma/ (last accessed 19 July 2016).

[22] Butane is currently subsidised at a rate of MAD 7/kg of butane.

This combination of taxes incentivises the purchase of smaller, cheaper cars. In addition, customs duties must be paid on all vehicles imported from countries other than members of the European Union,[23] which provides a strong price signal to purchase imported European cars over those from Asia or America. Excise duties have also been reduced to 2.5% for hybrid vehicles (IEA, 2014b).

As a result of the tax regime and the comparatively high price of fuel since the removal of diesel subsidies, the rated fuel economy of the new passenger-car fleet in Morocco is relatively good, conforming to EU 2015 targets (CEDARE, 2015).

Vehicle standards and labelling

On 1 January 2015, Morocco introduced Euro 4 emissions standards for all new light-duty vehicles sold in Morocco. The introduction of the standards had been originally proposed for 2013 but was delayed by two years following protests by a coalition of stakeholder groups who argued that the changes would require a significant adjustment (given the absence of minimum standards to this point).

MEMEE and ADEREE are currently in the process of drafting a decree on mandatory vehicle fuel efficiency labels for all new cars sold in Morocco, which are going to be closely aligned to European labels.

Public transport

The Moroccan government has recently invested in tram systems in Casablanca and Rabat, in an effort to improve urban public transport options and reduce traffic in its major cities.

The government plans to significantly improve intercity public transport through the construction of a fast train network. The first line (from Tangier to Casablanca) is currently under construction (estimated at 78% complete at the time of writing) and is expected to be operational in the first quarter of 2018. Other lines to be constructed between now and 2035 include: Casablanca-Marrakech-Agadir and Casablanca-Fès-Oujda.

By reducing the travel time between major cities, trains will offer a service that is competitive with private vehicles for long journeys, which is likely to have a significant impact on annual vehicle passenger-kilometres per person.

Training for efficient driving

In partnership with the Office of Professional Training and the Promotion of Work (OFPPT), ADEREE is developing an eco-driving training course for professional drivers of buses and trucks. The course will focus on teaching heavy-duty vehicle users how to drive efficiently and use less fuel, through methods such as anticipating speed changes and turning off the engine for stops longer than 30 seconds (ADEREE, 2016a).

Regulations on fleet renewal

Morocco has introduced a programme to renew the taxi fleet. Under the programme, by the end of 2015 around 8 000 used Category 2 taxis were replaced by new vehicles, stimulated by a generous MAD 50 000 government subsidy. To replace used Category 1 taxis, the government offers a subsidy of MAD 80 000, and by the end of 2015 it was estimated that around 2 800 owners had taken up the subsidy (more than 70% of the eligible used vehicle stock). The programme has obtained funds to continue into 2016 (MEF, 2016).

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[23] Customs duties for all products imported from the European Union were removed in 2012.

Similar to the taxi fleet renewal scheme, the Department of Transport manages a freight transport and bus fleet renewal scheme, which offers incentives for renovating or retiring old vehicles. The third phase of the scheme began in 2014 and ends in 2016. During the first two phases of the scheme, which began in 2008, 1 374 vehicles were retired, including 387 tractors and 987 freight vehicles, which reduced the average age of the freight vehicle fleet from around 14 years to 12.45 years old (MTPNET, 2013).

A further measure to rejuvenate the vehicle fleet involves prohibiting the import of vehicles older than five years.

1.2.3 Industrial sector

Industrial policy

Under the National Pact for Industrial Emergence (PNEI) (2009-15), the Moroccan government sought to promote growth in several industries: transport equipment manufacturing (both automobile and aeronautical); electronics; textiles and leather; food processing; and "offshoring". These industries were identified as those for which Morocco has a competitive advantage. Building on the PNEI, in 2014 the government announced the Plan for the Acceleration of Industry (PAI). An allocation of USD 2.18 billion has been made to continue growth in the above industries, as well as in the pharmaceutical industry.

Some of these industries are energy intensive and their growth could lead to increases in their share of total industrial energy consumption. For example, food processing and tobacco is already the second-largest energy-consuming subsector within industry and its share may grow if the industry expands.

In addition, energy-intensive industries not directly receiving government assistance under the PAI but related to PAI-target industries may also experience growth, and higher energy consumption. For example, phosphate-based fertiliser producers may expand production to satisfy demand from domestic farmers supplying raw foods to the food processing sector, particularly as the agricultural sector scales up production under Morocco's "Plan Vert" programme.

While transport manufacturing is not currently a high-consuming industrial subsector, its share of industrial energy consumption may grow as more manufacturers open plants in Morocco and production ramps up to meet domestic and international demand. Renault and Nissan Motor Co. operate plants in Tangier and Casablanca, and in 2015 the Moroccan government signed a EUR 570 million deal with PSA Peugeot-Citroen to construct a vehicle manufacturing plant in Ameur Seflia Commune in Kenitra province, expected to be operational in 2019. The Moroccan new vehicle market is already dominated by locally produced passenger vehicles, such as the Dacia Logan, Sandero and Dokker, and demand for inexpensive Moroccan vehicles is also strong in Europe. That said, as the facilities are new, energy efficiency opportunities may not be widespread at this point in time.

Growth in construction

As Morocco's cities have modernised, major infrastructure projects and housing construction has provided a steady market for locally produced steel and cement, two energy-intensive industries. In recent years production has slowed, partly due to economic circumstances and partly due to international competition. However, in the medium term, significant construction is set to take place for projects such as the new fast train network, as well as various government programmes to increase the residential and commercial building stock (see 1.2.4 below). This will provide opportunities for growth in industries such as steel and cement (Oxford Business Group, 2015).

1.2.4 Residential and commercial sectors

According to analysis undertaken for Morocco's new building energy efficiency standards (ADEREE, 2016b), energy consumption in the residential and commercial sectors is expected to increase quickly in coming years, driven by:

- Rapid development of the building stock due to the impact of several major programmes including:
  - Plan Azur, designed to increase the hotel stock to encourage tourism
  - the National Education Emergency Programme, that will increase the number of educational facilities
  - the 150 000 New Houses a Year Programme, to increase the housing stock.
- A significant increase in the uptake of household appliances such as air-conditioning equipment, lighting and hot water, driven by improving livings standards and lower appliance prices.

To curb the impact of these drivers of energy use in these sectors, in late 2015 ADEREE introduced regulations on the thermal performance of new buildings. The regulations cover social housing and freestanding buildings in the residential sector and hotels, offices, educational facilities and hospitals in the commercial sector. The regulations will focus on urban areas initially, due to the higher energy requirements of urban versus rural buildings and the increasing rate of urbanisation (ADEREE, 2016b).

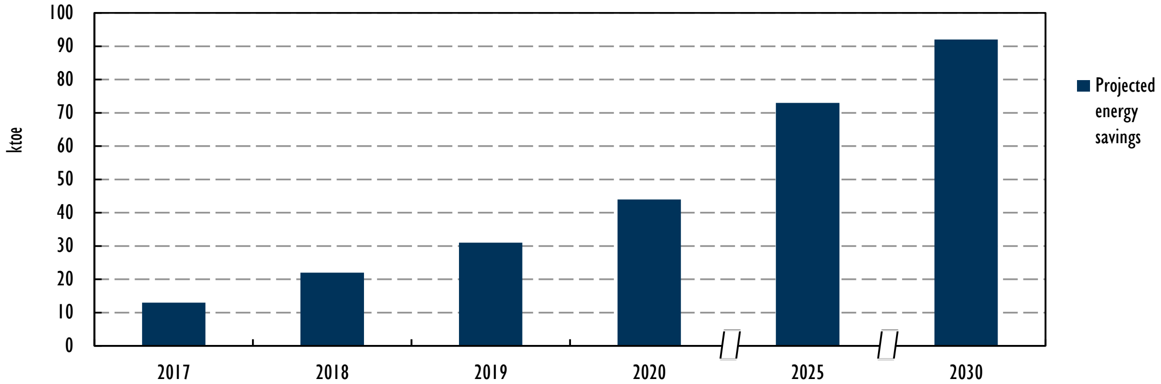
The second major component of the plan involves introducing appliance standards and labelling. This is part of the energy efficiency strategy is currently being considered by the government at the time of writing.

Shemsi SWH programme

In both the residential and commercial sectors, water heating energy use could be reduced through the deployment of SWHs. ADEREE's Shemsi Programme includes targets to increase the installed SWH capacity to 1.7 million m^2 by 2020 and 3 million m^2 by 2030. The plan was being reviewed by government at the time of writing, but is understood to revolve around four axes: funding, labelling and certification, communication, and training and regulation.

ADEREE projects that the programme will cumulatively save 847 ktoe from its inception until 2030 (Figure 44).

Figure 44 • Projected energy savings from the proposed Shemsi Programme



Source: ADEREE internal estimates shared with IEA.

1.2.5 Summary of priority subsectors

Table 8 shows the priority subsectors and end-uses analysed in this publication. Within the transport sector, road transport is selected as the priority subsector, owing to its large share of energy consumption. Within road transport, passenger and heavy-duty vehicles are the highest priority, based on current and projected energy consumption within the sector, given that per capita private vehicle ownership and road freight transport is likely to continue increasing in line with economic growth.

In the industrial sector, high priority subsectors include food processing (particularly the sugar industry), chemicals, paper, and textiles industries, all of which use significant amounts of steam. These are also industries that have been identified as particularly energy intensive in previous studies (for example, DOCC, 2015; Enerdata, 2013).

In the residential sector, cooking, appliances, water heating, space cooling and lighting are end-uses where technological improvements could have major impacts on energy efficiency. Given that demand for active space cooling technologies is increasing, efficient building fabric technologies for the residential sector should also be examined as a priority. As noted above, energy-efficient cooking technologies provide an opportunity to improve efficiency across the entire sector.

The commercial sector could make major gains in reducing energy use by improving the energy efficiency of space cooling, cooking, lighting, IT use and water heating. Hammams are prioritised for special attention given their high wood consumption. As the largest consumer of electricity, public lighting is also a priority and has already been targeted as a priority by the Moroccan government, with the Energy Investment Company (SIE) investing in a number of municipal lighting upgrades (SIE, 2016).

Table 8 • Priority subsectors and end-uses for analysis

Sector:	Transport	Industry	Residential	Commercial and public services
Subsectors:	Road transport	Food processing (sugar) Textiles Paper Chemicals, rubber and plastics (phosphate-based products) Metals	n/a	Public lighting Hammams Shops and restaurants Offices Schools
End uses:	Passenger vehicles Heavy-duty vehicles		Cooking Appliances Water heating Space cooling Lighting	Space cooling Cooking Water heating Lighting IT

For the purposes of restricting the length of this publication, the remaining steps in the methodology will be demonstrated by focusing on one subsector, passenger vehicles, which consume over 40% of transport sector energy. Analysis of priority technologies for all priority sectors shown in Table 8 is provided at Annex A.

1.3 Priority energy efficiency technologies

1.3.1 Energy efficiency technology candidate lists

For passenger vehicles, a number of sources are available to assess global best practice energy efficiency technologies. The annual IEA Energy Technology Perspectives provides a high-level overview on technology trends, including for the road transport sector. In addition, the IEA publishes detailed technology roadmaps for various clean energy technologies. Three Technology Roadmaps have been published relating the road transport and passenger vehicles: Hydrogen and Fuel Cells (IEA, 2015d), Fuel Economy of Road Vehicles (IEA, 2012) and Electric and Plug-in Hybrid Electric Vehicles (IEA, 2011).

The International Clean Council on Transportation and Global Fuel Economy Initiative are two organisations that produce useful information on global road transport technology trends.

Energy efficiency technologies for passenger vehicles fall broadly into three groups: engine technologies, non-engine technologies, and road surface technologies. The potential energy efficiency improvements to be gained from these technologies differ depending on the vehicle engine type.

Tables 9 and 10 show a representative list of best-practice technologies that could be expected to improve passenger-vehicle energy efficiency. These were provided to experts in Morocco who graded them using the methodology outlined in the companion paper to this pilot study (IEA, 2016a).

Table 9 • Estimated fuel economy improvement for passenger vehicles with engine-related energy efficiency technologies relative to a baseline vehicle

Technology	Percentage energy efficiency improvement over baseline vehicle
High-efficiency diesel	38%
High-efficiency gasoline	22%
Hybrid	38%
Plug-in hybrid	75%
Electric	88%

Source: IEA analysis, using data from carfueldata.direct.gov.uk; baseline vehicle is assumed to consume 4.86 litres per 100 km, the average for new cars sold in Morocco according to CEDARE (2015), *Fuel Economy and CO_2 Emissions of Light-Duty Vehicles in Morocco*.

Table 10 • Estimated fuel economy improvement and costs for gasoline and diesel passenger vehicles of non-engine-related energy efficiency technologies relative to a 2005 vehicle

	Efficiency (gasoline)	Typical cost (EUR/vehicle) (gasoline)	Efficiency (diesel)	Typical cost (EUR/vehicle) (diesel)
Low-friction design and materials	2%	35	-	-
Combustion improvements	-	-	4%	50
Tyres: low-rolling resistance	3%	35	3%	35
Aerodynamics improvement	2%	50	2%	50
Reduced drivetrain friction	1%	50	2%	50
Lightweight components other than BIW	2%	50	2%	100

Thermal management	3%	100	3%	100
Variable valve actuation and lift	2%	230	1%	250
Auxiliary systems improvement	5%	350	6%	440
Thermodynamic cycle improvements	14%	400	-	-
Strong downsizing	17%	520	10%	600
Dual clutch transmission	6%	700	5%	700
Strong weight reduction	12%	1 000	10%	1 000
Cumulative before hull hybridisation	51%	3 520	39%	3 375
Full hybrid electric drive	25%	2 750	22%	2 750
Cumulative after hull hybridisation	63%	6 270	52%	6 125

Note: BIW = body in white.

Source: IEA (2012), *Technology Roadmap: Fuel Economy of Road Vehicles*.

1.3.2 Results of the energy efficiency technology screening process for prioritisation

As part of this pilot study, policymakers at various Moroccan government agencies were asked to apply the CETAM EET prioritisation screening tool (IEA, 2016a) to a list of candidate EETs for each priority sector (transport, residential, commercial and public services and industry). In practice, only certain agencies were able to complete the task (and only to a limited extent) because in many cases policymakers felt their technical knowledge of EETs was too limited. In addition, it emerged that existing energy consumption surveys and industry energy audits do not capture the level of detail required to make accurate judgements about the market penetration of technologies.

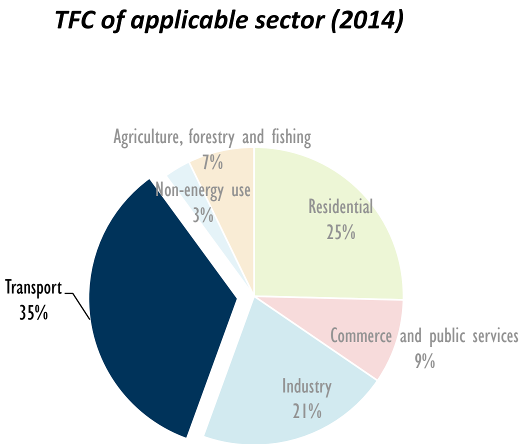
Given these constraints, the priority technology screening results for Morocco presented in this paper represent estimates made by IEA technology experts, based on international technology adoption trends and data applied to the Moroccan case, taking into account local conditions, including climate, major energy using sectors, and economic structure. The full results are provided at Annex A.

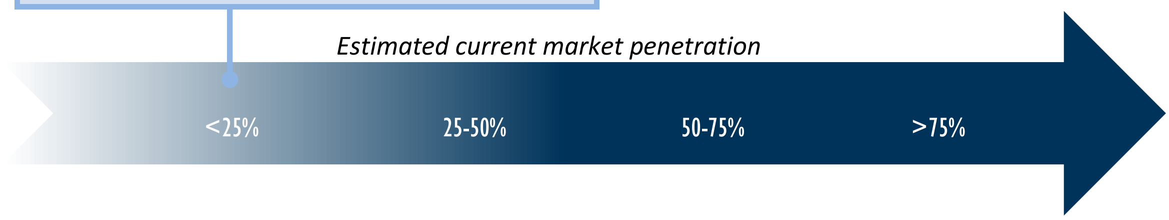
The priority EET short list for passenger vehicles within the transport sector are shown at Figure 45, which also shows these technologies' estimated current market penetration. Results for the residential, commercial and public services, and industrial sectors are shown at Annexes B to D.

Figure 45 shows a range of priority technologies are available which could be applied to Moroccan passenger vehicles. Figure 45 also shows that all of these technologies are estimated to have low current market penetration, meaning there is a significant remaining potential for deployment. Of these technologies, some already have a high diffusion potential (for example, low rolling resistance tyres), while others, such as electric vehicles, will need time before the Moroccan market is ready for widespread deployment. That said, if Morocco implements its ambitious plans for renewable electricity, the case for switching to energy efficient transport technologies that use electricity (such as electric vehicles), will grow stronger, and the market conditions for their deployment may rapidly improve.

Figure 45 • Priority EETs and estimated current market penetration for the passenger vehicles subsector

Energy Savings	End Use	Technology
★★★	Vehicle modifications	Tyres: low rolling resistance
★★★	Vehicle modifications	Lightweighting (high-strength steel)
★★★	Vehicle modifications	Dual clutch transmission
★★★	Vehicle modifications	Lightweighting (aluminium)
★★★	Vehicle switching	Electric vehicles
★★★	Vehicle switching	Fuel cell electric vehicles
★★	Vehicle modifications	Engine low friction design and materials
★★	Vehicle modifications	Lightweight components other than Body in White (BIW)
★★	Vehicle modifications	Variable valve actuation and lift
★★	Vehicle modifications	Starter-alternator (increased battery)
★★	Vehicle modifications	Aerodynamics - spoilers
★★	Vehicle modifications	Aerodynamics - front air dams
★★	Vehicle modifications	Aerodynamics - side skirts
★★	Vehicle modifications	Aerodynamics - under-body panels
★★	Vehicle modifications	Direct injection





Notes: The estimated current market penetration rates and energy savings for these technologies are based on expert judgement; these estimates do not represent the views of the IEA; the star ratings indicate where energy savings from deploying the technology are estimated to be high (3 stars), medium (2 stars) or low (1 star).
Source: The pie chart is based on IEA data (IEA, forthcoming), *Energy Balances of Non-OECD Countries*, www.iea.org/statistics/.

To limit the length and complexity of this publication, one technology has been selected to demonstrate the remaining steps of the methodology: low rolling resistances tyres (LRRTs). LRRTs score well against the screening criteria as shown in Table 11. In particular, the potential for a 3-5% energy efficiency increase at a comparatively low cost is significant, given the current contribution of passenger vehicles to Morocco's overall energy use. LRRTs have also be selected here because they are a transport technology directly involving the *end user*, thus providing an interesting case study for monitoring over time the enabling factors that affect technology deployment.

Table 11 • Rating LRRTs against energy efficiency technology selection criteria

Criteria	Rating
Technical applicability	LRRTs are compatible with a range of vehicle types and sizes and will continue to be so even with future changes to the vehicle fleet (e.g. with petrol, diesel, hybrid or electric vehicles). It is highly technically feasible to fit them to the Moroccan passenger-vehicle fleet.
Diffusion rate	LRRTs can be fitted to both new and old vehicles and as tyres are replaced more frequently than cars, there is a large market for the technology

	(comprising both the existing fleet and new vehicles).
Absolute saving potential	LRRTs are estimated to increased energy efficiency by 3-5%. This is significant, given the contribution of passenger vehicles to Morocco's TFC.
Cost effectiveness	Typical additional costs per vehicle, compared to the baseline technology, are low (EUR 35 per vehicle). As a proportion of total vehicle costs, they are negligible. Energy efficiency gains might be maximised if LRRTs are partnered with tyre pressure monitoring systems (TPMSs) (EUR 15-25 (IEA, 2012).
Maturity	LRRTs are a mature technology and are manufactured and sold in most major markets. LRRTs have been tested in several other markets worldwide. Governments in the European Union and South Korea have introduced mandatory tyre efficiency standards to encourage the uptake of LRRTs and several other countries have introduced rating and labelling schemes.

Notes: Costs for TPMSs in IEA (2012) were originally quoted in US dollars; these were converted to EUR using an average exchange rate for 2012 obtained from www.oanda.com; USD 1 = EUR 0.778.

1.3.3 Enabling factors for market success

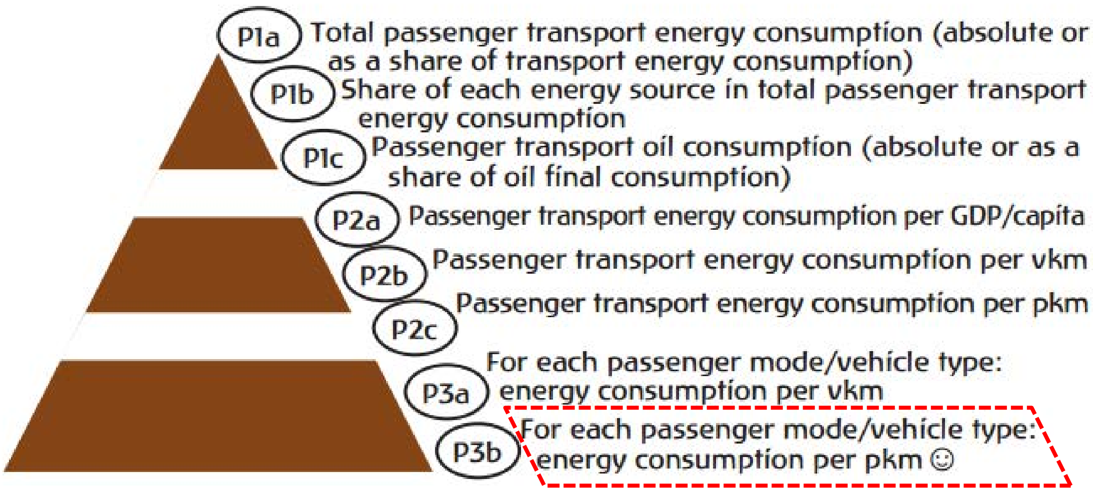
In addition to the criteria above, deployment of LRRTs will be affected by the broader enabling environment. A range of enabling factors should be analysed over time and these are presented under Step 3.

Step 2: Indicators, metrics and data

2.1 Identifying appropriate energy indicators

The IEA recommends the most appropriate indicator to capture changes in passenger-vehicle energy efficiency is passenger-transport energy consumption per passenger-kilometre (pkm) by vehicle type (IEA, 2014b) (Figure 46).

Figure 46 • Pyramid of passenger transport indicators with the recommended indicator for capturing changes in passenger vehicle energy efficiency highlighted



Note: vkm = vehicle-kilometre.

Source: IEA (2014b), *Energy Efficiency Indicators: Fundamentals on Statistics*.

This requires the following datasets:

- energy consumption of passenger transport by vehicle type
- number of pkm per passenger-vehicle type.

Morocco has an established system of energy efficiency indicators to track energy efficiency progress across a range of sectors. Currently, the most detailed level of indicator assembled for passenger vehicles is P3a (energy consumption per vkm by vehicle type).

2.2 Energy efficiency technology penetration metrics

To measure the penetration of LRRTs, a sales-based approach is likely to be the most appropriate. Sales data can be obtained from retailers and compiled to provide an overall market share by comparing sales of LRRTs with standard tyres. Over time, data can reveal whether the percentage of LRRTs sales is increasing.

In the absence of sales data, import data can be a useful substitute. Given Morocco does not have a local tyre manufacturing industry, tyre import data can be a close proxy for sales data.

As with all energy efficiency technologies, to measure the additional energy savings achieved through increased market penetration of LRRTs, it is necessary to establish the energy use of a "baseline" technology. In this case the baseline should be derived from tyre sales data for a baseline year.

Step 3: Technology monitoring system

3.1 Data collection system

In the road transport sector, the Directorate of Observation, Communication and Cooperation (DOCC) within MEMEE collects data via a survey conducted periodically, with the most recent survey conducted in 2011. This process allows for the collection of data on energy consumption (by fuel) of passenger-vehicle types and annual vkm by vehicle type. This means that the current system does not completely meet the data requirements to assemble the preferred energy efficiency indicator identified in Step 2.1.

The 2011 transport survey contained over 4 400 responses, from 19 industrial and commercial sectors as well as the residential sector. A stratified random sampling approach was used to select respondents, to ensure representation from a broad cross-section of vehicle users.

In years where the survey is not conducted, indicators of vehicle fuel efficiency must be estimated by combining assumptions of vkm travelled (from recent survey data) with overall fuel consumption data for road transport, and administrative data on vehicle fleet composition provided by the Ministry of Transport (collected annually).

The IEA publication *Energy Efficiency Indicators: Fundamentals on Statistics* (IEA, 2014b) notes that a number of factors affect the quality of data gathered via passenger-vehicle use surveys, including the approach, sample design and size, frequency, legal status and response rates (among others). In Morocco's case, the current frequency of transport sector surveys (aimed at being conducted once every five years) is lower than the frequency in other parts of the world, which tend to conduct surveys every one to three years on average (IEA, 2014b). A higher frequency ensures continuity of data and would help improve data quality over time.

Morocco currently has no established centralised system to capture data on LRRT market penetration, or more broadly data to show technological change across the passenger-vehicle fleet. However, datasets are emerging from various government programmes (for example, the taxi fleet rejuvenation scheme) that could form the basis for such a system. For LRRTs in particular, tyre retailers should be approached (potentially through an industry association) to establish a regularly updated tyre sales database, taking caution to protect data that is commercially valuable.

Table 12 presents a summary of the data collection system that could be established to capture passenger-vehicle energy efficiency indicators and LRRT market penetration indicators.

Table 12 • Ideal data collection system for monitoring passenger-vehicle energy consumption, market penetration of LRRTs and their possible impact

Data type	Responsible entity	Collection method	Collection frequency	Quality control
Vehicle mobility survey	DOCC	Survey of a large sample of vehicle users	1-3 years	Internal
Passenger-vehicle energy efficiency indicators	ADEREE, DOCC	Survey of vehicle users, energy balances	1 year	Internal
LRRT sales	Tyre wholesalers/retail associations	Survey of major wholesalers and retailers	1 year	Ministry of Transport
All tyre sales	Tyre wholesalers/retail associations	Survey of major wholesalers and retailers	1 year	Ministry of Transport
Sales information on all energy efficiency technologies in the transport sector	DOCC	Surveys major wholesalers and retailers, surveys of households	1 year	DOCC
Information on other vehicle energy efficiency technologies	Vehicle manufacturers/ importers association, Ministry of Transport	Survey of vehicle manufacturers and importers, administrative data on vehicle models	1 year	Ministry of Transport, ADEREE

Recommendations for implementing the data collection system

- Improve mobility survey by including questions to capture pkm travelled. This will allow for the compilation of the P3b level indicator.
- Increase the frequency of data collection for all data sources, but particularly the mobility survey, so that data are captured on a more regular basis.
- Engage with vehicle manufacturers and importers to establish a detailed database of technologies in vehicles sold in the Moroccan market.
- Ensure administrative data systems collect information on vehicle models.
- Engage with tyre retailers and importers to capture sales/import data on tyres by model, including LRRTs.

3.2 Key enabling factors for monitoring

The market penetration of LRRTs in Morocco will depend on a number of enabling factors, which are discussed according to type. A qualitative analysis of enabling factors is employed in this case, rather than a quantitative approach that scores the enabling environment.

Technical and infrastructure factors

The potential for LRRTs to achieve efficiency improvements in the range of 3-5% will depend on a number of factors, but most important is correct tyre inflation. Studies have shown that each 1 pound per square inch (psi) drop in tyre pressure can lead to an increase in rolling resistance of at least 1.4% (Pike, 2011).

To help ensure that LRRTs are inflated correctly, it is necessary to ensure that vehicle users have easy access to tyre pressure gauges and pumps. In Morocco, access to pressure gauges and pumps is commonplace but these will need to be regularly maintained (for example, to ensure that pressure gauges provide accurate readings).

TPMSs, which warn vehicle users of low tyre pressure, are a technical solution to help ensure tyres are inflated to their minimum level. TPMSs were made mandatory in 2007 for all vehicles sold in the United States and mandatory in 2012 for vehicles sold in Europe. According to TPMS manufacturer Schrader International Inc., Japan, Korea, China and India are all in the process of adopting legislation to make TPMSs mandatory (Schrader International Inc., 2016). No such legislation currently exists for passenger vehicles sold or manufactured in Morocco.

While these factors are more related to the technical performance of LRRTs in Morocco and may not directly affect the *market* success of LRRTs, if LRRTs do not perform as expected, due to inadequate infrastructure, demand for LRRTs may be affected.

Financial and market factors

Since the exit of the General Tyre Company and Goodyear from Morocco, the country now has no local tyre production facilities. Given the current customs regime, in which the European Union enjoys zero tariffs, this should provide a market advantage to European tyre manufacturers, which are now subject to European minimum tyre efficiency standards.

However, despite the customs regime, other exporters (primarily Chinese manufacturers but also Tunisian and Egyptian) are still able to offer competitively priced products, even after customs duties are applied and therefore a range of non-European tyres are sold on the market (L'Economiste, 2013). If these are not subject to the same minimum efficiency standards as European tyres, the appeal of LRRTs may be undercut by cheap, low-efficiency tyres.

Social factors

Without clear and accurate information explaining the benefits of LRRTs, consumers may be put off by their higher up-front costs. Therefore information at the point of sale is vital to ensure consumers understand the energy, environmental and cost benefits of LRRTs. In addition, some consumers may require reassurance of the durability and safety features of LRRTs in comparison to other tyres.

Tyre rating and labelling schemes are an important measure to overcome information barriers and help inform consumers' purchasing decisions at the point of sale. Such schemes are in place in various countries globally (including the European Union, South Korea and Japan), and can provide a range of information to consumers on tyre performance, including rolling resistance. Labelling schemes can be either voluntary or mandatory, with mandatory labelling ensuring the entire market is covered. ADEREE's energy efficiency strategy lists implementing a tyre labelling scheme as a "medium priority" measure in the period 2014-16.

Information and education campaigns on proper tyre inflation and maintenance are also required to ensure correct usage of LRRTs, as studies have shown consumers are often unaware of when and how to check tyre pressure (Pike, 2011).

Regulatory and institutional factors

Morocco's national energy efficiency strategy and target of achieving a 12% reduction in transport sector energy use (by 2020) provides a strong overall basis for implementing policies and regulations that would help achieve targets.

Several regulatory measures can directly encourage the uptake of LRRTs. According to the ICCT, the first step in strengthening the regulatory regime is generally to introduce a mandatory efficiency rating and labelling scheme (see Social factors) to create sufficient "pull" factors for LRRTs (Pike, 2011). ADEREE lists a tyre rating and labelling scheme in its measures targeting the transport sector under Phase I of the Energy Efficiency Strategy. The strategy was being considered at the time of writing. Alongside ratings and labelling schemes, mandatory minimum efficiency standards can create "push" factors for LRRT uptake, helping to increase market share by removing the lowest efficiency tyres from the market. Morocco is currently investigating the implementation of tyre efficiency standards, a measure that is listed as a "medium priority" in the national energy efficiency strategy.

Indirectly, vehicle fuel efficiency standards can also affect the market penetration of LRRTs. For example, in the United States, vehicle fuel efficiency standards require that new vehicles are sold with the same tyres that are used in fuel efficiency tests. This creates an incentive to sell new cars with LRRTs. In Europe and China, vehicle fuel efficiency standards do not contain this requirement (Pike, 2011).

At the time of writing, Morocco's institutional framework for clean energy technologies (including energy efficiency technologies) was under review. Reforms to the institutional arrangements are expected to be announced later in 2016; however, the IEA can offer the following observations, which may affect the enabling environment for energy efficiency technologies generally:

- ADEREE is currently designated as the primary programme delivery agency for energy efficiency programmes. ADEREE has formulated several plans to date, but in practice concrete programmes and regulations which could spur energy efficiency improvements have been slow to materialise. Budgetary constraints and delays at the political level have been cited as issues that may be hampering progress on programme delivery and these should be addressed to ensure ADEREE is able to properly carry out its functions as an energy efficiency technologies programme delivery agency.
- It is unclear which agencies have overall responsibility for monitoring Moroccan energy efficiency by maintaining the country's energy efficiency data and indicators. While MEMEE recently published a report on Moroccan energy efficiency (MEMEE, 2015b), indicating that it maintains a database on energy efficiency, previous studies (Enerdata, 2014) have indicated that ADEREE has responsibility for maintaining a database of energy efficiency indicators.

Conclusion on enabling environment

A number of factors may affect the enabling environment for LRRTs. Key factors that should be monitored over time include:

- development of the proposed minimum tyre energy efficiency standards and labelling scheme, and mechanisms in the scheme to "ratchet up" minimum standards over time
- introduction of government incentives for energy-efficient tyres
- public awareness of LRRTs and knowledge of proper tyre inflation
- changes in the local vehicle stock and the share of vehicles that ship with TPMSs.

The first of these factors, in particular, is likely to have a significant impact on deployment levels. It will be important to capture the change in deployment recorded after the introduction of minimum standards and labelling, should these measures be implemented, not least to quantify the energy efficiency benefits resulting from the policy intervention.

Lessons learned from the pilot study

Data availability on energy efficiency technologies

MEMEE is responsible for collating energy data. However, it is unclear which agency has responsibility for monitoring energy efficiency, as multiple agencies appear to be producing energy efficiency indicators. In 2013, ADEME, Alcor and Enerdata conducted a project on energy efficiency indicators with ADEREE, leading to the establishment of indicators for all major end-use sectors of the Moroccan economy. The project report (Enerdata, 2013) indicates that an energy efficiency indicator database was established and would be managed by ADEREE. In late 2015, DOCC (part of MEMEE) published its own assessment of energy efficiency across the economy from 2004-13, which did not appear to reference the ADEREE database. It is therefore unclear whether the ADEREE energy efficiency indicator database continues to be maintained.

There is currently no known database of quantitative information on energy efficiency technology deployment, although the existing system of surveying the energy consumption of different economic sectors could provide a basis for gathering detailed information on technologies. In the meantime, data on energy efficiency technologies must be gathered in a piecemeal fashion, by speaking to various different agencies and industry associations to obtain a qualitative indication of energy efficiency technology deployment.

In carrying out this pilot study, it became clear that Morocco's energy balance, as submitted to the IEA, required significant improvement. In particular, 13% of industrial energy consumption data was recorded as "non-specified". As a result of this study, the IEA has worked directly with Moroccan statisticians to understand why the balance was reported in this way and suggest changes to improve Morocco's international reporting. This will allow for much more accurate benchmarking against other countries in future.

Recommendations on future users of the methodology in Morocco

As ADEREE appears to be the primary agency responsible for increasing energy efficiency in Morocco, it would be a logical agency to apply the methodology to energy efficiency technologies in the future. The involvement of MEMEE would also be crucial in future, as it is the key agency responsible for co-ordinating overall energy policy, and for co-ordinating data collection.

Conclusions

RETs

With some of the best resource potential in the world, a wide choice of renewable technologies is available for Morocco to increase the share of renewable energy in the energy mix. Morocco has already made good progress in prioritising and deploying renewable energy technologies and has established an enabling environment that is broadly supportive of their deployment.

Strengths include:

- Setting ambitious short-term targets for the design and deployment of a project pipeline to achieve targets.
- Providing a very clear contractual framework for large-scale generation projects and using competitive tenders to drive down costs. Morocco's auctions have been able to produce some of the lowest bids in the world for both wind and CSP.
- An innovative use of international finance and risk allocation between public and private sectors to attract record low bids for projects.
- Tying renewable energy technology development into broader industry policy, by recognising the potential job creation benefits from local manufacturing of components.
- Establishing an institutional framework that attempts to address each stage of the renewables deployment process, from R&D to programme delivery.

Areas for improvement include:

- Conducting detailed resource assessment of renewable resources that are currently understudied. This includes biomass, geothermal, marine and offshore wind.
- Establishing a system to monitor renewable energy technology costs over time. As a first step, MASEN could consider publishing a short study comparing renewables costs to non-renewable technologies.
- Strengthening energy demand modelling capacity to ensure future demand projections are accurate. This is vital for forecasting the potential range of energy mixes, including the contribution of renewable energy.
- Ensuring the new electricity market regulator and legal framework operate effectively to create a level playing field for private developers to bring forward projects under Law 13-09. In addition, ensuring clear, up-to-date information on processes, costs and timing for bringing forward renewables projects would be beneficial.
- Strengthening the institutional framework to ensure there is a clear delineation of responsibilities between agencies, particularly for renewable resource assessments, small-scale renewables deployment and renewables programmes and policies and monitoring.
- Improving the enabling environment for small-scale renewables, including on-grid solar PV and SWHs. This could include carefully designed incentive schemes, but at a minimum should mean removing barriers stopping small-scale renewables from connecting easily to the grid. Targeted information campaigns on the benefits of small-scale renewables would also be beneficial, particularly for SWHs.

Revisiting the IEA's specific recommendations for solar energy (IEA, 2014a), it is clear that Morocco has made some progress in orienting the development of large CSP plants to priority production during peak hours after sunset, and has begun to open up the medium-voltage market and to encourage the supply of renewable energy at low voltage.

However, work remains to be done to unlock the potential for PV production in the low- and medium-voltage electric grids belonging to ONEE and the distributors, and to implement programmes to accelerate the deployment of residential and commercial SWHs and PV pumping for irrigation purposes.

Furthermore, a comprehensive study is still required to identify the heating needs of the agricultural, industrial and service sectors by temperature level and time period, and the specific technologies to meet these needs economically through solar energy.

EETs

As Morocco undergoes a period of sustained economic growth, leading to rapid changes in the building, industrial and vehicle stock, there is a good opportunity to ensure that infrastructure across all sectors avoids "locking in" inefficient technologies. This period of change may also allow Morocco to "leapfrog" certain technological phases and reach an advanced level of energy efficiency more quickly than many developed countries achieved.

Strengths include:

- a designated R&D agency (IRESEN) that has plans to establish a Green Building Park to test how energy efficiency technologies perform in Moroccan conditions, including accounting for behavioural factors
- new building standards, which will help to spur energy efficiency technology deployment in the residential and commercial sectors
- partial removal of fuel subsidies, which will help to incentivise uptake of energy efficiency technologies
- plans to implement a comprehensive energy efficiency programme.

Areas for improvement include:

- clearly defining which agency will maintain Morocco's system of energy efficiency indicators
- improving energy consumption data, including by conducting sectoral surveys more frequently
- strengthening energy demand modelling capacity to ensure future demand projections are accurate
- improving energy efficiency indicators by increasing the detail of information collected through surveys, modelling and administrative data
- strengthening the regulatory factors for energy efficiency technology deployment by expediting the creation of minimum energy performance standards for appliances and equipment, and introducing fuel economy ratings for vehicles and vehicle components such as tyres
- strengthening market and finance factors for energy efficiency technology deployment by removing remaining subsidies for butane and electricity, while ensuring social impacts are minimised through targeted support for vulnerable parts of the population
- expediting the implementation of the upcoming energy efficiency strategy.

Annex A. Results of the EET prioritisation screening methodology

The full results of the EET prioritisation screening can be found under the following links:

Transport short-list for Morocco

Industry short-list for Morocco

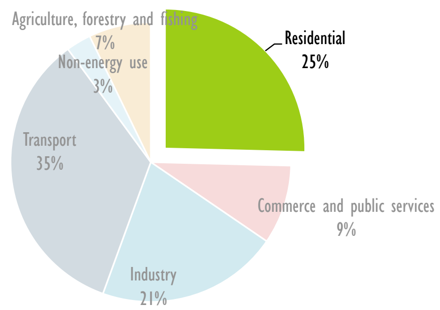
Residential buildings short-list for Morocco

Commercial buildings short-list for Morocco

The information contained in this Annex is based on data gathered by the IEA including through consultation with the EBRD and relevant parties in Morocco, and it is provided on an "as available" basis. This paper and its Annexes do not constitute advice on any specific issue or situation and it is not intended to be relied upon in making any decisions.

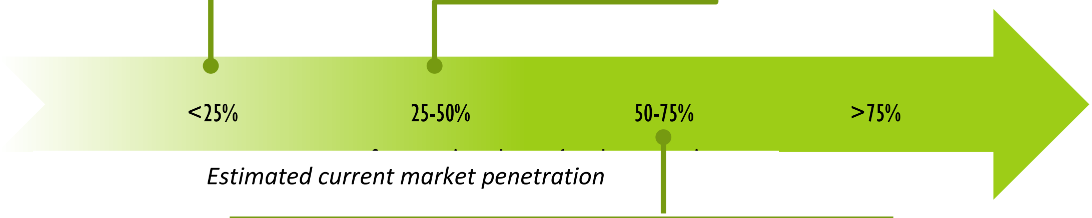
Annex B. Estimated market penetration of residential sector priority EETs

TFC of applicable sector (2014)



Energy savings	End use	Technology
★★★	Appliances	Washing machines - EU labelling - A+++
★★★	Appliances	Dishwashers - EU labelling - A+++
★★★	Appliances	Refrigerators - EU labelling - A+++
★★★	Cooking	Induction cookstove
★★★	Space cooling	Loft insulation (200 to 300 mm)
★★★	Space cooling	Loft insulation (100 to 200mm)
★★★	Space cooling	Floor insulation
★★★	Space cooling	Double glazed windows
★★★	Space cooling	Triple glazed windows
★★★	Space cooling	Solid wall insulation
★★	Space cooling	Absorbtion chillers
★★	Lighting	Daylight sensors
★★	Cooking	Solar cook stoves
★★	Cooking	Electric hobs
★★	Cooking	Electric oven
★★	Space cooling	Energy-plus windows in cold climates (highly insulating and dynamic solar)
★★	Space cooling	Window attachments (automatic solar control, e.g. exterior solar shades and blinds)
★★	Space cooling	Window attachments (highly insulating, e.g. cellular shades, low-e films)

Energy savings	End use	Technology
★★★	Appliances	Washing machines - EU labelling - A++
★★★	Appliances	Dishwashers - EU labelling - A++
★★★	Appliances	Refrigerators - EU labelling - A++
★★★	Lighting	LED



Estimated current market penetration

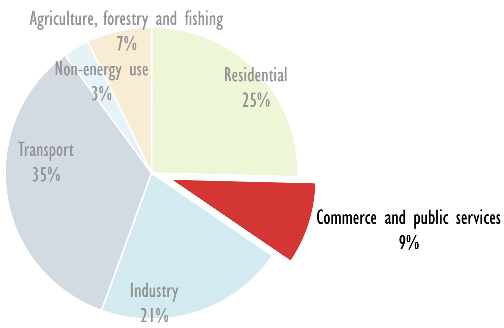
Energy savings	End use	Technology
★★★	Lighting	High-Intensity Discharge Lamps (HID)
★★	Lighting	Linear fluorescent bulb
★★	Lighting	CFL bulb
★★	Appliances	Washing machines - EU labelling - A+

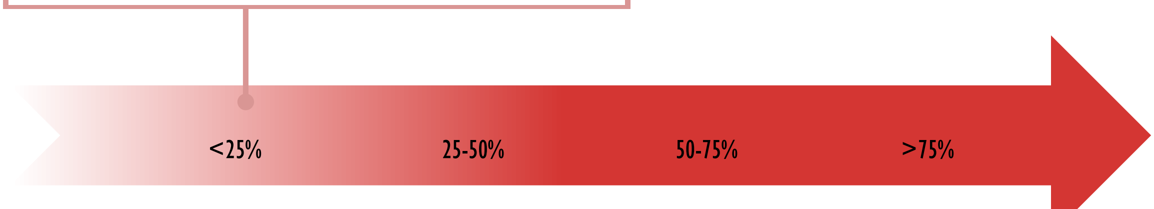
Notes: The estimated current market penetration rates and energy savings for these technologies are based on expert judgement; these estimates do not represent the views of the IEA; the star ratings indicate where energy savings from deploying the technology are estimated to be high (3 stars), medium (2 stars) or low (1 star).

Annex C. Estimated market penetration of selected commercial and public services sector priority EETs

Energy savings	End use	Technology
★★★	Lighting	LED
★★★	Lighting	High-Intensity Discharge Lamps (HID)
★★★	Lighting	Presence sensors
★★★	Appliances	Refrigerators - EU labelling - A++
★★★	Appliances	Refrigerators - EU labelling - A+++
★★★	Appliances	Dishwashers - EU labelling - A++
★★★	Appliances	Dishwashers - EU labelling - A+++
★★★	Appliances	Televisions - EU labelling - A++
★★★	Appliances	Televisions - EU labelling - A+++
★★★	Appliances	Washing machines - EU labelling - A+++
★★★	Appliances	Tumble driers - EU labelling - A
★★★	Appliances	Combined washer driers - EU labelling - A
★★★	Space cooling	Air conditioner - EU labelling - A
★★★	Space cooling	Air heat pump - EU labelling - A
★★★	Space cooling	Triple glazed windows
★★★	Space cooling	Low-E windows
★★★	Heating	Conventional water heater - EU labelling - A
★★★	Water heating	Solar water heater - EU labelling - A
★★★	Water heating	Heat pump water heater - EU labelling - A
★★★	Water heating	Hot water storage tank - EU labelling - A
★★	Space cooling	Reflective walls/roofs
★★	Space cooling	Window attachments (highly insulating, e.g. cellular shades, low-e films)

TFC of applicable sector (2014)



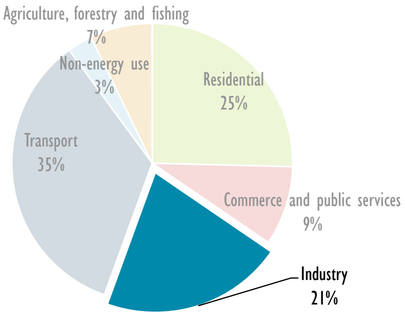


Estimated current market penetration

Notes: The estimated current market penetration rates and energy savings for these technologies are based on expert judgement; these estimates do not represent the views of the IEA; the star ratings indicate where energy savings from deploying the technology are estimated to be high (3 stars), medium (2 stars) or low (1 star).

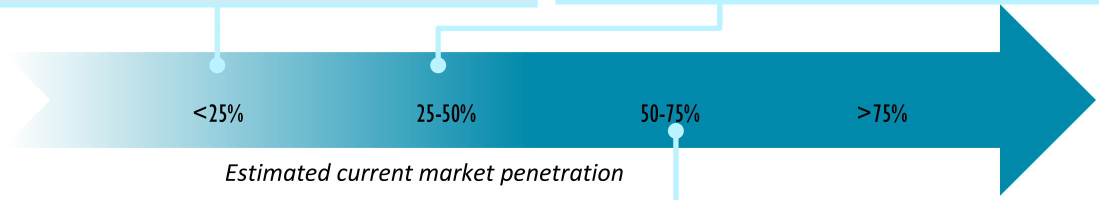
Annex D. Estimated market penetration of industry sector priority cross-cutting EETs

TFC of applicable sector (2014)



Energy Savings	End Use	Technology
★★★	Furnaces	Flue gas heat recovery
★★★	Furnaces	Oxygen enrichment
★★★	Refrigeration	Improved compressor / heat exchanger
★★★	Refrigeration	Multi-level compression and soprtion process
★★★	Compressed Air Systems	Size replacement compressor to meet demand
★★	Boilers	Flash condensate
★★	Boilers	Vapour recompression
★★	Boilers	Vent condenser
★★	Refrigeration	Improved insulation
★★	Compressed Air Systems	Replace existing condensate drains with zero loss type
★★	Compressed Air Systems	Install dedicated storage with metered recovery

Energy savings	End Use	Technology
★★★	Boilers	Improved process control (including flue gas monitoring)
★★★	Boilers	Feedwater economiser
★★★	Boilers	Return condensate
★★★	Boilers	Minimise short cycling (via multiple boiler operation and/or boiler downsizing)
★★★	Furnaces	Reducing Wall heat losses
★★★	Furnaces	Reducing Radiation heat losses
★★★	Refrigeration	Speed-controlled compressor and fan
★★★	Refrigeration	Multicompressor refrigeration systems
★★★	Pumps	Install variable speed drive
★★★	Pumps	More efficient pump
★★★	Pumps	More efficient motor
★★★	Fan	Install variable speed drive
★★★	Fan	Replace oversized fans with more efficient type
★★★	Fan	More efficient motor
★★★	Compressed Air Systems	Variable speed drive
★★★	Compressed Air Systems	Improvement of automatic control
★★	Steam Piping	Heat exchanger
★★	Boilers	Insulate valves and fittings
★★	Steam Piping	Automatic monitoring of steam traps
★★	Furnaces	Efficient design burners (e.g. low NOx)
★★	Refrigeration	Electronically controlled pumps
★★	Refrigeration	Systems optimisation
★★	Refrigeration	Improved process measuring and control
★★	Pumps	Use of pressure switches
★★	Compressed Air Systems	Eliminate artificial demand with pressure optimisation/control



Estimated current market penetration

Energy savings	End Use	Technology
★★★	Furnaces	Improved process controls (e.g. air-to-fuel ratio)
★★★	Compressed Air Systems	Sequencer
★★	Pumps	Isolate flow paths to no-essential equipment

Notes: The estimated current market penetration rates and energy savings for these technologies are based on expert judgement; these estimates do not represent the views of the IEA; the star ratings indicate where energy savings from deploying the technology are estimated to be high (3 stars), medium (2 stars) or low (1 star).

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Acronyms, abbreviations and units of measure

Acronyms and abbreviations

ADEREE	Agency for Renewable Energy and Energy Efficiency
CETAM	Clean Energy Technology Assessment Methodology
CO_2	Carbon dioxide
CCGT	Combined-cycle gas turbine
COP21	The 21st session of the Conference of the Parties to the UNFCCC
COP22	The 22nd session of the Conference of the Parties to the UNFCCC
CPI	Climate Policy Institute
CSP	Concentrated solar power
DNI	Direct normal irradiance
DOCC	Directorate of Observation, Communication and Cooperation
EBRD	European Bank for Reconstruction and Development
EET	Energy efficiency technology
ETC(s)	Early transition countries
EU	European Union
FINTECC	Finance and Technology Transfer Centre for Climate Change (EBRD)
FAO	Food and Agriculture Organization
GDP	Gross domestic product
GDP PPP	Gross domestic product at purchasing power parity
GEF	Global Environment Facility
GHG	Greenhouse gas
GHI	Global horizontal irradiance
GIZ	German Federal Enterprise for International Co operation
IEA	International Energy Agency
IRESEN	Institute for Research in Solar and New Energies of Morocco
IMF	International Monetary Fund
INDC	Intended Nationally Determined Contribution
ICCT	International Clean Council on Transportation
LCOE	Levelised cost of electricity
LNG	Liquefied natural gas
LPG	Liquefied petroleum gas
LRRT	Low rolling resistances tyre
MAD	Moroccan Dirhams
MASEN	Moroccan Agency for Solar Energy
MEMEE	Ministry of Energy and Mineral Resources
MSW	Municipal solid waste

OECD	Organisation for Economic Co operation and Development
OFPPT	Office of Professional Training and the Promotion of Work
ONEE	National Agency for Electricity and Water
ONE	National Office for Energy
ONEP	National Office for Potable Water
PAI	Plan for the Acceleration of Industry
PERG	Global Rural Electrification Project
PNEI	National Pact for Industrial Emergence
PPA	Power purchase agreement
PROMASOL	Programme for the Development of the National Market for Solar Water-Heaters
PV	Photovoltaic
R&D	Research and development
SEMED	Southern and Eastern Mediterranean
SIE	State Investment Company
SPC	Solar Power Company
SWH	Solar water heater
TFC	Total final consumption
TPES	Total primary energy supply
TPMS	Tyre pressure monitoring system
UAE	United Arab Emirates
USD	United States dollar
WACC	Weighted average cost of capital

Units of measure

bcm	billion cubic metres
GW	gigawatt
GWh	gigawatt hour
KW	kilowatt
kWh	kilowatt hour
kWh/m^2	kilowatt hours per square metre
ktoe	kilo tonne of oil equivalent
m	metre
m^3	cubic metre
MWh	megawatt hour
m/s	metres per second
Mtoe	million tonnes of oil-equivalent
MW	megawatts
pkm	passenger-kilometre
psi	pound per square inch
vkm	vehicle kilometre

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Clean Energy Technology Assessment Methodology Pilot Study

Morocco

To reduce its heavy dependence on imported fossil fuels, achieve its ambitious climate goals and meet growing energy demand, the Moroccan government has launched a comprehensive plan to increase the share of renewable energy and improve energy efficiency. It set a target of 42% of its installed electricity generation capacity to come from renewable sources, with the goal rising to 52% by 2030. At the same time, Morocco aims to reduce its energy consumption by 12% by 2020, and 15% by 2030 through increased energy efficiency.

Due to the country's determination to increase energy efficiency and its supportive policy environment, the IEA selected Morocco for a pilot study of the new Clean Energy Technology Assessment Methodology (CETAM). This methodology, developed with the European Bank of Reconstruction and Development (EBRD), aims to provide clear, transparent information about clean energy technology markets in emerging economies. The goal is to identify the most promising clean energy technologies for policy support and investment and to establish metrics for tracking their deployment over time.

Morocco has an abundance of renewable resources, especially wind and solar power, and is a regional leader in deploying clean energy technologies. This report assesses the range of technological options on both the demand and supply side to determine which show the most potential for further development, in line with the country's policy goals and resource endowment.