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Morocco's Decarbonization Pathway - Part III: The Costs and Benefits of the Energy Transition[1]

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I. Introduction

Morocco's significant renewable energy resources offer an unprecedented opportunity to anchor the country's economic and political choices in the energy transition, and to turn the transition into an essential lever for economic development. This is all the more relevant as the costs of renewable energies have dropped over the past 10 years[2], and now offer strong potential, not only for creating green jobs but for ensuring a dynamic and resilient economic growth as well. In 2020, nearly 20% of Morocco's electricity production was provided by renewable energy resources (RES), while the installed capacity of RES was around 36%. Morocco's ambition is to reach a target of 52% of installed RES capacity by 2030, reinforcing the country's commitment to energy transition and decarbonization. However, this transition must also be sustainable from a socio-economic point of view and must ensure that 'no one is left behind'. It is, therefore, necessary to quantify the costs and benefits of the energy transition, in order to identify the right policy approaches and mitigate the potential negative effects of the transition on growth, particularly in terms of industrial competitiveness, employment, and citizens' purchasing power.

Part II[3] of the Morocco's Decarbonization Pathway Policy Brief series presented an update of the decarbonization scenarios. It revealed that in the Increased Ambition and Green Development scenarios, Morocco would achieve higher decarbonization targets than the current policy. Decarbonization targets will be achieved mainly thanks to extensive electrification of the final sectors and increasing RES in the generation mix. More specifically, the transportation, power generation, and residential sectors will be crucial to the decarbonization of Morocco's energy consumption. This third Policy Brief in the series presents the results of a cost-benefit analysis, performed to identify the technological levers of the energy transition in Morocco, and to estimate the global economic benefit of modeled scenarios presented in Part II, both at national and sectoral levels.

1.The technical component of the study pertaining to modeling was carried out by AFRY, under the strategic and policy direction of the Policy Center for the New South and Enel Green Power Morocco. This study was conducted in 2020, prior to the release, in June 2021, of Morocco's new Nationally Determined Contribution. Therefore, the NDCs in this study refer to those of 2016.

2. During the COVID-19 pandemic, raw material prices have increased because of the economic disruption to supply chains, impacting cross-cutting sector activities.

3. The Decarbonization Pathway for Morocco: Updated Decarbonization Scenarios, Part II.

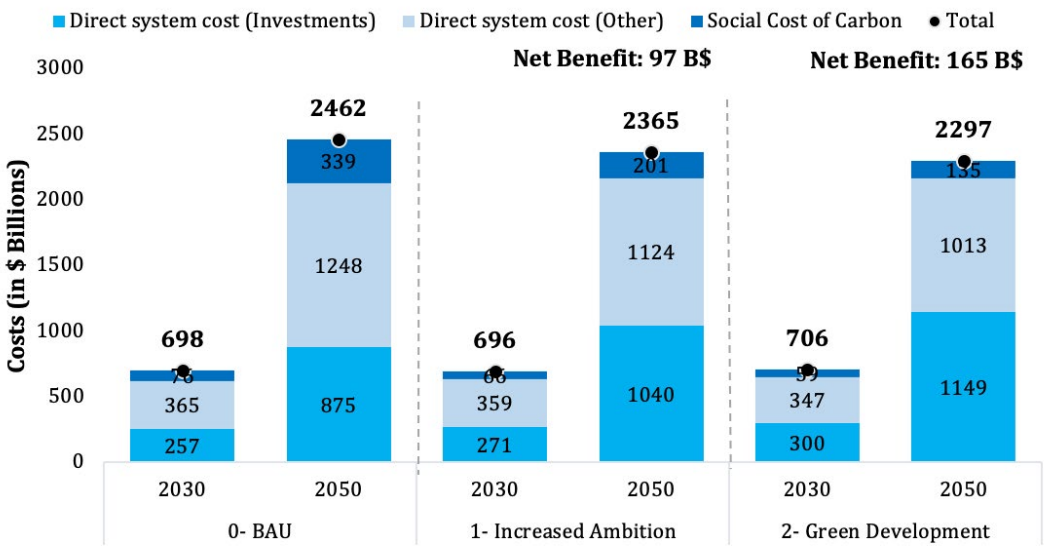
The full economic cost of the decarbonization scenarios, over the 2020-2050 period, is calculated as the sum of direct system costs and social costs of carbon. Direct system costs include system expenditures (CAPEX[4], OPEX[5], commodity costs, and taxes), including infrastructure cost, and are calculated based on a levelized cost of electricity (LCOE)[6] analysis for each technology. The social cost of carbon represents the implicit cost of carbon emissions, factoring in multiple impacts on the system, including social and health costs. The social cost of carbon adopted in this study is based on the 2016 U.S. Environmental Protection Agency report[7] adjusted to 2019 monetary values. It has also been re-proportioned to a discount rate of 2.35%, in line with direct cost actualization. Generally speaking, the scenario with the lowest full economic cost produces the greatest global economic benefits to the system.

II. Costs and Benefits of the Energy Transition in Morocco

1. At National Level

Decarbonization is a lengthy process, which will require significant investment to deploy renewable energy, increase energy efficiency, and electrify end-use sectors. Overall economic benefits will be felt only in the long run. While the full economic cost for the aggregated sectors of the Moroccan economy shows little difference between the three scenarios in 2030, the cost increases significantly in 2050 (Figure 1). The decomposition of the full economic cost indicates that the more ambitious decarbonization goals are, the higher the investment needs will be, which are captured in the direct system costs. On the flip side, other direct system costs, apart from investments, as well as the social cost of carbon, gradually decrease as decarbonization increases. As a result, the full economic cost in the decarbonization scenarios is lower than in the BAU scenario, generating a net economic benefit relative to business-as-usual of $97 billion and $165 billion in the Increased Ambition and Green Development scenarios respectively.

Figure 1: Aggregated Results of the Cost-Benefit Analysis for the Moroccan Economy in Cumulated $ Billions

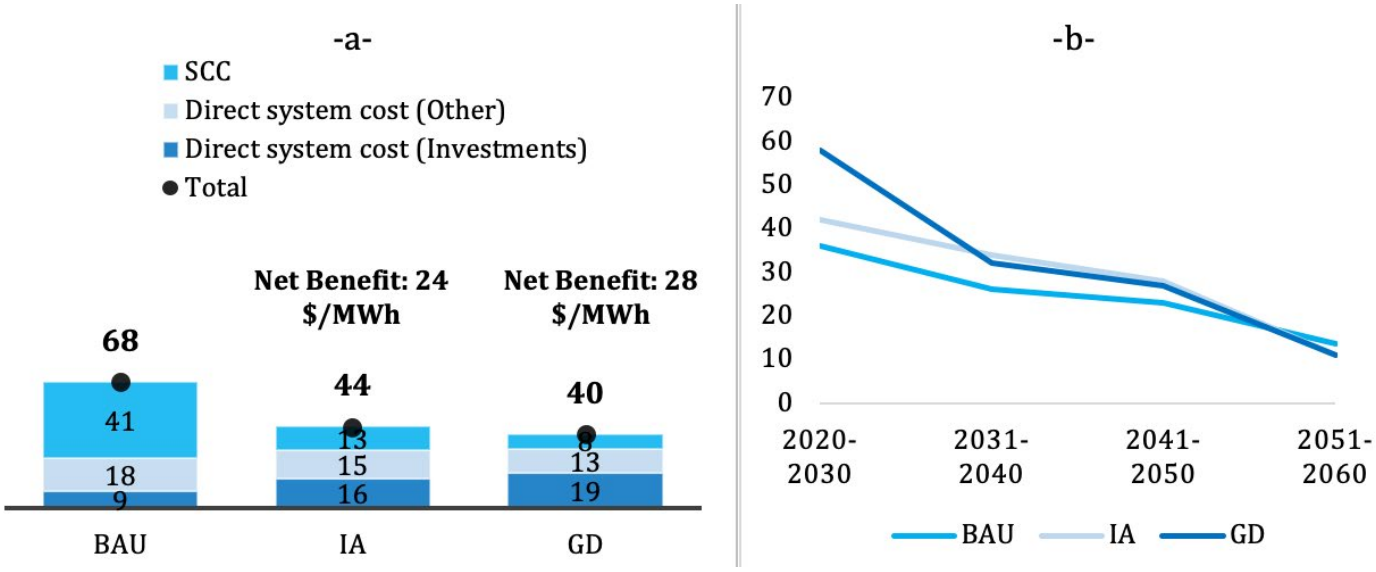


Source: Authors calculations[8]. Notes: The net benefits shown in the graph are calculated for 2050 and are relative to the BAU. Discount rate of 2.35% (yield of 10Y Moroccan Bond). Social cost of carbon-based on US benchmark from 77$/tonCO2 to 124 $/tonCO2 for the considered period. For transport, calculations refer to road vehicles; for Agriculture, calculations refer to livestock, heating and irrigation. Direct system cost includes investment in development of hydrogen production sites, grid infrastructure, and power sector costs.

4. Capital expenditure is money spent on buying or improving fixed assets (land, buildings, equipment etc.).
5. Operating expenses refer to ongoing operational costs, required for the day-to-day functioning, and not accounted for as either fixed or capital expenditure.
6. The levelized cost of electricity is a measure of the average net present cost of electricity generation for a generating plant over its lifetime. It is used for investment planning and to compare different methods of electricity generation on a consistent basis.
7. Oudejans, L, 2017.
8. For the remainder of the document, refers to AFRY under the policy orientations of the Policy Center for the New South and Enel Green Power Morocco.

Regarding the power sector, the full economic cost will be significantly reduced compared to business-as-usual, leading to a net benefit of $24/MWh and $28/MWh on average during the 2020-2050 period, in the Increased Ambition and Green Development scenarios respectively (Figure 2). This will be achieved through a lower social cost of carbon and other direct system costs in both decarbonization scenarios compared to BAU, more than offseting the increase in direct system costs. The latter is mainly due to additional investments in renewable energy capacity in order to replace coal, and to additional battery energy storage (BESS) and gas storage to ensure system security and flexibility on the grid. The evolution of direct system costs (investment and other) over time between 2020 and 2060 indicates that the stabilization of electricity demand in the long-term will likely result in lower direct system costs for electricity generated in the decarbonized scenarios.

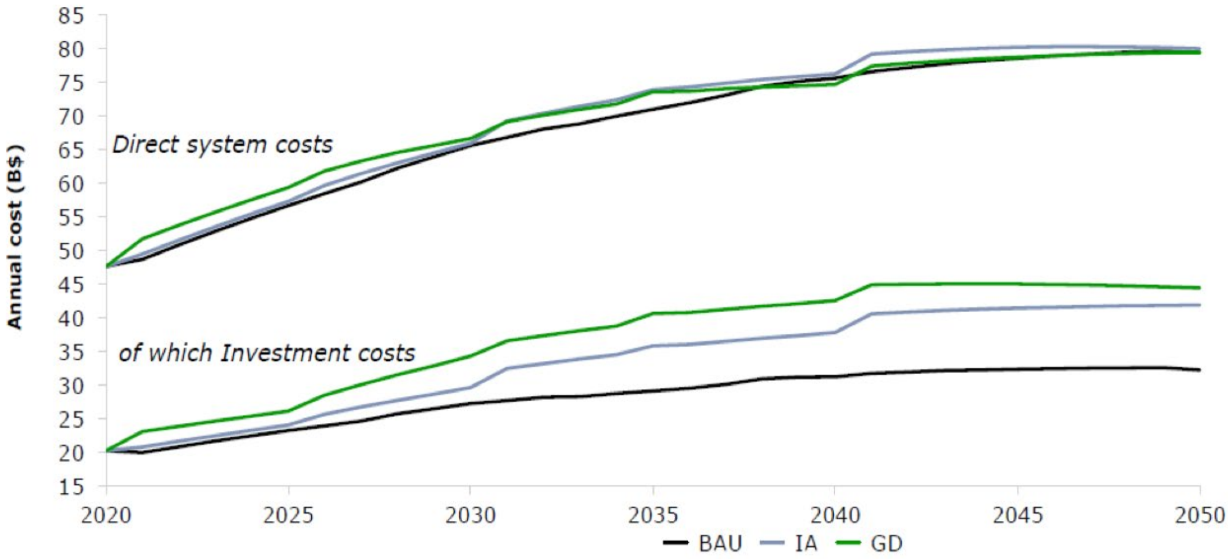
Figure 2: (a) Aggregated Full Economic Cost of Electricity Produced, 2020-2050 Average (in$/MWh);
(b) Direct System Cost Evolution of the Power Sector in the Green Development Scenario ($/MWh)



Source: Authors calculations. Note: IA: Increased Ambition. GD: Green Development. SCC: Social Cost of Carbon.

At the national level, the analysis of the evolution of direct system costs from 2020 to 2050 indicates that, overall, the three scenarios would involve similar direct system costs. But investment is needed to sustain decarbonization, especially for the 2031-2050 period (Figure 3). The high investment costs are mainly driven by the transport sector, though it provides for a reduction in the direct system costs after 2030. Beyond 2050, direct system costs under decarbonized scenarios are expected to be lower than the BAU scenario, thanks to a reduction in variable costs led by investments in new technologies.

Figure 3: Aggregated Direct System Costs and Investment Costs ($ Billions)



Source: Authors calculations. Note: Direct system costs include CAPEX, OPEX, commodity, and taxes actualized with a 2.35% rate (all sectors including power gen, grid costs, and H2 prod. sites). Investment costs include CAPEX actualized with a 2.35% rate (all sectors including power gen, grid costs, and H2 prod. sites).

2. At Sectoral Level

a. Transport sector

Decarbonizing the transport sector is a decisive issue in the battle against climate change, given its contribution to greenhouse gas emissions and its dependence on fossil fuels. Achieving this will not be without challenges.

The levelized cost of electricity (LCOE) calculation, expressed in dollars per year, reveals the following findings:

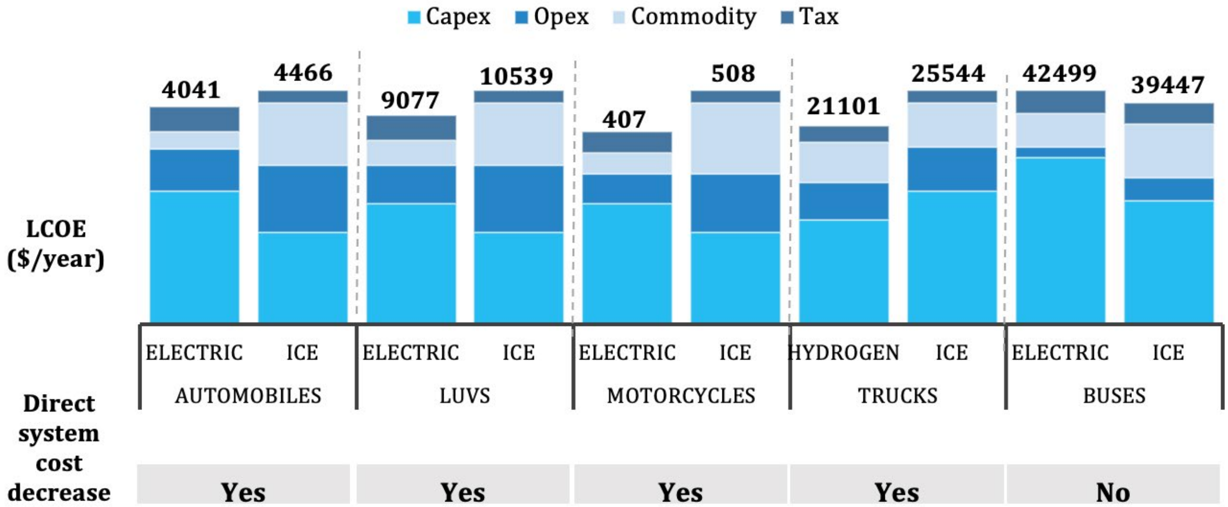
- Electric buses (e-buses) are the only technology that experiences an increase in direct system cost over the 2020-2050 period, making diesel buses more advantageous over the period considered thanks to a lower LCOE, if no incentives for electric technology are provided (Figure 4). The difficulties faced by e-buses in the LCOE analysis lie in the high CAPEX and corresponding taxes. Therefore, reducing these costs can align technologies' LCOEs[9].

- Electric automobiles, light-utility vehicles (LUVs), motorcycles, and trucks all exhibit a decrease in direct system cost as well as a lower total LCOE than the internal combustion engine (ICE) counterparts. This occurs despite higher capital expenditure (CAPEX) and shorter lifetimes for electric technologies, which are offset by lower commodity costs and operating expenditures (OPEX)[10]. Hydrogen trucks are also economically feasible, mainly driven by lower CAPEX compared to diesel trucks.

9. The CAPEX for electric technology starts at a high of $520,000 in 2020, compared to $236,000 for diesel buses. An average CAPEX of $350,000 was used in the study for electric buses to account for the lower cost of BESS technology for the period 2025-2050. In addition, reduced average fuel consumption of 1.1kWh/km (currently 1.5kWh/km) was considered to include the efficiency improvement. The replacement of the battery pack was considered to increase the lifetime of the electric bus from 300,000km to 600,000km (compared to 400,000km for diesel buses). For the replacement of the BESS pack, a decrease in the cost of the technology was considered (average battery cost for the period 2040-2050).

10. The analysis also considers the decreasing cost of electric technology.

Figure 4: LCOE Analysis for the Transport Sector, 2025-2050



Source: Authors calculations. Tax refers to VAT. ICE: internal combustion engine.

Before we come to the results of the cost-benefit analysis, let us recap the modeled scenario assumptions presented in Part II. The assumptions underlying the three modeled scenarios for the transport sector are based on the 41st action of Morocco's nationally determined commitment (NDC)[11] and the following energy efficiency provisions: (i) Mandating the retirement of 7,500 obsolete and fuel-inefficient goods vehicles; (ii) promoting the withdrawal of 1,700 obsolete public passenger transport vehicles, (ii) removing 250,000 vehicles over 20 years in 2025, and (iii) lowering the emission level thresholds. The BAU scenario assumes that diesel accounts for 20% of the energy consumed in the transport sector by 2050. Neither electrification nor hydrogen technology measures are considered in this scenario. The Increased Ambition and the Green Development scenarios call for the complete elimination of diesel by 2050, with various transport electrification targets[12].

The analysis of the evolution of the direct system costs of the aggregated transport sector during the 2020-2050 period indicates the following (Figure 5):

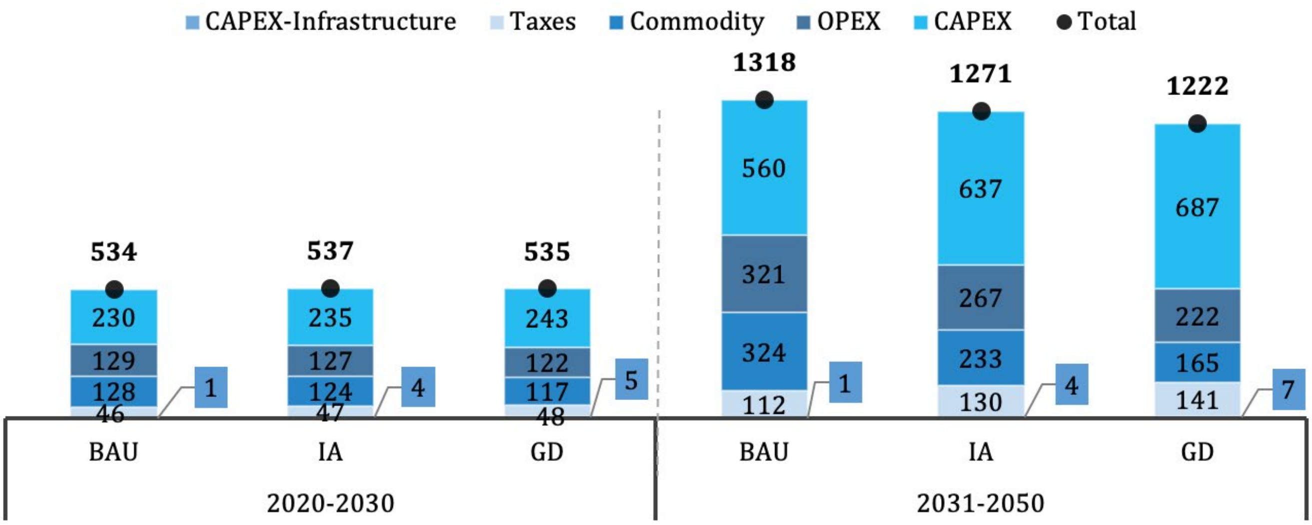
- Transport requires additional investment to replace the current polluting fleet. The Increased Ambition scenario will require CAPEX in the order of $5 billion in the medium term (2020-2030) and $77 billion in the longer term (2031-2050) compared to BAU. The Green Development scenario calls for much higher CAPEX due to the higher penetration of electric vehicles, estimated at $13 billion in the medium term and $127 billion in the longer term.

- In the longer term, the total direct system cost is lower in both decarbonized scenarios since the lower costs of commodity and OPEX for low-carbon vehicles compensate for the higher investments needed. The calculated commodity and OPEX savings compared to the BAU scenario reach $145 billion in the longer term (2031-2050) for the Increased Ambition scenario, and $258 billion in the longer term for the Green Development scenario. In the short term, the total direct system cost in the decarbonization scenarios is slightly higher.

11. Upgrade utility vehicles of 20 years and older to cut their fuel consumption, between 2025 and 2030.

12. In the Increased Ambition scenario, (i) the share of electric vehicles in the total vehicles fleet reaches 80% in urban areas, and 30% in rural areas, (ii) full electrification of buses and railways is achieved by 2030 and 2040 respectively, and (iii) the share of hydrogen trucks reaches 50% by 2050. In the Green Development scenario, (i) the share of electric vehicles in the total vehicles fleet reaches 100% in urban areas and 70% in rural areas, (ii) full electrification of buses and railways is achieved by 2030 and 2040 respectively, and (iii) the share of hydrogen trucks reaches 85% by 2050.

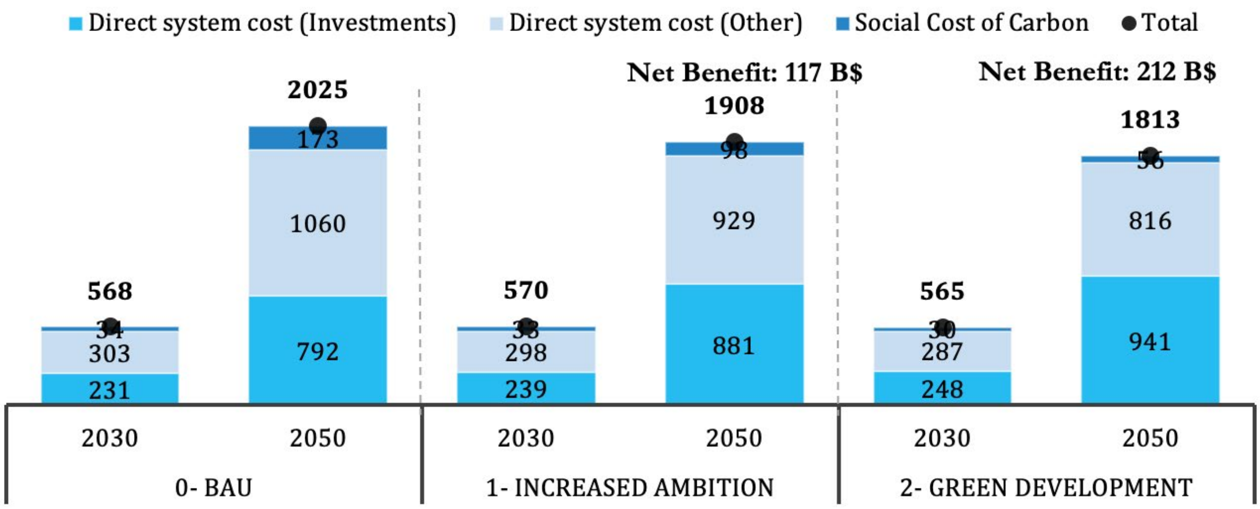
Figure 5: Evolution of Direct System Costs and Investment Costs ($ Billions)



Source: Authors calculations. Note: IA: Increased Ambition. GD: Green Development.

The full economic cost of the transport-sector transition indicates that decarbonization is cost effective in the long term (Figure 6). Although investment increases in the Increased Ambition and Green Development scenarios, because of higher spending on electric vehicle deployment and charging infrastructure construction, these expenditures will be offset by the benefits generated from the reduction of the social cost of carbon and lower commodity and operating costs. This will thus lead to net benefits of $117 billion and $212 billion by 2050, under the Increased Ambition and Green Development scenarios respectively.

Figure 6: Aggregated Full Economic Cost for Transport (Direct System Cost + Social Cost of Carbon) in Cumulated $ Billions



Source: Authors calculations.

b. Residential Sector

Morocco's residential energy consumption is quite unique, as it depends on a liquefied petroleum gas (LPG), called butane, which is used for cooking, space, and water heating, and it accounts for 63% of Morocco's residential energy consumption[13], compared to an average of 13% for most International Energy Agency countries.

The LCOE analysis starts by financially evaluating two configurations to meet the heating and cooling, water heating, and cooking energy needs of one household:

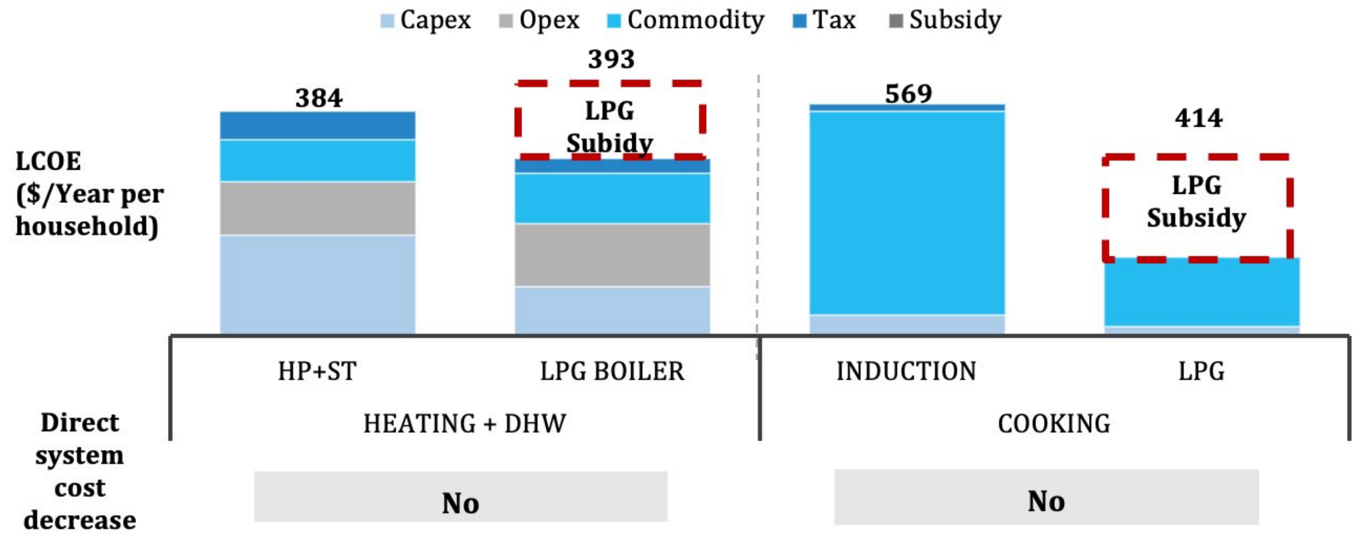
- A fossil-fuel configuration: This applies to a business-as-usual residential energy system and is composed of a single LPG boiler to meet both heating and domestic water heating (DWH) demand, an LPG stove to meet cooking demand, and a heating, ventilation, and air-conditioning (HVAC) system to provide air conditioning.

- A low-carbon configuration: This configuration provides two different technologies for heating and DWH, namely heat pumps (HP)[14] and solar thermodynamic (ST), while cooking is met by induction cooktops.

The LCOE calculation (Figure 7), expressed in dollars per household per year, gave the following results:

- Heating and DWH: Heat pumps and solar thermodynamic systems used for heating and DWH in the low carbon configuration, although calling for higher CAPEX investments and more taxes, lead to important OPEX, commodity, and subsidy savings, making this option overall cheaper compared to the fossil-fuel configuration pre-subsidy. However, once LPG subsidies, which allow end-consumers in Morocco to access LPG at one of the lowest prices in the world, are injected, these savings are counteracted. Overall, lower CAPEX makes LPG boilers $78/year/household cheaper—post-subsidy—than the HP+ST configuration.
- Cooking: The low price of LPG stoves compared to induction cookers make the fossil configuration for cooking cheaper by $362/year/household post-subsidy.

Figure 7: LCOE Analysis of Two Configurations to Meet Energy Needs of One Household



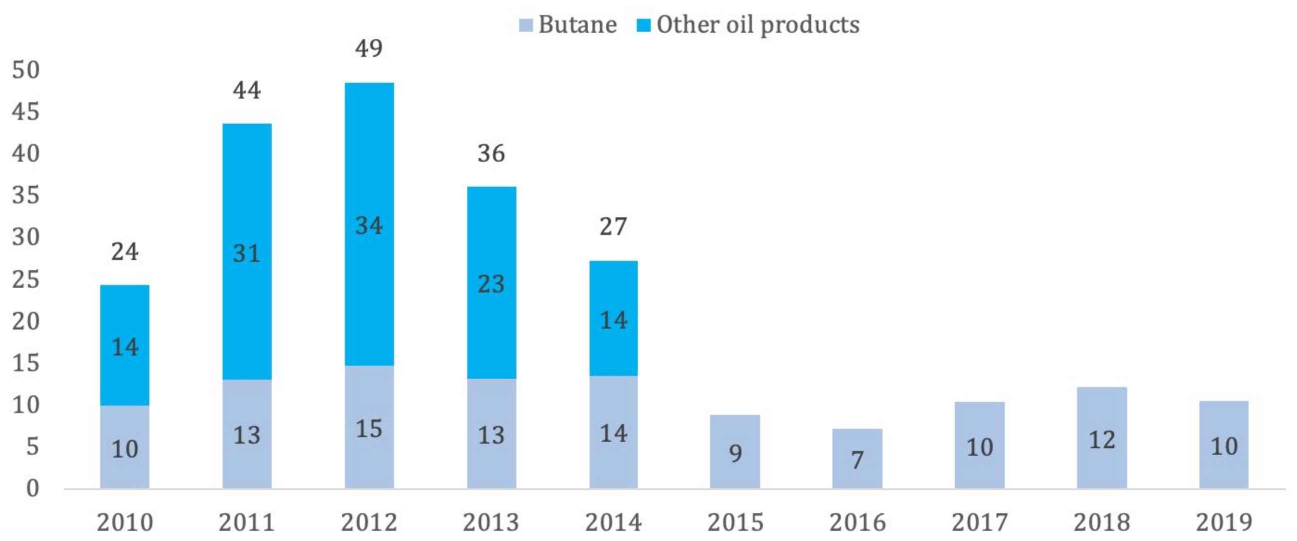
Source: Authors' calculations. Note: Air-to-water technology used for residential heat pumps. Tax refers to VAT on purchase.

13. The other main energy demands in the residential sector are for refrigeration, lighting and electric appliances. Space heating and air conditioning represent a very small share of total residential energy consumption (IEA, 2020).

14. Air to water technology

The issue of the LPG subsidy is sensitive. Although Morocco was one of the pioneers among developing countries in successfully reforming fossil-fuel subsidies to help reduce the budget deficit and mitigate balance of payments risks, butane is still excluded because of social considerations, which puts massive pressure on the state budget since the supply of the national market with LPG is done entirely through direct importation[15]. The subsidies are in the billions of dollars annually and fluctuate from year to year depending on international market prices[16] (Figure 8).

Figure 8: Moroccan Subsidies for Oil Products from 2010 to 2019 (in Billions of MAD)



Source: Ministry of Economy and Finance[17].

At the household level, it seems that the fossil-fuel configuration is cheaper than the low-carbon configuration. In light of these findings, it remains highly questionable whether residential sector decarbonization is economically justified at the national level. To settle this issue, let us recall our modeled scenario assumptions.

The residential sector's decarbonization scenarios assumptions are based on: (i) the energy-efficiency strategy[18]; (ii) the 29th[19], 30th[20] , and 31st[21] NDC actions, and (iii) on the program for rooftop photovoltaic (PV). The BAU scenario does not implement these strategies. Under the Increased Ambition scenario, about 40% of the energy consumption for domestic hot water comes from solar thermal systems (70% under the Green Development scenario) and 50% of the energy consumption for lighting is from LED bulbs (70% under the Green Development scenario). Under both the Increased Ambition and the Green Development scenarios, 2.5 GW of low voltage rooftop PV is installed by 2030 and 4.6 GW by 2050 through the MEME program, and further electrification measures (heat pumps and induction cookers) are considered.

15. The main LPG suppliers to Morocco are the United States, followed by the EU and Algeria.

16. Commercial butane is packaged in bottles of 3kg, 6kg and 12kg, while propane is marketed mainly in bulk (up to 90%) and the rest is distributed in bottles of 34kg.

17. The Ministry of Finance compensation reports of 2020 and 2021.

18. Promote solar water heaters and impose obligation of solar water heaters for new construction.

19. 1.7 million solar panels by 2030.

20. 14.7 million low-energy light bulbs by 2030.

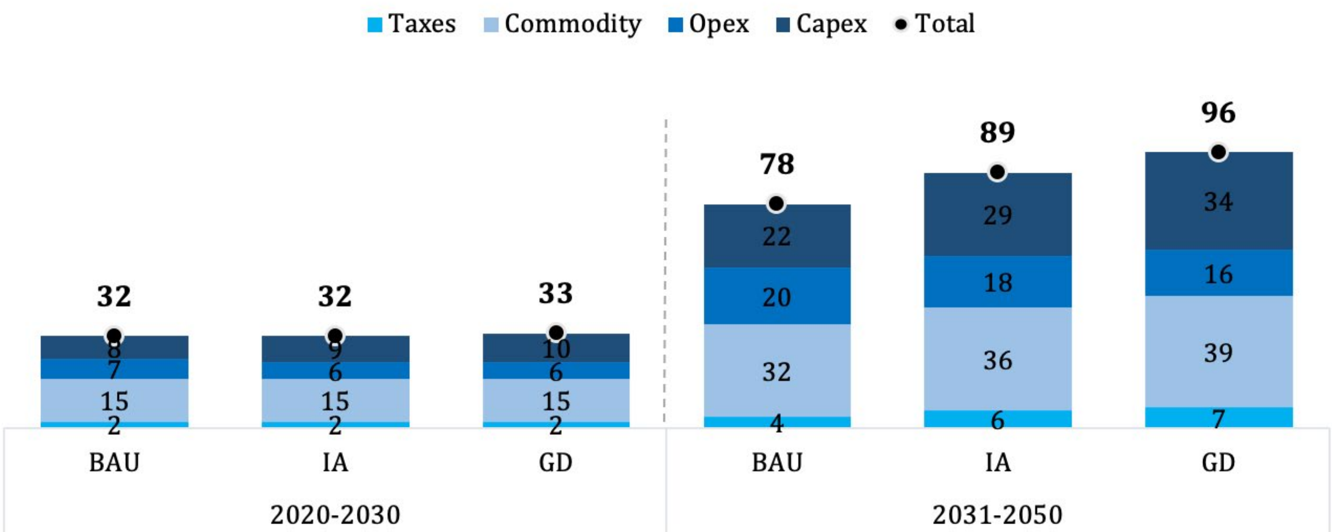
21. 1GW of low-voltage PV solar by 2030.

The analysis showed that total direct system costs (Figure 9) are higher in both the Increased Ambition and Green Development scenarios, for two reasons:

- CAPEX: Initial capital costs of electric appliances, especially heat pumps and solar thermal systems, are higher than for LPG stoves and boilers. Investments vary depending on the level of penetration of the low-carbon configuration. The Increased Ambition scenario will require additional investments in the order of $1 billion from 2020-2030, and $7 billion from 2031-2050, while the Green Development scenario will require much higher investments in the order of $2 billion in the medium term (2020-2030) and $12 billion in the long term (2031-2050).

- Commodity costs: The electrification of real estate will also be costlier commodity-wise, especially with the penetration of induction cookers, as LPG benefits from subsidies. From 2031 to 2050, commodities will increase by $4 billion in the Increased Ambition scenario and $7 billion in the Green Development scenario.

Figure 9: Direct System Costs and Investment Costs of Residential Sector Decarbonization

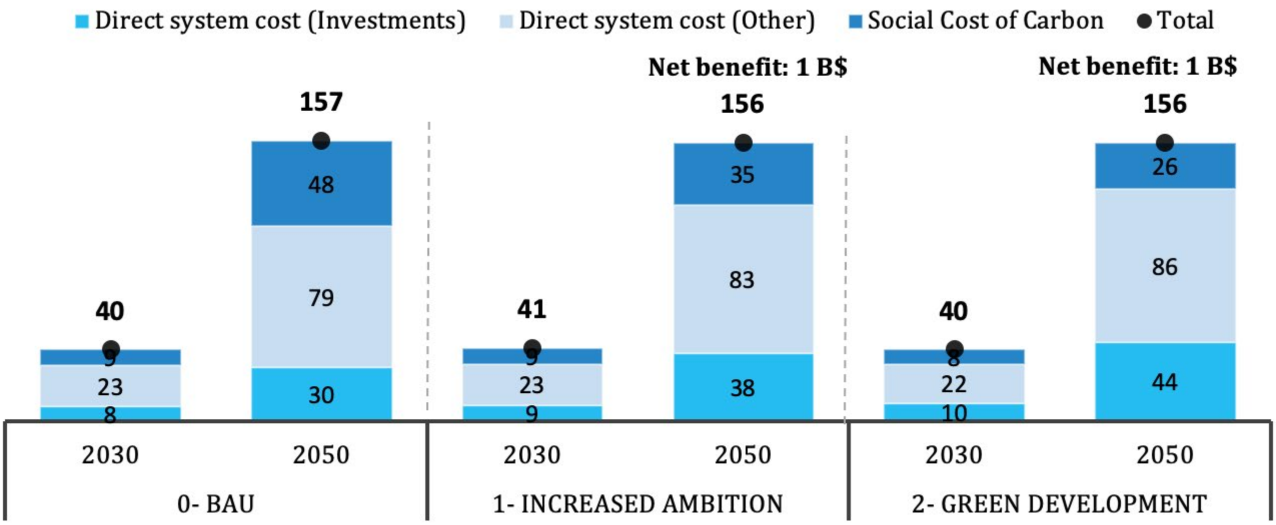


Source: Authors' calculations.

The full economic cost analysis of the residential sector transition (Figure 10) showed that the determining factor rendering this transition economically viable is the incurred social benefits derived in the long run from curtailing carbon emissions (by 2050)[22], as the direct system costs are clearly higher in the two decarbonization scenarios in net present value. Overall, savings in both low-carbon scenarios will be in the order of $1 billion by 2050.

22. The Social Cost of Carbon (SCC) in this brief is based on the U.S. benchmark from 77$/tonCO2 to 124 $/tonCO2 for the considered period.

Figure 10: Full Economic Cost of Residential Sector Transition (Direct System Cost + Social Cost of Carbon)



Source: Author's calculations.

c. Agricultural sector

The agricultural sector is a pillar of the Moroccan economy. As its value-added increases, its energy consumption rises, of which 74% is met by fossil fuels (mostly diesel and LPG)[23]. In the agricultural sector, energy is mostly required to power machinery, irrigation pumps, and livestock heating. As outlined in the previous policy brief, our decarbonized model only focuses on the two latter elements, by introducing new electrification measures such as electric pumps for irrigation and heat pumps for livestock heating.

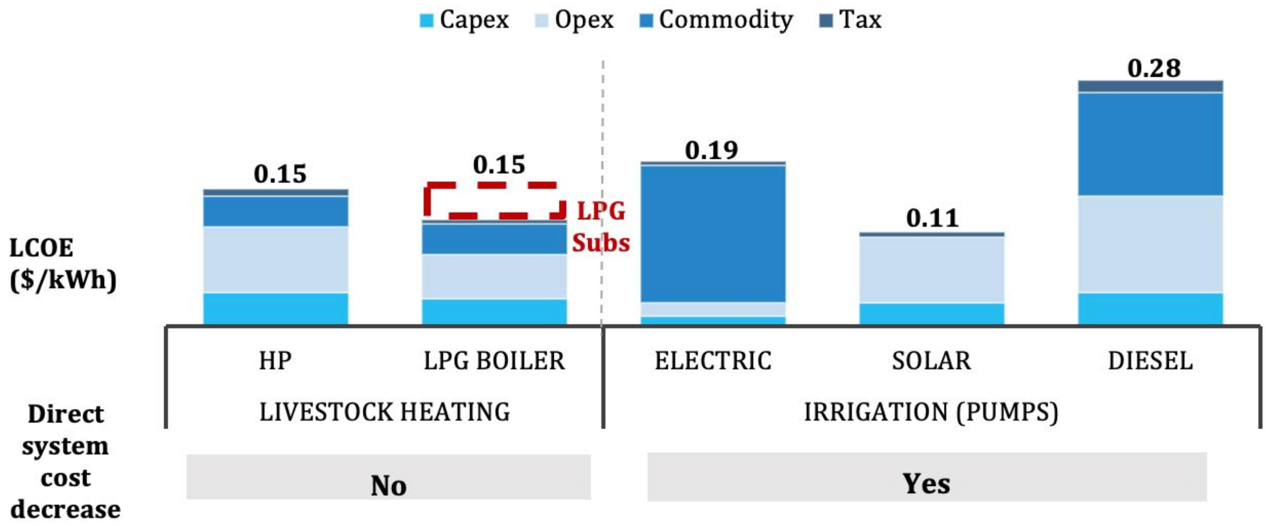
In terms of technology choice, the LCOE analysis of electric versus fossil fuel-based livestock heating and irrigation pumps gave the following results (Figure 11):

- Livestock heating: Lower CAPEX and OPEX[24] costs, and subsidies that greatly reduce commodity expenditures for LPG boilers, mean that a transition to HPs[25] will be slightly more costly, as the usual LPG boilers are $0.03/kWh cheaper.

- Irrigation: Lower CAPEX and maintenance costs for electric pumps compared to diesel pumps make electric technology convenient; moreover, solar pumps are even more advantageous since the operating and initial capital costs of PV panels are more than compensated for by the avoided electricity costs and the higher investment requirements for a diesel pump. The savings will be in the order of $0.83/kWh and $0.17/kWh respectively for electric and solar pumps compared to diesel.

23. IEA database, 2020, 2020a.
24. OPEX costs of livestock heat pumps since more appliances are needed compared to a LPG boiler.
25. OPEX costs of livestock heat pumps since more appliances are needed compared to a LPG boiler.

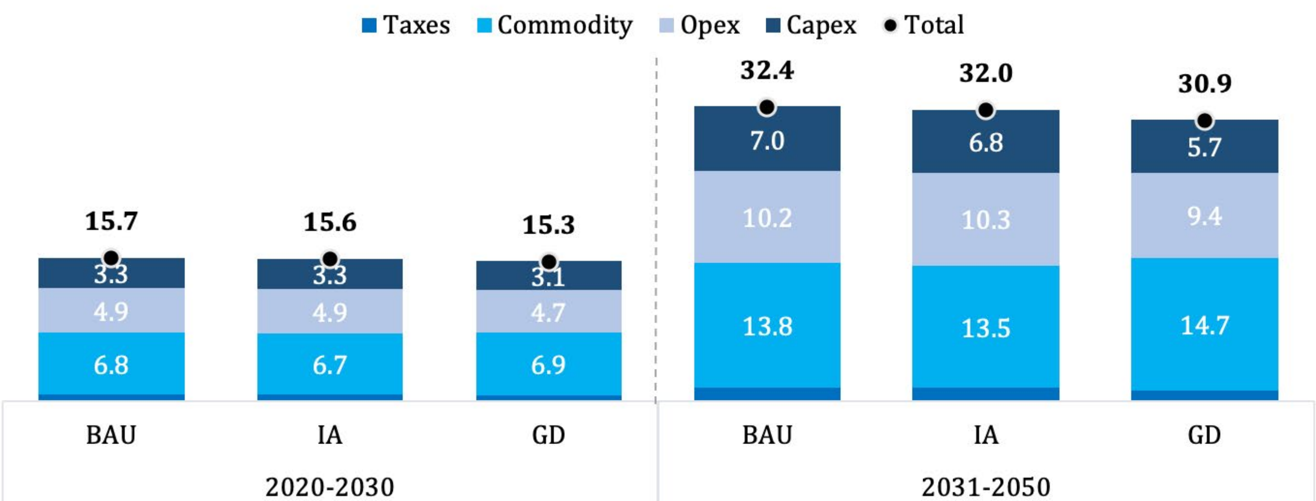
Figure 11: LCOE Analysis (Technology Choice)



Source: Authors' calculations. Note: Tax refers to VAT on purchase.

If we extrapolate nationally (Figure 12), the above-mentioned transition in the agricultural sector, both in the Increased Ambition and Green Development scenarios, is justified in terms of initial capital costs and full direct system costs. Closely examining those investments reveals that CAPEX savings are zero in the medium term (2020-2030) and reach $0.2 billion in the long term (2031-2050) for the Increased Ambition scenario, and $0.2 billion in the medium term and $1.3 billion in the longer term for the Green Development scenario. Direct system savings are in the order of $0.1 billion and $0.4 billion in the medium term, and $0.4 billion and $1.5 billion in the longer term for the Increased Ambition and Green Development scenarios respectively.

Figure 12: Direct System and Investment Savings on a National Level

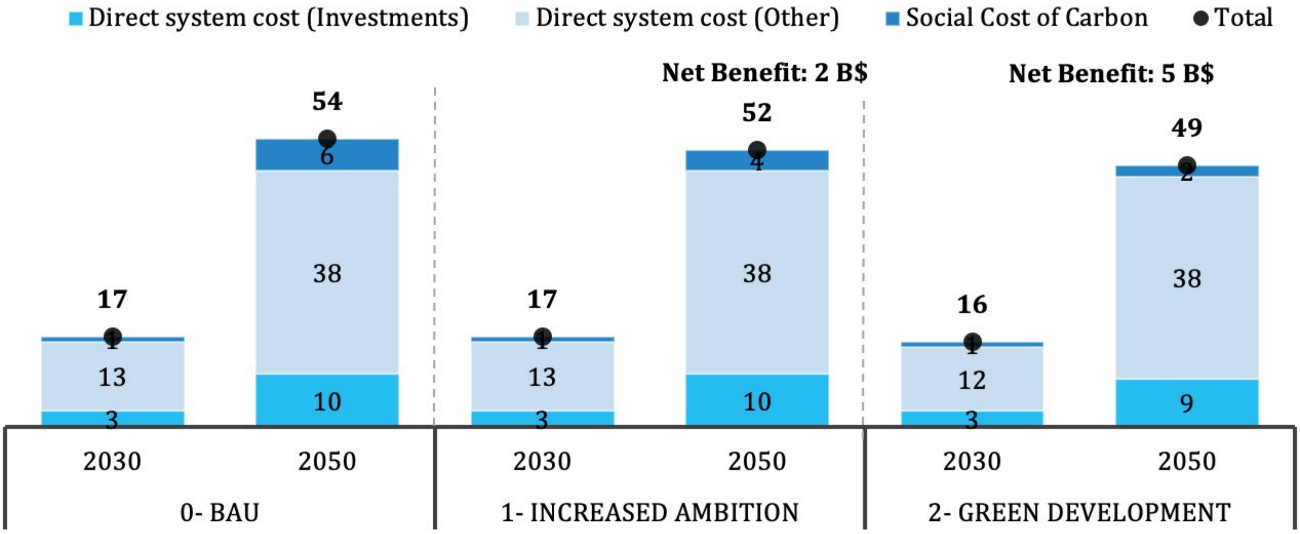


Source: Authors' calculations. IA: Increased Ambition. GD: Green Development.

Concerning the full economic costs (figure 13), when added to the marginal benefits of curbing greenhouse-gas emissions, the lower capital, operating, and commodity costs of electric and solar pumps offset the slightly higher costs of HPs. By

2050, the full net economic benefit in present value of this transition will be in the order of $2 billion for the Increased Ambition scenario and $5 billion for the Green Development scenario.

Figure 13: Full Economic Cost for Agriculture (Direct System Cost + Social Cost of Carbon)



Source: Authors calculations.

d. Industry and the Tertiary Sector

Oil and power are ostensibly the lifeblood of industry. By 2018, industrial oil consumption had registered a 70% leap, from 1225 kilotons of oil equivalent (ktoe) in 1990 to more than 2080 ktoe. Industry's electricity consumption has on the other hand tripled from 345 ktoe in 1990 to almost 1040 ktoe in 2018[26]. While the tertiary sector's energy needs are far less than industry, they have more than tripled in the past three decades from 142 ktoe in 1990 to 638 ktoe in 2018[27]. In the context of the sector's predicted future energy needs, it is important that an energy-efficiency plan be devised.

Industry

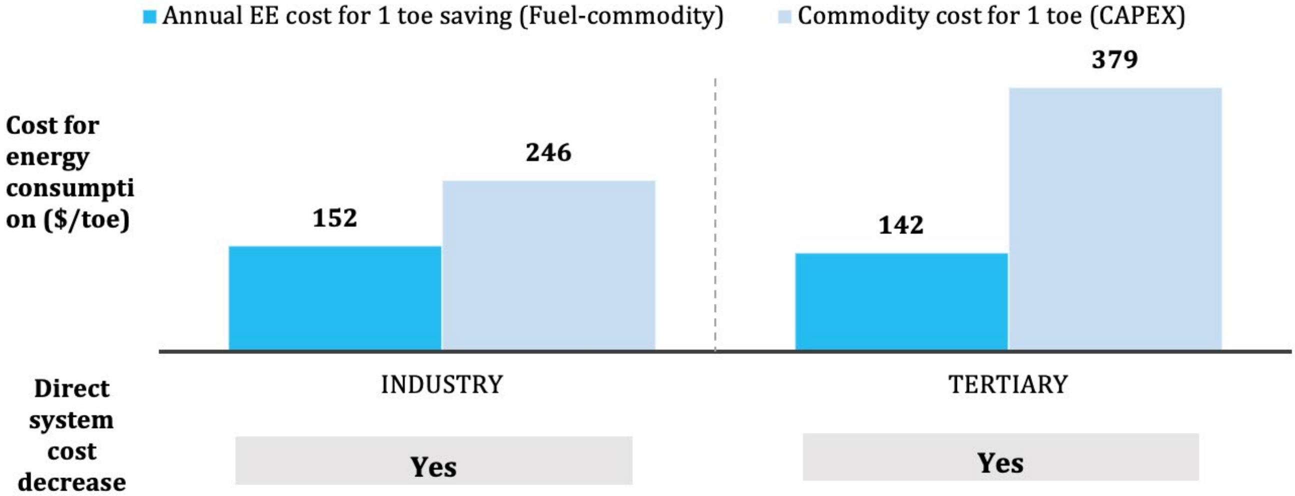
Our cost-benefit analysis for the industrial sector has shown that with sectoral intervention in energy-intensive industries (mainly food, petrochemicals, and machinery), the annual investment required to save 1 ton of oil equivalent (toe) is far less than that spent on 1 toe of commodities. In other words, in the industrial sector, energy-efficiency investment required to save 1 toe will be in the order of $152, which is more than compensated for by the avoided commodity costs, which would normally amount to $264/toe[28] (see Figure 14).

26. IEA database, 2020, 2020a

27. IEA database, 2020, 2020a

28. Energy efficiency investment costs based on EU benchmark (CAPEX per avoided toe/year), lifetime of investments assumed 25 years.

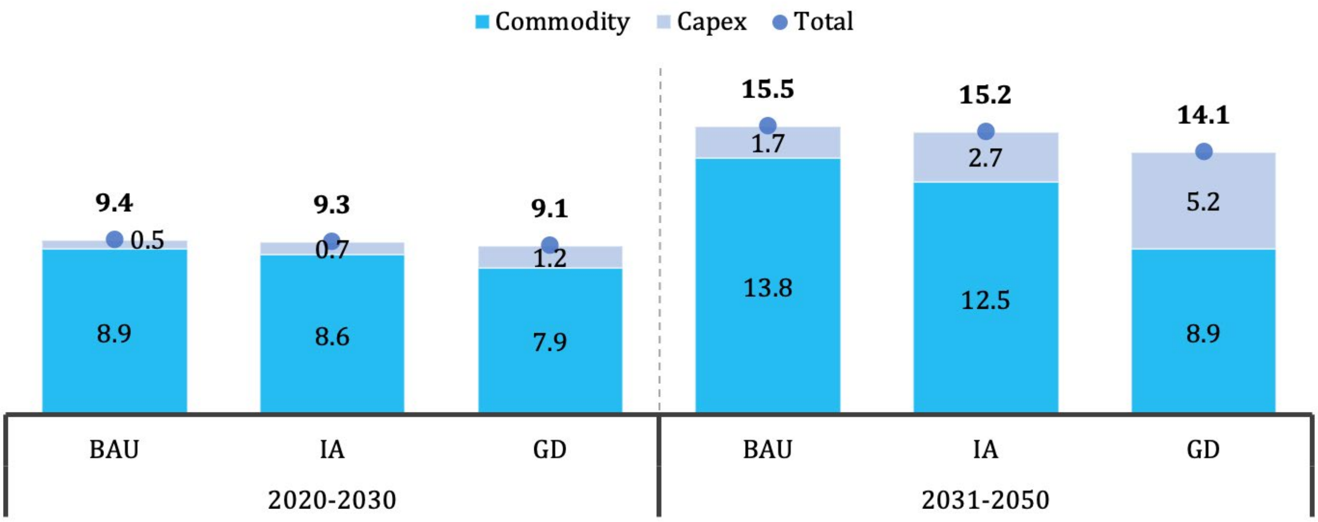
Figure 14: Investment Costs to Reduce Energy Consumption by 1 toe Compared to 1 toe of Commodity Cost



Source: Authors' calculations.

On a national level (Figure 15), the benefits derived from energy efficiency will directly translate into commodity savings for both the Increased Ambition and Green Development scenarios, compared to a BAU scenario. The calculated commodity savings compared to the BAU scenario reach $0.3 billion in the medium term (2020-2030) and $1.3 billion in the longer term (2031-2050) in the Increased Ambition scenario, and $1.0 billion in the medium term and $4.9 billion in the longer term in the Green Development scenario. However initial capital costs are higher in both decarbonized scenarios compared to BAU, depending on the level of energy-efficiency penetration: a cost increase of $0.2 billion in the 2020-2030 period and $1 billion in the 2031-2050 period in the Increased Ambition scenario, and $0.7 billion and $3.5 billion in the Green Development scenario.

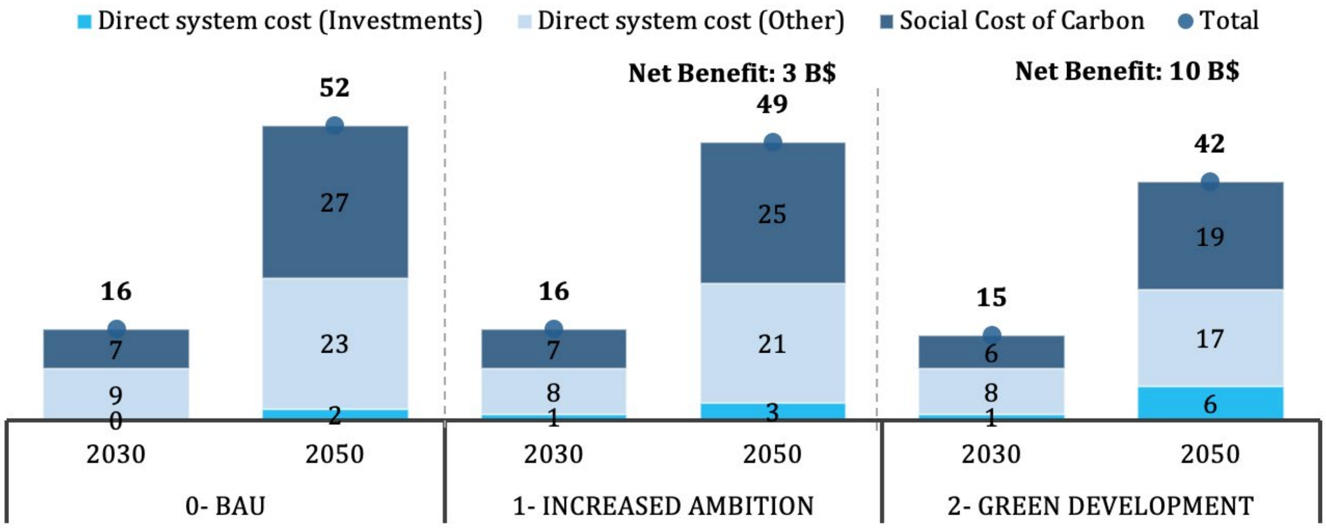
Figure 15: Focus on the Direct System and Investment Costs in Introducing Energy Efficiency Measures to the Industrial Sector ($ Billions)



Source: Authors' calculations. IA: Increased Ambition. GD: Green Development.

In terms of the full economic benefits to the industry sector (Figure 16), there are also additional advantages to energy efficiency derived from cutting carbon emissions, and overall the added capital expenditures will be offset. In dollar terms, by 2030, the net economic benefits of this transition will be zero in the Increased Ambition scenario and around $1 billion in the Green Development scenario, while it will amount to $3 billion in benefits in the Increased Ambition scenario and $10 billion in the Green Development scenario by 2050.

Figure 16: Full Economic Cost for Industry Decarbonization (Direct system cost + Social Cost of Carbon) in $ Billions



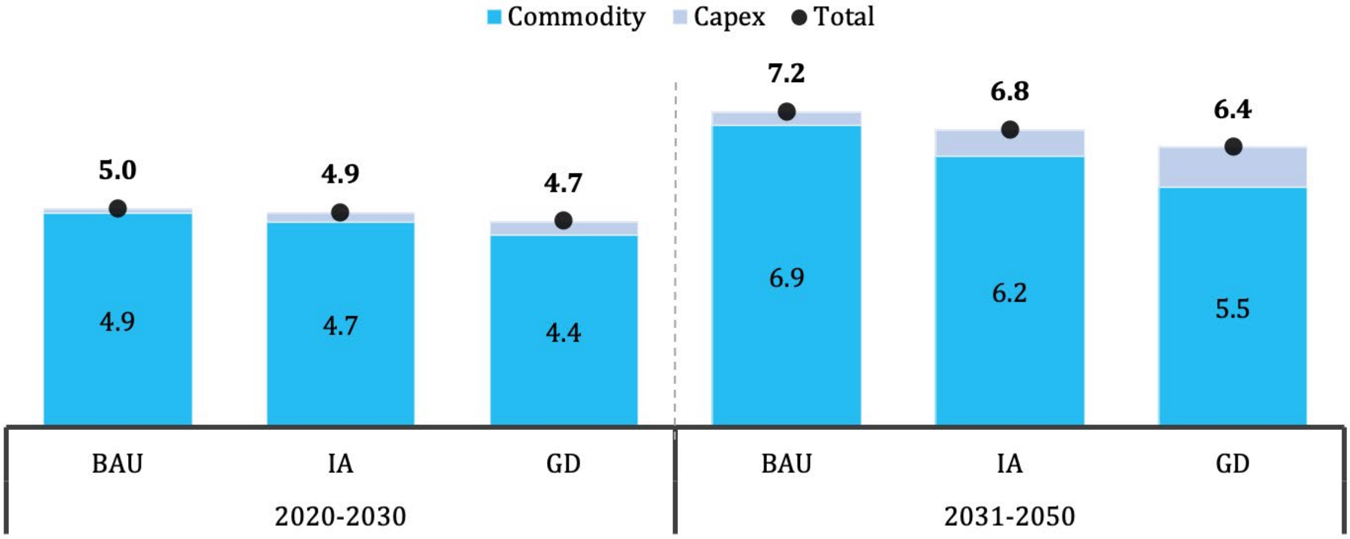
Source: Authors' calculations.

Tertiary Sector

Using the same approach, retrofitting its heating, cooling, and conditioning systems[29] to slash 1 toe, will result in $237 commodity savings annually in the services sector (Figure 14). On a national level, commodity costs will be reduced, while CAPEX will slightly increase, but overall savings will significantly outweigh additional costs (Figure 17). The full economic benefits derived from energy efficiency in the tertiary sector are $0.2 billion and $0.4 billion by 2030, and $1 billion and $2 billion by 2050 in the Increased Ambition and Green Development scenarios respectively, compared to BAU (Figure 18).

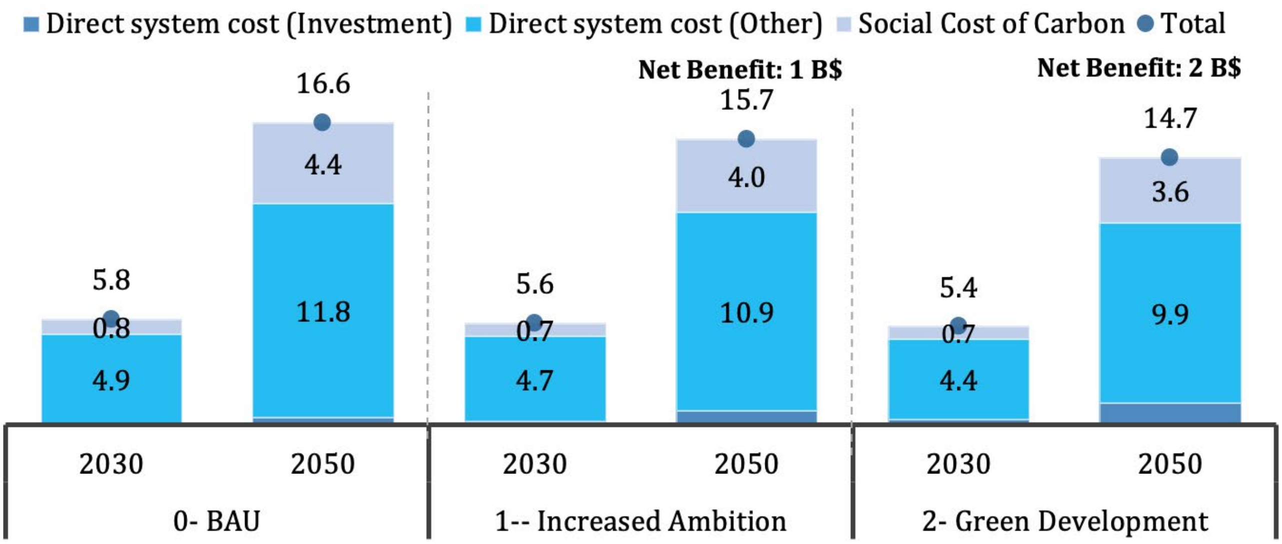
29. Which represent about 25% of its total energy uses (See Policy Brief 2).

Figure 17: Focus on the Direct System and Investment Costs of Introducing Energy-Efficiency Levers to the Tertiary Sector



Source: Authors' calculations.

Figure 18: Full Economic Costs of Energy-Efficiency Transition in the Tertiary Sector



Source: Authors' calculations.

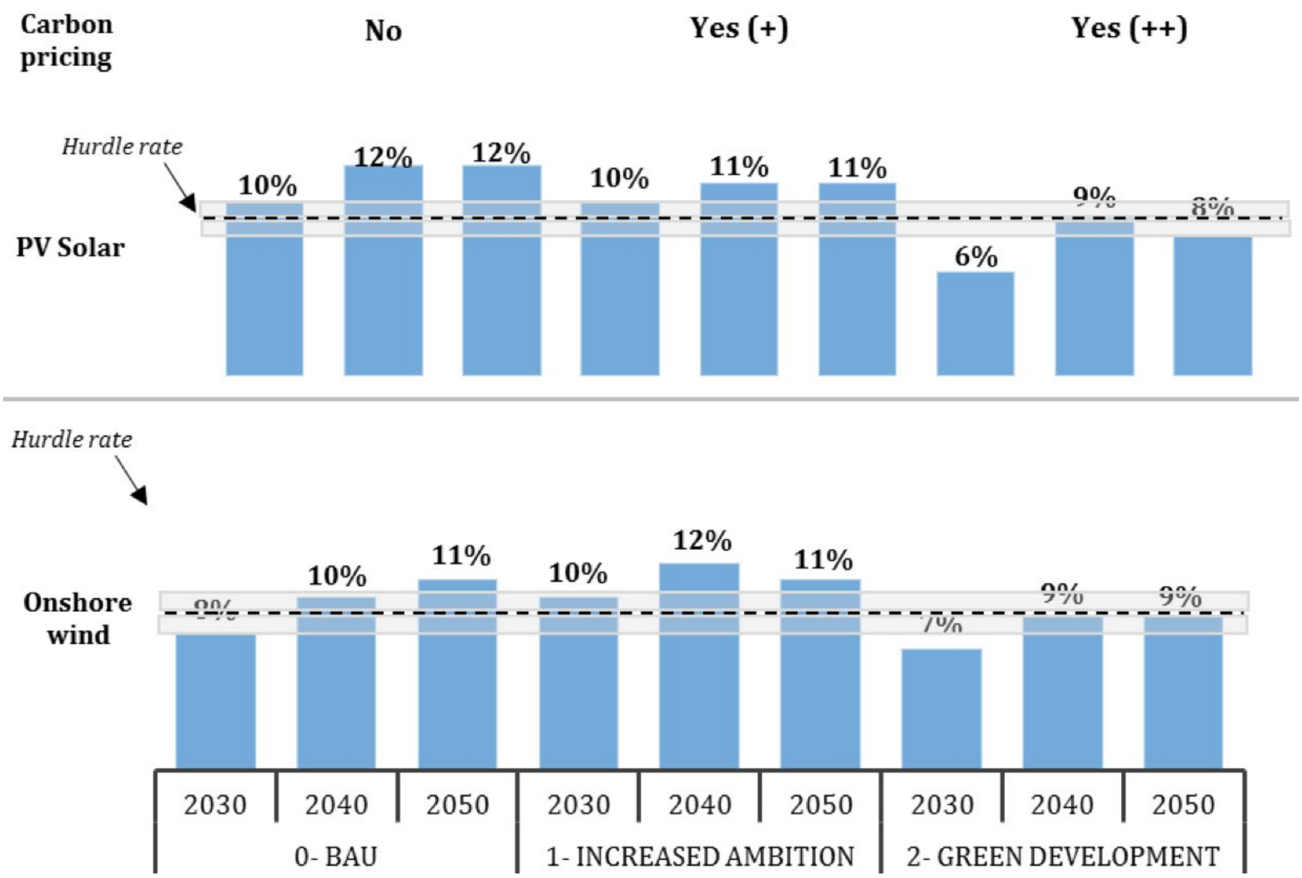
e. Power Sector

The modeled scenarios for the power sector discussed in Part II of the "Decarbonization Pathway for Morocco" Brief series, indicate that the Increased Ambition and Green Development scenarios call for the phase-out of coal by 2040, and rely on solar PV and wind to meet increased electricity demand, requiring an expansion of installed capacity. The increased deployment of renewables in the power generation sector in the decarbonization scenarios will be possible, in part, because of the implementation of carbon pricing, which will make RES projects more attractive to investors.

In this study, carbon pricing was implemented differently over time, with: (i) a partial adherence to the European Union emission trading system (EU ETS) from 2040 onwards in the Increased Ambition scenario, following gradual implementation starting in 2030, and (ii) full adherence to the EU ETS from 2030 onwards in the Green Development scenario following gradual implementation starting in 2020.

The analysis of the internal rate of return (IRR)[30] for PV solar and wind projects shows that their IRR of PV is greater than the hurdle rate in the BAU and Increased Ambition scenarios (Figure 19). This would result in no need for direct financial incentives. However, in the Green Development scenario, the projects have a satisfactory IRR only after 2030 (due to higher CAPEX for new investments in renewable energy technologies), meaning that some direct financial incentives are needed in the short term (to make investment more attractive for financial partners).

Figure 19: Projects IRR from Power Modeling (%)



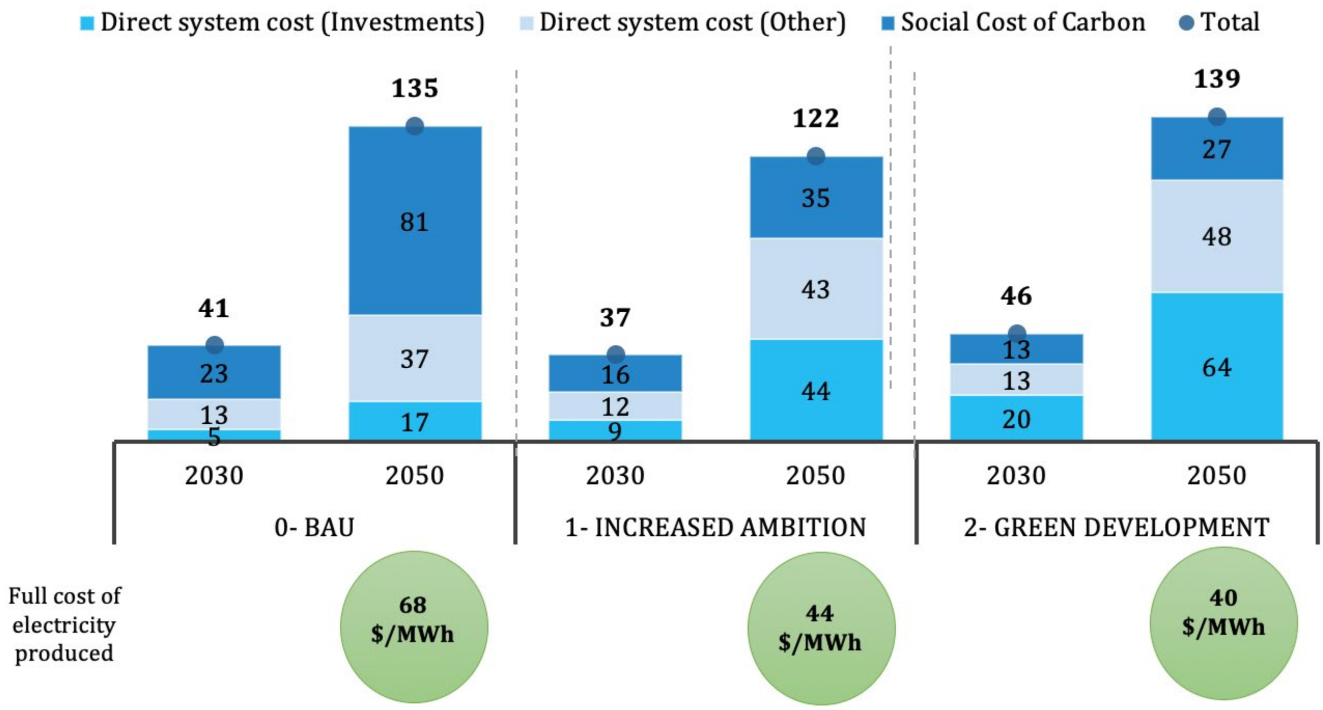
Source: Authors calculations.

The analysis of the full economic cost of the power sector reveals that decarbonization under the Increased Ambition scenario leads to a net benefit of $13 billion, compared to the BAU scenario, stemming primarily from major benefits derived from the reduction in the social cost of carbon. In the Green Development scenario, however, the full economic cost of the power sector is higher than the BAU scenario (Figure 20). Indeed, decarbonizing the power sector will require additional investments, mainly due to the additional RES capacity needed to meet the higher electricity demand. The increased deployment of renewable energy sources requires greater efforts in investments for grid infrastructure reinforcement. Given the greater decarbonization aims of the Green Development scenario, investment needs increase

30. In order to estimate the profitability of potential investment, financial analysts use the internal rate of return (IRR), which is the rate at which the project breaks even. Generally speaking, the higher an IRR, the more attractive the investment becomes. The hurdle rate represents the minimum IRR acceptable for an investor for the related project.

the most. Furthermore, additional expenditure on grid infrastructure reinforcement and hydrogen (H2)[31] production will be required to sustain the two decarbonization scenarios and meet the higher peak demand. These additional costs can be however offset by reducing this peak demand through activation of demand response (DR) during peak hours.

Figure 20: Full Economic Cost for the Power Sector (Direct System Cost + Social Cost of Carbon), in cumulated $ Billions



Source: Authors calculations.

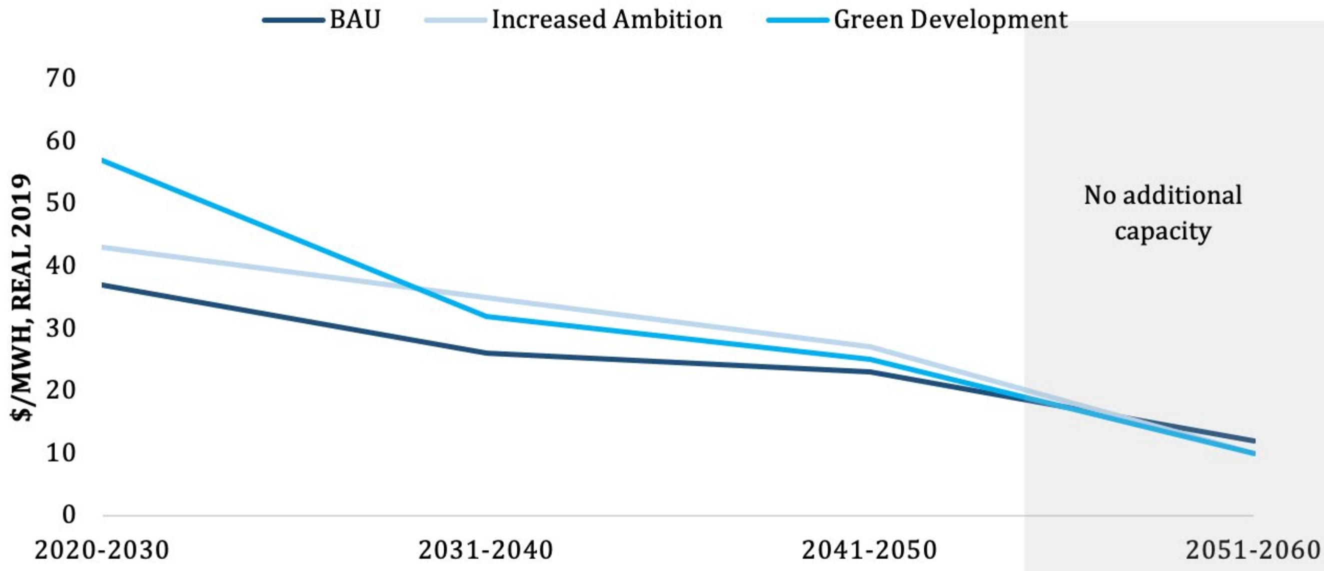
Nonetheless, decarbonization is still worthwhile, even in the Green Development scenario, because it leads to lower cost per MWh produced (Figure 20). The full economic cost of electricity produced[32], comprised of direct costs (investment and other) and the social cost of carbon, is established at $44/MWh and $40/MWh, on average, during the 2020-2050 period, in the Increased Ambition and Green Development scenarios respectively, and gives a net benefit of $24/MWh and $28/MWh, respectively. This is mainly due to a significant decrease in the social cost of carbon in all three scenarios, outweighing the increase in direct costs (investments), resulting from additional RES capacity investments to meet the higher electricity demand of electrified sectors, replacement of coal, and implementation of additional BESS and gas to ensure system security and flexibility. Over time and beyond 2050, the direct system cost[33] of electricity produced decreases in the decarbonized scenarios, and falls below BAU values because of RES technology cost decreases and less need for additional capacity to meet electricity demand (Figure 21).

31. H2 costs were already included in the system cost for the transport sector as commodity costs for H2 trucks. However, investment is needed to develop production sites.

32. Direct cost of electricity produced calculated as the sum of the power sector direct system cost (CAPEX, OPEX, commodities) divided by the total electricity production in the period.

33. CAPEX, OPEX and Commodity.

Figure 21: Evolution of Direct System Cost of Electricity Produced



Source: Authors calculations.

III. Conclusion

A pressing question in relation to green transition plans is whether climate change actions will divert too many resources and will ultimately harm the economy. Moreover, the mismatch between climate change as a long-term problem and the very short time horizon of some of society's imminent needs (including healthcare, providing employment, and infrastructure) is often a recurrent charge afflicting environmental planning.

By analyzing and exposing the overall full economic costs of this transition, both on a national level and sector by sector, this brief shows that the economic benefits of such a transition will amount to hundreds of billions of dollars, even taking into account the added capital expenditures required to retrofit the sectors covered. From this perspective, there is no reason why fossil-fuel consumption could not be substantially decoupled from economic growth; quite the contrary as decarbonization can encourage growth indirectly. For instance, when industries are faced with the challenge of retrofitting themselves for a greener economy, they will spend amply on research and development, which will stimulate innovation and in turn, make for more dynamic, stronger, and more sustainable economic growth.

However, there is also the question of whether decarbonizing the economy will have significant distributional effects because of inherent horizontal inequalities in society, since between long-term needs and long-term opportunities are short-term markets. One question is how households with different income levels will be affected. Different social movements have taught us to be mindful and protect the vulnerable parts of the population when considering climate-change policies. Even the new economic development plan has further emphasized the importance of renewable energies as a lever of sustainable development and the equal access to energy to all constituents of society. The aim should be to design a package to encourage decarbonization while ensuring no one is left behind, which is the premise of the next and final policy brief in our series.

The fourth Policy Brief will address the barriers that still hinder the energy transition in each sector, and propose short-term and long-term recommendations to sustain decarbonization, including financial and non-financial policy measures, while being mindful of distributional concerns and impacts.

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About Enel Green Power Morocco

Enel Green Power was founded in December 2008 inside the Enel Group to develop and manage power generated from renewable resources worldwide.

The company is present in 32 countries across 5 continents and has over 1,200 plants. It has around 49 GW of installed renewable capacity generated from a mix of resources, including wind, solar, hydroelectric and geothermal. Enel Green Power is playing a fundamental role in the energy transition, as it is one of the world's leading renewable energy companies. Its goal is to accompany the planet into a new era in which everyone has access to sustainable, decarbonized energy.

Enel Green Power is also a founding member of RES4MED, Renewable Energy Solutions for the Mediterranean and Beyond, an association created in 2012 to promote renewable energy and the infrastructures needed to deliver the generated electricity throughout the Mediterranean area.

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Policy Center for the New South, is a Moroccan policy-oriented think tank based in Rabat, Morocco, striving to promote knowledge sharing and to contribute to an enriched reflection on key economic and international relations issues. By offering a southern perspective on major regional and global strategic challenges facing developing and emerging countries, the Policy Center for the New South aims to provide a meaningful policy-making contribution through its four research programs: Agriculture, Environment and Food Security, Economic and Social Development, Commodity Economics and Finance, Geopolitics and International Relations.

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