

# MOROCCO ENERGY POLICY MRV

Emission Reductions from Energy Subsidies Reform and Renewable Energy Policy

June 2018  
World Bank Group



# ABBREVIATIONS AND ACRONYMS

AFOLU	Agriculture, Forestry and Other Land Use
ASA	Advisory Services and Analytics
BAU	Business as Usual
C&I	Commercial and Industrial
CAGR	Compound annual growth rate
CCGT	Combined cycle gas turbine
CDM	Clean Development Mechanism
CEO	Chief Executive Officer
CFL	Compact Fluorescent Light Bulbs
CO <sub>2</sub>	Carbon Dioxide
CPF	Carbon Partnership Facility
CSP	Concentrated Solar Power
DEREE	Directorate of Renewable Energy and Energy Efficiency
DOCC	Directorate for Observation, Coordination and Cooperation
EIA	U.S. Energy Information Administration
ENTSOE	European Network of Transmission System Operators for Electricity
ESMAP	Energy Sector Management Assistance Program administered by the World Bank.
EU	European Union
FOM	Fixed operation and maintenance costs
GHG	Greenhouse gases
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit, GmbH
GWh	Gigawatt-hour
IEA	International Energy Agency
IMF	International Monetary Fund
kWh	Kilowatt-hour
LED	Light Emitting Diode Light Bulbs
LNG	Liquified Natural Gas
M-EPM	Morocco Energy Policy MRV tool
MAD	Moroccan dirhams
MASEN	Moroccan Agency for Sustainable Energy
MEF	Ministry of Economy and Finance
MEMDD	Ministry of Energy, Mining, and Sustainable Development
META	World Bank's (ESMAP) Model for Electricity Technology Assessment
MRV	Measurement, Reporting and Verification
MtCO <sub>2</sub>	Million metric tons of carbon dioxide
MW	Megawatt
NDC	Nationally Determined Contribution
ONEE	National Electricity and Water Utility– Electricity Branch
PV	Solar Photovoltaic
STEP	Station de Transfert d'Énergie par Pompage (French pumped-storage hydro)
T&D	Transmission and Distribution
TCAF	Transformative Carbon Asset Facility
UN	United Nations
UNFCCC	United Nations Framework Convention on Climate Change
US\$	United States of America Dollar
VOM	Variable operating and maintenance costs
WEO	World Energy Outlook (an IEA publication)

# Table of Contents

Acknowledgement .....	iv
Executive Summary .....	vi
Chapter 1: Introduction .....	8
I. Energy sector and policy context .....	9
II. Scope of activity .....	13
III. Policy package .....	15
Chapter 2: Methodology .....	18
I. Overview of M-EPM tool .....	20
II. Key assumptions and inputs .....	26
III. Model calibration .....	30
Chapter 3: Scenarios and Results .....	32
I. Description of scenarios .....	32
A. Policy Scenario .....	33
B. Baseline Scenarios .....	35
II. Modeling Results .....	37
A. Ex-post policy impact (2009-2016) .....	37
B. Ex-ante policy impact (2016-2030) .....	40
C. Cumulative emission reduction impacts (2009-2030) .....	44
III. Policy synergy and sensitivity .....	44
Chapter 4: Application to Climate Finance .....	47
I. Policy matrix and scenarios .....	49
II. Emission reduction estimates .....	52
Chapter 5: Conclusion .....	54
References .....	55
Technical Appendix .....	58
Appendix 1: Key Assumptions .....	58
Appendix 2: Comparison with other power sector models .....	61

# Acknowledgement

This report was prepared by a team led by Suphachol Suphachalasai (Climate Change Group, World Bank) and Manaf Touati (Energy Global Practice, World Bank), and consisting of Frank Ackerman, Pat Knight, Devi Glick, Ariel Horowitz (Synapse Energy Economics), John Allen Rogers, and Tayeb Amegroud (Consultants, World Bank).

The report is a deliverable under *Morocco Energy Policy MRV* Analytical and Advisory Services (P158888) which has been implemented under the overall guidance of Mme. Maya Aherdan, Director for Observation, Coordination and Cooperation (DOCC), Ministry of Energy, Mining, and Sustainable Development (MEMDD) and her team including Mme. Fatiha Machkori, Division Chief of Observation and Forecasting (DOCC), Mr. Abdelmonim Chentouf, Division Chief of Observation and Energy Documentation (DOCC), Mr. Ibrahim Benrahmoune Idrissi, Division Chief of Cooperation (DOCC), and Mr. Karim Benamrane (DOCC).

The project activities and this report could not have been completed without inputs and advice from Moroccan government officials of the Ministry of Energy, Mining, and Sustainable Development (MEMDD), the Moroccan Agency for Sustainable Energy (MASEN), the National Electricity and Water Utility– Electricity Branch (ONEE), and the Ministry of Economy and Finance (MEF). The team expresses sincere appreciation for significant contributions from the following colleagues:

MEMDD: Mme. Zohra Ettaik, Directorate of Renewable Energy and Energy Efficiency (DEREE), Mr. Allal Reqadi, Division Chief, Directorate of Electricity, Mme. Amina Ouattassi, Division Chief of Energy Efficiency, (DEREE), Mme. Hind Abdaoui, (DEREE), Mr. Abdelrhani Boucham, Division Chief for Climate Change, Department of Environment, and Mr. Mohamed Nbou, Director for Climate Change, Biodiversity and Green Economy.

MASEN: Mr. Obaid Amrane, Member of the Management Board and Deputy CEO, Mr. Mohamed Sahri Project Development Senior Manager, Ms. Boutaina Benchekroun, Project Development Expert, Ms. Kamelia Naimi, Project Development Specialist, Ms. Meryem Lakhssassi, Sustainability Development Manager, and Ms Nadia Taobane, former Structuration Director.

ONEE: Mme. Asmaa Sghiouar, Point Focal Banque Mondiale, Direction Financière, Mr. Mohammed Tabet, Chef Division Environnement, Mme. Kaoutar Ennachat, Cadre Financier Mr. Braham Boutmoila, Chef Service Financements, Mme Loumia Mellouki, Direction Stratégie et Planification, Mr. Mohamed Fait, former Division Chief for Multilateral Financing and Donor Coordination, and Mr. Mohammadi Allach, former Deputy Director General.

MEF: Mr. Abdelouahab Belmadani, Head of Energy Department, Directorate of Budget

Development partners: the team would also like to thank Mr. Mohamed Boussaid, Principal Technical Advisor, 4C project, GIZ, Ms. Imane Chafiq, Technical Advisor, 4C project, GIZ, and Ms. Christel Dischinger, Programme Officer, Swiss Cooperation for their valuable advice.

The *Morocco Energy Policy MRV* ASA project, and this report in particular, greatly benefited from comments and suggestions from the peer reviewers: Mike Toman (Development Research Group, World Bank), Pierre Audinet (Energy Global Practice, World Bank), and Debabrata Chattopadhyay (Energy Global Practice, World Bank). At the concept stage, the project received advice from the same colleagues and also from Rama Chandra Reddy and Jagjeet Singh Sareen (Climate Change Group, World Bank).

The ASA project has been successfully and timely executed under the overall leadership and guidance of Marie Françoise Marie-Nelly (Country Director) and John Roome (Senior Director, Climate Change Group, World Bank), as well as Jaafar Friaa (Program Leader), Erik Fernstrom (Practice Manager, Energy Global Practice), Marc Sadler (Practice Manager, Climate Change Group), and Stephen Hammer (Practice Manager, Climate Change Group).

Several colleagues provided valuable inputs and suggestions at various stages of the ASA implementation. The team would like to gratefully acknowledge Klaus Oppermann, Nuyi Tao, Jose Andreu, Petr Charnik, Debabrata Chattopadhyay, Pierre Audinet, Mike Toman, Andrea Liverani, Rick Zechter, Zijun Li, Jason Smith, Juha Seppala, Grzegorz Peszko, Adrien de Bassompierre, Hari Gadde, Alexandrina Platonova-Oquab, Rama Chandra Reddy, Kirtan Sahoo, Venkata Putti, Moez Cherif, and Morgan Bazilian.

The *Morocco Energy Policy MRV* is funded by the Carbon Partnership Facility. Useful guidance and suggestions were received from donor countries that participate in the Carbon Partnership Facility and the Transformative Carbon Asset Facility, both administered by the World Bank.

## Executive Summary

1. **Morocco is a global leader in transforming its energy sector to one that is more energy secure and efficient, as well as financially and environmentally sustainable.** The country's remarkable progress on energy subsidies reform and ramping up renewable electricity generation are instrumental to effective implementation of Morocco's National Energy Strategy 2009-2030 and its Nationally Determined Contribution (NDC). Looking forward, Morocco needs make substantial additional policy efforts to enable its ambition of reaching 52% renewable installed capacity by 2030, while preserving valuable fiscal resources from wasteful and inefficient energy subsidies and protecting those people who could be adversely affected by these policies.
2. **The progress on the implementation of National Energy Strategy has so far resulted in electricity savings, greater renewable energy generation, and significant emission reductions.** The government of Morocco started the implementation of its National Energy Strategy in 2009. The *Morocco Energy Policy MRV* analysis shows that energy subsidies reform and renewable policies to date, resulted in the reduction of 5.6 million metric tons of carbon dioxide (MtCO<sub>2</sub>) during the 2009-2016 period relative to the baseline. The policy package saved 378 GWh of electricity in 2016, equivalent to 1.1% of electricity generation, and increased renewable energy in that year to 32% of total installed capacity, as opposed to 26% estimated in the baseline<sup>1</sup>.
3. **More needs to be done for the Moroccan electric system to achieve long-term financial-energy-climate sustainability.** During 2014-2016, electricity tariffs had been raised causing the cost-revenue gap in the power system to be reduced. However, this increase was not sufficient to recover the system cost, which still exhibited a sizeable shortfall of US\$356 million in 2016 (10.5% of total system cost). In the ex-post analysis of the 2009-2016 period, it can be seen that with the policy package in place, electricity was generated significantly less from oil, and more from natural gas, wind, hydro, and coal, relative to the baseline. But fuel switching between oil and particularly coal, is not desirable from the climate change perspective.
4. **Continuation of energy subsidies reform and tariff reform, and acceleration of renewables are key to the success of the National Energy Strategy and the NDC.** In the future period of policy implementation (2016-2030), there should be significantly less generation from coal and liquefied natural gas (LNG), as renewables are scaled up. Electricity savings could reach 7,121 GWh by 2030—11% of baseline generation. These changes are expected to reduce 35 MtCO<sub>2</sub> in 2030 (48.6% of the reduction committed in the NDC). In cumulative terms, the policy package reduces 371 MtCO<sub>2</sub> during 2016-2030. The Policy Scenario does involve higher investment costs of renewables (additional US\$280 million per year by 2030), but the overall *net*

---

<sup>1</sup> The ex-post analysis considers the 2009-2016 period relative to the 2009 base year, and the ex-ante analysis looks at the 2016-2030 period relative to the 2016 base year. These baselines (2009 and 2016) represent policy cut-off points and reflect different policy conditions used as points for comparison with the Policy Scenario. See Chapter 3, Section I, for detailed descriptions of the two baselines.

system cost is lower than in the baseline. These sustained reforms need to be accompanied by building public support, and effort to leverage private investment in renewable energy and necessary infrastructure.

5. **Synergy exists between fossil fuel subsidies reform, cost-based tariffs, and renewable energy policy.** The expansion of renewable energy to meet the NDC target, on its own, would achieve significant emission reductions, but even more emission reductions can be achieved by the whole policy package. The other two policies, on their own, could have perverse effects, but become clearly beneficial as part of the policy package. With Morocco's existing generation capacity, including ample coal-burning capacity but limited renewable energy, removal of oil subsidies alone could cause a shift from oil to coal and natural gas, slightly increasing carbon emissions on a net basis. In contrast, combining with rapid expansion of renewable energy, the removal of oil subsidies can lead to a shift from oil to renewables, reducing emissions.

6. **Morocco would benefit from continuing to utilize the *Morocco Energy Policy MRV* tool to track policy implementation and access international climate finance and markets.** *Morocco Energy Policy MRV* (M-EPM) tool offers multiple benefits: tracking policy performance and measuring impact on key indicators, informing and improving policy design, supporting NDC implementation, as well as facilitating access to climate finance/markets. The preparation of a pilot program is underway--in the frameworks of the Transformative Carbon Asset Facility and the Carbon Partnership Facility administered by the World Bank--to use the M-EPM tool as a platform to evaluate and monetize emission reduction assets from the country's energy subsidies reform and renewable policies. Such program provides an opportunity to use international support to advance transformational policies that can deliver large-scale climate mitigation outcomes and has a potential for replication in other countries. Once again, Morocco is leading the way in developing innovative and transformative approach to support the global climate goal.

7. **Conduct further analytical work to support tariff reform and renewable energy scale-up, and advancing on policy implementation.** In terms of analytical work, this report highlights the benefits to Morocco of continuing to (i) analyze the broader impacts (economic, fiscal, social, and distributional) of energy subsidies reform and rapid transition to renewable energy, (ii) develop a better understanding of the trade-offs between design options of reform and different pathways toward the 52% renewable goal, (iii) carry out in-depth study to develop grid integration strategy for large-scale renewable and strategy for scaling up energy storage technologies to fill the knowledge gap; and (iv) explore cross-boundary trades of renewable-based electricity between Morocco and Europe, as well as Africa. With respect to policy implementation, the report recommends that Morocco (i) addresses critical barriers to continued tariff reform and private sector investment in renewables, (ii) puts in place additional complementary measures to minimize adverse policy impacts and build public support, (iii) continues to improve investment climate and provide incentives for renewable energy investment to further leverage private sector finance; and (iv) strengthen the use of grant funding, concessional finance, and climate finance to make additional progress on energy subsidies reform and renewable energy deployment.



## Chapter 1: Introduction

8. Morocco's energy sector transformation through aggressive efforts to completely remove energy subsidies and strengthen policy and regulatory frameworks to scale-up renewable electricity generation is a leading example of how ensuring energy security and improving fiscal/financial sustainability benefits the global climate in a very significant way. *Morocco Energy Policy MRV*<sup>2</sup> Advisory Services and Analytics (ASA) was initiated in response to the request of the Ministry of Energy, Mining, and Sustainable Development (MEMDD), particularly the Directorate of Observation, Coordination and Cooperation (DOCC), to support its mandate in evaluating the socioeconomic and environmental impacts of the National Energy Strategy (2009-2030) – the driving force behind Morocco's energy transformation. As a first step, the Ministry and the World Bank decided to focus this ASA activity on the electricity sector and relevant policies in this sector.

9. This ASA has developed the *Morocco Energy Policy MRV* (M-EPM) tool for *ex-post* evaluation of specific policies that have been implemented and/or are currently in effect, as well as for an *ex-ante* projection to help understand the potential impacts of future policies. In this setting, a 'policy' represents a continuum of dynamic actions to put in place/enhance an institutional, incentive, and regulatory framework that shifts investment decision and consumers' behavior toward more efficient and cleaner patterns. Building on existing policies and reforms, Morocco still needs to make substantial additional efforts to enable its ambition for renewables to reach 52% of installed capacity by 2030, while preserving valuable fiscal resources from wasteful and inefficient use of energy subsidies and protecting those people who could be adversely affected by the policies.

10. The M-EPM tool<sup>3</sup> has been tested with the real-world data, and its design and development have been extensively consulted with the local stakeholders to best serve their needs. The Policy Scenario is designed to explicitly represent main policy pillars of the National Energy Strategy and the Nationally Determined Contribution (NDC), namely fossil fuel subsidies reform, electricity tariff adjustment, and renewable energy policy<sup>4</sup>. For tool demonstration purposes, this report presents key findings from selected scenarios. The report is one component of the ASA deliverables that include MRV tool development, pilot implementation, and capacity building<sup>5</sup>. The tool is also seen as a potential vehicle to support Morocco in tapping international climate

---

<sup>2</sup> MRV stands for Monitoring, Reporting, and Verification. Although this report focuses on the monitoring and reporting parts, it builds a framework that allows verification. In practice, verification will be undertaken by an independent party. This MRV tool should be utilized within the national MRV system to maintain consistency.

<sup>3</sup> The tool comprises (i) model, (ii) database, (iii) user interface, and (iv) user manual.

<sup>4</sup> The M-EPM tool has the capability to consider other policies such as carbon pricing, energy taxation, energy efficiency, financial incentives for renewable, and other regulations and standards within the power sector.

<sup>5</sup> This ASA is part of the overall World Bank Group's effort to support NDC implementation and energy sector transformation.



finance and the next generation of carbon market that look to engage transformative policy interventions.

11. The report is organized as follows. The remainder of this chapter sets the stage by providing the context of Morocco's energy sector and policies. It describes the scope of this particular ASA and the policy package considered for the MRV analysis. Chapter 2 provides an overview of the M-EPM tool, summarizes key input assumptions, and describes the model calibration process. Chapter 3 defines the scenarios adopted in this report, presents modeling results from the ex-post and ex-ante perspectives, and discuss the sensitivity of results. Chapter 4 illustrates the utilization of the M-EPM tool for supporting a climate finance and carbon market transaction, based on the actual case in Morocco. Finally, Chapter 5 concludes and recommends a way forward.

12. A key difference between Chapter 3 and 4 is that the scenarios analyzed in the former are intended to illustrate the full impact potentials of the policies, whereas the latter designs scenarios to rigorously measure policy increment and increase in policy ambition over time. Specifically, Chapter 3 compares Policy Scenario with the base-year condition (i.e. adopting a frozen policy baseline/counterfactual scenario) for tool demonstration purposes. In contrast, Chapter 4 compares Policy Scenario with dynamic policy baselines (with policy progress embedded in the baselines). Refer to Chapter 4 for details of different baseline concepts that are used for capturing *incremental* increase in policy efforts.

## I. Energy sector and policy context

13. Almost 91% of energy used in Morocco is imported. This includes oil, petroleum products and coal from international markets, gas from Algeria and electricity from Spain. Despite a long history of exploration, Morocco has developed only a small amount of national gas and no commercial sources of oil (IEA 2014). The last coal mine in the north of the country ceased operation in 2004. The only traditional domestic energy sources have been biofuels, waste energy and hydroelectricity, which in an average year has provided about 7.5% of domestic electricity supply.

14. From 2003 to 2014, electric consumption in Morocco grew at an average rate of 6.5 % per annum. This is due to a number of factors, including increasing rural electrification (its electrification rate in 2014 was 98.95 %, compared with only 18% in 1995), economic development (for instance, the completion of a number of government infrastructure projects and the introduction of large automobile manufacturing initiatives in Tangiers), urbanization, and greater access to electricity (Hamane 2016).

15. With relatively strong economic growth— even after the financial crisis of 2008 – electricity demand and overall energy demand have continued to rise sturdily. The energy import bill is a critical element on the balance of payments, and fuel subsidies have been an important fraction of the government's national budget in the past (Amegroud 2015). The sustained high international oil and fuel product prices from 2011 to 2014 brought this challenge into even sharper focus and

led to a widening of the Moroccan budget deficit to reach 7.3% in 2012 of which 6.6% was directly related to the cost of energy subsidies.

16. Despite the recent reduction in the annual budget deficit and the improvement in the balance of payments, the energy import bill in 2013 remained unsustainably high, around MAD 90 billion (Moroccan dirhams) to MAD 100 billion (approx. US\$11 to 12.5 billion) and financial support for oil products still represented around MAD 28 billion per year (approx. US\$3.4 billion) – about two-thirds of the annual budget deficit.

17. With regards to fossil fuel subsidies, Morocco has successfully removed gasoline and industrial fuel subsidies since January 2014 and fully embraced market-based pricing since November 2015. In June 2014, subsidies on fuel used for electricity generation were eliminated (IMF 2017)<sup>6</sup>. At the same time, electricity tariffs were increased, but more has to be done to achieve cost-recovery electricity tariffs in the future. Given the backdrop of Morocco's rapidly increasing energy demand and changing power generation profile, a targeted support is needed to accelerate subsidy reform measures, put in place appropriate structure/mechanisms of energy and electricity pricing, and provide the right incentives in the electricity sector.

18. Reform of the electricity generation sector, to support low-carbon energy and economic growth, is a core component of the NDC for Morocco and many other countries. For Morocco, which has no oil or other fossil fuel supplies, but abundant renewable energy potential, low-carbon energy can provide an added economic benefit, by replacing dependence on imported fossil fuels with domestic sources of solar power, wind, and hydroelectric generation.

19. Morocco has recognized the importance of climate change for years, ratifying the United Nations Framework Convention on Climate Change (UNFCCC) in 1995 and the Kyoto Protocol in 2002. National targets for GHG emission reductions date back to the National Energy Strategy, adopted in 2009 (IEA 2014). Adoption of an ambitious NDC under the 2015 Paris Agreement continues Morocco's commitment to active climate policies. Morocco's 2011 constitution guarantees sustainable development as a right for all citizens; its climate change vision is to "make its territory and civilization more resilient to climate change while ensuring a rapid transition to a low-carbon economy."<sup>7</sup>

20. Morocco's NDC sets a conditional target of 42% reduction below business as usual (BAU) emissions by 2030 – implying a mere 5% growth in emissions from 2010 to 2030, a period of rapid economic growth and expansion of demand for energy services.<sup>8</sup> This commitment will only be possible if Morocco gains access to new sources of finance and to additional support relative to support received in recent years. BAU emissions would reach 171 million tons of CO<sub>2</sub>-equivalent (MtCO<sub>2</sub>e) by 2030; the NDC target requires reduction in energy-related emissions of 58 MtCO<sub>2</sub>e

---

<sup>6</sup> The total energy subsidy associated with fuel consumption by the national power utility was estimated at around US\$ 600 million in 2014 (Cour de Comptes 2014).

<sup>7</sup> *Morocco – Nationally Determined Contribution under the UNFCCC* (hereafter cited as *Morocco NDC*).

<sup>8</sup> Calculated from *Morocco NDC*.

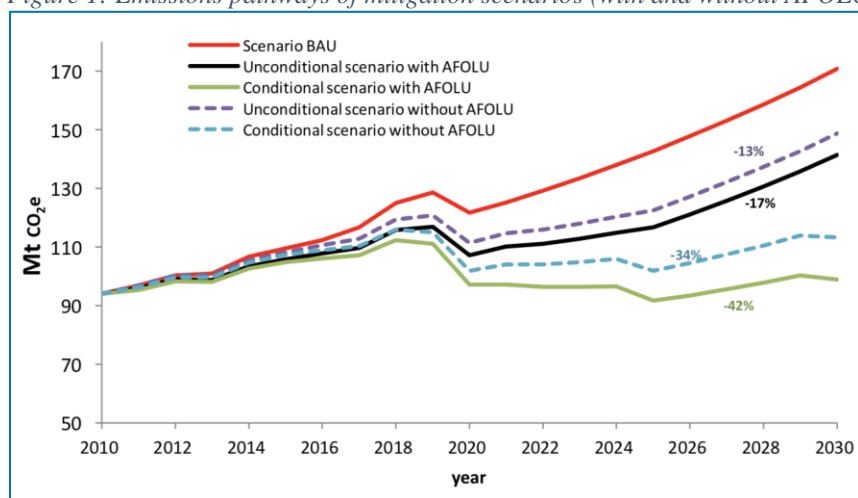
below BAU.<sup>9</sup> While emission reductions in other sectors would also be needed to reach the targeted reductions, electricity generation accounts for more than 40% of total national emission-reduction effort including AFOLU actions, or more than 60% if focused only on energy supply and use.

21. The commitment to mitigation is supported to a large extent on a major transformation of Morocco's energy sector. That transformation builds on four pillars:

- (i) increasing the share of renewable energy in electricity production to 52 % of installed capacity by 2030;
- (ii) increasing demand-side energy efficiency to reduce domestic demand by 15 % by 2030;
- (iii) substantially reducing fossil fuel subsidies and continuing recent significant efforts towards this end; and
- (iv) substantially increasing use of natural gas by building the infrastructure needed to increase liquefied natural gas imports, replacing higher-emission use of coal and oil.

22. The NDC commitments are well aligned with the National Energy Strategy that has been in effect since 2009. Policy efforts under the National Energy Strategy have aimed primarily to optimize the electricity fuel mix, accelerate the development of renewables, focusing on wind and solar power, and establish energy efficiency as a national priority. These policies are also consistent with the electricity sector development and sustainability plan that emphasizes progressive sector liberalization and deployment of clean/renewable energy.

Figure 1: Emissions pathways of mitigation scenarios (with and without AFOLU)



Source: Morocco NDC

Note: AFOLU stands for Agriculture, Forestry and Other Land Use

23. A summary of Morocco's key commitments regarding the conditional and unconditional mitigation scenarios in its NDC are shown in Figure 1. Climate Action Tracker<sup>10</sup> reports that

<sup>9</sup> The target also assumes smaller reductions in emissions associated with agriculture, forestry, and land use.

<sup>10</sup> <http://climateactiontracker.org/countries/morocco>

Morocco's conditional NDC target is well below BAU. The country is on track to meet its 2020 renewable energy targets, and is at an advanced planning stage to meet its 2030 renewable energy targets (Figure 10). The Tracker rates Morocco's NDC as "1.5°C Paris Agreement compatible". By 2015 Morocco had an installed capacity of 8,160 MW of which 66% was thermal (Table 1). The net energy demand in that year was 34,413 GWh from 5.4 million clients. Of this, 29,914 GWh was generated in Morocco with the remainder imported from Spain and Algeria.

*Table 1 - Total Installed Capacity in 2015*

Type	MW	Share
Classical Hydro		17%
STEP <sup>11</sup> pumped storage		6%
Total Hydro	1,770	22%
ONEE Wind Farms		3%
Private Wind Farms		3%
IPP Wind Farms		4%
Total Wind	798	10%
CCGT Ain Beni Mathar (Solar Part)		0.2%
Ouarzazate Solar Power Plant Noor 1		2%
Total Solar	180	2%
Natural Gas		10%
Coal		31%
Heavy Fuel Oil & Diesel		25%
Total Thermal	5,411	66%
Total Installed Capacity	8,160	100%

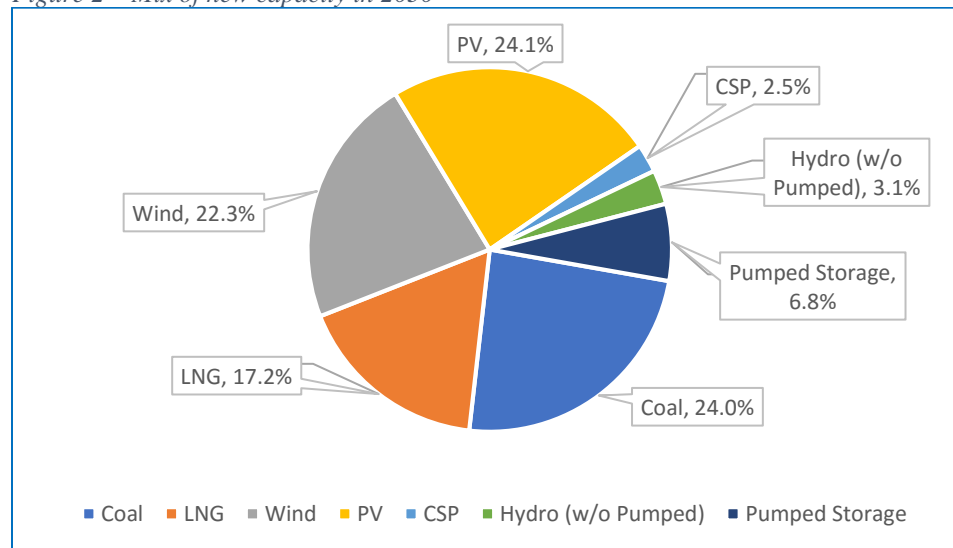
Source: ONEE

24. According to its National Energy Strategy, Morocco estimates that its electricity demand will grow at an average annual rate of 5.6% between 2015 and 2030, taking into account the planned demand-side energy efficiency improvement of 15% by 2030—a growth of 220% over this period to 74,400 GWh. Clearly, maintaining this power mix, where almost all the fuel used for thermal generation is imported, without subsidy removal and tariff reform would be fiscally unsustainable.

25. The projected transformation of the sector changes this mix drastically towards renewables. Between 2017 and 2030, the planned new development reference scenario will commission 13,900 MW of new generating capacity of which 58.7% will be renewables—consisting of 22.3% wind, 24.1% solar photovoltaic (PV), 2.5% Concentrated Solar Power (CSP) and 9.9% hydro (split between 6.8% pumped storage and the remainder conventional hydro). Figure 2 shows the expected final mix of new plants in 2030 and Figure 3 illustrates the proposed commissioning of these new plants by year. Added to existing plants, this allows the country to meet its target of 52% installed capacity from renewables by 2030.

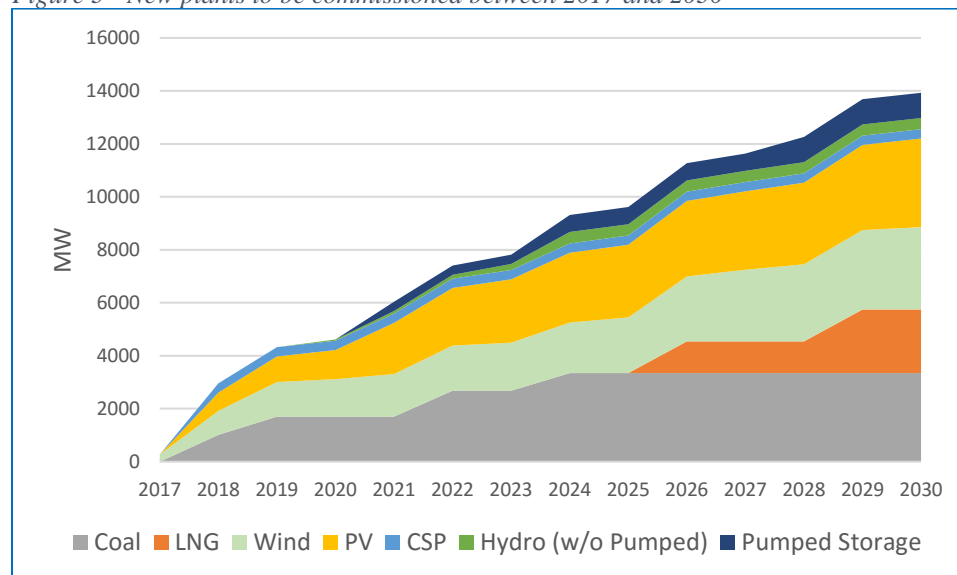
<sup>11</sup> The Station de Transfert d'Énergie par Pompage (STEP) Abdelmoumen pumped-storage project is located in the hills above Afourer of Azilal Province, Morocco. The scheme consists of two power stations with a combined installed capacity of 465 megawatts. Construction on the project began in 2001 and was complete in 2004

Figure 2 – Mix of new capacity in 2030



Source: ONEE—Schéma Directeur Production 2017-2030

Figure 3 - New plants to be commissioned between 2017 and 2030



Source: ONEE—Schéma Directeur Production 2017-2030

## II. Scope of activity

26. This ASA activity assists the Government of Morocco in assessing the impact of selected energy policies on greenhouse gas (GHG) emissions, through the development and implementation of the *Morocco Energy Policy MRV* (M-EPM) tool and capacity building activities. The M-EPM tool is expected to play an important role in the national MRV system and support the implementation of Morocco's NDC. Furthermore, the tool can inform energy policy design and serves as a building block for potential financial support in the future, through

innovative climate/carbon finance instruments such as the Carbon Partnership Facility (CPF) and the Transformative Carbon Asset Facility (TCAF) administered by the World Bank.

27. The activity focuses on the electricity sector and associated fossil fuels. The core components include (i) developing an objective and evidence-based tool including a modeling framework, database, and user interface, that allows ex-ante and ex-post assessment, (ii) piloting the implementation of the tool and document findings in this report, and (iii) helping to build capacity of key stakeholders in Morocco in conducting and maintaining tool, through a series of hands-on training.

28. The project intends to develop M-EPM tool that is flexible, transparent/open-source, and user-friendly, so it can also be manipulated, updated, and reviewed by non-modelers and policy makers. The tool relies on relevant modeling techniques to attribute the impact of policies through well-defined ‘impact channels’. The tool is also meant to be fully traceable and have a clear analysis boundary (i.e. being transparent on what is and is not accounted for). Although the model inputs and results presented in this report are entirely specific to Morocco, the same approach and concept could be applied to many countries and other sector than power generation.

29. From the ex-post MRV perspective, rigorous evaluation of the success of current policies can help guide future policymaking and can confirm the contributions of individual policies to emission reductions as part of the effort to reach NDC targets. An observed change in energy use or emissions may reflect many factors in addition to recent policy decisions. Therefore, the M-EPM tool has been developed to support the *attribution* of emission reductions associated with specific policy measures in a robust and credible manner. Such verified emission reductions are carbon assets that can be used toward NDC commitments and/or traded in international climate markets.

30. The Clean Development Mechanism (CDM), under the Kyoto Protocol, required methods for verification of the emission reductions attributable to an individual project or investment. The question of ‘additionality’—that is, demonstration that project-related emission reductions were additional to the baseline emissions trajectory expected in the absence of the project—was a recurring concern for CDM proposals. The M-EPM model seeks to do for policies what the CDM process did for individual projects: to verify the emission reductions attributable to a policy, and to address concerns about additionality, showing that the emission reductions would not have occurred in the absence of the policy. Therefore, a robust and credible baseline setting is a critical element of the M-EPM tool.

31. Development of the M-EPM model, and application to Morocco, required creation of a software framework capable of representing, and modifying, numerous details and assumptions about a national electric system, along with collection of the best available data inputs to describe electricity generation and energy policies in Morocco. For this initial application of the model, the focus is on key aspects of current and proposed energy policies: energy subsidies reform (involving elimination of fossil fuel subsidies and adoption of cost-based electricity tariffs) and rapid expansion of renewable energy capacity.

### III. Policy package

32. Specific policy measures that are included as part of the policy package for the analysis and modeling work under this *Morocco Energy Policy MRV* activity are described in this section. These policies are selected for evaluation because they are key policy pillars of the National Energy Strategy and the NDC.

33. ***Sustainable and ambitious energy subsidy reform***, combines a continuation of fossil-fuel subsidy reform for electricity generation with electricity tariff increase and restructuring to close the gap between the current and the future cost-recovery level.

- a. With respect to the subsidies to fossil fuels for power generation, fuel oil subsidy has been removed since June 2014, and market-based pricing mechanism has been put in place since December 2015 (IMF 2017, Maroc 2014, Kojima 2016). Table 2 shows the past trend of annual fossil fuel subsidies to the power generation sector.
- b. After an extended period of fixed electricity price, a rise of 5% on retail tariffs was announced in January 2014, followed by a rise of 2.9-6.1% in July 2014 in nominal terms. These increases do not apply to those consuming less than 100 kWh per month. The tariff further increased toward January 2017 and beyond (Laaboudi, 2014; Bulletin Officiel, Cent-troisième année – N° 6288 8 kaada 1435). This pillar builds on the recent tariff increase during the 2014-2017 period, according to the Bulletin Officiel, and Morocco’s vision to continue to achieve cost-based tariff looking forward. Table 3 and 4 show the residential and industrial tariff structures and tariff increases during the 2014-2017 period.
- c. A more ambitious and continued reform is needed given the rising electricity demand and changing power generation profile. Beyond 2017 and for the ex-ante analysis, the tariff under Policy Scenario is set to gradually rise to meet the cost-recovery tariff trajectory.

*Table 2 Fossil fuel subsidies to power generation (MAD billions)*

	2009	2010	2011	2012	2013
Normal Fuel ONEE	1.0	2.3	3.6	4.3	3.7
Special Fuel ONEE	0.1	0.5	2.7	2.9	1.5

Source: Bulletin Officiel, Cent-troisième année – N° 6288 8 kaada 1435



*Table 3 Residential tariff structure*

Consumption lower bound	Consumption upper bound	2014	2015	2016	2017
kWh / month	kWh / month	nominal MAD/kWh	nominal MAD/kWh	nominal MAD/kWh	nominal MAD/kWh
0	100	0.90	0.90	0.90	0.90
101	150	0.97	1.00	1.04	1.07
151	200	0.97	1.00	1.04	1.07
201	300	1.05	1.09	1.13	1.17
301	500	1.25	1.29	1.34	1.38
500		1.44	1.49	1.54	1.60

Source: Bulletin Officiel, Cent-troisième année – N° 6288 8 kaada 1435

Note: no tariff adjustment during 2009-2013

*Table 4: Industrial tariff structure (nominal MAD/kWh)*

	2014	2015	2016	2017
High voltage	0.75	0.78	0.81	0.85
Medium voltage	0.75	0.79	0.82	0.86
Low voltage	0.76	0.80	0.83	0.87

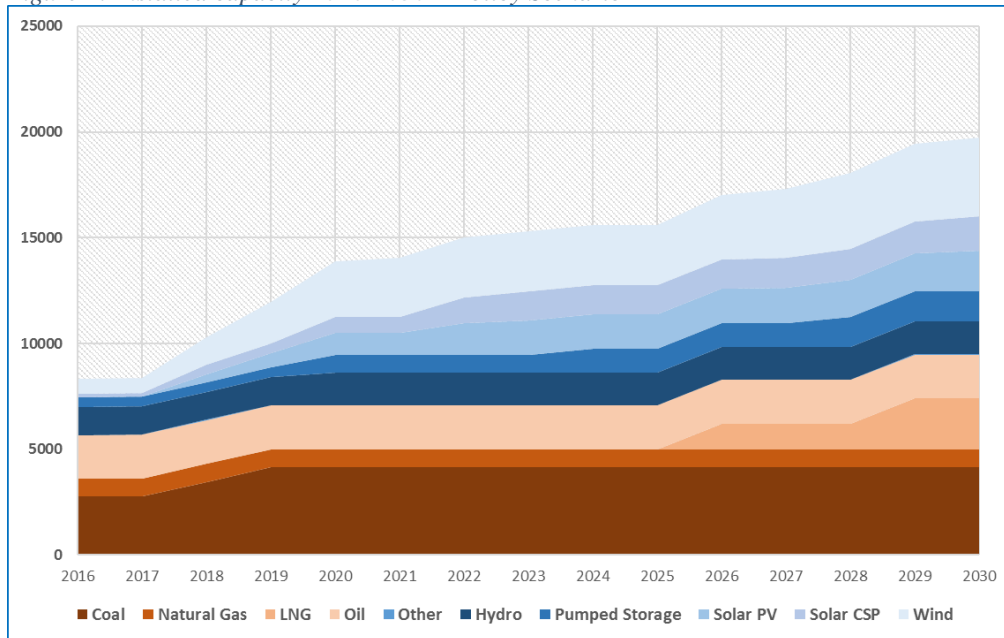
Source: Bulletin Officiel, Cent-troisième année – N° 6288 8 kaada 1435

Note: no tariff adjustment during 2009-2013

34. **Rapid and large-scale deployment of renewable energy** with the goal of 52% penetration rate by 2030 (Figure 4) supported by a framework of incentives and regulations to promote renewables, particularly Law 13-09 and Law 58-15. This pillar is anchored in the power sector masterplan (Schéma Directeur Production 2017-2030, ONEE), the National Energy Strategy, as well as the NDC—all well aligned and consistent in targets and goals.

- a. Law No. 13-09 was brought into force by Decree No. 1-10-16 of 26 Safar 1431 (February 11, 2010) for the promotion and liberalization of the renewable energy sector.
- b. Law No. 58-15 was then brought into force by Decree No. 1-16-3 (January 12, 2016) amends and supplements Law No. 13-09 to permit and encourage private-sector investments, through (i) increasing the installed capacity threshold of hydro projects, (ii) allowing renewable electricity producers access to the low voltage, the medium, high, and very high voltage electricity networks, and (iii) allowing the sale of excess electricity from renewable sources to ONEE for the facilities connected to the high and very high voltage networks.

Figure 4: Installed capacity 2016-2030 – Policy Scenario



Source: World Bank task team, based on Schéma Directeur Production 2017-2030

## Chapter 2: Methodology

35. Analysis of energy policies does not have the luxury of performing controlled experiments. There is of course no way to run recent history twice, once with and once without a policy. Yet comparison of history with, and the same history without, a policy is precisely what is needed for measurement and verification of emission reductions or other results of the policy.

36. The solution to this dilemma is to create the best possible counterfactual scenario, describing what would have happened in the absence of the policy, holding all other assumptions and inputs constant. The effect of the policy is then measured as the difference between what actually happened (with policy) and what would have happened in the counterfactual scenario (without policy). This report will often refer to these as the ‘Policy Scenario’ and the ‘baseline’/ ‘without-policy’ scenario, respectively. In retrospective, or ex-post, analysis of existing policies, the Policy Scenario is characterized by actual and observed data, while the baseline scenario is counterfactual.

37. An analogous comparison of with-policy and without-policy scenarios occurs in prospective, or ex ante, analysis. The difference is that for future policy impacts, both scenarios are model simulations. The M-EPM model allows either ex-post or ex-ante analysis, or a combination of the two. The time span of the model, currently set at 2009-2030, allows several years of ex-post analysis and several years of ex-ante analysis. These time periods can be combined or run separately, simply by choosing the starting and ending years for an analysis.

38. Underpinning the M-EPM tool is a full-fledged bottom-up partial equilibrium power sector model that is specifically designed for attribution of emission impacts to individual policies or to any mix of policies<sup>12</sup>. The tool builds on existing reporting protocols, institutional framework, and to the extent possible, official local data sources, such as ONEE annual reports, official statistics published by Ministries, Bulletin Officiel, Cour-de-comptes, NDC, National Energy Strategy, plant-level characteristics, electricity load profile, etc. It also makes use of credible international sources for filling data gaps, such as future technology cost parameters, fuel price projections, and price elasticity for electricity demand.

### *Analytical framework*

39. Broad analytical steps toward calculating the emission impact of power sector policies using the M-EPM tool include:

- 1) Collect data of all electricity generating units/plants and other relevant parameters within the electric system;

---

<sup>12</sup> The model attempts to mimic the real world to the extent possible and does it in a transparent manner building on verifiable data. However, like others, this model has limitations and relies on assumptions. A key aspect of this exercise is therefore building consensus among the stakeholders with respects to model structure, data inputs and assumptions, as well as the scenarios.

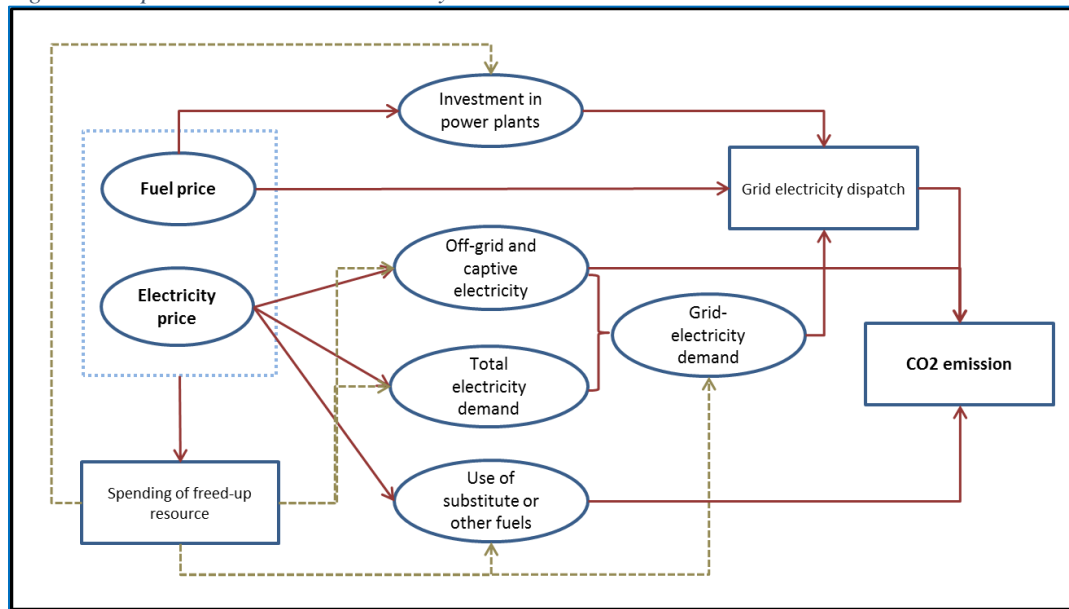
- 2) Determine the actual principles of system dispatch, key operational constraints, and the utilization of sources other than domestic grid supply (i.e. captive, off-grid, and electricity import);
- 3) Calibrate the methodology with the dispatch principles, key constraints, and other characteristics identified in step (2), and develop an emission inventory of the power generation system. The objective of this step is to establish the ‘with-policy’ emission from all sources;
- 4) Develop the counterfactual ‘baseline’ conditions of what could be expected to have happened without the policy by running the methodological procedures through all ‘impact channels’, based on the same dispatch principles and constraints/characteristics above, to compute emission level of the “without-policy” scenario;
- 5) Calculate emission impact as the difference between the emission levels obtained from step (3) and (4).

40. Note that (3) establishes evidence-based, actual level of emission that is a result of all determining factors (economic, political, social, demographic, etc.) including the policies in question. The key objective of the M-EPM tool is to develop a counterfactual level of emission—*ceteris paribus*—without the policy under investigation; thereby singling out the emission impact of the policies. This implies that all other factors that cause the emission in a particular year (be it economic shock, diffusion of new technology, or demographic shift) are included in the counterfactual emission level as well.

41. The effects of policy changes ripple throughout the system, flowing through five major impact channels in this methodological framework (Figure 5). Changes in policies such as fossil fuel subsidies reform, electricity tariff reform, and incentives/policies to promote renewable electricity generation may impact

- (i) the electricity generation profile and dispatch of grid-connected power plants
- (ii) the decision on investment and construction of new power plants
- (iii) the operation of off-grid and captive capacity
- (iv) electricity demand in end-use sectors, and
- (v) the use of revenues received from the implementation of policies.

Figure 5: Impact channels and electric system interactions.



Source: World Bank task team

## I. Overview of M-EPM tool

42. The M-EPM tool is a license-free, user-friendly, Excel-based model that can estimate GHG emission reductions resulting from changes to specific electric-sector policies. The tool builds on a bottom-up partial equilibrium power sector modeling framework and is coupled with a software that is designed to be easily updated as new data become available and allow policy makers and practitioners, without background in modeling and programming, to simulate policy changes.

### *Modeling goals and uses*

43. The M-EPM model is a transparent model of intermediate complexity that was developed to quantify the GHG emission reductions that result from implementing changes to electric-sector policies. Its primary purpose is to measure, report, and verify emission reduction achieved by policies recently adopted, using approximated system dispatch. A secondary purpose is to use the same apparatus to examine proposed policies, in the short- to medium-term future (e.g., through 2030).

44. The model executes this quantification through scenario analysis. Within the model, users set up two separate versions of the electric system in the past and/or future. Users can then adjust policies in one or both scenarios to understand and quantify the resulting emissions impact. Advanced users can employ the same apparatus for sensitivity analyses, turning off or changing the level of a specific inputs to test its impact on overall results.

45. Power sector technical staff at national agencies, and policy makers with knowledge and experience in power sector policies and regulations, should be able to run the model and, if desired, examine its internal workings and algorithms. Other stakeholders should be able to interpret its results and request additional runs, when needed, to analyze policy proposals. This model does not require trained experts, specialized software or hardware, or licensing fees (other than for Microsoft Excel). A graphical user interface is included to facilitate access to and understanding of the model.

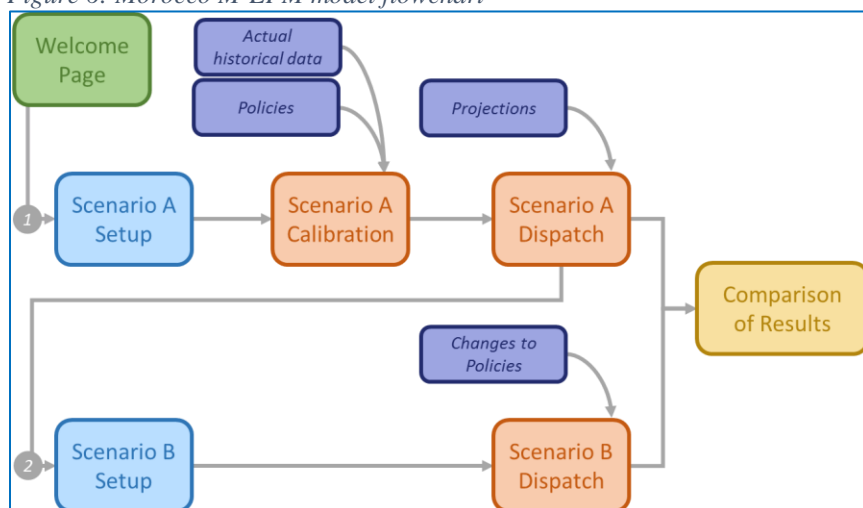
### *Model design and features*

46. In general, conducting analysis within the M-EPM model consists of three main steps:

1. Setting up input assumptions for a first scenario, with policy (Scenario A)
2. Setting up input assumptions for a second scenario, without policy (Scenario B)
3. Making comparisons between the two scenarios

47. Figure 6 provides a high-level overview of the tool. The M-EPM model guides the user through the multiple categories of data entry needed to describe the electric system. It then performs the calculations that reflect the interactions, and reports generation, capacity, costs, and carbon emissions for each year of each scenario. The reported results include the differences between two scenarios in each of these areas, highlighting the effects of a policy change. For the first scenario, users specify input assumptions from actual historical data, along with projections of future trends for each scenario. These specifications are then automatically passed along to the second scenario, where users may instead choose to apply changes to one or more policies.

*Figure 6: Morocco M-EPM model flowchart*



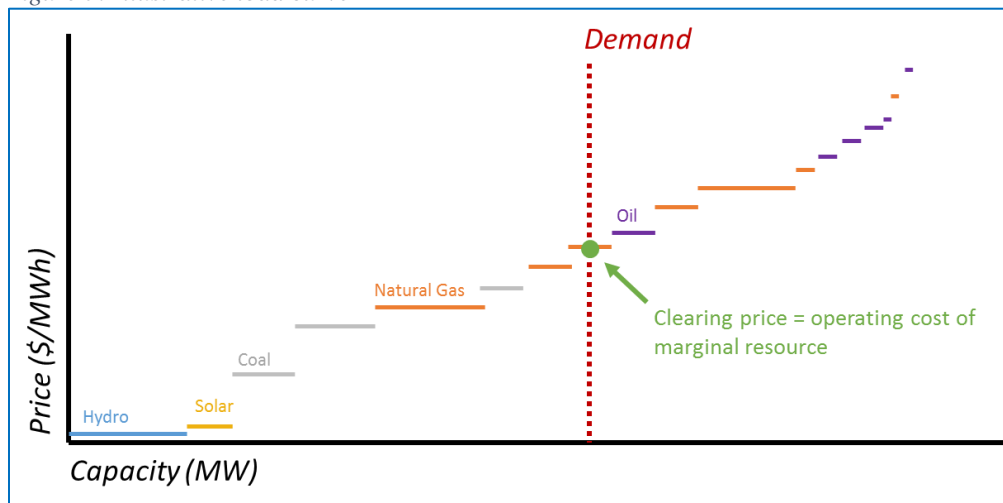
Source: World Bank task team

48. Scenario construction always begins from a default data set, based on the best available public information about the electric system. Any item of this default data can easily be replaced with user-specified alternatives, but most users will find it convenient to accept the default values for almost all inputs currently set up in the M-EPM model.

## Model algorithms

49. There are five key algorithms that are the basis for the model's calculations. The least-cost system dispatch algorithm is the first key algorithm and is at the core of the M-EPM model. Under this algorithm, for each defined time period, all of the power generating units are sorted from high to low in terms of their marginal cost of operation.<sup>13</sup> Each of the units has some amount of available capacity with which they can generate electricity. Depending on the resource type, this capacity might be limited by unexpected outages, maintenance outages, or ramping constraints (typical for conventional generators like coal, gas, or oil-fired power plants), seasonal variability (typical for hydroelectric power plants), or daily variability (typical for solar or wind power plants which are simply non-operable at certain points of the day). The available capacities for each unit are then summed in order from least-cost to highest-cost, forming a supply curve (Figure 7).

Figure 7: Illustrative load curve



Source: World Bank task team

50. At some point along the supply curve, the amount of available capacity intersects with the requested demand during that time period. Under merit-order dispatch, the resource that occurs at the point where supply and demand intersect is said to be the marginal or ‘clearing’ resource—that resource, and all other resources with lower marginal costs are declared to be in merit, and will generate electricity for that time period. All resources with higher marginal costs are out-of-merit and will not generate electricity.<sup>14</sup> Importantly, this intersection between demand and supply also sets the clearing price: the price that it costs the marginal unit to operate at is the price that all

<sup>13</sup> Unit-specific marginal costs of operation are based on the sum of (a) variable operation and maintenance costs, (b) fuel costs, and (c) any other adders (e.g., a price on carbon dioxide) that a power generating unit might incur on a per-MWh basis. These costs do not include capital costs or fixed operating and maintenance costs (i.e., costs that are incurred by a power plant regardless of whether or not it is generating electricity during the period of interest).

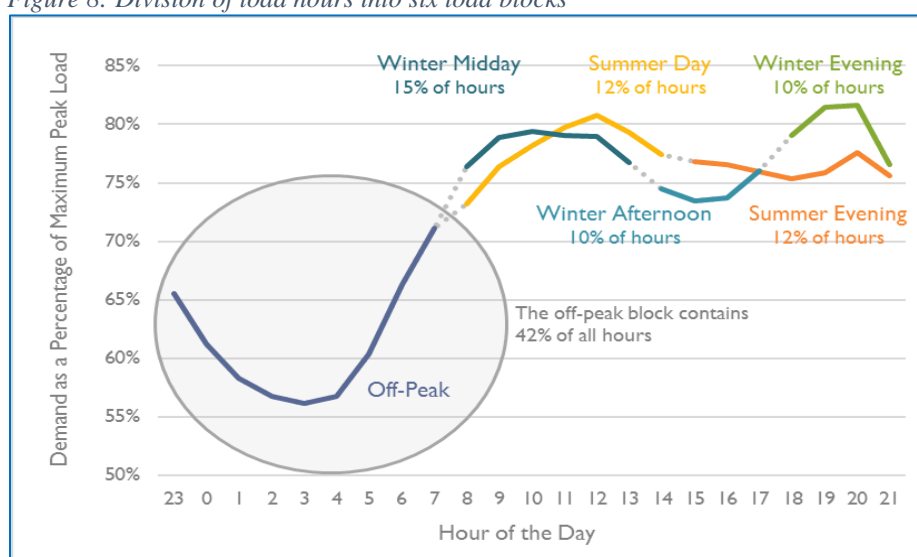
<sup>14</sup> In real electricity systems, in some cases, as a result of ramping or transmission constraints, resources that are declared to be out-of-merit run anyway.



generators declared to be in-merit will be paid. As a result, resources with relatively low marginal costs are frequently paid at rates far above their marginal cost of generation.<sup>15</sup>

51. Although production costs models (and real-time dispatching) may perform this algorithm at very fine levels of temporal resolution, the M-EPM model has simplified this operation to occur for six ‘blocks’, meant to represent different types of daily and seasonal operation throughout the year.<sup>16</sup> These six blocks based on the review of several years’ worth of hourly load data for Morocco. Each hour of the year has been grouped into one of these load blocks. Together, within each load block, we also determine the block-wide availability of each resource type (coal, gas, hydro, solar, etc.). Then, all available capacity within each block is dispatched using the least-cost system dispatch algorithm.

Figure 8: Division of load hours into six load blocks



Source: World Bank task team

52. A second key algorithm in the M-EPM model dispatches electricity and estimates CO<sub>2</sub> emissions. For each modeled historical year (2009 through 2016), users can compare the outputs of the model with actual data, and make adjustments to the model set up and calibrate it to ensure that the model accurately represents the past and the current characteristics of the Moroccan power system. The calibrated system in the model is then used across all scenarios to achieve consistency in the analysis. See also below for model calibration.

53. A third key algorithm in the tool addresses the need to build capacity to meet electricity demand. The M-EPM model goes about this in two ways: first, users may add resources

<sup>15</sup> This is counterbalanced by the fact that many of these resources (e.g., wind, solar, nuclear) have relatively high capital or fixed operating costs.

<sup>16</sup> Other, more sophisticated electric system dispatch models often use a similar approach: they may group hours into blocks, “load bins”, or monthly on-peak and off-peak groupings. Very few industry-grade electric dispatch models are operated on an hourly basis—even when models feature this capability, the mathematical complexity of this operation typically prohibits modelers from running more than an example month or year at the hourly level.

exogenously. Users may choose to add capacity for combined cycle power plants (fueled using either pipeline natural gas or liquefied natural gas), natural gas-fired combustion turbines, coal-fired power plants, hydroelectric (hydro) plants, photovoltaic solar (solar PV), concentrating solar (solar CSP), and onshore wind.

54. Given inputs for existing units and any exogenously added capacity, the model calculates the remaining need for additional capacity, and automatically constructs endogenous capacity on a least-cost basis. In other words, in each year with an additional capacity demand the M-EPM model performs an assessment of the least-cost resource and builds as necessary<sup>17</sup>. This ‘least-cost’ basis is different than the one used to calculate dispatch; while least-cost dispatch is based on short-run marginal costs, least-cost capacity expansion is instead based on levelized costs. In this context, levelized costs are the sum of marginal operating costs, fixed operating costs, and amortized capital costs. For this reason, they are sometimes referred to as ‘all-in costs’.

55. This fundamental difference in framework (utilized by electricity planners and operators around the world) is a result of the different planning horizons relevant to each decision. In a dispatch framework it is optimal for system operators to dispatch power from the existing resource that can provide the lowest variable cost. In contrast, when choosing the technology of new capacity to be added to the system, fixed operating costs and amortization of capital have to be figured-in.

56. Users have the option to build ‘backup’ generation alongside renewable energy such as wind and solar.<sup>18</sup> In some cases, electric operators or power plant developers propose that construction of new renewable capacity be accompanied by new capacity from fast-ramping resources (such as conventional gas peaking plants, batteries, or pumped storage). This “firming” is typically a requirement in situations in which adequate ramping capacity is not already existing or available to balance periods of low generation from intermittent resources such as wind and solar. As a result, additional firming capacity is likely to be unnecessary in situations in which adequate ramping capacity is already in existence, or in situations in which the new renewables themselves include some level of storage or on-demand ramping capability (as is the case with some types of solar CSP). Within the M-EPM model, if users require that backup generation be built alongside the renewable capacity, the incremental cost of this backup generation is added to the incremental cost of the renewable capacity (in levelized terms) to determine the final levelized cost used for least-cost capacity expansion.

---

<sup>17</sup> The main utilization of the MRV model is to ex-post evaluate policy impact. In practice, the capacity (by plant) is entered into the model ex-post based on the actual/historical information. For this, the model allows manual input to capacity addition. However, in the ex-post counterfactual/baseline scenario, the system may encounter slight upward shift in demand (e.g. due to lower/subsidized tariff). In this situation, the model adds capacity endogenously based on levelized costs of electricity generation that takes into account suitability of different technologies in each block, as well as the cost for back-up capacity as necessary. In the ex-post mode, plant commissioning and electricity generation are based on the historical information. The model therefore already incorporates actual transmission planning and investment. In the ex-ante context, the model strictly follows Morocco power sector development plan that is based on in-depth power sector planning exercise that considers all aspects of power system planning on the ground. The MRV model is not intended to duplicate this effort and is complementary to that approach.

<sup>18</sup> The cost of this backup generation is automatically incorporated in the least-cost evaluation.

57. Another key algorithm is concerned with the policies that users of the M-EPM model can enable, disable, or modify in the course of their scenario analyses. These policies include:

- Fuel subsidies: Fuel subsidies are economic policy instruments where the government covers a portion of the fuel cost leaving the customer to pay only a fraction of the commodity's actual price. Fuel subsidies are fuel-specific and used generally to lower or stabilize prices, to stimulate demand, or to give specific resources a competitive advantage over others.
- Electricity tariffs: Electricity tariffs are the price paid by consumers for electricity, measured in the model in dollar-per-megawatt-hour (\$/MWh) terms. Users may revise historical tariffs or implement changes to future tariffs exogenously. Alternatively, they may enable "cost-based tariffs", wherein the M-EPM model calculates the \$/MWh price that results in equilibrium between costs and revenues.
- CO<sub>2</sub> prices: A carbon price is a cost assigned per ton of CO<sub>2</sub> emitted by a fossil fuel-powered generator. A carbon price internalizes some or all the environmental cost associated with CO<sub>2</sub> emissions and makes it more expensive to run a fossil-fuel based resource.
- Renewable energy incentives: Renewable energy incentives reduce the cost to develop new solar (PV and CSP) and wind projects. These incentives are measured in \$/MWh terms. Implementing renewable energy incentives may result in more renewable capacity being endogenously added as opposed to fossil-fueled generation.
- Revenue allocation: Users may model the impact of recycling revenues that result from enacting policies. For example, this might entail applying a CO<sub>2</sub> price, collecting revenue from existing generators, and then redistributing that to other aspects of the electric sector to produce desired policy outcomes.

#### Impact mechanisms in M-EPM tool

58. As outlined above, energy policies (e.g. pricing reforms and renewable promotion) can impact the electricity generation profile and dispatch of grid-connected power plants, decisions on investment and construction of new power plants, operation of off-grid and captive capacity, electricity demand in end-use sectors, and/or uses of revenues received from implementation of energy pricing policies.

59. These five mechanisms are incorporated in the M-EPM tool as follows:

1. Prices drive the M-EPM model estimates of generation and dispatch, subject to plant availability and other constraints; this calculation is at the core of the model.
2. When a scenario calls for additional capacity, prices/costs are determining factors of the choice and technology of plants to be constructed. This mechanism is not visible in default scenarios, since Morocco currently has capacity in excess of reserve requirements. It can be seen in scenarios that project very rapid growth of demand or other changes that require new capacity. Users can specify a fixed schedule of capacity additions, potentially overriding the model's calculations.

3. Data entry screens for generation resources allow users to enter the amount of available off-grid capacity and the threshold price (\$/MWh) at which it comes on-line. All off-grid generation is assumed to be sold to high-voltage industrial customers.
4. When end-user electricity tariffs change, the M-EPM model adjusts the electricity demand based on price elasticity effects. In scenarios that assume cost-based tariffs, this change in demand could require changes in supply and hence modify tariffs.
5. Data entry screens for policy measures include options for user-specified application of policy revenues. In scenarios that generate additional policy revenues, that are applied to improve system operation, these options can have important effects on emissions and energy use.

## II. Key assumptions and inputs

60. As a default, the M-EPM model is populated with data specific to Morocco. Local sources include, for example, ONEE annual reports, official statistics published by Ministries, Bulletin Officiel, Cour-de-comptes, NDC, National Energy Strategy, plant-level characteristics, electricity load profile, etc. Where necessary, the model gap-fills with data from international sources, such as Platts, the International Energy Agency, the U.S. Energy Information Administration, and existing literature. Although these values are populated in the tool by default, users can overwrite any of these values if they have more relevant data or wish to test different assumptions.

### *System-wide inputs*

61. The model allows users to adjust all parameters and assumptions that apply to the entire electricity system. These assumptions include electricity demand, load profile, fuel prices and subsidies, reserve margin, energy efficiency, transmission and distribution losses, off-grid demand, price elasticity, and imports and exports. The model provides a summary of these input assumptions.

#### *Fuel prices and subsidies*

62. Historical data on fossil fuel prices and subsidies are from Cour de Comptes 2014 Rapport sur Le système de compensation au Maroc Diagnostic et propositions de réforme, and Ministry of Economy and Finance, and the United Nations Comtrade Database. Electricity price data are from Bulletin Officiel Cent-troisième année – N° 6288 8 kaada 1435. The model assumes that unit prices of fossil fuels in future years follows the trajectory outlined in IEA’s 2017 World Energy Outlook. Users can use the default values or customize historical and future prices for natural gas, coal, N2 Petroleum (i.e., “Number 2” heavy fuel oil or diesel-grade), and “Special” petroleum (a special grade of fuel oil lower in heavy metals and sulfur).

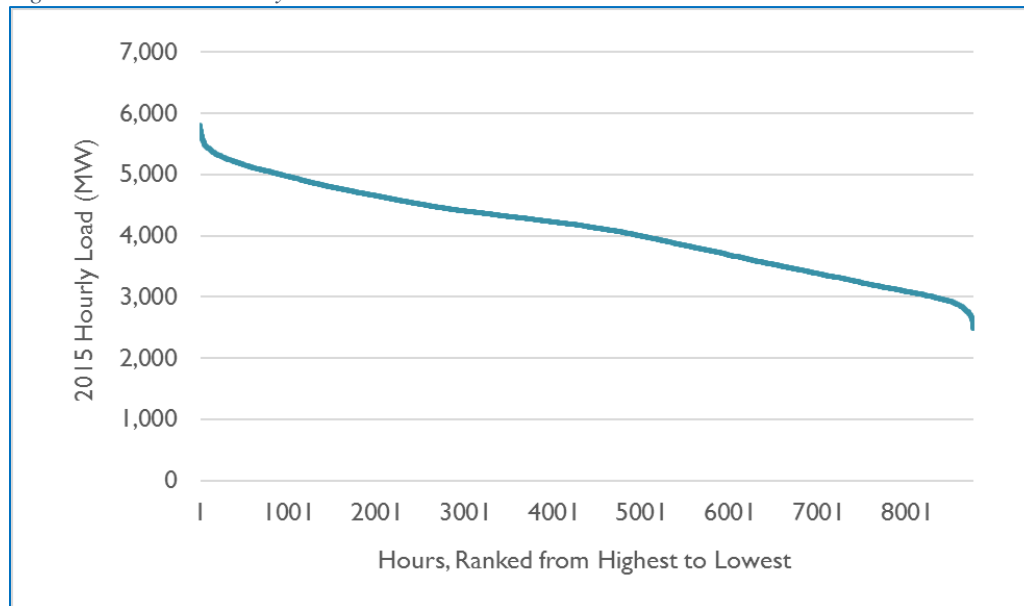
#### *Electricity demand*

63. The model assumes that electricity demand (for all types of customer classes) follows the trajectory outlined by ONEE in its 2017 Schéma Directeur Horizon 2030 document. This document projects an annual average growth rate in electricity sales of 5.6%. Annual electricity sales are broken down into three customer classes: residential, low-voltage industry, and high-

voltage industry. This projection includes the 15% improvement in end-user energy efficiency by 2030, projected by ONEE that is consistent with the National Energy Strategy. In aggregate, these assumptions produce 2030 sales that are 114% higher than 2016 sales.

64. Morocco's hourly load demand curve and peak demand used in the M-EPM model are from 2015 (Figure 3). This same load curve is scaled to all of the other years under consideration on the basis of annual electricity demand.

Figure 9: Morocco hourly load curve 2015



Source: M-EPM model, based on ONEE

65. In addition, users can adjust end-user energy efficiency. End-user energy efficiency refers to energy savings (GWh) from programs and measures taken by customers to reduce their total amount of energy consumption. Common examples of energy efficiency measures include switching out incandescent or CFL light bulbs for LEDs, upgrading to more efficient appliances, and changing energy-consumption behaviors. End-user energy efficiency is applied to electricity sales, and therefore is broken down into the same three customer classes: residential, low-voltage industry, and high-voltage industry.

#### Reserve margin

66. The reserve margin is an indicator that tells the model what level of capacity (above projected peak) is needed to meet system reliability requirements. Reserve margins are used to account for uncertainty in weather, demand, unit performance, and other variables that can be highly variable and hard to project. Reserve margins are typically set at a level that balances system reliability with customer cost. The default reserve margin in the model is set to 20% throughout the modeling time horizon.

## Losses

67. Losses refer to the amount of electricity that is generated but not accounted for in utility sales. There are two categories of losses reflected in the M-EPM model: technical and commercial. Technical losses refer to electricity lost in the transmission and distribution (T&D) system in the process of transporting it from the generator to the end users. Commercial losses refer to electricity not accounted for due to theft, uncollected account balances, and other accounting discrepancies. The historical data on total losses are from ONEE annual reports, and ranges between 12-18% during the 2009-2016 period. The default losses for future projection is assumed at the 2016 level.

## Electricity import and export

68. Users can specify assumptions relating to electricity imports and exports between Morocco and its neighbors. The default values for price and capacity of historical imports and exports come from the European Network of Transmission System Operators for Electricity (ENTSOE) for Spain, and the Arab Union of Electricity for Algeria. The current model version assumes that the imports and exports with Spain and Algeria remain at 2016 levels through 2030.

## Price elasticity of electricity demand

69. While electricity is a relatively inelastic good (meaning that quantities of purchases by customers are relatively unaffected by changes in electricity pricing), the M-EPM model accounts for sales reductions associated with price increases. The short-term elasticity estimates applied in this analysis is based on a recent meta-analysis which found more than 500 published estimates of the price elasticity of electricity (Labandeira et al 2017). Perhaps surprisingly, the meta-study found only modest differences between estimates for developed countries and developing countries – further supporting the use of international estimates for Morocco.

70. Relying on this study, the M-EPM model develops default values for the short-term price elasticity of demand for electricity (-0.233 for residential, -0.254 for commercial, and -0.191 for industrial consumers). The default values can be replaced if better Morocco-specific or international estimates become available. They can also be varied in sensitivity analyses to evaluate the impact of price elasticity.

## *Resource-specific inputs*

71. These are inputs that apply to specific power plants. These parameters and assumptions include start-up dates, plant availability and must-run requirements, variable costs, fixed costs, heat rate, emissions rate, retirement date, new resources, new availability, and import/export availability. This section provides a summary of these input assumptions.

## Plant online date and status

72. Online dates for each power plant in Morocco were assembled based on the Platts database and data from ONEE. Within the M-EPM model, plants may have different statuses, including “Operational,” “Planned,” “Under Construction,” or “Retired.” Users can also set assumptions for plant retirements. Most units do not have a reported retirement date and are assumed not to retire

during the model period. These statuses can be modified in any scenario, allowing users to examine the impact of power plants coming online or offline in any given year.

#### Resource availability

73. Resource availability refers to the percentage of time that a resource can produce electricity during the given block. Within the M-EPM Model, these “blocks” represent non-contiguous time periods that nevertheless share similar demand characteristics. Within each block, an availability of 100% means the plant can produce electricity in all hours in that block; a percentage less than 100% means that the plan can only produce electricity for a portion of that time. The six blocks are:

- Block 1: Off-Peak: 11pm–9am, year-round
- Block 2: Summer Day: 9am–4pm, May through September
- Block 3: Summer Evening: 4pm–11pm, May through September
- Block 4: Winter Morning: 9am–3pm, October through May
- Block 5: Winter Day: 3pm–7pm, October through May
- Block 6: Winter Evening: 7pm–11pm, October through May

74. In addition to plant availability, users can also set up “must-run” assumptions. There are certain units that are required to run outside of economic dispatch, operate for reasons other than electricity market price signals (i.e., cogenerating facilities), or most frequently dispatch during extreme peak hours. To better quantify this type of generation, users can set up “floor” assumptions to dispatch generation in both historical and future years. By default, these limits are only applied to oil generators. Capacity factors are from ESMAP’s Model for Electricity Technology Assessment (META) and are consistent with ONEE 2017 Schéma Directeur Horizon 2030. Intermittent backups—that is, the additional natural gas combustion turbine capacity required to backup dynamically built intermittent renewables relative to the new renewable capacity—is set at 26 % as the default value.<sup>19</sup>

#### Cost parameters

75. Users can also specify plant-specific costs. All capital costs and changes in capital costs assumptions are from the U.S. EIA’s *Annual Energy Outlook*. This is consistent with the assumptions used in the power sector development plan. Variable operating and maintenance costs (VOM) and fixed operation and maintenance costs (FOM) are from the Model for Electricity Technology Assessment (META). VOM and FOM costs are held constant throughout the model time frame.

76. VOM costs refer to the marginal costs that are incurred for every MWh of electricity that a power plant produces.<sup>20</sup> Common examples of VOM costs include allowance costs for emissions, or costs for catalysts that are used to scrub plant stack emissions. Conventional fossil fuel-based

---

<sup>19</sup> Model testing found, in scenarios with extremely (unrealistically) rapid demand growth, a backup value of 26 % was needed to avoid paradoxical results.

<sup>20</sup> Note that all costs modeled in the Morocco M-EPM model are in real 2016 USD unless otherwise specified.



generation resources are estimated to have variable costs in the range of \$3 to \$10/MWh, whereas hydroelectric and other renewables typically have very low or no variable costs.

77. Unlike VOM costs, FOM costs are costs that are incurred regardless of the plant's level of generation. Common FOM costs include labor and minor equipment purchases. As with VOM, FOM costs can be constant for the entire model period or vary over time. Fixed costs average around \$10 to \$15/KW-year, with large hydroelectric resources on the low end of about \$5/kW-yr and newer (ultra-supercritical steam) coal and wind plants at the upper end of over \$20/kW-yr.

#### Heat rates and CO<sub>2</sub> emission

78. Plant efficiency, or 'heat rate', is also important in determining overall plant economics. A plant's heat rate describes its efficiency; i.e., the amount of energy produced by the plant (measured in MWh) relative to the amount of energy consumed by the plant (measured in terms of fuel energy content, e.g., MJ).<sup>21</sup> Linked to the heat rate and the fuel type is the CO<sub>2</sub> emissions rate. The CO<sub>2</sub> emissions rate describes the CO<sub>2</sub> output of the plant for every MWh of electricity produced. Each plant has a different CO<sub>2</sub> emission rate based on the carbon intensity of the fuel that it uses (natural gas, N2 Petroleum, and "Special" Petroleum) and the technology and emission controls that are installed. Both heat rates and CO<sub>2</sub> emission rates are from the Model for Electricity Technology Assessment (META).

### III. Model calibration

79. Model calibration is an important step in the M-EPM model and its scenario analysis. In the historical period (2009-2016), calibration helps ensure that the 'Policy Scenario' models the power system in the past as it actually operated. Using the tool's calibration feature, the model makes alterations until the modeled output data on capacity, generation, sales, and emissions match historical reported data on these same variables.<sup>22</sup> This calibration step also set up the M-EPM model parameters that are used consistently across the modeling time horizon, as well as the scenarios (with and without policy).

80. Table 5 displays the generation, sales, and emissions observed in the Policy Scenario versus the same values from actual historical data for 2009 through 2016 (the latest year for which actual historical data is available). While values do not match completely, in the vast majority of cases, each individual value is within 10 % of its counterpart. This calibration indicates that the datasets, algorithms, and expert assumptions being employed within this analysis produce results that closely resemble actual system operation, lending credibility to the comparisons performed for historical years, and to the values being generated in years after 2016.

---

<sup>21</sup> Heat rates are sometimes described using a %age (e.g., amount of energy output for every unit of energy input).

<sup>22</sup> The majority of actual historical data was assembled using publicly available information in annual reports published by the Office National d'Electricité et de l'Eau Potable (ONEE) from 2009 to 2016.

Table 5: M-EPM model calibration with historical data

Scenario A123									
Generation		2009	2010	2011	2012	2013	2014	2015	2016
Coal	GWh	10,823	11,130	11,950	11,586	11,721	15,700	17,024	16,793
Hydro + PS	GWh	2,819	3,357	2,035	1,676	2,707	1,523	1,913	1,133
Natural Gas	GWh	3,044	2,752	3,706	6,486	6,240	5,810	5,796	6,188
Oil	GWh	3,545	4,527	5,581	5,664	4,576	2,502	2,084	2,811
Solar PV + C	GWh	0	0	0	0	0	0	0	3
Wind	GWh	396	654	702	714	1,342	1,943	2,517	3,450
Imports	GWh	4,683	3,963	4,637	4,791	5,296	5,909	4,938	5,036
Other	GWh	129	150	141	141	141	141	141	142
Total	GWh	25,439	26,532	28,753	31,058	32,023	33,530	34,413	35,556
Sales and Losses		2009	2010	2011	2012	2013	2014	2015	2016
Retail Sales	GWh	22,415	23,749	25,634	27,559	27,781	28,825	29,381	30,019
Losses	%	13%	12%	12%	13%	15%	16%	17%	18%
Emissions		2009	2010	2011	2012	2013	2014	2015	2016
CO2	MMTCO2	14.8	16.1	17.8	21.2	19.5	23.1	24.1	21.3
Actual historical data from ONEE annual reports									
Generation		2009	2010	2011	2012	2013	2014	2015	2016
Coal	GWh	10,863	10,866	11,678	11,856	12,029	15,818	17,053	16,861
Hydro + PS	GWh	2,952	3,413	1,959	1,569	2,714	1,514	1,858	1,133
Natural Gas	GWh	3,054	2,963	4,051	6,201	5,824	5,600	5,784	5,909
Oil	GWh	3,498	4,522	5,516	5,673	4,532	2,465	2,092	2,750
Solar PV + C	GWh	-	-	-	-	-	0	6	401
Wind	GWh	391	659	692	728	1,356	1,924	2,519	3,142
Imports	GWh	4,630	3,940	4,607	4,842	5,400	6,010	4,974	5,154
Other	GWh	51	169	250	189	168	198	128	206
Total	GWh	25,439	26,532	28,753	31,058	32,023	33,530	34,413	35,556
Sales and Losses		2009	2010	2011	2012	2013	2014	2015	2016
Retail Sales	GWh	22,415	23,749	25,634	27,559	27,781	28,825	29,381	30,019
Losses	%	13%	12%	12%	13%	15%	16%	17%	18%
Emissions		2009	2010	2011	2012	2013	2014	2015	2016
CO2	MMTCO2	15.0	16.3	18.3	18.8	Data not yet available			

Note: In this figure, the 'Scenario A123' represents 'Policy Scenario'.

## Chapter 3: Scenarios and Results

81. This chapter describes the Policy Scenario and the baseline scenarios analyzed in this report. It then presents key modeling results associated with these scenarios focusing on key result indicators and the impact channels. The ex-post analysis considers the 2009-2016 period relative to the 2009 base year, and the ex-ante analysis looks at the 2016-2030 period relative to the 2016 base year. These baselines (2016 and 2009) represent policy cut-off points and reflect different policy conditions used as points for comparison with the Policy Scenario. The last section of this chapter discusses the sensitivity of the modeling results and takes a deeper look at the impact of individual policies vis-à-vis the overall policy package.

### I. Description of scenarios

82. Table 6 provides an overview of the Policy Scenario and two baseline scenarios adopted in this report. The Policy Scenario applies to both ex-post and ex-ante analyses and runs through the entire modeling period (2009-2030). The 2009 baseline, assuming continuation of conditions prevailing in 2009, is used primarily for comparison with the Policy Scenario in the ex-post analysis of changes that have already happened, including subsidy removal and the first stages of expanded investment in renewables. The 2016 baseline, assuming continuation of conditions in 2016, is used for ex-ante analysis of policies not yet implemented, such as the transition to cost-based tariffs and most of the planned expansion of renewable capacity.

*Table 6: Scenario Overview*

Scenario	Policies		
	Fuel price subsidies	Electricity tariff	Renewable energy policy
Policy Scenario	No fuel subsidies in place during 2014-2030;  Subsidies as officially reported during 2009-2013	Bulletin Officiel 2014-2017 tariff increase;  Cost-based tariffs implemented in 2018-2030; phased in between 2018 and 2020	Renewables are built according to Schema Directeur Horizons 2030; wind, solar, and hydro make up 52% of installed capacity in 2030.  Consistent with NDC and include both Law 13-09 and Law 58-15
Baseline 2009	Subsidies continues at 2009-2013 average during 2014-2030;  Subsidies as officially reported during 2009-2013	2013 tariffs are in place from 2014-2030 (no Bulletin Officiel 2014-2017 tariff increase)	All existing and planned renewables are removed if they were built after 2009 (without Law 13-09 and Law 58-15)

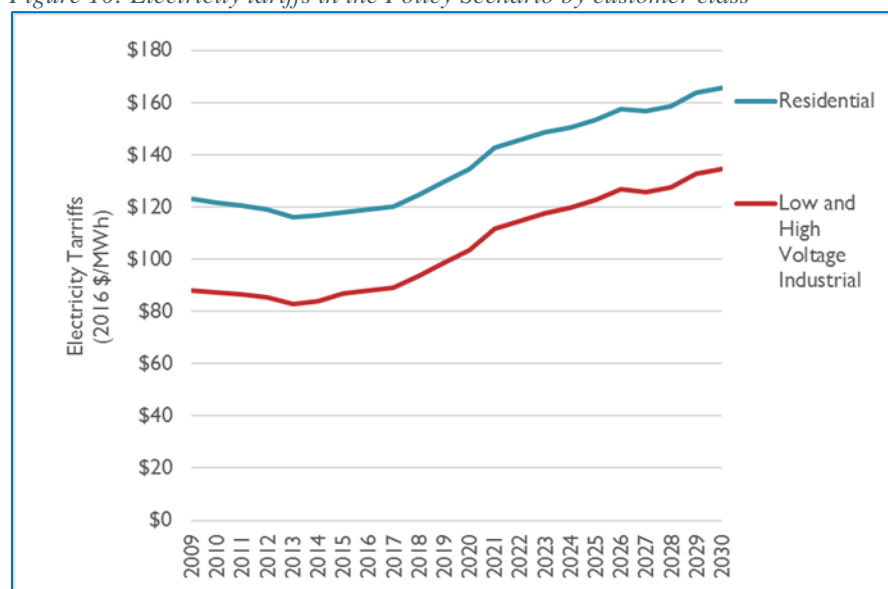
Baseline 2016	No fuel subsidies in place during 2014-2030;  Subsidies as officially reported during 2009-2013	2015 tariffs are in place from 2016-2030 (partial Bulletin Officiel 2014-2017 tariff increase)	All existing and planned renewables are removed if they were built in or after 2016 (with Law 13-09 but without Law 58-15)
---------------	---	--	--

Source: World Bank task team

## A. Policy Scenario

83. Section III ‘Policy Package’ in Chapter 1 describes the policy measures that are included as part of the Policy Scenario, namely (i) complete phase out of fossil fuel subsidies to power generation by 2014, (ii) electricity tariff increase during 2014-2017 and toward cost-recovery level in the future periods, and (iii) renewable laws that enable ramping up of renewable generation installed capacity to 52% of total capacity by 2030. Refer to that section for specific details of the three policy pillars.

Figure 10: Electricity tariffs in the Policy Scenario by customer class



Source: M-EPM model simulation.

Note: While low and high voltage industrial customers pay different retail electricity tariffs, these tariffs appear effectively identical. For simplicity, the figure uses it to represents both low and high industrial tariffs.

### Electricity tariffs

84. The Policy Scenario assumes that consumer electricity tariffs follow the recent increase during 2014-2017 and begin a phase-in towards ‘cost-based’ tariffs starting in 2018.<sup>23</sup> In 2018,

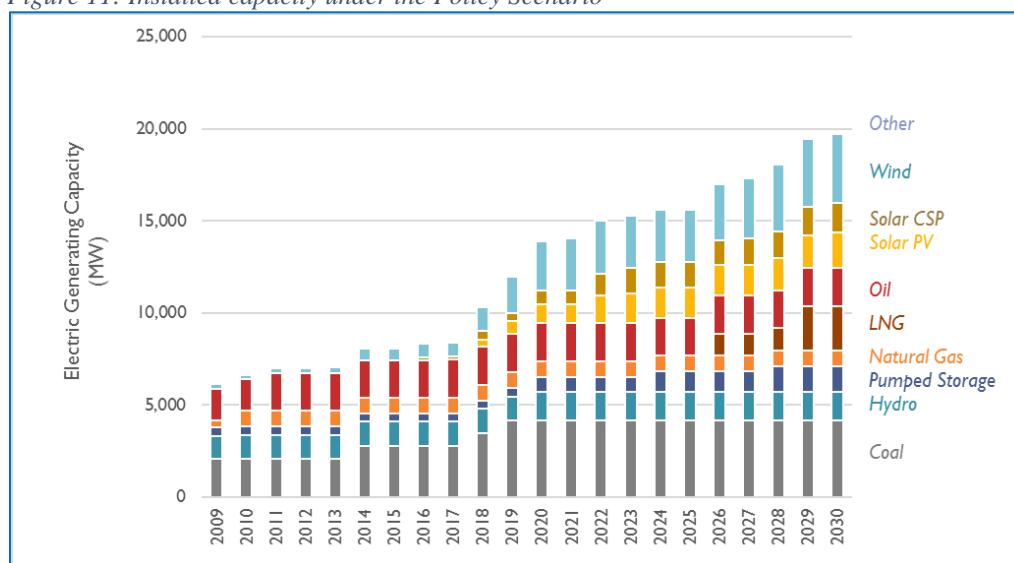
<sup>23</sup> Cost-based tariffs are tariffs calculated at levels such that the electric system revenues of the Moroccan electricity grid are in equilibrium. Historically, the costs of operating the Moroccan electricity system have exceeded the revenues collected from ratepayers. Typically, ONEE has waited several years between tariff adjustments at which point tariffs are raised to a point nearing cost-revenue balance. However, because several years may elapse between tariff adjustments, the cost-revenue equilibrium has not been maintained.

2019, and 2020, tariffs are incrementally increased on a linear trajectory until cost-based tariffs are fully in effect in 2021. The scenario then assumes that cost-based tariffs continue fully recovering electricity costs in all years through 2030. Throughout the study period, tariffs range from about 20% above 2016 levels (in the early years) to about 50% above 2016 levels (in constant-dollar terms, in 2030). Figure 10 illustrates the resulting tariffs in the Policy Scenario for each year between 2009 and 2030.

### Renewable capacity addition

85. This increased renewable capacity build fundamentally alters the makeup of Morocco's electricity capacity (Figure 11). Between present day and 2030, renewable capacity increases to reach 52% of the total capacity of the electric system by 2030. In addition, the Policy Scenario also features near-term increases in coal capacity linked with power plants that are currently under construction, and long-term additions in liquified natural gas capacity, associated with one of Morocco's other stated policy pillars to increase reliance on natural gas.

Figure 11: Installed capacity under the Policy Scenario



Source: M-EPM model simulation

86. Increased electricity demand and the construction of new generating capacity impact system costs, which increase to over \$7 billion on a real-dollar basis by 2030 (Figure 12). These increased system costs are matched by increases in system revenues, through the phase in of cost-based tariffs (described above in Figure 10)<sup>24</sup>.

### Revenue recycling

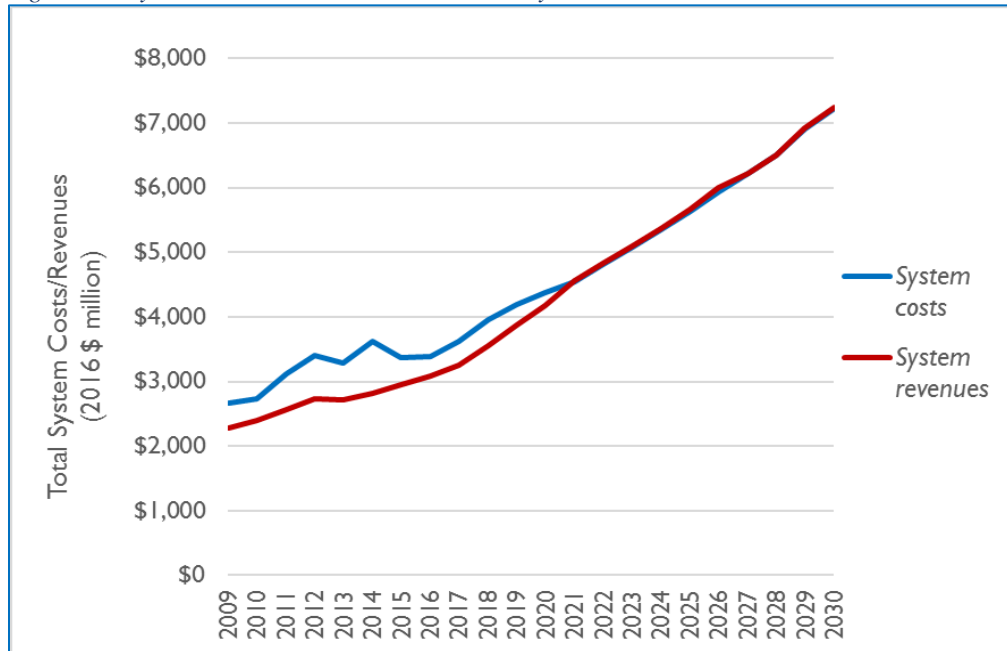
87. In addition to switching to cost-based tariffs, the Policy Scenario assumes that any revenue overcollection (up to \$10 million in each year) is recycled into the electricity system.<sup>25</sup> This

<sup>24</sup> Important to note that the 'cost' concept in this report reflects the costs associated with electric system operation and investment only, and does not include potential social costs of policies and reform measures.

<sup>25</sup> Up to \$10 million is invested in each following year, as long as it does not cause revenues to become negative in any future year.

revenue is used to fund additional energy efficiency (above and beyond what is modeled as an exogenous assumption), improvements to the transmission and distribution grid which reduce technical losses, and subsidies for renewable projects.

Figure 12: System costs and revenues in the Policy Scenario



Source: M-EPM model simulation

## B. Baseline Scenarios

### Baseline 2009

88. The first baseline scenario, Baseline 2009, imagines a world in which policies that were in effect in the 2009-2013 time period are largely continued throughout the study period. These assumptions include:

- **Fuel subsidies:** This scenario assumes that instead of ceasing fuel subsidies at the end of 2013, subsidies for oil are continued for the entire study period. These fuel subsidies continue at a level commensurate with the average subsidy in place between 2009 and 2013.
- **Electricity tariffs:** This scenario assumes Moroccan electricity consumers continue to pay the same for electricity as they did in 2013 in all years between 2014 and 2030. In addition, this assumes that cost-based tariffs are not implemented at any point and that revenue recycling does not occur at any time.
- **Renewable resources:** This scenario assumes, except for any renewables built in 2009 or prior years, Morocco does not build any renewables in the period between

2010 and 2030. In effect, this setting assumes that Laws 13-09 and 58-15 (important post-2009 policies facilitating investment in renewables), were not implemented. Renewables that were constructed in 2010 to 2016, in planning or under construction, or were simply exogenously added generic additions are all affected by this assumption.

89. With the exception of these changes, all other input assumptions (e.g., fuel costs, electricity sales, energy efficiency) are unchanged from the main Policy Scenario.

#### Baseline: 2016

90. The second baseline scenario, Baseline 2016, imagines a world in which policies that were in effect in 2016 are largely continued throughout the time period. These assumptions include:

- Fuel subsidies: Like the Policy Scenario, the Baseline 2016 scenario assumes that there are no fuel subsidies in effect in Morocco's electricity system from 2014 onward.
- Electricity tariffs: This scenario assumes that Moroccan electricity consumers continue to pay the same for electricity as they did in 2015 in all years between 2016 and 2030. As with the Baseline 2009 scenario, this scenario assumes that cost-based tariffs are not implemented at any point and that revenue recycling does not occur at any time.
- Renewable resources: This scenario assumes except for any renewables built in 2016 or prior years, Morocco does not build any renewables in the period between 2017 and 2030. In effect, this setting assumes that while Law 13-09 was implemented, Law 58-15 was not. Renewables that are in planning or under construction or were simply exogenously added generic additions are all affected by this assumption.

91. With the exception of these changes, all other input assumptions (e.g., fuel costs, electricity sales, energy efficiency) are unchanged from the main Policy Scenario.

92. Profiles of the two baseline scenarios are remarkably similar. Both scenarios continue to be heavily dependent on fossil fuels for generation. The main difference between the two scenarios is the additional renewables that came online in Morocco between 2009 and 2016. These are present in Baseline 2016 and not in Baseline 2009. Additionally, fuel subsidies are modeled in Baseline 2009 but not Baseline 2016. These fuel subsidies effectively reduce the generating cost of oil-fired power plants, resulting in more generation from these resources in Baseline 2009 than in Baseline 2016. As a result, in the Baseline 2009 scenario, this cheaper oil displaces both generation from coal (a higher-emitting resource) and generation from natural gas (a lower-emitting resource).

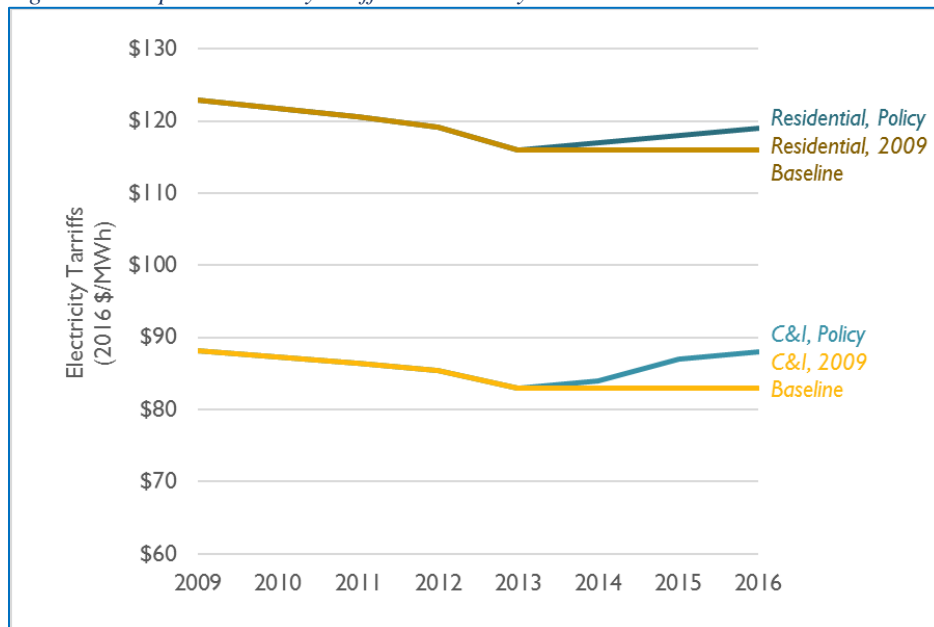


## II. Modeling Results

### A. Ex-post policy impact (2009-2016)

93. Electricity tariffs in the Policy Scenario and the Baseline 2009 scenario were the same during 2009-2013, since there was no tariff increase/reform in this period<sup>26</sup>. After 2013, the baseline scenario assumes no tariff increase; thus the same level of electricity tariffs were in effect in 2014 and all future years – US\$117/MWh for residential and US\$84/MWh for commercial and industrial (C&I) tariffs. In the Policy Scenario, residential tariff has increased from US\$117/MWh in 2014 to US\$119/MWh in 2016, while C&I tariff has increased from US\$84/MWh in 2014 to US\$88/MWh in 2016 (Figure 13).

Figure 13. Ex post electricity tariffs in the Policy Scenario and the 2009 Baseline



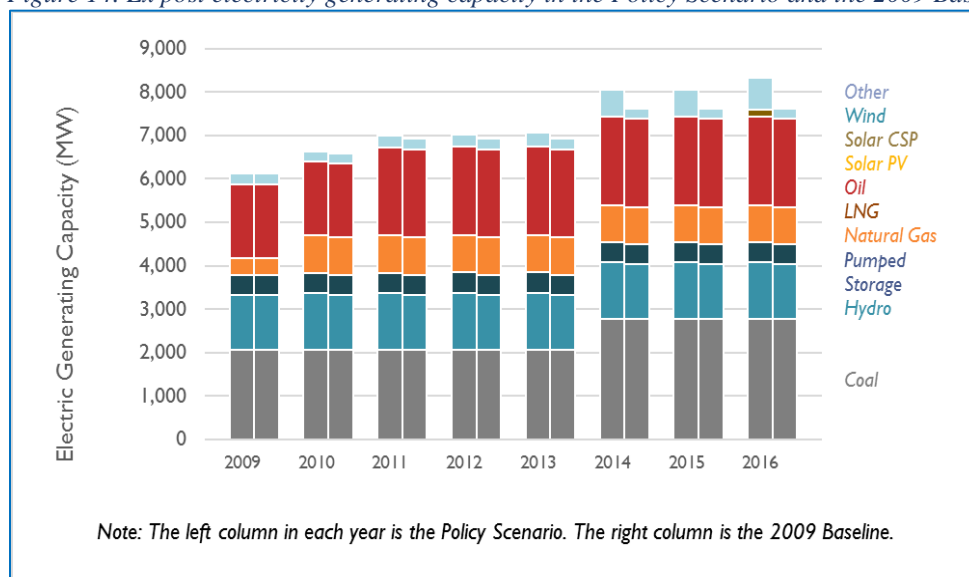
Source: M-EPM model simulation

Note: While low and high voltage industrial customers pay slightly different retail electricity tariffs, these tariffs appear effectively identical in this figure.

94. Total installed capacity increased in the Policy Scenario from 6,135 MW in 2009 to 8,340 MW in 2016, in response to a rapidly growing demand. By 2016, the Policy Scenario has built 51 MW hydro, 161 MW solar (PV and CSP), and 487 MW wind *more* than those built in the baseline scenario (Figure 14). This resulted in the total capacity being 699 MW higher in the Policy Scenario, with 32% of renewable in total installed capacity in 2016, as compared to 26% renewable in the same year of the baseline scenario.

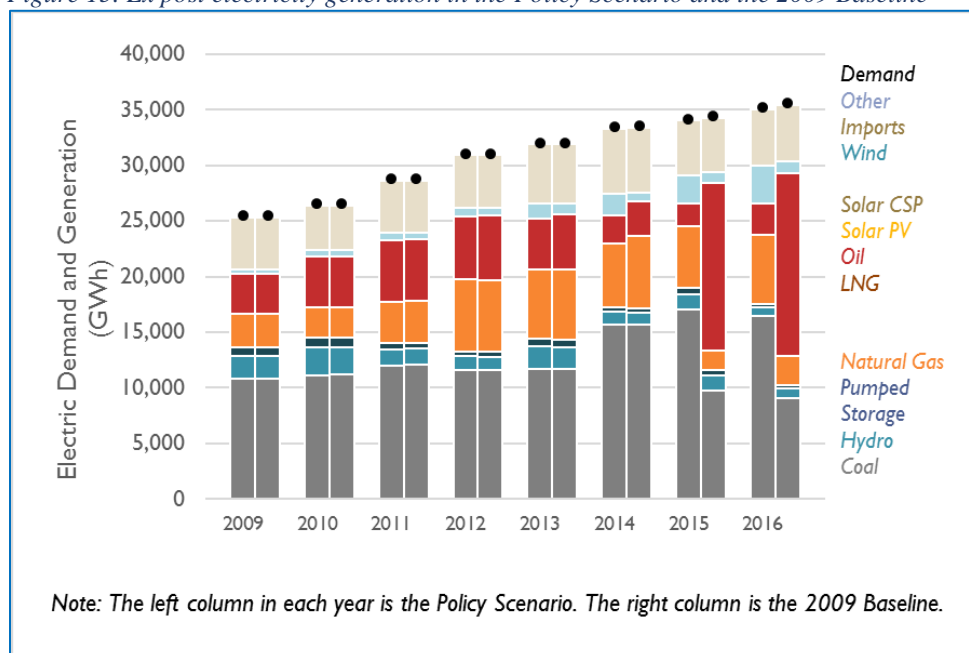
<sup>26</sup> The analysis expresses tariffs in real 2016\$ terms, while the official tariff policies are in nominal dirham terms. Because the inflation, the real tariff during 2009-2013 appear decreasing, although there is no tariff change in the nominal terms.

Figure 14. Ex post electricity generating capacity in the Policy Scenario and the 2009 Baseline



Source: M-EPM model simulation

Figure 15. Ex post electricity generation in the Policy Scenario and the 2009 Baseline



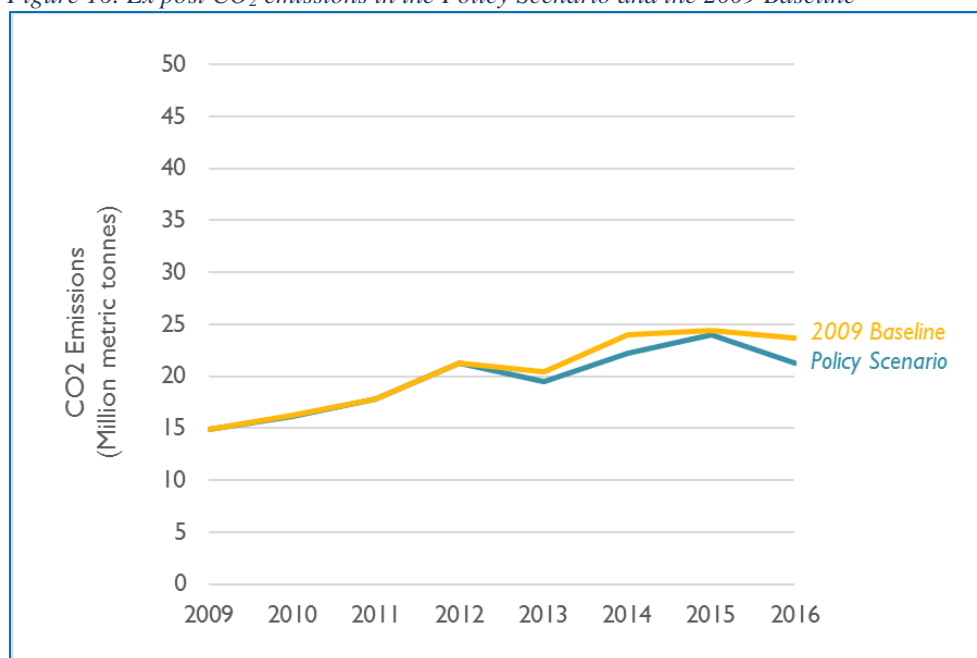
Source: M-EPM model simulation

95. Due to the modest electricity tariff increase during 2014-2016, the Policy Scenario saved 378 GWh of electricity in 2016, equivalent to 1.1% of electricity generation compared to the baseline scenario (Figure 15). In terms of the generation mix, the two scenarios have performed similarly up to 2013. The impact of fuel subsidies reform, particularly the removal of fuel oil subsidies, became visible from 2014 onward – the Policy Scenario generated significantly less from oil, and more from natural gas, wind, hydro, and coal, relative to the baseline scenario. In

other words, the Moroccan electric system would have been over-run with oil-fired power plants without the oil subsidy reform.

96. The changes in the Policy Scenario have resulted in the total reduction of 5.6 million metric tons of carbon dioxide (MtCO<sub>2</sub>) during the 2009-2016 period relative to the baseline, averaging about 1-2 MtCO<sub>2</sub> per year between 2013 and 2015 (Figure 16). The fuel switching between oil and other fossil fuels (such as coal and natural gas) is not ideal from the climate change mitigation viewpoint. However, the subsequent section of the report suggests that acceleration of the policy and reform measures under the Policy Scenario in the future period will alleviate this transitional issue and result in substantial reduction of coal and other fossil fuels in the long-term.

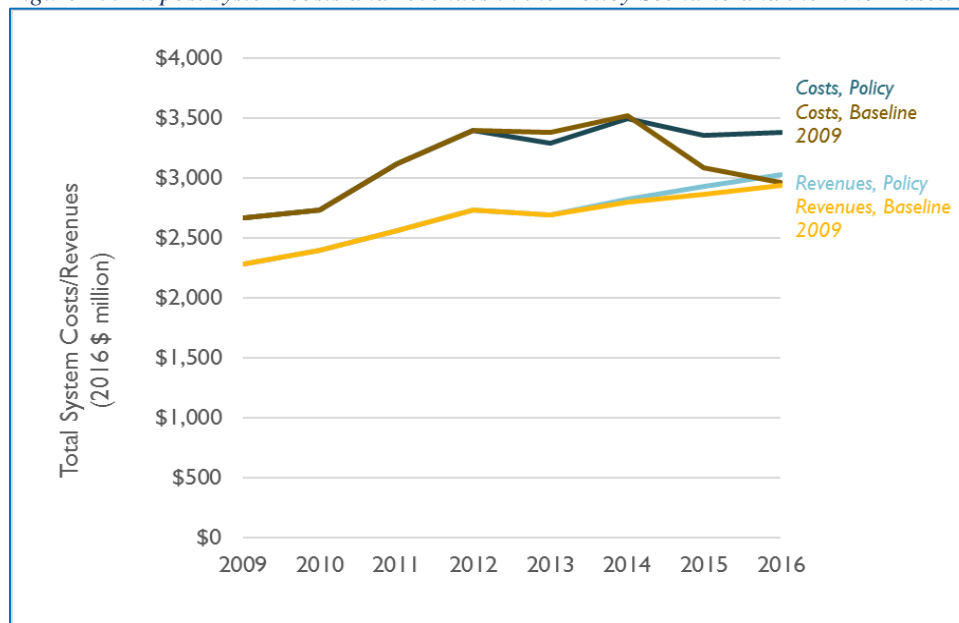
Figure 16. Ex post CO<sub>2</sub> emissions in the Policy Scenario and the 2009 Baseline



Source: M-EPM model simulation

97. With respect to the financial side of the power system, the baseline generation costs are lower than in the Policy case as fuel subsidies are extended in the former between 2014 and 2016 (Figure 17). These fuel subsidies act essentially as “free” revenue to the electric sector, driving down costs and producing more balance between costs and revenue, while the broader economic/fiscal cost of subsidies were not captured in the scope of the power system. The analysis also shows that, although electricity tariffs have been raised and the cost-revenue gap had narrowed down in the Policy Scenario, they were not sufficient to recover the system cost during the 2009-2016 period and led to a sizeable shortfall of US\$356 million in 2016 (10.5% of total system cost).

Figure 17. Ex post system costs and revenues in the Policy Scenario and the 2009 Baseline



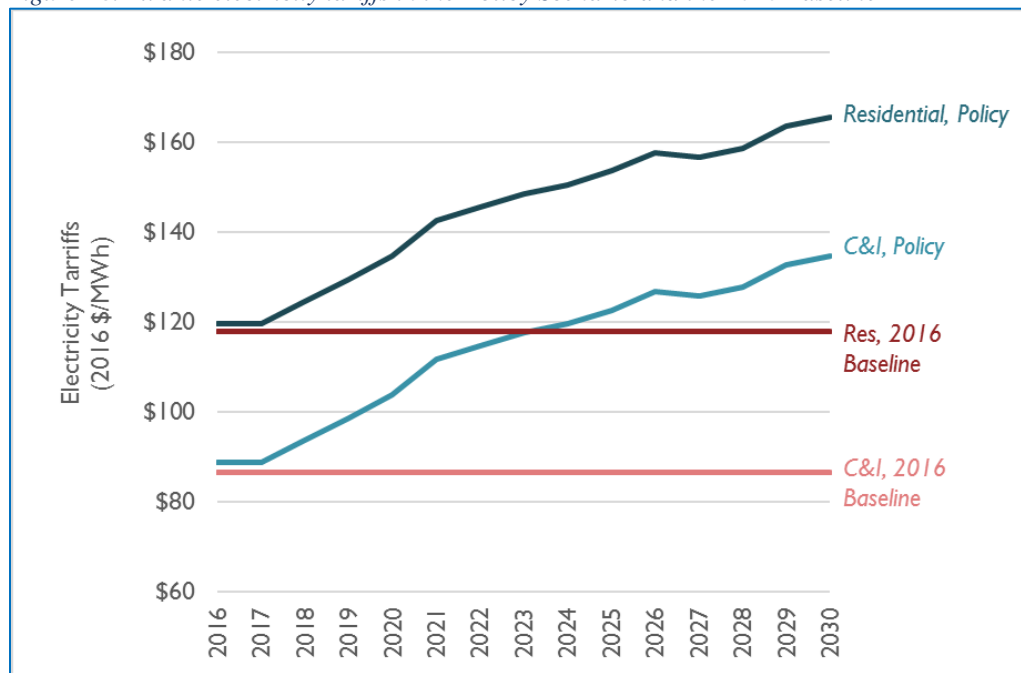
Source: M-EPM model simulation

### B. Ex-ante policy impact (2016-2030)

98. Electricity tariffs increase over time in the Policy Scenario during the 2016-2030 period. The tariffs ramp up from 2018 to meet the cost-recovery levels by 2021 then continue to be set at levels that recover costs in the Policy Scenario until the end of the modeling period in 2030 (Figure 18). By 2030, residential tariff is projected to reach US\$166/MWh and C&I tariff to increase to US\$135/MWh in the Policy Scenario. Under the baseline scenario, there is no tariff increase beyond the 2015 level (US\$118/MWh for residential tariff and US\$87/MWh for C&I tariff), implying a partial success of the recent tariff reform.

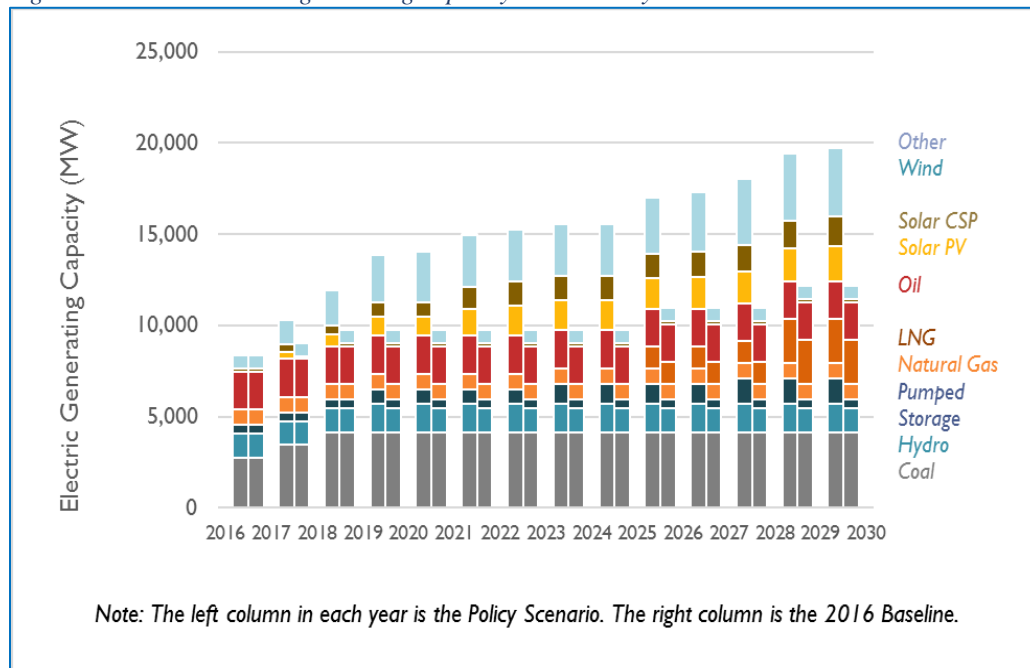
99. Total installed capacity increases in the Policy Scenario from 8,340 MW in 2016 to 19,751 MW in 2030. This is 62% higher than the installed capacity required in the baseline scenario in 2030, mainly due to scaling up of renewable energy capacity (Figure 19). By 2030, the Policy Scenario is projected to develop 223 MW conventional hydro, 950 MW pumped storage hydro, 1,922 MW solar PV, 1,475 MW solar CSP, and 3,016 MW wind *in addition to* those built in the baseline scenario. By design, the Policy Scenario has 52% of renewable energy installed capacity by 2030, whereas it is projected to comprise only 22% of total capacity in the baseline by 2030. In the baseline, peak demand for electricity would be mainly met by existing plants, augmented in part by under construction or planned fossil resources which would come online in the near future (coal units) and late 2020s (LNG combined cycle units).

Figure 18. Ex ante electricity tariffs in the Policy Scenario and the 2016 Baseline



Source: M-EPM model simulation

Figure 19. Ex ante electric generating capacity in the Policy Scenario and the 2016 Baseline

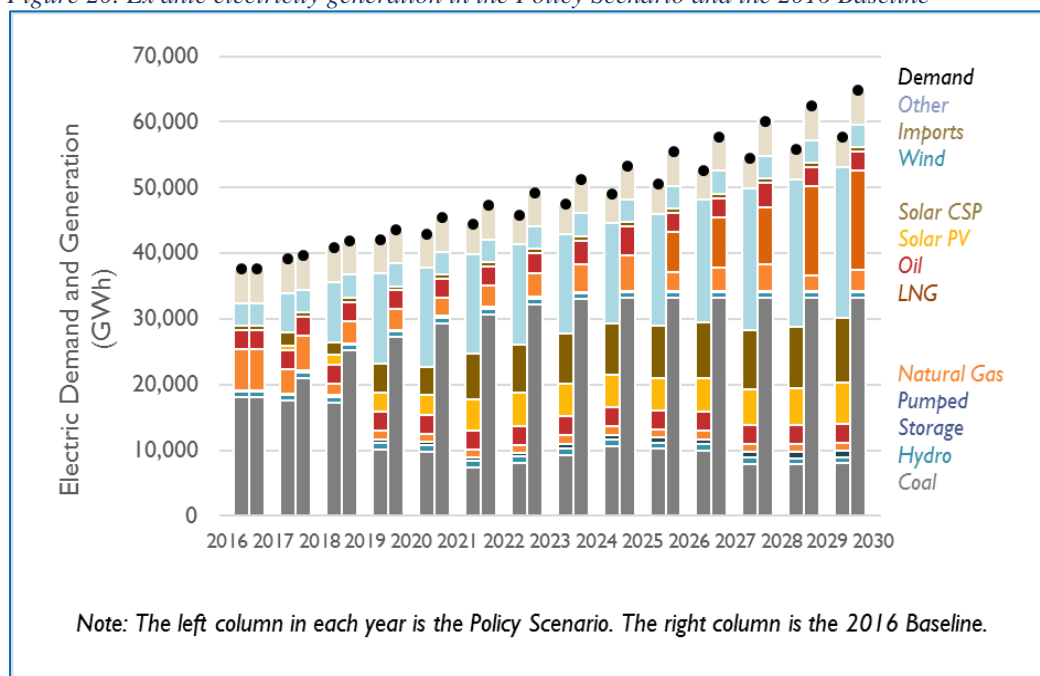


Source: M-EPM model simulation

100. Beginning in 2017, substantial differences in generation between the baseline and the Policy Scenario are observed (Figure 20). In the Policy Scenario, there would be significantly less generation from coal (24% of what would have been in the baseline in 2030) and imported LNG (16% of baseline in 2030), as more renewables are built to meet the 52 % policy goal by 2030.

Electricity saving from the policies is projected to increase over time and amount to 7,121 GWh by 2030 (approximately 11% of baseline generation). Furthermore, the Policy Scenario results in less electricity import requirement from abroad.

Figure 20. Ex ante electricity generation in the Policy Scenario and the 2016 Baseline



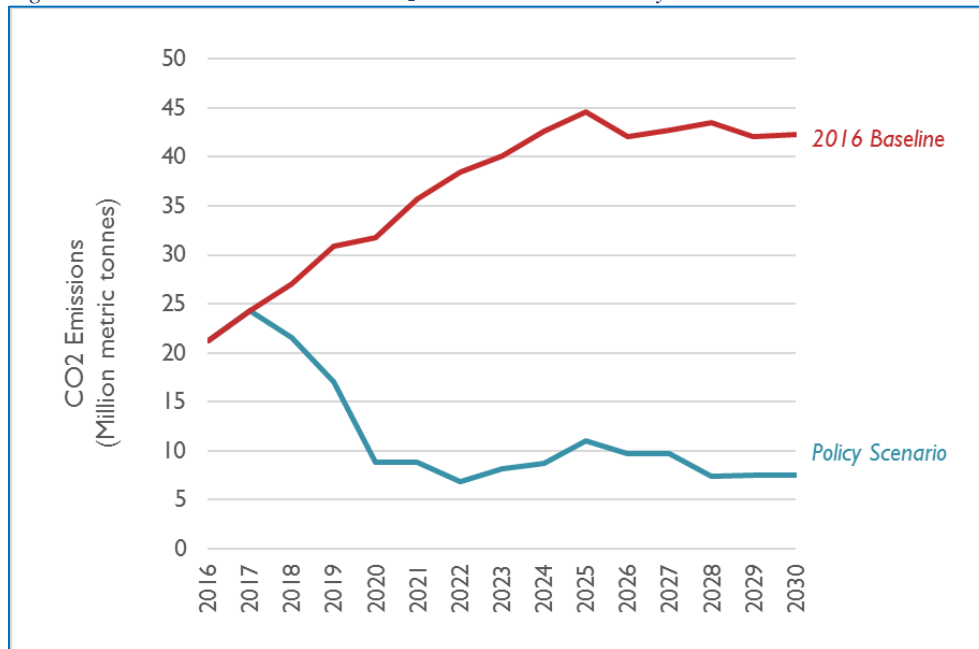
Source: M-EPM model simulation

101. Compared to the baseline, the Policy Scenario reduces 23 MtCO<sub>2</sub> in 2020 and further reduces 35 MtCO<sub>2</sub> in 2030. The projected emission reduction in 2030 is equivalent to 48.6% of the total emission reduction committed in Morocco NDC (Figure 21). This suggests that continuation of energy subsidies reform and renewable energy policies are instrumental to effective implementation of NDC in Morocco. In cumulative terms, the Policy Scenario reduces 371 MtCO<sub>2</sub> during the 2016-2030 period.

102. The changes to electric generating capacity and tariffs suggest stark differences in terms of ex-ante system costs and revenues, as compared to the ex-post analysis (Figure 22). Without continued policy and reform efforts, system costs and revenues diverge over time in the baseline, with costs outpacing revenues in every year. However, under the Policy Scenario and by design, cost-based tariffs allow the Moroccan electric system operators to recover exactly the revenue needed to balance electric system costs in every year between 2021 and 2030.<sup>27</sup> In both cases, system costs will rise implying a need for continued effort to raise electricity tariff over time.

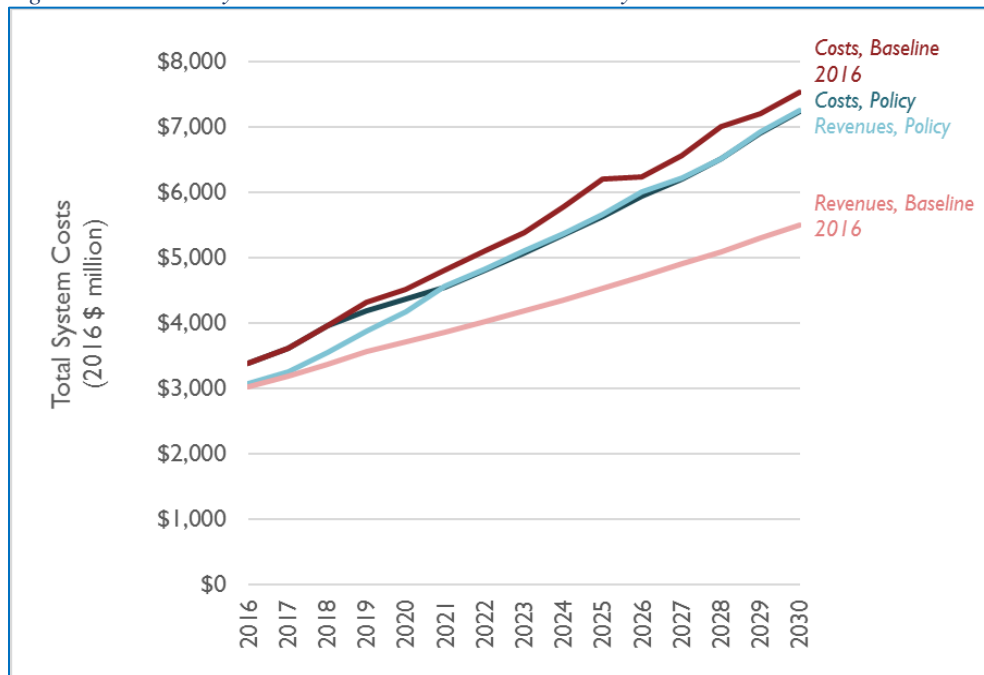
<sup>27</sup> Due to rounding in the cost-based tariff algorithm, costs and revenues may not exactly match in every year. Revenues may exceed costs in some years, although never more than 1 %.

Figure 21. Ex ante electric sector CO<sub>2</sub> emissions in the Policy Scenario and the 2016 Baseline



Source: M-EPM model simulation

Figure 22. Ex ante system costs and revenues in the Policy Scenario and the 2016 Baseline



Source: M-EPM model simulation

103. The higher costs under the baseline are driven largely by the expensive costs associated with fossil imports of coal, LNG, and heavy fuel oil. Although the Policy Scenario involves higher investment costs of renewable energy capacity (about US\$280 million per year on average by 2030 – 3.9% of overall system cost), the net system cost is projected to be consistently lower than the

baseline. Overall, the Policy Scenario envisages a Moroccan power system that achieves financial sustainability, better energy security due to less reliance on imports and optimizing the use of domestic renewable potential, as well as mitigate a significant amount of CO<sub>2</sub> emissions.

### *C. Cumulative emission reduction impacts (2009-2030)*

104. Table 7 compares the cumulative CO<sub>2</sub> emissions observed over the entire 2009-2030 modeling time horizon among the three scenarios. As expected, the Policy Scenario features the lowest level of emissions, which are attributable to greater levels of renewables, less reliance on fossil fuels, and lower electricity demand driven by higher tariffs. As a consequence of the Policy Scenario, the total CO<sub>2</sub> emission reductions are 371.1 MtCO<sub>2</sub> and 401.7 MtCO<sub>2</sub> under the 2016 and 2009 baseline scenarios, respectively.

*Table 7: Difference in CO<sub>2</sub> emissions (million metric tons)*

	<b>Policy Scenario</b>	<b>Baseline: 2009</b>	<b>Baseline: 2016</b>
CO <sub>2</sub> emissions, 2009-2030	315.1	716.8	686.2
Difference, relative to Policy Scenario	-	401.7	371.1
% Difference, relative to Policy Scenario	-	127%	118%

*Source: M-EPM model simulation*

## **III. Policy synergy and sensitivity**

105. The three policies combined in our main Policy Scenario have synergistic effects. The expansion of renewable energy to meet the NDC target, on its own, would achieve significant emission reductions, but even more is achieved by the package of three policies. The other two policies, on their own, could have perverse effects, but become clearly beneficial as part of the policy package.<sup>28</sup>

106. Removal of subsidies makes oil-fired generation more expensive, relative to available alternatives. With Morocco's existing generation capacity, including ample coal-burning capacity but limited renewable energy, removal of oil subsidies *alone* could cause a shift from oil to coal and natural gas, slightly increasing electric system carbon emissions on a net basis. In combination with rapid expansion of renewable energy capacity, the removal of oil subsidies can lead to a shift from oil to renewables, reducing emissions.

107. Switching to cost-based tariffs, when the electric system would otherwise be running a deficit, amounts to increasing the retail price of electricity. The price elasticity effect then causes a slight reduction in demand and generation, reducing emissions. However, cost-based tariffs can

---

<sup>28</sup> These conclusions are based on additional sensitivity analyses, not shown here; details available from the authors on request.



have the opposite effect if the electric system would otherwise be running a surplus: the price of electricity goes down, causing an increase in generation and emissions. This unexpected outcome occurs if cost-based tariffs are introduced in a scenario that assumes continuation of oil subsidies.<sup>29</sup> The availability of artificially cheap oil reduces electric system costs, and hence reduces cost-based tariffs.

108. Several sets of model sensitivities are performed to better understand how individual policy measures and underlying key assumptions contribute to the CO<sub>2</sub> emission reduction outcomes. Table 8 summarizes these findings. The first set of sensitivities focused on the impact of the three main policy measures: fuel price subsidies, tariff design, and renewable energy.

109. Fuel subsidy reform has a negligible impact on emissions, simply because the analysis captures only the minimal changes during the final stage of reform (completed in 2014). Cost-based tariffs caused a moderate (14 %) reduction in CO<sub>2</sub> emissions relative to the without cost-based tariff scenario. The renewable policies that enable the 52 % renewable energy by 2030 has a very large impact on CO<sub>2</sub> emissions, roughly cutting CO<sub>2</sub> emissions by half relative to baseline.

110. The second set of sensitivity analyses is carried out to test whether and how underlying assumptions such as energy efficiency improvement on the demand side, fuel price escalation, and price elasticity of electricity demand affect the emission differences between the Policy Scenario and the baselines. Note that both energy efficiency improvement and fuel price increase are in the Policy Scenario, as well as the baselines.

111. Using the 371.1 MtCO<sub>2</sub> difference between the Policy Scenario and the 2016 Baseline as a point for comparison, not including the demand-side energy efficiency improvement leads to 336.7 MtCO<sub>2</sub> reduction (9% lower CO<sub>2</sub> reduction relative to the main case), holding fuel prices constant results in a 323.5 MtCO<sub>2</sub> reduction (12% lower), and adopting a more conservative price elasticity found in the meta-analysis described in Chapter 2—approximately half of the main elasticity used—yields a 348.8 MtCO<sub>2</sub> reduction (6% lower).

---

<sup>29</sup> This also assumes that the cost of subsidies is not paid by the electric system; it is, in effect, a free resource provided to electric system planners by another government agency.

Table 8: Scenarios and sensitivities

Table 8. Scenarios and Sensitivities							
Scenario / Sensitivity Name	Releive Scenario	Policies				CO <sub>2</sub> emissions (2009-2030 MMT)	
		Fuel subsidies	Tariff Assumptions	Renewables	Other	Result	Diff. from relevant Scenario
Baseline and Policy Scenarios							
B_2009	-	Subsidies are continued at 2009-2013 average from 2014-2030	Tariffs from 2013 are in place from 2014-2030	All existing and planned renewables are removed if they were built after 2009	-	716.8	-
B_2016	-	No fuel subsidies in place after 2013	Tariffs from 2015 are in place from 2016-2030	All existing and planned renewables are removed if they were built in or after 2016	-	686.2	-
Policy Scenario (A123)	-	No fuel subsidies in place after 2013	Cost-based tariffs implemented in 2018-2030; phased in between 2018 and 2020	Renewables are built out according to Schema Directeur Horizons 2030; wind, solar, and hydro make up 52% of generation in 2030 (and a large %age in many earlier years)	-	315.1	-
Main Policy Sensitivities - Changes relative to the relevant baseline or Policy Scenario							
A1	Policy Scenario	-	Tariffs from 2015 are in place from 2016-2030	No renewables built after 2016	-	686.2	+371.1
A2	Policy Scenario	Subsidies continued at 2009-2013 average from 2014-2030	-	No renewables built after 2016	-	641.2	+326.1
A3	Policy Scenario	Subsidies continued at 2009-2013 average from 2014-2030	Tariffs from 2015 are in place from 2016-2030	-	-	355.6	+40.5
A12	Policy Scenario	-	-	No renewables built after 2016	-	626.4	+311.3
A13	Policy Scenario	-	Tariffs from 2015 are in place from 2016-2030	-	-	366.7	+51.6
A23	Policy Scenario	Subsidies continued at 2009-2013 average from 2014-2030	-	-	-	313.7	-1.4
Other Sensitivities – Changes relative to the relevant baseline or Policy Scenario							
B_2009 No EE	Baseline: 2009	-	-	-	No exogenous EE	752.9	+36.1
B_2016 No EE	Baseline: 2016	-	-	-	No exogenous EE	720.3	+34.1
A_123 No EE	Policy Scenario	-	-	-	No exogenous EE	383.6	+68.5
B_2009 Fuel	Baseline: 2009	-	-	-	No fuel price escalation	664.3	-52.5
B_2016 Fuel	Baseline: 2016	-	-	-	No fuel price escalation	638.9	-47.3
A_123 Fuel	Policy Scenario	-	-	-	No fuel price escalation	315.4	+0.3
A_123 Elasticity	Policy Scenario	-	-	-	Price elasticity reduced to -0.126 across all customer classes for all years	337.4	22.3

## Chapter 4: Application to Climate Finance

112. This chapter offers preliminary insight into how the Morocco M-EPM tool is being deployed to support Morocco in accessing innovative climate finance and tapping international carbon markets to contribute to its NDC implementation. In this context, the government of Morocco and the World Bank are working together to design and develop a results-based policy-level carbon crediting approach, building on the policy pillars described in the previous sections of this report. The crediting program is designed to ensure policy additionality. Therefore, a clearly defined policy cut-off point that aligns with the start of the crediting period, and a robust MRV with strict crediting baselines to ensure policy additionality—increased policy ambition/policy improvement—are key elements to the design of the program.

113. The Morocco M-EPM tool will be implemented ex-post and on an annual basis to monitor policy results and emission reductions associated with the policies under the consideration of this program. Appropriate discounts on emission reductions due to policy shortfall/gap relative to benchmark, as well as subtracting other carbon-credited operations (such as the Clean Development Mechanism—CDM) will also apply. In principle, policy revenue recycling/allocation should be used for further emission reduction to ensure environmental integrity. The remainder of the chapter provides an overview of the program design (see also Box 1) and emission reduction potential.

### Box 1: Key Program Features

**Approach:** results-based policy-level carbon crediting that is applied to nation-wide policy measures with power sector focus.

**Baseline:** ensure policy progress and increased policy ambition, and discount emission reductions from policy shortfall/gap relative to benchmark.

**Program period:** 2016-2023 (tentative). Policies that are in effect prior to 2016 are not eligible for emission reduction quantification.

**Additionality:** clearly defined policy cut-off point that is consistent with the start of the crediting period; robust MRV and crediting baseline to ensure increased policy ambition.

**Innovation:** policy-level crediting based on purpose-built policy-level MRV system (M-EPM tool), that allows quantification of emission reductions from transformative policies.

**Size:** 4.9-6.3 million tons of CO<sub>2</sub> emission reduction cumulative over the 2016-2023 period (in the worst-case scenario), with potential of emission reduction up to 20-22 million tons of CO<sub>2</sub> per annum (in the policy scenario). See scenario details below.

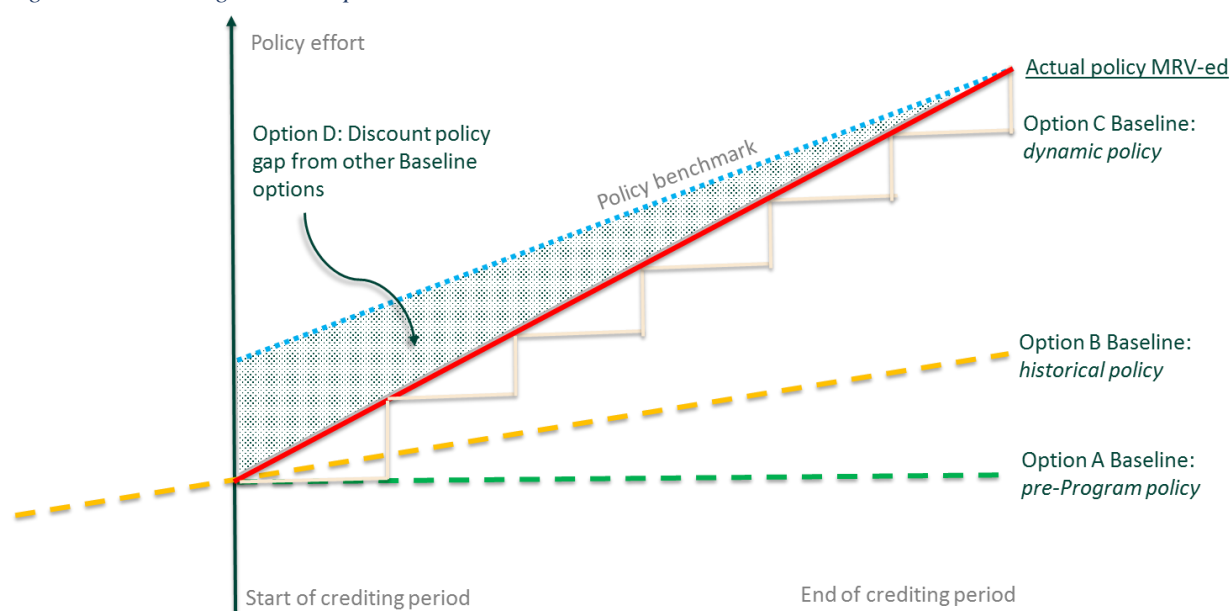
## Crediting baselines

114. The chosen baseline will provide an appropriate benchmark against which policy progress and increased ambition can be measured. This program analyzes emission reductions from four crediting baseline options. The baseline options reflect the various possible counterfactual policy efforts with varying degrees of conservativeness in measuring emission reductions and rigor in establishing basis for increase in policy ambition.

- **Option A.** Set baseline at the level of policy effort observed in pre-program period
- **Option B.** Set baseline based on the historical policy effort over a certain pre-program period
- **Option C.** Set baseline such that incremental policy effort is increased year over year – the impact only above and beyond the level of policy effort in the previous year
- **Option D.** Close the gap approach: applying discount of emission reductions based on policy gap/shortfall with respect to the policy benchmark (e.g. gap between cost-recovery tariff and actual tariff). This can be use in tandem with other baseline options.

115. Option C, in combination with Option D, represents the most rigorous and robust way of measuring increase in policy ambition and this Program Note puts this forward as the preferred baseline approach, to be further discussed and developed moving forward. Figure 23 illustrates the four baseline concepts that are applied in this program proposal for the energy subsidies reform and renewable energy policy pillars.

Figure 23: Crediting baseline options



Source: World Bank task team

## I. Policy matrix and scenarios

116. This section presents the matrix of policies and scenarios considered in the estimation of emission reductions under this crediting program. Scenario design follows directly the policy package and the baseline options described in Chapter 2 of this report. Table 9 summarizes the policy actions modeled under each pillar, and along the lines of Policy Scenario versus the baseline options. Two Policy Scenarios are considered. One is the main Policy Scenario which assumes the full policy package is implemented effectively and in a timely manner. The other is a slow progress Policy Scenario where efforts on energy subsidies reform and renewable development lag behind.

*Table 9: Policy Matrix – Scenarios (2016 start of the crediting period and policy cut-off point)*

	Fossil fuel subsidies reform	Electricity tariff reform	Renewable energy policy*
<b>Main Policy Scenario</b>			
<b><i>Policy package**</i></b>	No fuel subsidies in place during 2014-2030; subsidies as officially reported during 2009-2013	Cost-based tariffs implemented in 2018-2030; phased in between 2018 and 2020	Renewables are built according to Schema Directeur Horizons 2030; wind, solar, and hydro make up 52% of generation in 2030
<b><i>Baseline A***</i></b>	Same as Policy package scenario	2015 tariffs are in place from 2016-2030	All existing and planned renewables are removed if they were built in or after 2016
<b><i>Baseline B</i></b>	Same as Policy package scenario	Historical increase (0.91% increase per year for residential tariff, and 2.04% increase per year for industrial tariffs)	Renewables are built according to Schema Directeur Horizons 2030, but with 5 years delay
<b><i>Baseline C</i></b>	Same as Policy package scenario	Tariff increase with 1 year lag (equivalent to adopting previous year level as the baseline for the current year)	Renewables are built according to Schema Directeur Horizons 2030, but with 5 years delay
<b>Slow progress Policy Scenario</b>			
<b><i>Slow progress policy</i></b>	Same as Policy package scenario	Historical increase (0.91% increase per year for residential tariff, and 2.04% increase per year for industrial tariffs) – equivalent to Baseline B	Renewables are built according to Schema Directeur Horizons 2030, but with 5 years delay – equivalent to Baseline B

<b>Baseline A</b> <i>(used for slow progress policy)</i>	Same as Policy package scenario	2015 tariffs are in place from 2016-2030	All existing and planned renewables are removed if they were built in or after 2016
<b>Baseline C</b> <i>(used for slow progress policy)</i>	Same as Policy package scenario	Tariff increase with 1 year lag from slow progress policy (equivalent to adopting previous year level as the baseline for the current year)	Renewables are built according to Schema Directeur Horizons 2030, but with 2 more years delay from slow progress policy (i.e. 7 years delay from original schedule)

Source: World Bank task team

\*see the two paragraphs immediately below Table 9 on how the baselines for renewable are constructed.

\*\* this is identical to the Policy Scenario in Chapter 3.

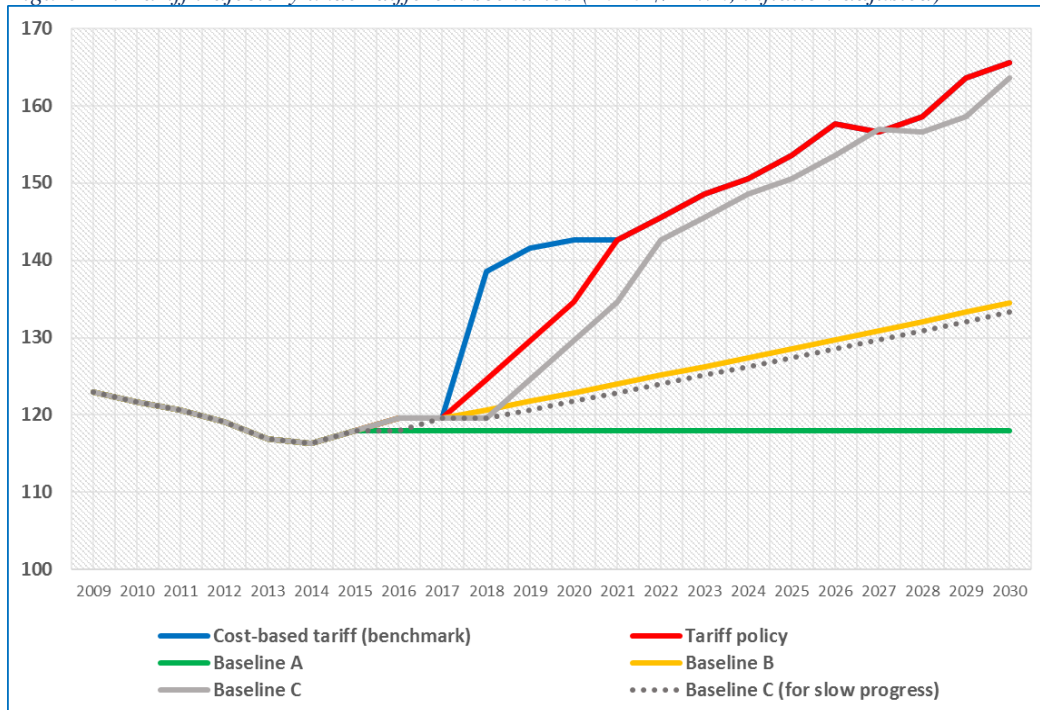
\*\*\* this is the same as Baseline 2016 scenario in Chapter 3.

117. The analysis shows that renewables (particularly utility-scale solar PV) will become relatively cost-competitive by 2023 and will be the technology of choice by 2026<sup>30</sup>. In other words, absent the renewable laws, solar PV would autonomously become the baseline technology 7-10 years after the start of the crediting period. To be conservative on baseline setting, baseline option B and C assume that this would have happened in 5 years without the renewable laws.

118. Note that option B, with respect to renewables, does not adopt strictly the definition of historical trends because this would be nearly the same as option A, and would not be sufficiently conservative (Figure 25). Furthermore, option B and C for renewables are intentionally designed to be identical. It is not appropriate to measure power sector capacity expansion performance on a yearly basis. Lead time for development of renewable projects ranges between 3-5 years, and deliberate operational decisions are made in response to system demand that typically cause advances/delays on plant development. In this context, the program proposes setting a 5-year lag on renewable capacity expansion as conservative baseline for the main Policy Scenario. The same logic applies when setting the same for the slow-progress scenario.

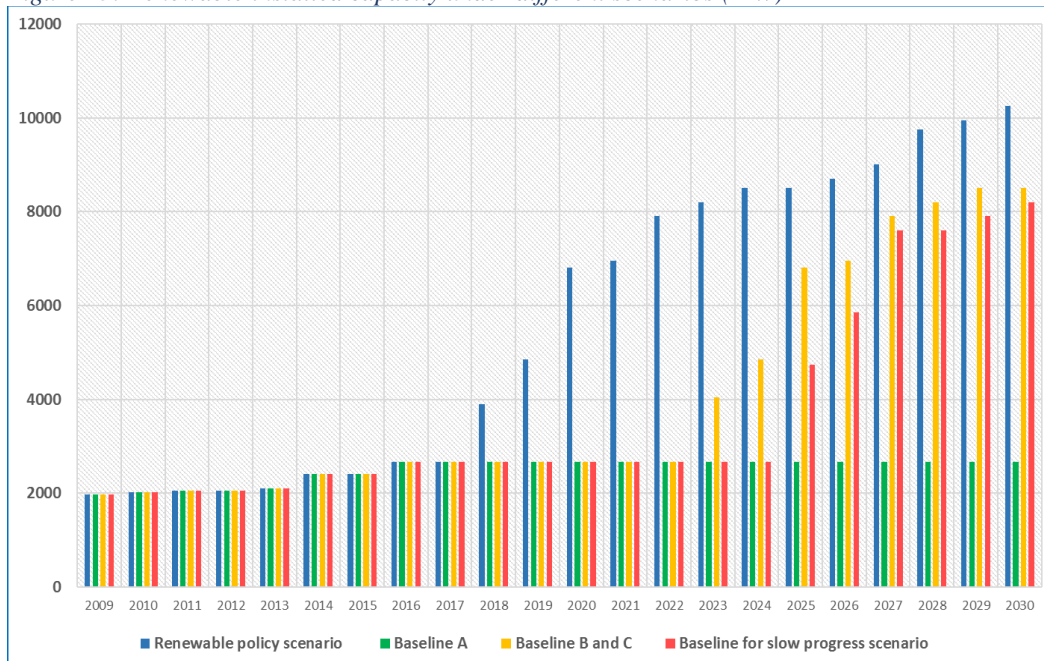
<sup>30</sup> The M-EPM tool suggests that the levelized cost of electricity generation of solar PV with necessary back-up will be around US\$ cents 7.96/kWh (2016\$) in 2026 – cheaper than other fossil fuel based generation technologies, hydro, and on-shore wind at that time. However, this calculation does not include all renewable grid integration costs. With other costs/barriers considered, it could have taken longer than 7-10 years for solar PV to be competitive. IRENA (2018) projected that Solar PV's LCOE will be around US\$ cents 6/kWh (2016\$) in 2020.

Figure 24: Tariff trajectory under different scenarios (2016 \$/MWh, inflation-adjusted)



Source: M-EPM model simulation

Figure 25: Renewable installed capacity under different scenarios (MW)



Source: M-EPM model simulation



## II. Emission reduction estimates

119. This section reports key findings from the M-EPM model analysis based on the scenarios and policy matrix discussed above. Table 10 shows annual emission reductions associated with selected scenarios. It is important to note that these emission reduction estimates take into account discounting (removing) emission reductions reported from all CDM projects in Morocco (equivalent to 1.4 million tons of CO<sub>2</sub> per year).

Table 10: emission reduction estimates under different scenarios (million tons of CO<sub>2</sub>)

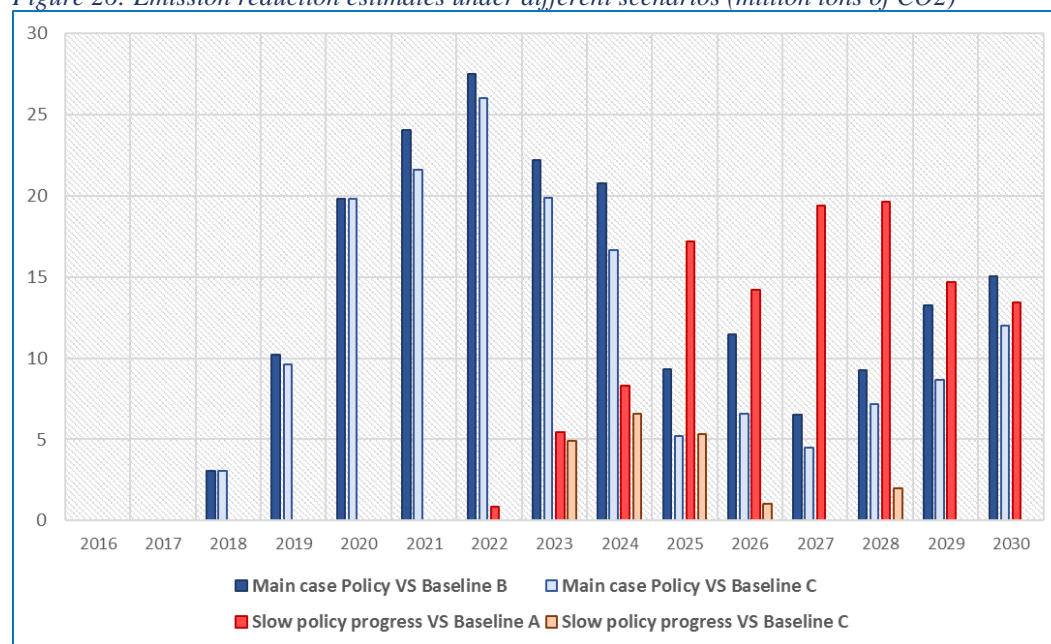
MtCO <sub>2</sub>	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2016-30	2016-22	2023-30
<b>Main policy case</b>																		
Baseline B	0.0	0.0	3.0	10.2	19.8	24.1	27.5	22.2	20.8	9.3	11.5	6.5	9.3	13.2	15.0	192.4	84.6	107.8
Baseline C	0.0	0.0	3.0	9.6	19.8	21.6	26.0	19.9	16.6	5.2	6.6	4.5	7.2	8.7	12.0	160.8	80.1	80.6
<b>Slow policy progress case</b>																		
Baseline A	0.0	0.0	0.0	0.0	0.0	0.0	0.8	5.5	8.3	17.2	14.2	19.4	19.6	14.7	13.4	113.1	0.8	112.3
Baseline C	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.9	6.6	5.3	1.0	0.0	2.0	0.0	0.0	19.8	0.0	19.8

All scenarios include discounting ER due to policy gap and CDM

Source: M-EPM model simulation

120. In the slow policy progress case, 4.9-6.3 million tons of CO<sub>2</sub> emission reduction cumulative over the 2016-2023 period is expected to be available depending on baseline options. Within the same crediting period, the emission reduction potential from the main Policy Scenario is estimated to be 100.0-106.8 million tons of CO<sub>2</sub> cumulatively, translated into 20-22 million tons of CO<sub>2</sub> per annum (Table 10 and Figure 26).

Figure 26: Emission reduction estimates under different scenarios (million tons of CO<sub>2</sub>)



Source: M-EPM model simulation



121. Compared to other climate/carbon finance instruments, this crediting program provides an opportunity to use international support to advance transformational policies that can deliver climate mitigation outcomes at a large-scale, and has a potential for replication in other countries. However, this kind of crediting program faces a number of challenges. These include, for example, policy reversal or discontinuity that results in much lower/no mitigation impacts, risk of not meeting NDC target from the perspective of the host country, double counting of emission reduction, as well as risk of carbon leakage. Therefore, the program should be carefully designed and piloted, and could be further scaled up once the pilot has been successfully carried out.

## Chapter 5: Conclusion

122. The findings from the *Morocco Energy Policy MRV* demonstrate that the country has made significant progress on the implementation of its National Energy Strategy. The effort has so far resulted in electricity demand saving, more renewable energy generation, and significant emission reduction. However, more needs to be done for the Moroccan electric system to achieve long-term financial, energy, and climate sustainability. Moving forward, continuation of energy subsidies and tariff reform, and acceleration of the incorporation of renewables are instrumental to the success of the National Energy Strategy and NDC. Building public support and leveraging private investment in renewable energy and supporting infrastructure will be critical to its success.

123. Building on the analyses in the previous parts of the report, this chapter suggests way forward in the following three areas.

124. Utilization of the M-EPM tool. Key recommendations include:

- Continue to use the M-EPM tool to track policy implementation, evaluate policy performance, and build the supporting technical capacity;
- Improve the M-EPM tool to enhance the quality of data inputs, framework, and the capability to assess a larger set of relevant policies;
- Institutionalize the M-EPM tool for systematic use and for different purposes such as access to climate finance/market, supporting NDC implementation, and reporting emissions as part of national MRV system and greenhouse gas inventory; and
- Coordinate MRV activity through a cross-agency institutional framework.

125. Further research and analytical work. Key recommendations include:

- Analyze the broader impacts (economic, fiscal, social, and distributional) of energy subsidies reform and rapid transition to renewable energy-dominant power system
- Understand the potential trade-offs between various design options of policy reform and different pathways toward achieving the 52% renewable capacity goal;
- Conduct in-depth study to develop grid integration strategy for large-scale renewable development and strategy for scaling up energy storage technologies; and
- Explore cross-boundary trades of renewable-based electricity generation between Morocco and Europe, as well as Africa.

126. Advancing on the implementation of policy and reform. Key recommendations include:

- Develop action plan to address critical barriers to continued electricity tariff reform and private sector investment in the renewable sector;
- Put in place additional complementary measures that are needed to support policy implementation, minimize/avoid adverse impacts, and build public support;
- Continue to improve investment climate and provide incentives for renewable energy investment to further leverage private sector finance; and
- Optimize the use of grant funding, concessional finance, and climate finance to make additional progress on energy subsidies reform and renewable energy scale-up.

## References

- Amegroud, T. 2015. Morocco's Power Sector Transition: Achievements and Potential. IAI Working Paper 15-5, February 2015.
- Arab Union of Electricity. Statistical Bulletins 2004-2016. Accessed 2017.
- Arefi, A., J. Olamaei, A. Yavartalab, and H. Keshtkar. 2012. "Loss reduction experiences in electric power distribution companies of Iran." *Energy Procedia* 14: 1392-1397.
- Bulletin Officiel, Cent-troisième année – N° 6288 8 kaada 1435.
- Cour des comptes, Royaume Du Maroc. 2014. *Le système de compensation au Maroc. Diagnostic et propositions de réforme. Royame du Maroc.*
- European Network of Transmission System Operators for Electricity. "Detailed Electricity Exchange (in GWh)." Accessed 2017.
- Federal Reserve Bank of Minneapolis. "Consumer Price Index, 1913- ." Accessed 2017.
- Hamane, T. 2016. A Snapshot of Morocco's Power Sector. 2016 Africa Energy Yearbook, Africa Energy Forum.
- International Energy Agency. 2014. Morocco 2014, Energy Policies Beyond IEA Countries. IEA, Paris.
- International Energy Agency. 2017. World Energy Outlook 2017. IEA. Paris.
- International Monetary Fund. 2017. If Not Now, When? Energy Price Reform in Arab Countries. Annual Meeting of Arab Ministers of Finance, April 2017.
- International Energy Agency. 2014. *Morocco 2014: Energy Policies Beyond IEA countries.*
- Kojima, M. 2016. Fossil Fuel Subsidy and Pricing Policies Recent Developing Country Experience, World Bank, Washington D.C.
- Labandeira, X., J. M. Labeaga, and X. López-Otero. 2017. "A meta-analysis on the price elasticity of energy demand." *Energy Policy* 102: 549-568.
- Laaboudi, J. (2014, January 1). L'électricité et l'eau seront plus chères au Maroc en 2014 . Retrieved February 11, 2015.
- Ministere de l'Economie et des Finances, Royaume Du Maroc. 2014. *Project de loi definances pour l'anne budgetaire 2014.*

Morocco – Nationally Determined Contribution under the UNFCCC.

OANDA Corporation. “Average Exchange Rates.” Accessed 2017.

Office National de l'Electricite et de l'Eau Potable. 2017. *Adequation Offre-Demande, Schéma Directeur Production 2017-2030*.

Office National de l'Electricite et de l'Eau Potable. 2017. *Rapport d'activités 2016*.

Office National de l'Electricite et de l'Eau Potable. 2016. *Rapport d'activités 2015*.

Office National de l'Electricite et de l'Eau Potable. 2015. *Rapport d'activités 2014*.

Office National de l'Electricite et de l'Eau Potable. 2014. *Rapport d'activités 2013*.

Office National de l'Electricite et de l'Eau Potable. 2013. *Rapport d'activités 2012*.

Office National de l'Electricite et de l'Eau Potable. 2012. *Rapport d'activités 2011*.

Office National de l'Electricite et de l'Eau Potable. 2011. *Rapport d'activités 2010*.

Office National de l'Electricite et de l'Eau Potable. 2010. *Rapport d'activités 2009*.

S. R. Schiller. 2017. “Estimating the cost of saving electricity through U.S. utility customer-funded energy efficiency programs.” *Energy Policy* 104: 1-12.

Suphachalasai S. and Rogers. J. 2017. Ex-post quantification of CO<sub>2</sub> emission impact of energy pricing in the power generation sector: a methodology, World Bank.

“The UDI World Electric Power Plants Database (WEPP).” Platts.com. Select data for Morocco was provided to Synapse Energy Economics by the World Bank on March 1, 2017.

United Nations. “UN Comtrade Database.” Accessed 2017. Available at: <https://comtrade.un.org/data/>

U.S. Energy Information Agency. *Annual Energy Outlook 2017*. Available at: <https://www.eia.gov/outlooks/aeo/>

U.S. Energy Information Agency. *Annual Energy Outlook 2016*. Available at: <https://www.eia.gov/outlooks/aeo/>

U.S. Energy Information Agency. *Annual Energy Outlook 2015*. Available at: <https://www.eia.gov/outlooks/aeo/>

U.S. Energy Information Agency. *Annual Energy Outlook 2014*. Available at: <https://www.eia.gov/outlooks/aeo/>

U.S. Energy Information Agency. *Annual Energy Outlook 2013*. Available at: <https://www.eia.gov/outlooks/aeo/>

U.S. Energy Information Agency. *Annual Energy Outlook 2012*. Available at: <https://www.eia.gov/outlooks/aeo/>

U.S. Energy Information Agency. *Annual Energy Outlook 2011*. Available at: <https://www.eia.gov/outlooks/aeo/>

U.S. Energy Information Agency. *Annual Energy Outlook 2010*. Available at: <https://www.eia.gov/outlooks/aeo/>

Verme, P. et al. 2014. Reforming Subsidies in Morocco. Economic Premise, World Bank, February 2014.

World Bank. Model for Electricity Technology Assessment (META) Model. Accessed 2017.

# Technical Appendix

## Appendix 1: Key Assumptions

127. This appendix describes the input assumptions, split into ex post assumptions (i.e., those assumptions addressing the historical modeled period from 2009 to 2016) and ex ante assumptions (i.e., those assumptions addressing the forecasted, future modeled period from 2017 to 2030).

Model assumptions held constant across all scenarios		
	<i>Ex post</i> assumptions (2009–2016)	<i>Ex ante</i> assumptions (2017–2030)
Electricity demand and sales		
Electricity Sales	Electricity generation and demand data from ONEE's annual report 2009–2016	5.6% average annual growth rate applied to all customer classes (residential, low- and high-voltage industry) starting with 2016
Off-Grid Demand		
Quantity (GWh)	Off-grid generation estimated at 5-10% of system sales or 2000 GWh	
Threshold price (\$/MWh)	The marginal clearing price estimated at 10% below the 2010 clearing price, which is equivalent to \$38/MWh	
Energy Efficiency <i>End-user measures</i>	No energy efficiency	Energy efficiency ramped up from 0–15% from 2020 to 2030
Imports and Exports		
Spain	Price and capacity data from the European Network of Transmission System Operators for Electricity (ENTSOE)	Price and capacity data held constant at 2016 levels
Algeria	Price and capacity data from Arab Union of Electricity	
Elasticity	Elasticity values broken out by customer class and held constant over the model time frame. Values are from a 2017 met-analysis study published in <i>Energy Policy</i>	
Costs		
Fuel Prices		
Coal	Coal commodity imports data from the UN Comtrade Database on weight and trade value <a href="https://comtrade.un.org/data/">https://comtrade.un.org/data/</a>	Values calculated by applying the 2016–2030 CAGR of fossil fuel import prices forecasted from the IEA WEO 2017 to the 2016 EU coal price
N2 Oil	Non-crude oil commodity imports data from the UN Comtrade Database	Values calculated by applying the 2016–2030 CAGR of fossil fuel import

Model assumptions held constant across all scenarios		
	<i>Ex post</i> assumptions (2009–2016)	<i>Ex ante</i> assumptions (2017–2030)
Special Oil	on weight and trade value <a href="https://comtrade.un.org/data/">https://comtrade.un.org/data/</a>	prices forecasted from the IEA WEO 2017 to the 2016 crude oil price
Natural gas	Natural gas commodity imports data from the UN Comtrade Database on weight and trade value <a href="https://comtrade.un.org/data/">https://comtrade.un.org/data/</a>	Values calculated by applying the 2016-2030 CAGR of fossil fuel import prices forecasted from the IEA WEO 2017 to the 2016 EU natural gas price
LNG	EIA.gov data on LNG prices	
<b>Fixed Costs</b> <i>Costs incurred regardless of generation for new and existing resources</i>	Costs are from the Model for Electricity Technology Assessment (META) model. They remain unchanged through the model period.	
<b>Variable Costs</b> <i>Marginal generation costs for new and existing resources</i>	Costs are based on data from the Model for Electricity Technology Assessment (META) model. They remain unchanged through the model period.	
<b>Renewable Energy Incentives</b>	Morocco does not currently have, nor is there any indication that it plans to develop, renewable energy incentives. The value is set at 0\$/MWh.	
<b>CO<sub>2</sub> Prices</b>	Morocco does not currently have, nor is there any indication that it plans to develop, a CO <sub>2</sub> price. The value is set at 0\$/MT CO <sub>2</sub> .	
System constraints		
<b>System Reserve Margin</b>	20% of annual peak demand	
<b>System Losses</b> <i>commercial and technical losses</i>	Losses are calculated based on Total Net Energy for Generation and Total Sales values from ONEE Annual Report	Losses are calculated by applying the average growth rate for future year losses to the prior years' losses starting with the 2016 value
Resource operating characteristics		
<b>Heat Rates</b> <i>Plant efficiency for new and existing resources</i>	Rates are calculated based on World Bank data on plant efficiency and plant fuel type via the META model. Rate is constant for the entire model period.	
<b>CO<sub>2</sub> Emissions Rates</b> <i>For new and existing resources</i>	Rates are provided by The World Bank from the META model. They remain unchanged throughout the model period.	
<b>Resource Availability</b> <i>% of time a resource is available during each time block</i>	Six time blocks are developed based on an hourly load curve for 2015. Availability values are calculated to align historical generation and capacity.	Availability held constant at 2016 levels
<b>New Availability</b>	Same as existing resource availability	
Import and Export Availability <i>% of time imports or exports are available during each time block</i>		
Spain	Availability values from ENTSOE	

Model assumptions held constant across all scenarios		
	<i>Ex post</i> assumptions (2009–2016)	<i>Ex ante</i> assumptions (2017–2030)
Algeria	Availability values from the Arab Union	Availability held constant at 2016 levels
<b>Must-Run Requirements</b> <i>Requirement that units run outside of economic dispatch</i>	Requirement calculated to calibrate retrospective model results with observed historic values	Requirement held constant at 2016 level
<b>Retirement Dates</b>	Retirement dates from the Platts dataset	
New resources		
Max available capacity	No limit	
Capital cost change	Values from the US's EIA <i>Annual Energy Outlook</i> cost and performance characteristics report	
Capital cost		
Capacity factor	Model for Electricity Technology Assessment (META) and ONEE	
Intermittent backups <i>NGGT capacity required to be added to backup dynamically built intermittent renewables</i>	Value selected based on level needed to produce logical build results (26 %)	

*Note: Assumptions held constant throughout all baseline and Policy Scenarios as well as the main policy sensitivities. Some of these assumptions were changed in supplemental sensitivities.*



## Appendix 2: Comparison with other power sector models

128. The M-EPM Model is a bottom-up power sector partial equilibrium model, designed to examine effects of policies such as price changes, subsidies, and emissions taxes on the operation of an existing electric system. While it offers a powerful, comprehensive framework for evaluation of electricity system impacts, users should be aware of its limitations. The following section describes the two main kinds of models (capacity planning and production cost) and how these differ from the M-EPM.<sup>31</sup>

### Capacity Planning Models

129. Capacity planning models (or capacity expansion models) are used to inform long- run planning decisions for generation and transmission. Capacity expansion models typically have high detail within a limited geographic scope that encompasses a utility service territory, regional, or national scale, frequently with sales or purchases outside the utility system represented by a simple market price profile. These models may have different levels of temporal resolution ranging from each modeled year dispatched based on an annual hourly load duration curve to each modeled year being composed of a representative subset of hours in a year (i.e. every 4th hour, three days per week, or peak/shoulder/trough) to reduce computational requirements. They then extrapolate results accordingly.

130. Utility- scale capacity expansion models are often designed to track individual power plants or generating units, where each individual resource or resource type has specific operational characteristics. Models are often designed to choose the optimal resource mix that meets demand using a least- cost objective function. These models can handle constraints at the generating unit level (e.g., minimum operation, outage schedule), system level (e.g., emissions cap), and build options (e.g., maximum number of power plants built for a specific technology). However, the constraints related to power plants (as opposed to the system) are frequently more generalized than in production cost models—entire classes of resources may share attributes or be dispatched together in order to reduce computation time.

131. Alternatively, some models may require some types of expansion and retirement decisions to be made exogenously.<sup>32</sup> In addition, some capacity expansion models are unable to endogenously retire power plants and require these decisions to be made outside of the model construct.

### Production Cost Models

132. Production cost models are regularly used by utilities and grid operators in day- to- day operations and decision- making. Utilities run these models to forecast revenues and costs, assist

---

<sup>31</sup> More information on types of electric sector models is available at <http://www.synapse-energy.com/sites/default/files/Guide-to-Clean-Power-Plan-Modeling-Tools.pdf>.

<sup>32</sup> For example, it is not uncommon to perform energy efficiency growth calculations outside of the model, and apply energy efficiency impacts as a modification to demand, rather than as a supply-side resource.

in fuel and contract procurement, develop market intelligence, and support strategic decisions. Utility operators use these models to match demand against available generation supply and determine the least- cost feasible operating schedule for power generating units.

133. Production cost models are driven by economics (i.e., the variable cost of production) and usually account for the operational limitations of power plants such as maximum ramp rates, minimum up and down times, and minimum stable output of the generators. In addition to power plant operational constraints, these models operate within other system requirements and constraints, such as minimum reserve capacity requirements, thermal transmission limitations along specific transmission lines or aggregate “paths,” and emissions costs. These models do not optimize power plant additions or retirements; instead, changes in the electric system portfolio must be manually altered (i.e., through the use of capacity planning models).

134. Note that these are broad generalizations. Many of today’s electric sector models are capable of running in capacity planning-mode or in production cost-mode simultaneously, or are capable of running in both modes and performing iterations wherein information is passed from one module to another.

#### Policy Scenario Models

135. The M-EPM Model is a policy scenario model. While it is neither a long-run capacity planning model nor is it a production cost model, it contains aspects of both. It does not identify optimal future changes in generation or transmission capacity. However, it can accept user-specified changes in generation and transmission, in a counterfactual or future scenario. The M-EPM’s dispatch algorithm is not capable of planning daily and hourly operations, but the subannual and annual results generated by the model can be used to inform decision making that can then be confirmed (if necessary) using more complex or time-intensive models.

136. More generally, the M-EPM simplifies the algorithms normally used in capacity planning and production cost models in order to achieve a balance between complexity and usability. It is an Excel tool that can be used by virtually anyone with a modern computer and basic spreadsheet training and does not require years of training or massive computational power in order to produce a useful information.