
MENA SELECT

Project: **M**iddle **E**ast **N**orth **A**frica **S**ustainable **E**LECtricity
Trajectories (**MENA-SELECT**)

Energy for the Future

Evaluating different electricity generation technologies against selected performance characteristics and stakeholder preferences: Insights from the case study Morocco

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SUMMARY

Morocco's future electricity consumption is projected to increase rapidly. This will require the deployment of additional electricity generation capacities with volumes four times higher by 2030 and more than ten times higher by 2050 compared to available capacities today. Hence, the major part of the country's electricity infrastructure is still to be built and substantial investments in additional power generation capacities are yet to be made.

Given that electricity systems are developed not in isolation from a country's development challenges, but in continuous interaction with complex sociotechnical systems, this study sheds light on the interface between electricity generation technologies, sustainable development, and stakeholders' preferences in Morocco. The results of a multi-criteria decision analysis and an assessment of the performance of 4 renewable and 4 conventional electricity generation technologies, i.e., fossil-fueled generation including nuclear, against 11 sustainability criteria and different societal preferences in electricity planning provide guidance on how to expand Morocco's future electricity generation capacities in sustainable and socially robust ways.

Derived from a series of seven stakeholder workshops, the study's findings indicate that all renewable energy technologies are significantly superior in their compatibility with sustainable development and better reflect the preferences of Moroccan stakeholders than their conventional alternatives. In order to avoid a lock-in of the power sector in unsustainable pathways and conflictual technology assets, the results of this study are crucial for designing Morocco's electricity future sustainably and with great societal support.

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ABBREVIATIONS

ADEREE	National Agency for Renewable Energies and Energy Efficiency
AMCDD	Moroccan Alliance for Climate and Sustainable Development
CANAW	Climate Action Network Arab World
CAR	Cardinal Ranking
CCGT	Combined Cycle Gas Turbine
CCS	Carbon Capture and Storage
CNEDD	National Charter for Environment and Sustainable Development
CSP	Concentrating Solar Power
ESIAs	Environmental and Social Impact Assessments
GHG	Greenhouse Gas Emissions
GIS	Geographical Information Systems
GoM	Government of Morocco
INDH	National Initiative for Human Development
LCOE	Levelized Cost of Electricity
LNG	Liquefied Natural Gas
MASEN	Moroccan Agency for Sustainable Energy
MADM	Multi-Attribute Decision Making
MAUT	Multi-Attribute Utility Theory
MCD	Multi-Criteria Decision Analysis
MCI	Manufacturing, Construction, and Installation
MEMEE	Ministry of Energy, Mines, Water, and the Environment
MorSEFF	Morocco Sustainable Energy Financing Facility
NES	National Energy Strategy
NLNGP	National Liquefied Natural Gas Plan
NSSD	National Strategy for Sustainable Development
OCGT	Open Cycle Gas Turbine
OM	Operation and Maintenance
ONEE	National Office of Electricity and Drinking Water
PPA	Power Purchase Agreements
PV	Photovoltaics
RE	Renewable Energy
SIE	State-funded Energy Investment Company

SMEs Small-and medium-sized enterprises

1 INTRODUCTION

The Government of Morocco (GoM) faces challenges from the convergence of rising needs for socio-economic development, environmental protection, climate change mitigation, and reducing its energy bill. New electricity infrastructures are important prerequisites for addressing these challenges as the capacity to generate and distribute electric power is directly linked to development needs. In Morocco the major part of the electricity infrastructure needed to respond to the increasing electricity demands is still to be built. In fact, the country is at a crossroads in regards to new electricity policies and investments. While the deployment of renewable energies (REs) is receiving great policy support, fossil fuels—especially coal and gas—as well as nuclear power are prominent alternatives in Morocco’s energy considerations (Schinke et al., 2016, p. 29-34).

This crossroads offers a unique opportunity to provide scientifically sound information on how to expand Morocco’s future electricity generation capacities in ways that are sensitive to the myriad of development challenges while considering potential for societal support of the technological options deployed in the future mix. Yet, despite a broad public debate on energy, so far the scientific and political discussion about the country’s future technology mix for supplying electricity has focused mainly on energy security objectives. As a consequence, technological system optimization (reliable/uninterrupted supply) and least-cost evaluation (affordable/competitive supply) tend to prevail in Morocco’s national energy decision-making (Kern et al., 2016).

Notwithstanding the importance of these aspects, their sole consideration in electricity planning cannot be regarded as sufficient (Kowalski et al., 2009). In fact, if electricity planning is understood only for assuring secure and low-cost electricity supply, the opportunity will be missed to optimize the interface between the deployment of power plants and their incremental development effects that could either hinder or enhance sustainable development at the national and local level. As a result, it is widely acknowledged that electricity planning cannot be reduced to a cost minimization or system optimization problem. Instead it should be viewed as a multiple-criteria decision-making problem that must be evaluated also from a sustainable development perspective before such decisions are made (Everett et al., 2012; Sovacool, 2015). Given that different electricity pathways could be selected in Morocco for fulfilling the growing energy needs, creating a better understanding of the interface between electricity and sustainable development is, therefore, crucial for designing a long-lasting and sustainable electricity future in the country.

Yet, at the intersection between electricity generation and sustainable development, determining energy policies and installing electric facilities becomes a “messy, con-

flictual, and highly disjointed process” (Meadowcroft, 2009, p. 323). This is because electricity systems are developed not in isolation from a country’s development challenges and its society, but in continuous interaction with social, economic, and environmental dimensions at the national and local level (Oltra et al., 2014; Renn, 2015). For example, energy systems and associated technologies could have significant impacts on people’s lives, both, positive and negative, as people nowadays basically “[...] live with, in, around, and through energy [...]” (Miller et al., 2015, p. 38). This challenge is further aggravated by the fact that different societal actors might have different perceptions and preferences based on different values and worldviews as to which electricity future is desirable and what trade-offs are acceptable (Madlener & Stagl, 2005; Stagl, 2006; Shortall et al., 2015; Lilliestam & Hanger, 2016).

Clearly, no technology choice is optimal but depends on the priorities set. In fact, Schmid et al. (2016) have shown that the determining factors for an energy transition, such as the German “Energiewende” are not of technological nature alone, but are fought out by different social actors as well. They conclude that greater awareness for normative aspects, i.e., values, worldviews, as well as more participative and deliberative processes, is an imperative when contemplating about future electricity pathways. Hence, taking into account different social perspectives and preferences by involving different stakeholders in a systematic and participatory way should be encouraged in energy research and electricity decision-making (Tsoutsos et al., 2009; Sovacool et al., 2015).

Shedding light on this process requires two things: greater scientific understanding of the technologies’ performance, but also greater knowledge of people’s preferences. Given that different electricity pathways could be selected in Morocco for fulfilling the country’s growing energy needs, the goal of this study is defined as follows:

To evaluate the multi-objective and value-biased complexity of future technology choices in the electricity sector of Morocco against a) their contribution to national energy planning objectives as well as their local impact sensitivity, and b) differing societal preferences, and thus the potential for societal support and/or conflict.

Despite the rather explorative character of this study, its results are intended to reach two objectives. On the one hand, they are intended to support informed and normatively-orientated policy and investment decisions regarding future technologies choices directed towards a sustainable and socially robust energy future in Morocco. On the other hand, the authors envision that the results will stimulate debates about different electricity pathways among different actors, including the general public, policy-makers (e.g., ministries, state agencies, and electricity utilities), pro-

ject developers (e.g., private sector organizations and banks), civil society organizations (e.g., national NGOs and local activist groups), and scientists (e.g., universities and research organizations).

2 DECISION CONTEXT

Faced by the dual challenge of being obliged to import almost all of its energy supplies as fossil fuels from abroad and being highly vulnerable to the impacts of climate change, Morocco defines its vision towards sustainable development as “reaching a low-carbon and climate-change resilient development” (MEMEE, 2014a, p. 18). This vision is in line with the objectives outlined in the Royal Message at the UN General Assembly on the Millennium Development Goals in 2010 and with the UN Sustainable Development Goals endorsed in 2015 (Kingdom of Morocco, 2015).

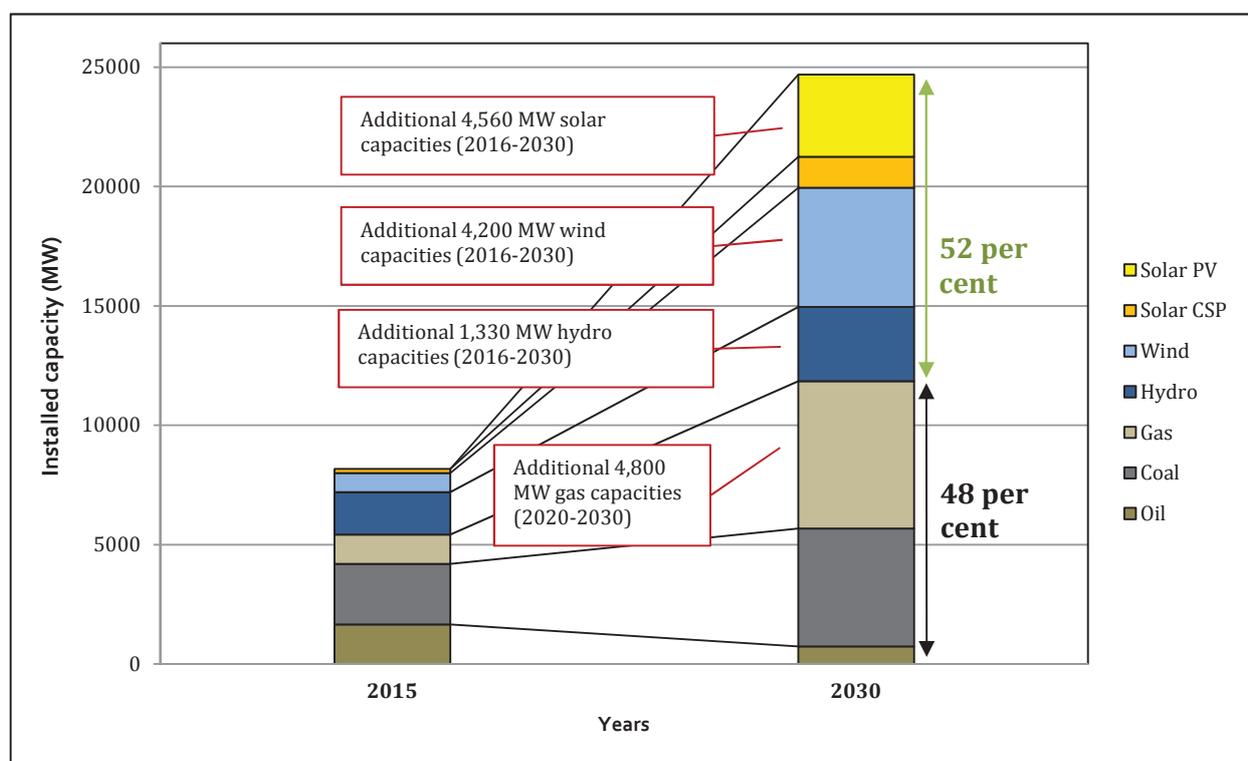


Figure 1: Total and assumed installed capacity in Morocco for 2015 and 2030 (authors' estimates, based on ONEE, 2015 (plus 180 MW CSP capacities); MEMEE, 2015a; MEMEE, 2015b; MEMEE, 2015c, p. 3; MEMEE, 2016a, p. 9).

As the capacity to generate electric power is directly linked to socio-economic progress, human development, and climate change mitigation, the GoM consequently considers investments in electricity infrastructures to be an important prerequisite for achieving its national vision. Yet, with electricity demand projected to rise more

Sector-based programs that address the economy

- \ *The National Industrial Emergence Pact (PNEI, 2009) and the New Industrial Strategy (2014);*
- \ *The National Innovation Initiative (MII, 2013);*
- \ *The Industrial Acceleration Plan (PAI, 2014);*
- \ *The National Green Investment Plan (GIP, 2015);*

Sector-based programs that address the environment

- \ *The National Action Plan for the Fight Against Desertification (PAN-LCD, 2001);*
- \ *The National Program for the Protection of Air Quality (2005);*
- \ *The National Liquid Sanitation and Wastewater Treatment Program (NSP, 2005);*
- \ *The Green Morocco Plan for Agriculture (Plan Maroc Vert, PMV, 2008);*
- \ *The National Water Strategy (SNE, 2009/10) and the National Water Plan (PNE, 2014);*
- \ *The National Master Plan for Solid and Hazardous Waste (PDNDD, 2010/2012) and the National Program for Solid Waste (PNDM, 2008);*
- \ *The National Plan Against Global Warming (PNRC, 2009) and Morocco's Intended Nationally Determined Contribution (INDC, 2015);*

Legislation that addresses good governance

- \ *Law No. 99-12 of the CNEDD;*
- \ *Article 36 of the Charter on Communal Development;*
- \ *Article 27 (right to information), 12, 136 and 139 (right to participation), 118 and 120 (right to accountability) of the National Constitution;*
- \ *Article 19 of the International Covenant on Civil and Political Rights (ICCPR) and Article 10 of the United Nations Conference on Environment and Development (UNCED);*

than five times by 2050, most of the electricity infrastructures needed to respond to the increasing demand are still to be built.

Based on the information provided by the National Office of Electricity and Drinking Water (ONEE) and the Ministry of Energy, Mines, Water, and the Environment (MEMEE) for the renewed National Energy Strategy (NES), the total power capacities required to address the country's increasing electricity demand are estimated to increase from 8,174 MW¹ (average ONEE and MEMEE numbers) at the end of 2015 to reach 15,000 MW by 2020, 20,000 MW by 2025, and eventually around 25,000 MW in 2030 (Schinke et al., 2016, p. 29-34 and Figure 1).

While conventional energy carriers will continue to be an important pillar in the electricity mix, the GoM also aims to increase its RE generation capacities from 34 per cent in 2015 to 52 per cent by 2030—thereby decreasing its long-standing dependence on volatile energy imports from 96 per cent to 82 per cent respectively.

By taking into consideration the nexus between sustainable development and electricity generation, the NES is embedded in Morocco's national development policy framework that aims to achieve the country's low-carbon development vision. Guided by Article 31 and 35 of the National Constitution this policy framework is operationalized through the National Charter for Environment and Sustaina-

¹ As the NES did not provide specific numbers on the amount of the total installed capacities anticipated to be reached by 2030, but instead referred to relative numbers—namely the envisioned additional capacities to be reached over the period 2016–2030—the authors recalculated the official RE targets for 2030 published in the NES in order to get estimates for the envisioned total installed capacities of all technologies by 2030. However, these estimates need to be interpreted with caution because a) the figures for installed capacities in 2015 differ between ONEE and MEMEE, and b) a recalculation of the envisioned future percentage share for the technologies (as provided by MEMEE for 2030) into MW installed capacities comes with significant uncertainties. The latest ONEE numbers can be found here: <http://www.one.org.ma/FR/pages/interne.asp?esp=2&id1=4&id2=53&id3=39&t2=1&t3=1>

ble Development (CNEDD, 2009) as well as its corresponding Framework Law 99-12 (2014). At the implementation level, the National Strategy for Sustainable Development (NSSD, 2010) and the National Initiative for Human Development (INDH, 2005 and 2011) translate the national vision into specific objectives via a comprehensive set of sector-based strategies and programs (see info box). These aim at promoting economic prosperity, conservation of natural resources, and good governance and are, therefore, directly related to investments in new power capacities (for more information, see Schinke et al., 2016).

3 TRANSDISCIPLINARY METHODOLOGY

The involvement of multiple stakeholders beyond the realm of science (i.e., citizens, civil society organization, and policy-makers) into scientific research is an expanding trend in an increasing number of areas, particularly those that go beyond technological aspects and touch upon socio-economic, environmental, and political dimensions (Kasemir et al., 2003; Mielke et al., 2016, p. 71). The following points are among the main reasons to involve different stakeholder groups in scientific research and to embed science directly in social and policy discourses:

- \ To gather extended information and knowledge about uncertain issues;
- \ To include multiple perspectives and preferences;
- \ To foster mutual learning and ownership;
- \ To increase credibility and legitimacy of results (Fiorino, 1990).

Transdisciplinary approaches, i.e., the adoption of an application-guided, problem-solving, dialogue-orientated, and participatory model of science, are, thus, increasingly recognized as a promising way to tackle the uncertainty, multi-objectivity, and ambivalence associated with complex decision problems (Omann et al., 2008; Lang et al., 2012; Wilkens and Schmuck, 2012; Spreng, 2014). Planning a sustainable electricity system that is comprised of several energy carriers with a myriad of different implications at multiple levels is such a complex decision-making problem that requires a multifaceted, transdisciplinary evaluation approach (Sovacool et al., 2015; Sovacool, 2016).

While transdisciplinary approaches have been applied extensively to the assessment of electricity generating options at the project, national, regional, and global levels (Afgan & Carvalho, 2002; Chatzimouratidis & Pilavachi, 2008; Schenler et al., 2009; Wilkens & Schmuck, 2012; Stein, 2013; Grafakos et al., 2015; Barros et al., 2015) and stakeholder involvement in electricity planning is relatively common nowadays in Europe (Tsoutsos et al., 2009; Schweizer et al., 2014; Sinclair et al., 2015; Schroeter

et al., 2016; Molinengo & Danelzik, 2016) and the US (Canfield et al., 2015; Klein & Whalley, 2015), it has so far not been conducted on electricity technologies in Morocco.

By evaluating future electricity generation technology choices against multidimensional performance characteristics and different stakeholder preferences within a transdisciplinary research methodology, this study intends to complement previous research on energy in Morocco that either focused on singular aspects of sustainable development, techno-economic aspects of electricity systems, or selected electricity technologies. The applied methodology consists of three key steps:

- \ Preselection of evaluation parameters: technology alternatives, evaluation criteria, and stakeholder groups (Chapter 3.1);
- \ Elicitation of stakeholder preferences: vision building, technology perceptions, stakeholder preferences, and elements of procedural and distributive justice (Chapter 3.2);
- \ Analysis of results: cluster analysis of similarities and differences as well as Multi-Criteria Decision Analysis (MCDA) (Chapter 3.3).

The result is a “compromise solution” on the “most sustainable and socially preferred” future technology mix of Morocco that allows electricity planning decisions to be geared towards sustainable development and societal support, while taking into account aspects of procedural and distributive justice in electricity policy-making at the local level. The following sections link the idea of transdisciplinary research to the methodology of the technology evaluation.

3.3 Preselection of evaluation parameters

The preselected evaluation parameters of the study consisted of a set of 11 criteria with 20 corresponding indicators, a selection of 8 electricity generation technologies, as well as 6 homogeneous stakeholder groups.

3.3.1 The technologies

The technologies of this evaluation were selected by reviewing the eight most prominent utility-scale² electricity generation technologies that are either widely applied or considered as viable options for the future electricity mix in Morocco. Four of

² The authors define “utility scale” projects as projects that feed into the grid, supply a utility with electricity, have a Power Purchasing Agreement (PPA) in place, and are generally in the range of 5 to 1000 MW.

these technologies are RE, while the other half encompasses conventional³ power generation (for more information, see Schinke et al., 2016):

- 1. Utility-Scale Photovoltaic (PV):** As part of the Moroccan Solar Plan utility PV capacities will increase from zero today to 3,440 MW by 2030 and from zero to 15 per cent of all installed capacities respectively (authors' estimates based on MEMEE, 2015a, p. 4; MEMEE, 2015c, p. 5; ONEE, 2016, p. 16).
- 2. Concentrated Solar Power (CSP):** Solar CSP capacities are envisioned to increase from 180 MW in 2016 to around 1,300 MW by 2030 and from 2 per cent to five per cent of all installed capacities respectively (authors' estimates based on MEMEE, 2015a, p. 4; MEMEE, 2015c, p. 5; ONEE, 2016, p. 16).
- 3. Onshore Wind:** The Moroccan Integrated Wind Program aims to increase the country's installed wind power capacity of 797 MW in 2015 to 5,000 MW by 2030 and from ten per cent to 20 per cent of all installed capacities respectively (additional 4,200 MW from 2016 to 2030) (authors' estimates based on MEMEE, 2015c, p. 3).
- 4. Utility Hydro-Electric:** Hydro-electric power capacity is expected to increase from 1,770 MW at the end of 2015 (ONEE, 2015) to 3,100 MW (additional 1,330 MW from 2016–2030) by 2030. This means a decrease in its shares in all installed capacities from 22 per cent to 12 per cent respectively (authors' estimates based on MEMEE, 2015c, p. 3).
- 5. Nuclear Power:** Although still undecided, 1,300 MW of installed nuclear capacities could become reality after 2030.
- 6. Lignite Coal:** 1,706 MW of new supercritical coal-fired power capacities fuelled by imported coal are planned to be added to the existing 2,545 MW (1,386 MW in Safi and 320 MW in Jerada), totaling in around 4,251 MW by 2020 (MEMEE, 2016a). Although the share of coal of all installed capacities is envisioned to decrease from 30 per cent in 2015 to 20 per cent by 2030, additional coal capacities of more than 800 MW (possibly in Nador) would become operable beyond 2020, eventually totaling around 5,000 MW (authors' estimates based on MEMEE, 2015c, p. 3; ONEE, 2016, p. 20).
- 7. Natural Gas:** According to the National Liquefied Natural Gas Plan (NLNGP, 2014) around 3,900 MW of new gas-fired combined cycle power capaci-

³ The usage of the term "conventional" power generation / power plant is not consistent in the literature. While Zahoransky et al. (2013, p. 25) use the term to include fossil-fueled power plants, but excluding nuclear, others (e.g., Würfel, 2015, p. 51; UBA, 2017) include nuclear power plants. In this publication, the term "conventional" includes all forms of fossil-based electricity generation, i.e., coal, gas, oil and nuclear power plants.

ties (CCGT)—mostly based on Liquefied Natural Gas (LNG) imports (2,400 MW)—will be added to the existing 1,230 MW by 2025. Between 2020 and 2030, 4,800 MW of additional gas capacities are estimated to become operational reaching around 6,100 MW⁴ in total and increasing their share of all installed capacities from 15 per cent in 2015 to 25 per cent by 2030 (authors' estimates based on MEMEE, 2014b, p. 7; MEMEE, 2015c, p. 3 and 5; ONEE, 2016, p. 20).

- 8. Heavy Fuel Oil:** 72 MW of new oil-fired capacities are to be connected to the grid and added to the existing 1,652 MW⁵ (in Laayoune) by 2020. Additional 16.5 MW are planned for Dakhla. Yet, the GoM aims to transform oil-fired power plants into gas plants in order to decrease its installed amount of oil capacities significantly to around 740 MW. By doing so, it intends to eventually reduce the shares of electricity generated from oil-fired plants from 20 per cent in 2015 to 3 per cent of all installed capacities by 2030 (authors' estimates based on IEA, 2014, p. 60; MEMEE, 2015c, p. 3; ONEE, 2016, p. 20).

3.3.2 The set of criteria

All technologies were assessed against a set of 11 criteria, with a corresponding total of 20 indicators. Out of these, 9 indicators are quantitative and 11 are qualitative⁶.

The criteria were selected in a threefold, iterative process⁷ (Schinke et al., 2017):

- \ Review of scientific literature: The first step of the selection process was based on an extensive literature review of scientific publications that developed criteria relevant to assessing the performance of energy systems and electricity technologies (i.e., Afgan et al., 2000; Hirschberg et al., 2007; Del Rio & Burguillos, 2008 and 2009; Kowalski et al., 2009; Wang et al., 2009; Grafakos et al., 2015; Grafakos et al., 2016);
- \ Screening of national policy frameworks in the target country: The second step involved the screening of Morocco's policy framework and complemented the criteria set with nationally relevant development criteria (see Schinke et al., 2016);

⁴ The 300-MW Open Cycle Gas Turbine (OCGT) plant in Mohammedia will be transformed into 450 MW CCGT.

⁵ The 300-MW oil-fired power plant in Kenitra will be transformed into 450 MW CCGT.

⁶ There is a range of other critical determinants in technology implementation, such as dispatchability and baseload capacity, economic viability, and technology maturity. Since these elements are primarily technical, however, they were excluded from this Work Package, but were again included in Work Package 1 and 3 of the MENA SELECT project.

⁷ The project constraints did not make it possible to select, validate, or refine the criteria set by national stakeholders other than the project partners, as was envisioned. Although not ideal, this approach has been regularly applied by other scholars as well (for an overview of similar approaches, see Grafakos et al., 2015, p. 10924–10926).

- \ Prioritization by the research team: In the third step, the research team evaluated each criterion according to its relevance to the decision-making problem (“high”, “medium” and “low”). This process included several interactions and iterations, through which the number of criteria was eventually narrowed down from 32 to the final set of 11 criteria.

The collection of data for establishing the performance characteristics for each technology and each criterion was based on different sources and methods. The indicators—also commonly referred to as “attribute values”—of the criteria set encompassed both quantitative and qualitative data. Primary quantitative data sources involved remote sensing data and Geographical Information Systems (GIS) maps. Secondary quantitative data sources included a total of more than 200 regionally specific and international scientific peer-reviewed articles, official policy reports, industry reports, Environmental and Social Impact Assessments (ESIAs), and real project case studies. Additionally, an expert survey was conducted in Morocco to obtain qualitative indicators where no quantitative data could be found or developed. For this, a purposive sampling was applied in order to consult a balanced diversity of experts from different fields of expertise and roles in society. Purposive or purposeful sampling is a technique often used in qualitative research where individuals are involved that are especially knowledgeable about a certain issue of interest. The identification and selection of individuals is influenced by practical considerations, such as the availability, willingness to participate or opportunities that emerge during the research process (Palinkas et al. 2015). Overall, 38 experts were asked via email to take part in the survey from which 20 responded (for details see the Annex in Schinke et al., 2017). Table 1 illustrates the performance characteristics of each technology against the selected criteria and corresponding indicators.

Criteria	Objective	Indicators	Units	Sub-Indicators	Utility PV	CSP	Onshore Wind	Utility Hydro	Nuclear	Coal	Gas	Oil	
1	The technology should decrease the dependence on foreign energy imports by tapping into domestic energy sources that are either available today or could be exploited in the mid- to long-term	1.1	Current domestic potential of each technology's energy carrier to decrease energy import dependence today	Qualitative with a 5-step descriptive scale, maximize		4.00	4.00	2.00	1.00	1.00	2.00	1.00	
		1.2	Future domestic potential of each technology's energy carrier to decrease energy import dependence by 2040/50	Qualitative with a 5-step descriptive scale, maximize		5.00	5.00	4.00	2.00	1.00	1.00	3.00	1.00
2	The technology should contribute to the mitigation of climate change	2.1	Total lifecycle Greenhouse Gas Emissions (GHG) (CO ₂ -eq) per generated kWh	Quantitative (CO ₂ -eq/kWh), minimize	46.00	22.00	12.00	4.00	16.00	1001	469	840	
3	The technology should have a high potential to use components and services provided by domestic industries throughout the entire value chain	3.1	Existing potential for the integration of domestic components and provide essential services during the Manufacturing, Construction and Installation (MCI) and Operation and Maintenance (OM) phases of the technology	Qualitative with a 5-step descriptive scale, maximize		3.50	3.00	3.00	3.00	2.00	2.00	2.00	1.50
		4.1	Effectiveness of educational policies to foster skill development and R&D	Qualitative with a 5-step descriptive scale, maximize		3.00	3.00	3.00	2.00	1.00	2.00	2.00	1.00
4	Based on existing policies, the technology should have a high potential to benefit from technology and knowledge transfer in order to stimulate future domestic value-added in electricity generation	4.2	Effectiveness of industrial policies to enhance industry linkages between domestic and foreign firms geared towards horizontal technology transfer	Qualitative with a 5-step descriptive scale, maximize		2.00	2.00	2.50	2.00	1.00	2.00	2.00	1.00
		5.1	Electricity generation cost measured as Levelized Cost of Electricity (LCOE) in €/MWh	Quantitative (€/MWh), minimize		67.57	130	24.47	45.2	97.75	48.65	89.9	194
5	The electricity system cost of the technology should be as low as possible in order to not constitute a burden for the countries overall budget	5.2	Estimated additional integration cost at increasing penetration levels based on uncertainty/variability and distance/location	Qualitative with a 5-step descriptive scale, minimize	Variability / Uncertainty / Distance / Location	3.00	2.00	5.00	2.00	2.00	1.00	1.00	1.00
		6.1	MCI: Average amount of labor in FTE person years per MW	Quantitative (FTE person years/MW), maximize		8.21	12.96	6.83	8.74	13.82	6.98	3.50	3.79
6	The technology should have a high potential to create direct on-site jobs over the entire lifetime of the power plant	6.2	OM: Average amount of labor in FTE permanent jobs per MW	Quantitative (FTE jobs/MW), maximize		0.83	0.41	0.15	0.24	0.19	0.17	0.26	
		7.1	Land requirement: The area of land directly required by the technology at the site of its deployment in ha/MW	Quantitative (ha/MW), minimize		2.77	3.61	0.31	-	0.42	0.11	0.05	0.05
7	The technology should cause minimal additional pressure on valuable land resources in terms of amount and value of required land in order to avoid the deprivation of any locally relevant livelihood resources	7.2	Land value: The importance of the land surrounding typical project sites for providing livelihood resources and services to adjacent communities	Qualitative with a 5-step descriptive scale, minimize	Land use potential / Residential proximity	1.30	1.30	3.30	-	4.00	2.30	2.60	
						0.30	1.00	1.20	-	1.10	1.70	1.20	1.50

8	Pressure on Local Water Security	The water consumption of the technology should be appropriate to the local water risk context and cause minimal pressure on local water security	8.1	Average operational water consumption of each technology measured in L/MWh	Quantitative (L/MWh), minimize	31.23	317.88	1.26	-	1611.95	629.51	421.63	316.80
			8.2	Average water risk at typical project sites of each technology based on the Gassert et al. (2014)	Qualitative with a 5-step descriptive scale, minimize	3.80	3.67	4.00	-	3.00	4.07	4.01	4.47
9	Occurrence and Manageability of Non-Emission Hazardous Waste	The disposal of non-emission hazardous waste produced during the operation of the technology as well as the risk stemming from national waste management capabilities should be low in order to minimize adverse consequences on human health and the environment	9.1	Disposal of non-emission hazardous waste	Qualitative with a 5-step descriptive scale, minimize	1.00	2.00	1.00	1.00	5.00	3.00	3.00	4.00
			9.2	Potential national capabilities to manage the disposal of the respective types of non-emission hazardous waste	Qualitative with a 5-step descriptive scale, maximize	4.00	3.00	4.00	4.00	1.00	2.00	2.00	2.00
10	Local Air Pollution and Health	The amount of air pollutants (NO _x , SO ₂ and PM) emitted by the technology should be low in order to minimize pressure on local air quality and health risks for people in adjacent communities	10.1	Air pollutants (NO _x , SO ₂ , and PM _{2.5}) emitted by O&M activities of power plants in kt/MWh	Quantitative (kt/MWh), minimize	0.00	0.00	0.00	0.00	0.00	198.15	56.39	4.44
						0.00	0.00	0.00	0.00	0.00	186.03	0.00	6.71
						0.00	0.00	0.00	0.00	0.00	8.95	0.19	0.30
			10.2	Premature deaths by PM _{2.5} /MWh of electricity produced (radionuclides for Nuclear)	Quantitative (deaths/MWh) minimize	0.00	0.00	0.00	0.00	13.95E-09	14082.61E-09	1350.25E-09	19848.96E-09
11	Safety	Severe accidents from the construction, operation and maintenance of electricity generating technologies, as well as during the transport and storage of resources and equipment, should be minimized in order to reduce accidents resulting in fatalities within and outside power plants	11.1	Fatalities from severe accidents in T&S and O&M of large-scale power plants per MWh	Quantitative (fatalities/MWh), minimize	0.00	0.00	6.11E-09	3.12E-09	0.062E-09	0.94E-09	9.09E-09	43.9E-09
			11.2	Potential of regulatory and operational emergency preparedness and response capabilities of the private and public sector to mitigate and manage the risk of catastrophic accidents with maximum and severe consequences during the construction and operation phase of each technology (hereafter referred to as "normalized fatalities"	Qualitative with a 5-step descriptive scale, maximize	4.00	3.00	4.00	3.00	1.00	2.00	2.00	1.50

Table 1- Attribute matrix for the 11 criteria under study based on Schinke et al., 2017.

The set of criteria was furthermore divided into two elements. Both elements contribute to societal support by covering the socio-economic, environmental, and social dimensions of sustainable development in the context of technology planning and deployment in Morocco.

National level: Expanding future electricity generation capacities in Morocco is not only geared towards secure, low-cost, and accessible power supplies but is envisioned to yield long-lasting development dividends. Five criteria were found to be of predominant relevance with regard to their contribution to national energy planning objectives in Morocco: use of domestic energy sources, climate change mitigation, technology and knowledge transfer, industry integration, as well as electricity system cost.

Local level: Electricity generation technologies are not only related to national objectives, but also have the potential to impact the livelihood of local communities in the vicinity of project sites. This is why six locally relevant criteria aim to shed light on the local impact sensitivity of certain electricity infrastructures. They encompass the aspects of land and water resources, on-site job creation, air pollution, hazardous waste, and safety issues. While these criteria also have national or even international relevance—in the case of nuclear waste or transnational water resource management, for example—their direct impacts are mostly felt at their source and therefore herewith considered to be predominantly local.

In line with the opinion of various authors (Wüstenhagen et al., 2007; Wolsink, 2007; Devine-Wright, 2008; Stern, 2014), these two elements—i.e., the national and the local level—are intended to give insights into whether the planning and implementation process of a specific technology could receive societal support or could be confronted with resistance and opposition—at the national and local level. Although often used interchangeably (Ekins, 2004), the term “support” was chosen over “acceptance” as the latter has a passive connotation thereby perpetuating the normative top-down perspective on people’s relationships with energy infrastructures. In contrast, the term “support” explicitly entails that stakeholders actively give approval for a decision and might participate in its implementation (Batel et al., 2013). Accordingly, societal support is herewith defined as: “the favorable or positive reaction towards the implementation or adoption of a proposed technology by the members (individuals and collective actors) of a given society [...] at the national and local level” (Oltra et al., 2014, p. 7).

3.3.3 The stakeholder groups

At the core of the study was a series of seven one-day stakeholder workshops. The first six workshops consisted of stakeholder groups that each shared homogeneous

backgrounds, whereas the final workshop encompassed a heterogeneous stakeholder group to which an equal number of previous participants were invited. In line with different scholars (Tsoutsos et al., 2009; Schweizer et al., 2014; Shortall et al., 2015; Bidwell, 2016) who recommend the inclusion of political, economic, scientific, and socio-cultural actors in electricity planning, six stakeholder groups of different domains were selected to participate in this research. Participants were identified based on a comprehensive stakeholder analysis and according to their power and interest in Morocco's electricity decision-making as well as to the extent to which they are impacted by electricity installations. The stakeholder analysis was facilitated as a desk-research and conducted by the research team in cooperation with the local partners. In a first step, broad stakeholder categories, for example, "Policy-makers", "Young Leaders" etc. in line with the above mentioned different domains were established. In a second step, these categories were broken down into more concrete sub-groups of these categories, e.g., for the category "Finance and Industry", small and medium-sized enterprises or national banks. In a final step, representatives of the sub-groups were determined. Consequently, the following stakeholder groups have been identified.

Policy-makers: stakeholders who are directly involved in electricity planning as well as generation and distribution, e.g., National Agency for Electricity and Water (ONEE), the Ministry of Energy, Mines, Water and the Environment (MEMEE), and Moroccan Agency for Solar Energy (MASEN);

Finance and Industry: stakeholders who are characterized by high electricity end-use as well as directly involved in the implementation and financing of power capacities, e.g., small and medium-sized enterprises (SMEs), national banks, the Morocco Sustainable Energy Financing Facility (MorSEFF), and the State-funded Energy Investment Company (SIE);

Academia: stakeholders who are scientifically interested and involved in the research and development of electricity systems, e.g., universities, research institutions, and think tanks;

Young Leaders: stakeholders who can be regarded as future decision-makers or opinion-leaders and have a strong interest in national energy planning due to their professional background, public engagement, and networks, e.g., the Young Leaders Program of the Friedrich Ebert Foundation in Morocco, bloggers, civil society activists, and university graduates;

National NGOs: stakeholders who have a strong interest in national energy planning and are involved in national NGOs working on environmental protection, social justice, and human development, e.g., the Moroccan Alliance for Cli-

mate and Sustainable Development (AMCDD), the *Group de Travail* of the WWF Morocco, and the Climate Action Network Arab World (CANAW);

Local Communities: stakeholders who live in close proximity to electricity generation technologies and are thus directly affected by national electricity planning, e.g., community members of Agadir, Safi, Ouarzazate, Essaouira, Mohammedia, and Ait Beni Mathar.

The involvement of different stakeholder groups in an intensive, discussion-oriented, and participatory process allowed a wide array of multidimensional perspectives on Morocco's energy future to be elicited. Yet, during all workshops, attention had to be focused on creating a climate that welcomes discussion, where different stakeholder views were respected and equally validated, while at the same time room for mutual learning and new information was provided. This was in particular the case for the final workshop where equally legitimate opinions and perspectives as well as mutual learning experiences had to be safeguarded by the moderators in order to allow a balanced representation of all stakeholder groups during the often heated debates among participants.

3.4 Elicitation of stakeholder preferences

Explorative methods were applied to identify stakeholder preferences and perceptions in the context of electricity planning in Morocco. A focus group set-up was chosen because this qualitative social research method allows for the elicitation of attitudes of the participants for a pre-defined set of topics (Sinclair et al., 2015). Additionally, it is well suited for the combination with other participative exercises as well as transdisciplinary techniques (ibid.). The aim of the stakeholder workshops was five-fold:

- a) Vision building: development of stakeholder visions for Morocco and discussion of aspirations and concerns as to how the deployment of new electricity generation technologies could enable or hamper the fulfillment of these visions;
- b) Technology perceptions: exploration of stakeholder perceptions in regard to the electricity generation technologies under study;
- c) Criteria discussion and gap analysis: discussion of the pre-selected set of evaluation criteria as well as identification of gaps for further research;
- d) Criteria ranking: elicitation of stakeholder preferences and achievement of a compromise on criteria ranking;
- e) Appraisal of procedural and distributive justice: discussion on the technology-specific need for participatory and fair decision-making processes at the community level.

This structure was followed by all six homogenous stakeholder workshops, whereas the final heterogeneous stakeholder workshop included only step d).

3.4.1 Vision building

In coherence with Lilliestam and Hanger (2016), stakeholder visions are defined as “[...] emotionally appealing descriptions of the problem to solve, the desired future system, and the policies and governance pathways to achieve that future” (Lilliestam & Hanger, 2016, p. 20). As stakeholders have different priorities, interests and normative assumptions, their visions fundamentally differ from each other and might clash. Consequently, this part highlights issues that embody to a certain degree the underlying worldviews and values and gives hints at what different stakeholder groups value most and what they hope for, what they are concerned about, and how they view the different electricity generation technologies.



During the six stakeholder workshops the participants were given 45 minutes to develop their individual vision of how they, as representatives of their specific stakeholder group, would like Morocco to be in the year 2050. Participants were provided a set of cards and asked to write down either a short sentence or an attribute for



their vision in three areas: the economy, the society, and the environment. Afterwards all cards were discussed on flipcharts and clustered in common themes where agreement was reached as well as in differences where perspectives diverged. The aim here was not to be comprehensive but to identify the top priorities in how different stakeholder groups imagine a desirable future for Morocco and how their visions are reflected by the GoM’s vision of sustainable development.

Following the vision development phase, the participants were given 60 minutes to express their aspirations and concerns in regard to the question of how the deployment of new electricity generation technologies in Morocco could enable or hamper the ful-

fillment of their vision economically, socially, and environmentally. To facilitate this task, short vignettes for each technology were distributed to provide unbiased, non-technical information on the basic functions and performances of the examined technologies. After discussing the specifics of the different technologies, participants again were provided a set of cards and asked to formulate their thoughts as representatives of their specific stakeholder group. Afterwards all cards were clustered around the main issues that emerged during the vision development and discussed openly. The picture illustrates how the group of “National NGOs” clustered their aspirations (green) and concerns (orange) around their vision (blue) (yellow cards represent criteria; see below).

3.4.2 Assessment of technology perceptions

The ways in which different stakeholder groups “subjectively construct” and attach meanings to electricity generation technologies are widely recognized as important issues shaping the achievement of energy planning objectives and the implementation of electricity projects (Webler & Tuler, 2010, p. 2691). Hence, in addition to the evaluation of stakeholder groups’ aspirations and concerns in the context of electricity planning, it was deemed important to explore how the stakeholder groups specifically perceive the different electricity generation technologies under study. The participants of each stakeholder group were given 30 minutes to discuss this task openly among themselves. Supplemental information was gathered additionally from the multiple discussions during the workshops and integrated into this task.

3.4.3 Discussion of criteria and gap analysis

Building on the previous tasks, the next 60 minutes were dedicated to reaching a common understanding of all the pre-selected criteria across all stakeholder groups as well as to identifying gaps in the set of criteria which could inspire potential future research. In order to achieve this goal, the task was split into two parts. The first step was to explain to the stakeholder groups the rationale behind the set of criteria, i.e., the development process of the criteria and their meaning, and to reword the criteria if the participants so required. In coordination with the stakeholder groups, the second step was to assign the criteria to the clusters of aspirations and concerns developed in the previous task (Chapter 3.2.1) and to recognize any gaps between the pre-selected criteria and the clusters identified for future research.

3.4.4 Criteria ranking

As stakeholder preferences are an indispensable element for a transdisciplinary evaluation process, it is important to choose a method that enables eliciting these preferences carefully. To combine the objective performance characteristics with

subjective stakeholder preferences, this study used the participatory weighting method “silent negotiation” (Pictet & Bollinger, 2005). “Silent negotiation” provides all stakeholder groups the opportunity to participate in the elicitation process and reaches at a “compromise solution” in a group setting that is based on mutual learning and verbal negotiation. The method is rooted in the ideas of deliberative and discursive democracy (Habermas, 1996; Dryzek, 2000), allowing participants to engage in a deliberative process wherein they can reframe their personal beliefs, value judgments, and underlying assumptions through the exchange of information, social learning, and strategic behavior (Howarth & Wilson, 2006). The method has been applied successfully by numerous scholars and to similar decision-making problems in the context of energy decision making (Omann et al., 2008; Kowalski et al., 2009; Wilkens & Schmuck, 2012). In this method, participants express their preferences directly for specific sustainability dimensions and indirectly for the examined electricity generation technologies a) by ranking the criteria in the form of colored cards, and b) by refining the criteria ranking with additional blank cards. To avoid lengthy discussions beyond the thematic scope and foreseen timeframe, Pictet and Bollinger (2005) separated the actual decision part from the discussion part where the criteria ranking is established silently without revealing the participants’ arguments and afterwards discussed openly among participants. All workshops provided participants 120 minutes to complete this task with the goal being to reach a “compromise solution” based on equal terms and a democratic decision-making process.



The criteria were known by the participants as they had discussed and jointly adjusted them in the previous sections of the workshops. For the ranking procedure, each criterion was inscribed on a colored card with its objective on the back of the card and arranged in a horizontal row on a large table—meaning that all cards were of equal importance. Now all participants, standing in a circle around a table (see picture), were asked successively to rank

the cards from the least important to the most important by moving the cards from the horizontal arrangement to a more vertical arrangement. (Cards higher in the ranking are more important than cards lower in the ranking; the card(s) on top of the ranking reflect the criteria with the highest importance and vice versa; equal ranks means equal importance.) This process involved four rounds of “silent negotiations” where the number of “moves” (which did not have to be used, but instead

could be passed on) decreased with each round and an open discussion after the first and third round to exchange arguments on the preliminary rankings⁸.

\ 1st round/8 moves per participant

\ 2nd round/5 moves per participant

\ 3rd round/3 moves per participant

\ 4th round/2 moves per participant

The reduced number of “moves” allowed for “disruptive behavior” to be limited and forced each participant to place their preferences strategically while taking into account the viewpoints and preferences of other participants that were exchanged during the open discussion between the third and the fourth round. Since the open exchange made participants rethink their opinion and adjust their preferences based on the arguments of others, the advantages of mutual learning during the open discussions were estimated higher by the authors than the potential disadvantages of opinions being influenced or undermined by dominant participants. As some participants saw the “starting position” as a strategic disadvantage, the starter was drawn by lot prior to each round.



After the final ranking was decided and a “compromise solution” found, participants were provided the opportunity to refine the ranking. This was done by introducing a set of blank cards. During three additional rounds with a decreasing number of “moves” and an open discussion after the second round⁹, participants were asked to

⁸ In principle, the number of rounds/moves could be indefinite until an agreement is reached. However, as this could result in a never-ending process, Pictet and Bollinger (2005) advised to limit the rounds and moves per participants to a practical number. As there is no exact suggestion for the number of rounds and moves, the research team tested different combinations during three test-workshops with members of the research team and lay people, and then decided on the combination that was found to be the most practical while still allowing for strategic behaviour.

⁹ In contrast to the revised Simos method (see Figueira & Roy, 2002), where additional information about the ranking in form of the so-called “Z-value” is necessary, this additional step is not required for calculating weights using the CAR method (see Chapter 3.3.1).

insert blank cards between two successively ranked criteria in order to express their strong preference between criteria.

\ 1st round/3 moves per participant

\ 2nd round/2 moves per participant

\ 3rd round/1 move per participant

Verbal expressions were used to define the meaning of white cards (e.g., a blank card in between two ranks increases/decreases the importance of the rank above/below the blank card). The number of blank cards is proportional to the difference of importance between the considered criteria.

\ No blank card: the rank above is *slightly more* important;

\ 1 blank card: the rank above the white card is *more* important;

\ 2 blank cards: the rank above the white cards is *much more* important;

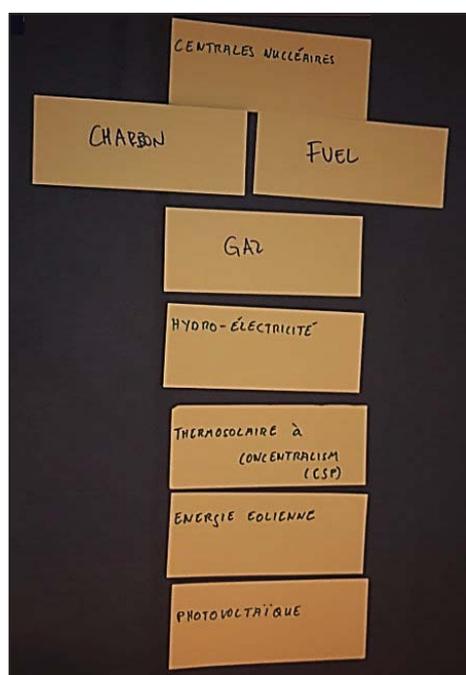
\ 3 blank cards: the rank above the white cards is *extremely more* important.

Since the series of the six homogenous workshops was facilitated over five months, the established final rankings of each workshop were handed to the representatives of each stakeholder group during the final “compromise solution” workshop. This not only allowed each stakeholder group to familiarize themselves again with their results and remember their preferences during the “silent negotiation” but also gave the groups the opportunity to present each ranking and their underlying arguments to the other participants during a short presentation round of five minutes per group prior to the actual ranking exercise.

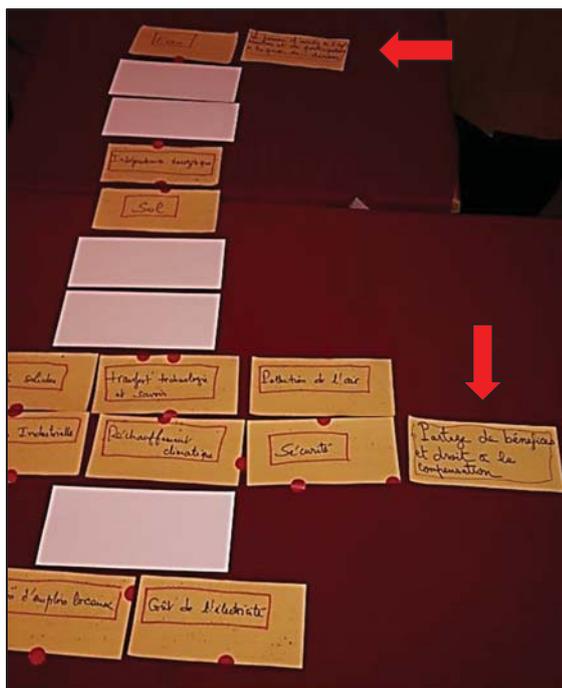
Although the method of “silent negotiation” had been explained in detail prior to the elicitation process and was easily grasped during all stakeholder workshops, the moderators had to ensure that the “rules of the game” were followed and every step understood throughout this exercise. While a final criteria ranking based on criteria cards and refining blank cards was the tangible outcome of the elicitation process, vivid discussions held between the rounds of “silent negotiations” provided additionally valuable insights—for example, on technology perceptions (see Chapter 3.2.2). In line with Whitton et al. (2015) who highlighted the importance of opening up the process of “silent negotiations,” these discussions revealed “invisible” lines of conflicting or common interests among participants and between stakeholder groups and thus became valuable for the further analysis (see Chapter 4).

3.4.5 Appraisal of procedural and distributive justice

Research shows that attitudes towards different electricity generation technologies are not exclusively influenced by project outcomes, but also depend on the subjective perceptions of fair and participatory decision-making processes (Gross, 2007; Devine-Wright, 2011; Schinke et al., 2015). This is particularly the case at the local level, where communities adjacent to power facilities tend to bear much of the socio-environmental externalities and usually see little of the benefits—especially since the electricity and economic revenues generated are transported to distant consumption and economic centers instead of being used locally. As a consequence, feelings of injustice and exclusion in the deployment of electricity facilities can arise and be exacerbated when decisions are made opaquely to benefit some sections of the local population at the expenses of others. Projects that are perceived to be unfair and imposed on local communities, e.g., projects that are developed in a “decide, announce, defend” (DAD) instead of a “meet, understand, modify” (MUM) manner (Vanclay et al., 2015) - can then result in mistrust towards project developers, social conflict, and significant community opposition—with the vulnerable and marginalized, such as ethnic, economic, or demographic minority groups being particularly disadvantaged. In Morocco several cases are documented where non-participative top-down processes for the deployment of power plants that did not take into account the voices of affected citizens led to protests and caused projects to be delayed or abandoned altogether (see Chapter 4.1.2).



However, actors may estimate the need for granting procedural and distributive justice to local communities differently for each electricity generation technology. This is due to varying perceptions on the transformative characteristics of different power plants. In order to shed light on the technology-specific need for participatory and fair decision-making processes at the community level, 60 minutes were dedicated during the six homogeneous stakeholder workshops to explore the need for procedural and distributive justice in the context of the eight technology options under study. In line with Hall et al. (2013), procedural justice, was herewith explained to the participants as the meaningful and participatory engagement of local citizens in the decision-making of power plant deployment (Hall et al., 2013, p. 205), whereas distributive justice was related to the distribution of benefits and burdens stemming from a specific electricity generation project (Hall et al., 2013, p. 204).



During this exercise two steps were conducted. First, the participants of each stakeholder group were asked to develop and discuss a ranking of technologies, where the technology with the highest need for procedural and distributive justice has to be on top of the ranking and the technology with the lowest need on the bottom. It was also possible to put technologies on the same rank, meaning that they have a similar need in accordance to the issue at hand (picture on page 30). Second, participants of each stakeholder group and the final “compromise solution” workshop were asked to integrate the two elements of procedural and distributive justice into their final criteria ranking as additional criteria and according to their relative importance compared to the other 11 criteria (picture to the right). All arguments and opinions were analyzed and summarized descriptively.

3.5 Analysis of results

The analytical part of the research methodology consisted of two key objectives:

- a) Analysis of potential conflict lines and commonalities: transformation of the criteria ranking into weights by applying the Cardinal Ranking (CAR) method and investigation of the different individual group weightings as well as the “compromise solution” with descriptive statistics, cluster analysis, and observations made during the workshops in order to identify potential conflict lines and commonalities between the different stakeholder groups; Additionally, a comparison based on the ranks was conducted;
- b) Multi-Criteria Decision Analysis (MCDA): establishment of a technology ranking based on stakeholder criteria preferences (weights) developed as the “compromise solution” and technology performance characteristics by applying the Multi-Attribute Decision Making (MADM) software DecideIT 2.82.

3.5.1 Analysis of potential conflict lines and commonalities

In order to statistically analyze potential conflict lines and commonalities between the different stakeholder groups as well as in the “compromise solution” the criteria rankings needed to be converted into weights. For the calculation of the weights the Cardinal Ranking (CAR) method was applied (Danielson & Ekenberg, 2015a). The CAR method builds on the idea of what are known as surrogate weights and con-

verts the cardinal criteria ranking including the blank cards into numerical weights. Thereby information loss is limited (Danielson & Ekenberg, 2015b). The numerical weights are calculated according to the following formula¹⁰ (for further details, see Danielson & Ekenberg, 2015b):

$$w_i^{CAR} = \frac{\frac{1}{p(i)} + \frac{Q + 1 - p(i)}{Q}}{\sum_{j=1}^N \left(\frac{1}{p(j)} + \frac{Q + 1 - p(j)}{Q} \right)}$$

Whereas:

Q = The total number of importance scale positions

$p(i) \in \{1, \dots, Q\}$ = Position of each criterion i on the importance scale,

such that for every two criteria c_i and c_j whenever $c_i > s_i c_j$, $S_i = |p(i) - p(j)|$

Based on the weightings of each stakeholder group and observations made during the workshops, the analysis of potential conflict lines and commonalities between the different stakeholder preferences was facilitated in four steps.

In the first step, different tools of descriptive statistics (e.g., the arithmetic mean and standard deviation) were applied to examine and describe the main patterns as well as similarities and differences between all group weightings. Additionally, observations and notes taken during the workshops were used to investigate the reasoning of the stakeholder groups behind their individual group weightings (see Chapter 4.1.4.1 to 4.1.4.1.1)

In the second step, a statistical cluster analysis was conducted to shed additional light on the commonalities and discrepancies between the different group weightings (see Chapter 4.1.4.1.2). Cluster analysis includes a variety of techniques that are used for the classification of objects (i.e., stakeholder preferences) into subsets (clusters) that tend to be similar to each other (Himes, 2007; Howitt & Cramer, 2011). It, therefore, can help to identify similarities and differences between stakeholder weighting sets (Kowalski, 2010) and has been applied for the analysis of stakeholder weightings by various MCDA scholars (e.g., Himes, 2007; Kowalski, 2010; Schenler et al., 2009; Garmendia & Gamboa, 2012; Sullivan, 2012). As it was not the goal to predefine a number of clusters, which would have been possible with k-means clustering, hierarchical clustering was the method of choice. As a distant measure, the squared Euclidean distance¹¹, which is one of the most common distant

¹⁰ For ease of use, an excel spread sheet was prepared to calculate the numerical weights using the CAR method.

¹¹ The squared Euclidean distance is also recommended as a distance measure in combination with the Ward's method (Hair et al., 2010, p. 494).

measures, and “Ward’s method”, which is one of the most common agglomeration algorithms, were applied (Sullivan, 2012; Mooi & Sarstedt, 2011) (see Annex 7 in suppl. material for a comparison of different agglomeration algorithms).

In the third step, the “compromise solution” was statistically analyzed with descriptive statistics (see Chapter 4.1.4.2) and in regard to the criteria movements made during “silent negotiation” (see Chapter 4.1.4.2.1). The tracking of the criteria movements allowed for the identification of potential lines of coalition/conflict based on the total number of moves for each criterion, the direction of movements, as well as a comparison of the standard deviation of the criteria movements with the standard deviation of the individual group weightings. Furthermore, the weighting of the “compromise solution” was also compared to the individual group weightings to reveal the representation of the stakeholder groups in the “compromise solution” (see Chapter 4.1.4.2.1). In this process, the distance was calculated from each individual stakeholder groups’ weight for a criterion to the weight of this criterion in the “compromise solution”. For example, the group of “Policy-makers” weighted the criterion “Use of domestic energy sources” at 13.95, while in the “compromise solution” the criterion was weighted at 16.62, resulting in a distance of 2.67 between the two weightings. Then, all calculated distances per group were added resulting in a cumulative distance per group that can be regarded as a reflection of the representation of this group within the “compromise solution”.

In a last step, the importance of the criteria was compared by using the rank position of the criteria within the individual group rankings taking into account the total number of ranks including white cards (see Chapter 4.1.5). This step was conducted in order to yield another analytical way to compare the individual group rankings, but also to disconnect the comparison from the mathematical calculated weights based on the CAR method. The surrogate weights based on the CAR method represent an approximation of the “real values” stakeholders have had indirectly in mind when determining the importance of a criterion. The CAR method, or any other weight approximation technique, is needed in order to conduct an MCDA as a numerical value representing the importance of the criterion is necessary for every criterion (see Chapter 3.3.2) (Danielson & Ekenberg, 2015a). However, the stakeholders stated their preferences arguably in the purest form with the position of the criteria in their rankings (e.g., on top, in the middle, or on the bottom of the ranking). A comparison based on the ranking position of the criteria constitutes a challenging problem as the total number of ranks was not restricted in any way in this study. Therefore, the individual group rankings were divided into five importance categories based on the total number of ranks (see Table 6 in Chapter 4.1.5; for details on how this table was developed see Annex 8 in suppl. material). Then, the importance

categories of the criteria based on their position within the rankings were compared with one another.

3.5.2 Multi-Criteria Decision Analysis (MCDA)

The performance of the different electricity generation technologies is one element of this study's evaluation process. Weighting derived from the preference elicitation is the other element. Together they provide the analytical base for conducting the technology evaluation. One method for structuring and evaluating a multi-actor and multi-objective decision-making problem is the Multi-Criteria Decision Analysis (MCDA). MCDA approaches are classified as integrated assessments since they integrate multiple objectives while including multiple stakeholders in the assessment process. The application of an MCDA combines information about the performance of different alternatives across a range of criteria (scores developed in the attribute matrix of Table 1) with stakeholder preferences about the relative importance of the evaluation criteria for achieving the vision 2050 (weights developed through silent negotiations and calculated with CAR). As part of the Multi-Attribute Decision Making (MADM) toolbox, the state-of-the-art MCDA software DecideIT 2.82 was employed in this study. In contrast to other regularly applied MCDA methods, DecideIT 2.82 follows the Multi-Attribute Utility Theory (MAUT) approach based on the delta method, which allows for the inclusion of uncertainties and imprecision (Ekenberg et al., 2011). Using this approach, the classical risk and decision evaluation process can be extended through the integration of procedures for handling qualitative and numerically imprecise probabilities and utilities. The cardinal ranking of DecideIT 2.82 compares the performance of each alternative to the average performance of all alternatives. This tool of comparison considers the entire range of values to be the alternatives present across all criteria. It depicts the differences between the possible minimum and maximum outcomes of the alternatives to indicate which alternative shows the probability to outrank the remaining. DecideIT 2.82 has been successfully used in various contexts, e.g., long-term storage of nuclear waste, choice of computer systems, and the analysis of bio-energy systems (Danielson et al., 2003; Danielson, 2005; Danielson & Ekenberg, 2007; Danielson et al., 2007). DecideIT 2.82 was applied to aggregate the given information into three results:

- \ Overall ranking of electricity generation technologies based on their specific performance characteristics and equal weights (i.e., the technology performance);
- \ Overall ranking of electricity generation technologies based on their specific performance characteristics and the weights established as "compromise solution" (i.e., the technology evaluation);

- \ Sensitivity analysis to test the robustness of the “compromise solution” against the ranges of attribute values and stakeholder group weights.

The results were presented directly after each workshop and participants’ feedback was collected during a 30-minute discussion.

4 RESULTS

The result section contains two analytical elements. The first step was to process and evaluate the stakeholder preferences derived from the workshops. The second step established the MCDA technology ranking based on the weightings reached as the “compromise solution” in the final workshop.

4.3 Analysis of stakeholder preferences

The analysis of the stakeholder preferences in electricity planning encompassed the five steps outlined in Chapter 3.2: 1) Visions; 2) Technology perceptions; 3) Gap analysis; 4) Criteria ranking; and 5) Appraisal of procedural and distributive justice. To identify potential conflict lines and commonalities between the different stakeholder groups, all results were evaluated separately using descriptive statistics and cluster analysis and by including observations made during the workshops. The last step was to present concluding remarks.

4.3.1 Description of stakeholder visions

Although the identified visions were characterized by slight differences, the majority of the stakeholder groups imagined the future of Morocco in similar ways, indicating that they interpreted the current state of Morocco through comparable lenses.

Economy: Albeit the country’s strong economic performance and boosted prosperity over the past decade as a result of the GoM’s efforts to improve the investment and business environment through structural reforms, Morocco still faces considerable socio-economic challenges (Schinke et al, 2016, p. 10-13). When asked how they would like to see the Moroccan economy by 2050, the stakeholders expressed visions that all referred to the existing socio-economic challenges, such as greening the economy, securing reliable and affordable energy supplies, poverty, joblessness, lack of industrial competitiveness, and the country’s high energy import dependence with its corresponding trade deficit. Accordingly, the prevailing economic vision across all groups is summarized as follows:

“A green and thriving economy where poverty is eradicated, reliable electricity is affordable and based on domestic energy sources, as well as national industries can compete on the world market due to improved framework conditions to attract foreign direct investments”

Society: Despite the GoM’s progress in pursuing political, judicial, and social reforms under the National Constitution adopted in 2011, multiple social challenges continue to threaten the country’s political stability, such as social inequalities in income and status, rural exodus, and economic deprivation (Schinke et al., 2016, p. 13-14). When asked about how they would like to see Morocco by 2050, the stakeholder groups mostly shared the same view on certain elements that were considered fundamental for enabling a new form of social contract in particular for inclusive human development, good governance, access to basic services, and social protection in health. Accordingly, the prevailing social vision across all stakeholder groups is summarized as follows:

“An inclusive, equal, solidary, and knowledge-based society with high levels of quality of life as well as improved framework conditions for participatory governance”

Environment: The environment in Morocco is subject to strong pressure due to demographic growth, urbanization, industrial activities, and the effects of climate change (Schinke et al., 2016, p. 14-17). When asked about how they would like to see the status of the Moroccan environment by 2050, the majority of stakeholders expressed visions referring to the overcoming of existing environmental challenges, such as water scarcity, exploitation of natural resources, pollution, and changing weather patterns. Accordingly, the prevailing environmental vision across all stakeholder groups is summarized as follows:

“A healthy and clean environment in which natural resources and biodiversity are protected by stricter environmental regulations and adaptation capacities are high to cope with climate induced risks”

Significant differences emerged not on controversial issues or between specific stakeholder groups, but only on additional narrative elements (see Table 2 and Annex 1 in suppl. material for the detailed summaries).

		Policy-Makers	Finance/Industry	Academia	Young Leaders	National NGOs	Local Communities
Economy	Green growth	X	x	x	x	x	x
	Energy security	X	x	x	x	x	x
	Poverty eradication	X	x	x	x	x	x
	Economic competitiveness	X	x	x	x	x	x
	Attractive business environment	X	x	x		x	
	Import independence	X	x	x		x	
Society	Social justice	X	x	x	x	x	x
	Participatory governance	X	x	x	x	x	x
	Solidarity	X	x	x	x	x	x
	Knowledge and education	X	x	x	x	x	x
	Quality of life and safety	X				x	x
Environment	Protection of natural resources	X	x	x	x	x	x
	Conservation of biodiversity	X	x	x	x	x	x
	Resilience to climate change	X	x	x	x	x	x
	Environmental regulations	X	x	x	x	x	x

Table 2: Key elements in the different stakeholder groups' visions.

The examination of the visions indicated a general agreement among Moroccan stakeholder groups on the GoM's policy framework towards low-carbon development and its corresponding policies to promote economic prosperity, good governance, and natural resources conservation (see Chapter 2). This finding pointed towards high levels of societal support on Morocco's chosen development pathway. The evaluation of the different stakeholder groups' aspirations and concerns around how the electricity sector could either foster or hinder the achievement of their vision for Morocco in 2050 indicated many similarities as well as differences. All stakeholder groups were unanimous in their views that new electricity generation capacities could pave the way towards their vision by contributing to solving today's most pressing challenges and utilizing existing opportunities. The aspirations and concerns that were mentioned by the majority of stakeholder groups as well as differing opinions can be summarized as follows:

Economy: When stakeholder groups were asked how electricity generation technologies could either hamper or foster the achievement of their vision towards green growth, poverty eradication, economic competitiveness, an attractive business environment, and import independence, the most dominant patterns among stakeholder groups were found on the following elements.

- ① Aspirations: Stakeholder groups aspired to have a diversified electricity system based on high shares of RE that would reduce the country's energy dependence, while, at the same time, be capable of opening new economic opportunities for employment, industry integration, and foreign direct investments.
- ⬇ Concerns: Affordability of electricity prices and a lack of absorptive capacities in domestic industries were among the most prominent concerns.
- ⊙ Differences: Differences were found on additional issues and especially between "Local Communities", "National NGOs", and "Young Leaders" on the one side and "Finance and Industry", "Policy-makers" and "Academia" on the other. The latter raised concerns about the maturity of certain electricity generation technologies, the stability of the electricity system, and the vulnerability of the country to global energy price fluctuations. It also had aspirations to benefit economically in electricity generation. The former did not mention any of those rather technological issues. Additionally, the perspectives of "Local Communities" differed in such a way that this group did not mention most of the rather nationally relevant aspirations and concerns mentioned by the other stakeholder groups or issues related to energy independence in particular.

Society: When stakeholder groups were asked how electricity generation technologies could either hamper or foster the achievement of their vision towards a society based on social justice, participatory governance, solidarity, knowledge, and a high quality of life, most dominant patterns were found in the following elements.

- ① Aspirations: Stakeholder groups hoped that the deployment of new electricity generation capacities would increase environmental awareness and national pride within the society and would be accompanied by initiatives to improve social equality, political participation, and skill development to benefit from knowledge and technology transfer.
- ⬇ Concerns: Transparency in energy planning, persisting mismatches between educational qualifications, and the labor market as well as risks of technology failure, e.g., accidents or break downs, were among the bulk of concerns.
- ⊙ Differences: "Local Communities" and "National NGOs" particularly differed from the other stakeholder groups as they raised additional concerns about the risk of elite capture, increased social divide, and reduced social cohesion within the Moroccan society. They also worried about negative local

effects in communities located in the vicinity of power plants, such as visual impacts as well as noise pollution.

Environment: When stakeholder groups were asked how electricity generation technologies could either hamper or foster the achievement of their vision towards a healthy environment based the protection of natural resources, conservation of biodiversity, resilience to climate change, and environmental regulations, dominant patterns among the groups were found in the following elements.

- 👉 Aspirations and concerns: Most of the stakeholder groups' environmental perspectives were ambivalent. Among the most prominent issues were the positive as well as negative impacts on water security, air quality, waste management, GHG emissions, and environmental regulations.
- 👉 Differences: "Local Communities" and "National NGOs" differed from the other stakeholder groups as their range of concerns was wider than the other groups' spectrum and included issues such as restricted land use, land degradation, loss of biodiversity, as well as sensitivity of technologies to climate change, e.g., with regard to the availability of water or higher evaporation of dam reservoirs or the functionality of technologies in a hotter environment.

Table 3 illustrates all aspirations and concerns mentioned by the six stakeholder groups during the workshops. A more detailed summary of the content depicted in Table 3 can be found in Annex 2 in suppl. material.

	Vision	Aspirations/Concerns	PM	FI	AC	YL	NGOs	LC
Economy	Green growth	Share of RE in the electricity mix	x	x	x	X	x	x
		Maturity of technologies	x	x	x			
	Energy security	Stability and reliability of the electricity system	x	x	x			
		Affordability of electricity prices	x	x	x	X	x	x
	Poverty eradication	Employment and income opportunities	x	x	x	X	x	x
	Economic competitiveness	Industry integration	x	x	x	X	x	x
		Lack of absorptive capacities in domestic industries	x	x	x	X	x	
	Economic attractiveness	Foreign direct investments	x	x	x		x	
		Economic participation in electricity generation	x	x	x			
		Policy coherence	x	x	x		x	
	Import independence	Use of domestic energy to improve national balance of trade	x	x	x	x	x	
		Diversification and regionalization of the electricity system	x	x	x	X	x	
Vulnerability to global energy price fluctuation		x	x	x				
Society	Social justice	Fairness and equality in energy planning			x	X	x	x
		Risk of elite capture					x	x
		Social exclusion				X	x	x
	Participatory governance	Political participation	x	x	x	X	x	x
		Non-inclusive and opaque energy planning		x	x	X	x	x
	Solidarity	National pride	x	x		X	x	
		Social conflict					x	x
	Knowledge and education	Technology and knowledge transfer	x	x	x	X	x	x
		Environmental awareness	x	x	x	X	x	x
		Mismatch of skills and competences	x	x	x	X	x	x
		Lack of education / industry cooperation	x	x	x	X	x	
	Quality of life and safety	Rural infrastructure and services		x			x	x
Landscape aesthetics and scenic attractiveness			x			x	x	
Noise						x	x	
Risk of technology failure		x		x		x	x	
Environment	Protection of natural resources	Water security	x	x	x	X	x	x
		Air pollution	x	x	x	X	x	x
		Land use					x	x
		Waste		x	x	X	x	x
	Conservation of biodiversity	Reforestation and regeneration of vegetation	x		x		x	
		Land degradation and loss of biodiversity					x	x
	Resilience to climate-induced threats	Greenhouse gas (GHG) emissions	x	x	x	X	x	x
		Sensitivity of technologies to climate change			x		x	x
Environmental regulations	Environmental regulations	x	x	x	X	x	x	

Table 3: Aspirations (green), concerns (red), and ambivalences (yellow) of the different stakeholder groups in the context of electricity planning and sustainable development (PM = Policy-makers, FI = Finance and Industry, AC = Academia, YL = Young Leaders, NGOs = National NGOs, LC = Local Communities). End-to-end colors are for the set of 11 pre-defined criteria, while additional issues are left blank.

4.3.2 Description of technology perceptions

Although there was a high variation in the familiarity and knowledge of the technologies among the different stakeholder groups, general patterns of similarities and differences between stakeholder perceptions and attitudes were identified. In spite of these general patterns, fossil fuel and RE technologies were not perceived as a unified monolithic block. Instead, stakeholders held a variety of views about the different technologies. These views are outlined as short summaries (snapshots) for each technology in the following paragraphs and thus not necessarily grounded on scientific facts, but rather reflecting what has been said and discussed during the workshops by the participants. Technology examples of existing power plants were frequently mentioned by stakeholders to underline their attitudes and are herewith also included as info boxes.

- \ Utility PV: All stakeholder groups were very positive about solar PV. Particularly because of its affordable costs and insignificant environmental impacts on air, water, and climate. Other advantages were seen in its promising economic prospects in regard to employment generation, industry integration, and its contribution to reducing the country's energy import dependence. Drawbacks were mentioned only by "Local Communities" in regard to the high land requirements, as well as by "Industry and Finance" and "Policy-makers" in the context of the reliability of this fluctuating energy source and in regard to the quality of technology imports from China.

580-MW CSP/PV solar complex in Ouarzazate

Although the introduction of the world's largest solar project *Noor* to the region of Ouarzazate was received very positively by the local population due to the project developer's (MASEN) efforts to align the technology deployment with broader human development objectives, social discontent in local communities also led to scattered community protests in 2013 and 2014. However, this opposition had little to do with the solar technology itself. Instead it centred on unfulfilled community expectations in regard to employment opportunities, procedural deficits to give affected communities a stake in the project—particularly in the land acquisition—as well as on concerns about the project's future water demands. Tensions eased when MASEN improved its community engagement strategy and established meaningful feedback and communication procedures (e.g., local team, on-site, mailbox) (Schinke et al., 2015).

- \ CSP: Ambivalent opinions among stakeholder groups were found in regard to solar CSP. While the technology was principally regarded as a clean and promising option for substituting imported fossil energy carriers with a domestic alternative, pockets of skepticism were found among all stakeholder groups. Resentments centered mainly on three aspects: intensive water consumption, high generation costs, and low technological maturity. Additionally, "Local Communities"

and “National NGOs” mentioned that employment creation and industry integration—despite being more promising than for fossil fuel alternatives—were perceived as rather low in the case of the Noor₁ project, which led to frustration among local community members (see info box above).

- \ Onshore wind: Wind farms were perceived favorably in terms of cost and environmental impacts—air, water, and climate—but less positively than utility PV. This was mainly because they were accused by “Local Communities,” “National NGOs” and “Finance and Industry” of spoiling the landscape aesthetics, having negative effects on birds, and reducing the attractiveness of certain regions—in particular in recreational, coastal, and touristic areas. Yet, it was a common opinion that electricity generated from onshore wind was clean, safe, and generally very beneficial in reducing Morocco’s high dependence on fossil energy imports.
- \ Utility hydro-electric: The opinions about utility hydro-electric were mostly positive. The technology was regarded as cheap, clean, and highly mature with great importance for national water and food security as well as for balancing the electricity grid. Yet, by referring to a recent case near the city of Midelt, “National NGOs” and “Local Communities” voiced concerns about involuntary resettlements and economic deprivation of communities adjacent to hydro-electric facilities (see info box). Furthermore, “Policy-makers” emphasized the limited capacities to further increase utility hydro-electric facilities in Morocco due to a lack of feasible sites and climate change impacts on soil erosion and sedimentation.

2.8-MW Tamalout dam near Midelt

The Tamalout dam is one of several dam projects that have been heavily criticized by Moroccan civil society and local residents for both their environmental impacts and the lack of fair community engagement procedures. Despite its promised benefits for water security, flood control, agriculture, and electricity generation (2.8 MW), the dam is faced with regular protests in adjacent villages. Concerns center on the destruction of natural habitats, the forced resettlement and economic deprivation of local residents in the village of Tizinou, as well as unfair community engagement procedures including insufficient compensation (AlJazeera, 2015).

- \ Nuclear: All stakeholder groups raised doubts about the necessity of having nuclear power altogether in Morocco. Considered a new technology with little national experience in managing it, anxiety remained high among all participants in regard to low-probability/high consequence accidents as well as the disposal of nuclear waste. Yet, “Policy-makers” mentioned advantages of nuclear electricity generation in terms of climate change mitigation and electricity system costs.
- \ Coal: Although coal was regarded as a reliable and comparably cheap energy source, the majority of stakeholder groups expressed high concerns about classi-

cal pollution problems, such as air, water, and soil pollution as well as global warming stemming from coal emissions and hazardous solid waste. Examples of Jerrada, El Jadida, and Safi (see info box) were given by “Local Communities” and “National NGOs” to underline these concerns. An exception was marked by “Policy-makers” who expressed confidence in the advantages that “clean” coal technologies including Carbon Capture and Storage (CCS) could bring to the people and the environment as well as a stabilizing baseload component to the electricity grid in general.

1,386-MW coal-fired thermal plant in Safi

Multiple mass protests have occurred in the city of Safi against the construction of a 1,386-MW coal-fired power plant since 2014. Opposition centers on two arguments: On the one hand, the project is accused of polluting the environment and of endangering human health (e.g., respiratory diseases) as well as aquatic sea life with its air emissions, thermal discharge into the sea, and possible leakage into the soil. On the other hand, residents hope to have a solar project in their neighborhood instead of the climate-polluting coal power plant—despite deploying “clean” coal technology (Observers-France24, 2015; AttacMaroc, 2015).

- \ Natural gas: Power plants based on natural gas appeared to be the least controversial electricity generation option among the conventional energy carriers. Explosions of gas pipelines and leakage were considered to be adverse side effects by “Local Communities” and “National NGOs”, but were still regarded as less harmful compared to oil-fired alternatives. Stakeholders from “Finance and Industry”, “Academia”, and “Policy-makers” highlighted the need to have natural gas-fired electricity generation in Morocco in order to stabilize the national grid with dispatchable electricity options especially in times of highly fluctuating RE. In contrast to the views of the other three groups they were also optimistic about exploring the potential of drilling for domestic natural gas reserves on and off the shores of Morocco.
- \ Oil: Attitudes towards oil power plants centered entirely on environmental and economic disadvantages. All stakeholder groups stressed that oil spills could leak into the soil and the sea with devastating impacts on human health and environmental integrity. Also, increasing world market prices were related to high economic costs as well as vulnerability to global price fluctuations—especially as oil resources are declining. The two oil-fired power plants in Ait Melloul/Tiznit and Laâyoune were mentioned by “Local Communities” and “National NGOs” to emphasize their arguments (see info box).

72-MW oil/diesel-fired power plant in Ait Melloul/Tiznit/Laâyoune

Two attempts to install a 72-MW oil-fired power plant in Ait Melloul and then in Tiznit failed due to civil society objections in 2010 and 2011. Both locations were rejected by local residents because of concerns over environmental pollution, loss of agricultural land, and frustration over opaque consultation procedures, such as limited information and possibilities for participation, as well as exclusion of community groups. In a last attempt, the *GoM* decided to move the project site 600 km south and extend an existing power plant next to Laâyoune with 72 MW of additional capacities. Despite scattered public protests with similar arguments as previously in Ait Melloul and Tiznit, the *GoM* has moved ahead with its plans and expects the power plant to become operable by 2017 (Schinke et al., 2015, p. 63; WSRW, 2015).

In summary, the results of this short evaluation show that there are converging stakeholder perceptions on electricity generation technologies. This implies the possibility of a balanced compromise being reached between economic, social, and environmental considerations among all stakeholder groups in the final workshop. Additionally, several observations can be drawn from this exercise:

- \ Firstly, the overwhelming response by all stakeholder groups was strongly positive toward RE technologies, with more pronounced tendencies towards utility PV and onshore wind, and rather negative attitudes toward their fossil fuel and nuclear counterparts.
- \ Secondly, while socio-economic and environmental issues were mentioned more frequently than technical aspects, uncertainties were high as to what constitutes an acceptable trade-off between environmental sustainability, human health, economic affordability, and reliability of electricity supply.
- \ Thirdly, a deficit of technical understanding on certain technologies did not equate with an absence of personal attitudes and opinions associated with technologies.
- \ Fourthly, attitudes were frequently rooted in subjective word-of-mouth information and associated with existing projects people heard of, rather than based on objective and scientifically sound information that stakeholders experienced firsthand¹². However, this was not the case in all workshops, but only on specific issues, such as, the LCOE of nuclear power plants or the water usage of CSP power plants.

¹² Participants mentioned in the discussions that some information was grounded in word-of-mouth. In other cases, where participants mentioned very clearly subjective not scientifically sound information about specific issues or projects the facilitators asked for the source of the information. In these cases, participants stated that they got the information from friends, colleagues etc.

- \ Lastly, participants of “Finance and Industry”, “Academia”, and “Policy-makers” balanced their opinions between socio-environmental and technical issues, thus having a more systemic understanding of electricity generation in general, whereas “Local Communities” and “National NGOs” frequently referred to existing cases in order to emphasize their opinion.

4.3.3 Description of criteria discussion and gap analysis

A comparison of the set of criteria described in Chapter 3.1.2 with the aspirations and concerns highlighted by the stakeholder groups in the context of electricity planning and development illustrated that a) the majority of the pre-selected criteria were mentioned as being of great relevance by all stakeholder groups, and b) that the stakeholder groups’ perspectives are very well in line with the national policy framework towards sustainable development in Morocco (see Chapter 2). This is an important finding that shows the high familiarity of the participants with the pre-selected set of criteria and thus reduced the risk of participants constructing their preferences during the criteria ranking instead of having preconceived preferences beforehand. Yet, two significant differences were found:

- \ The first was marked by “Local Communities” who did not mention the nationally relevant criterion “Use of domestic energy sources”. Instead this was the only group aside from “National NGOs” that highlighted the importance of “Pressure on local land resources” in the context of electricity planning.
- \ The second discrepancy was related to two predominantly local criteria and was marked by “Policy-makers” who did not refer to “Occurrence of non-emission hazardous waste” and by “Young Leaders” and “Finance and Industry” who did not discuss aspects of the “Safety” criterion.

As Table 2 and Figure 2 illustrate, gaps in the pre-selected set of criteria were found across all stakeholder groups but with different emphases. On the one hand, “National NGOs” and “Local Communities” highlighted locally relevant issues, such as impacts on traditional lifestyles and social cohesion, risk of elite capture, biodiversity, and sensitivity of technologies to climate change. “Policy-makers”, “Finance and Industry” and “Academia” on the other hand, suggested more technical additional criteria, such as maturity of technologies, stability and reliability of the electricity system, and vulnerability to global price fluctuations. Lastly, two additional criteria received agreement among the majority of stakeholder groups, namely diversification and regionalization of the electricity system as well as environmental awareness.

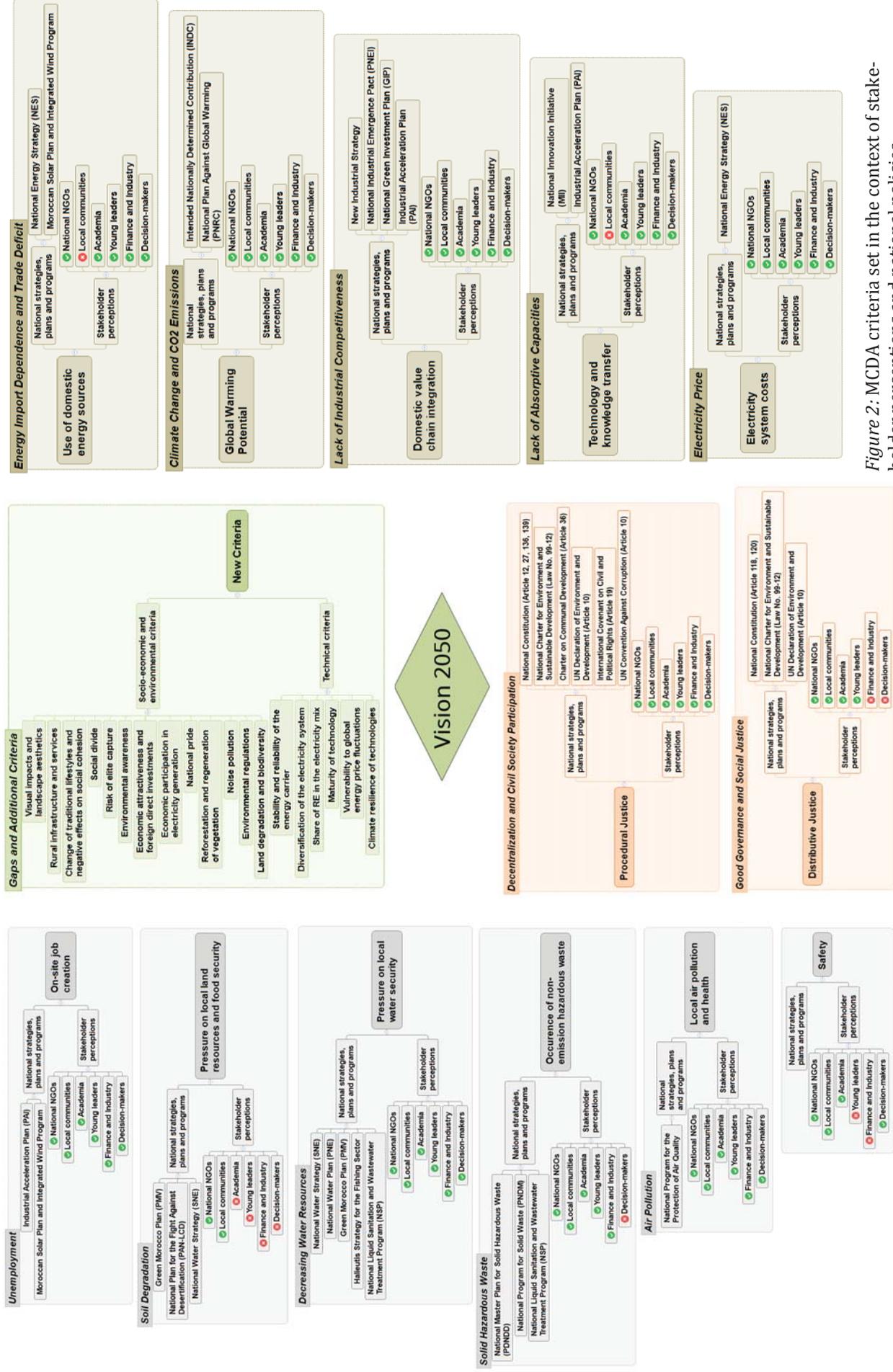


Figure 2: MCDA criteria set in the context of stakeholder perceptions and national policies.

4.3.4 Individual stakeholder group and compromise solution criteria rankings and weightings

Although the majority of stakeholder groups regarded the pre-selected set of criteria as very relevant for designing the future electricity system of Morocco (see Chapter 4.1.1 and 4.1.3), their individual preferences could differ significantly. To take legitimate differences into account, the elicitation of weights was regarded as a means for reflecting on diverse social preferences in the technology evaluation and for determining the importance stakeholder groups assigned to different criteria. Accordingly, this Chapter outlines the diverse preferences the different stakeholder groups developed in “silent negotiation” as a) their final ranking during the six homogenous workshops (Chapter 4.2.1) and b) as their “compromise solution” during the final stakeholder workshop (Chapter 4.2.2).

When all cardinal rankings are converted into numerical weights through the CAR method, comparisons can be made between individual stakeholder groups and between different criteria. This shed additional insights into “invisible” lines of conflicting or common interests among stakeholder groups (Chapter 4.2.3) and tested the robustness of the “compromise solution” (Chapter 4.2.4). In this regard, Table 4 presents the descriptive statistics of the weightings attached to each criterion including the arithmetical means and their associated standard deviations.

	Use of domestic energy sources	Global warming potential	Domestic value chain integration	Technology and knowledge transfer	Electricity system costs	On-site job creation	Pressure on land resources	Pressure on local water security	Non-emission hazardous waste	Local air pollution and health	Safety
<i>PM</i>	13.95	13.95	8.14	13.95	8.14	4.65	8.14	8.14	8.14	8.14	4.65
<i>FI</i>	23.38	5.71	8.33	8.33	16.48	6.99	2.13	9.78	2.13	6.99	9.78
<i>AC</i>	21.23	2.36	14.74	14.74	6.49	8.02	2.36	14.74	6.49	2.36	6.49
<i>YL</i>	15.09	6.29	3.77	15.09	15.09	3.77	6.29	9.43	9.43	6.29	9.43
<i>NGOs</i>	14.38	5.65	5.65	7.19	2.68	2.68	12.31	29.44	7.19	7.19	5.65
<i>LC</i>	7.77	10.36	5.53	10.36	10.36	7.77	10.36	20.73	3.45	5.53	7.77
<i>COMP</i>	16.62	8.31	11.08	16.62	8.31	8.31	6.23	11.08	2.77	6.23	4.43
<i>AM</i>	15.97	7.39	7.69	11.61	9.87	5.65	6.93	15.38	6.14	6.08	7.30
<i>SD</i>	5.12	3.75	3.53	3.14	4.78	2.05	3.80	7.59	2.56	1.85	1.88

Table 4: Overview of criteria weights according to all stakeholder groups including compromise solution (COMP), arithmetical mean (AM), and standard deviation (SD). PM = Policy-makers, FI = Finance and Industry, AC = Academia, YL = Young Leaders, NGOs = National NGOs, LC = Local.

Additionally, the boxplot diagram of Figure 3 displays the dispersion of the individual stakeholder groups’ weights, with each point representing the weight assigned to a criterion by one stakeholder group (for more details see Annex 4 in suppl. materi-

a). The grey boxes indicate the weighting range where 50 per cent of the weightings are located. The larger the boxplot, the higher the distribution of the weighting values, which further means that there is high disagreement between stakeholder groups on the weights assigned to the particular criterion.

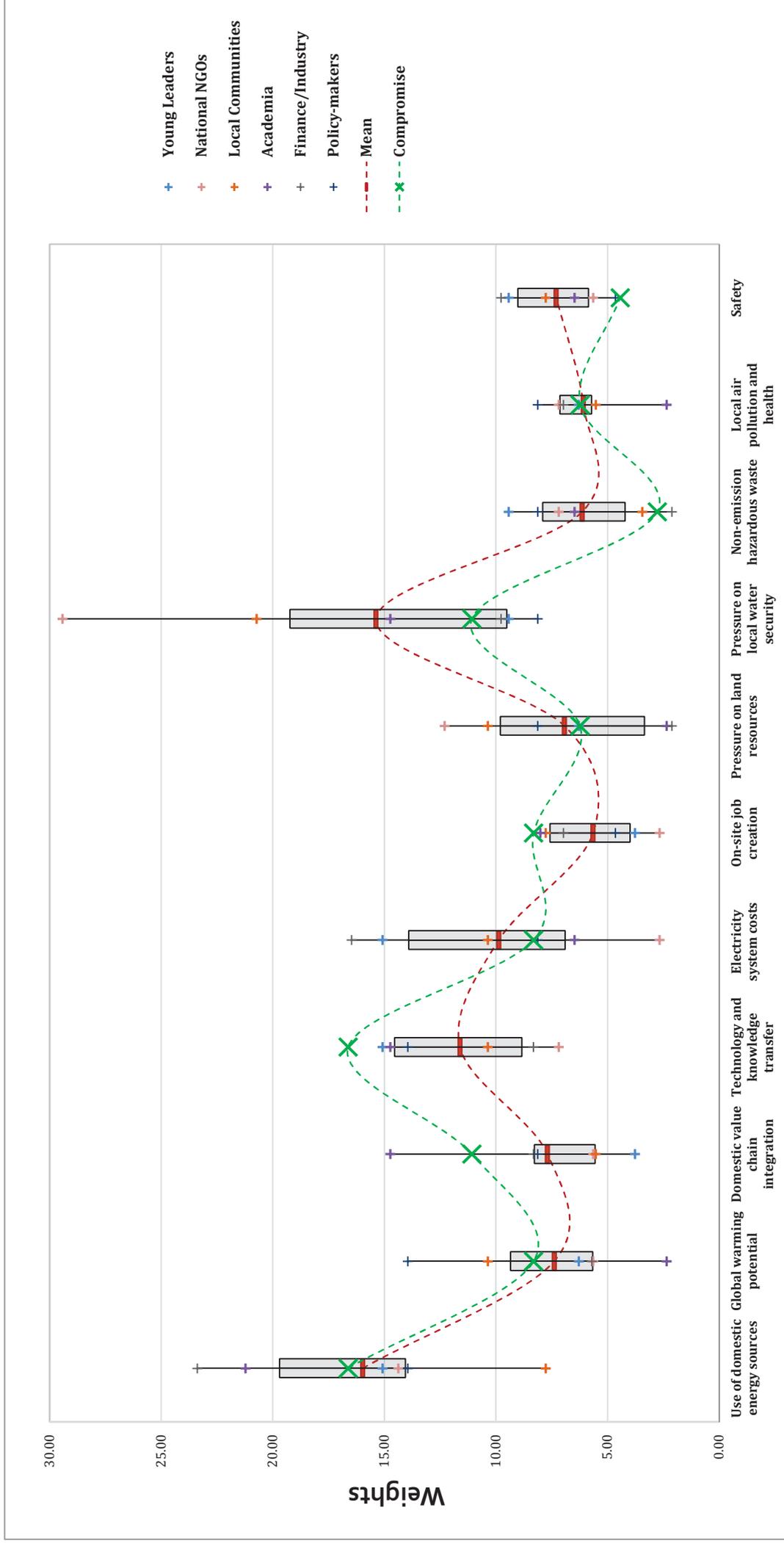


Figure 3: Boxplot of criteria weights according to all stakeholder groups. The red line indicates the arithmetical mean, the green cross the compromise solution achieved in the final workshop, and the grey shaded box the area between the second and the third quartile (i.e., containing 50 per cent of all stakeholder weights). Whisker ends represent the maxima and minima.

4.3.4.1 Description of individual stakeholder group weightings

This chapter describes the results of the individual stakeholder group weightings and the arguments provided by each stakeholder group during the ranking exercise. Five groups of importance categories¹³ were set by the authors in order to illustrate the different levels of stakeholder preferences that should be regarded as a proxy for high, high to moderate, moderate, moderate to low, and least importance of criteria. The importance categories were established by subtracting the lowest from the highest weighting for each individual group weighting. The result, which describes the range of the weightings, was then divided by five yielding five different ranking categories whereas the highest / lowest weighting marks the upper / lower boundary (for an overview of all individual rankings including the importance categories see Annex 3 in suppl. material).

Policy-makers

The ranking of the group “Policy-makers”¹⁴ had a standard deviation of 3.24, which was the smallest standard deviation of all groups showing a relative equal distribution of weights. The group ranked the criteria in the following order¹⁵:

- \ High importance: “Use of domestic energy sources” (13.95), “Technology and knowledge transfer” (13.95), and “Global warming potential” (13.95);
- \ Moderate to low importance: “Domestic value chain integration” (8.14), “Electricity system costs” (8.14), “Pressure on land resources” (8.14), “Pressure on local water security” (8.14), “Non-emission hazardous waste” (8.14), and “Local air pollution and health” (8.14).

¹³ These importance categories based on the weightings should not be mixed up with the importance categories based on the ranks in Chapter 4.1.5: Importance categories based on the weighting merely represent a verbal expression / categorization of the criteria importance, which is used to better illustrate the individual group rankings within this study.

¹⁴ The criteria ranking exercise had to be redone because policy-makers invited to the individual policy-maker workshop were not able to officially rank the criteria according to their associated institutions’ objectives in presence of other national institutions. Although relevant institution such as the *Moroccan Agency for Solar Energy (MASEN)*, the *National Agency for Electricity and Water (ONEE)*, and the *National Agency for Renewable Energy and Energy Efficiency (ADEREE)* did not participate despite their confirmation, a highly ranked member of the *Moroccan Ministry of Energy, Mines, Water, and Environment (MEMEE)* conducted the ranking in the name of his institution. As *MEMEE* is responsible for designing and implementing Morocco’s *NES*, its sole participation in the workshop was found adequate for receiving meaningful results.

¹⁵ The boundaries of the categories are: Least importance: ≥ 4.65 - < 6.51 ; Moderate-low importance: ≥ 6.51 - < 8.37 ; Moderate importance: ≥ 8.37 - < 10.23 ; High-moderate importance: ≥ 10.23 - < 12.09 ; High importance: ≥ 12.09 - ≤ 13.95 .

\ Least importance: “On-site job creation” (4.65) and “Safety” (4.65);

In the ranking of the group “Policy-makers” 58 per cent of the weightings were placed on national criteria and 42 per cent on local. Compared to the 45/55 ratio of equal weights, this clearly indicated the high priority assigned by this group to the national dimension in electricity planning. According to the arguments provided by the group, the ranking of the top three criteria was based on the national objectives towards achieving a “low-carbon and climate change resilient development” in Morocco (MEMEE, 2014a, p. 18). The second level cluster was centered on the *NES* and its goals to provide electricity at affordable and competitive prices while preserving the environment (land, water, air, and waste). As the generation of direct jobs was regarded a result of expanding electricity capacities and safety of power plant technologies was not considered a reason of concern in Morocco, these two criteria were placed at the bottom of the ranking.

Finance and Industry

The ranking of the group “Finance and Industry” had a standard deviation of 5.86. The group ranked the criteria in the following order¹⁶:

- \ High importance: “Use of domestic energy sources” (23.38);
- \ High to moderate importance: “Electricity system costs” (16.48);
- \ Moderate to low importance: “Pressure on local water security” (9.78), “Safety” (9.78), “Domestic value chain integration” (8.33), “Technology and knowledge transfer” (8.33), “On-site job creation” (6.99), and “Local air pollution and health” (6.99);
- \ Least importance: “Global warming potential” (5.71), “Pressure on land resources” (2.13), and “Non-emission hazardous waste” (2.13).

In the ranking of the group “Finance and Industry” 62 per cent of the weightings were placed on national criteria and 38 per cent on local. Compared to the 45/55 ratio of equal weights, this clearly indicated the high priority assigned by this group to the national dimension in electricity planning. With the exceptions of concerns over possible long-term implications in regard to water security and safety, the most remarkable result of this stakeholder group workshop was that the majority of environmental criteria were ranked as being of rather low importance in the context of deciding on Morocco’s electricity future. In contrast, socio-economic criteria were generally favored by this group. Nevertheless, agreement on this order was

¹⁶ The boundaries of the categories are: Least importance: ≥ 2.13 - < 6.38 ; Moderate-low importance: ≥ 6.38 - < 10.63 ; Moderate importance: ≥ 10.63 - < 14.88 ; High-moderate importance: ≥ 14.88 - < 19.13 ; High importance: ≥ 19.13 - ≤ 23.38 .

ambivalent: While the bottom of the ranking was agreed early during the “silent negotiation” exercise, the top was reason of considerable dispute and marked by numerous movements between the center and the top of the ranking. In the end, the group argued that electricity decision-making in Morocco should be geared towards the use of domestic energy sources at competitive prices and should prioritize socio-economic development prospects over conservation of natural resources (air, land, climate).

Academia

The ranking of the group “Academia” had a standard deviation of 6.03. The group ranked the criteria in the following order¹⁷:

- \ High importance: “Use of domestic energy sources” (21.23);
- \ High to moderate importance: “Technology and knowledge transfer” (14.74), “Pressure on local water security” (14.74), and “Domestic value chain integration” (14.74);
- \ Moderate to low importance: “On-site job creation” (8.02), “Electricity system costs” (6.49), “Non-emission hazardous waste” (6.49), and “Safety” (6.49);
- \ Least importance: “Local air pollution and health” (2.36), “Pressure on land resources” (2.36), and “Global warming potential” (2.36).

In the ranking of the group “Academia” 60 per cent of the weightings were placed on national criteria and 40 per cent on local. Compared to the 45/55 ratio of equal weights, this clearly indicated the high priority assigned by this group to the national dimension in electricity planning. Participants were united in their views that reducing the country’s dependence on foreign energy imports should be considered the top priority in national electricity planning as it would allow for sustainable economic growth in the mid- to long-term. Similar arguments were raised in regard to the need to benefit from technology transfer and the inclusion of domestic industries in electricity deployment. Taking the water-energy nexus into account when deciding on future electricity generation technologies was also emphasized as being of rather high importance given the general water scarcity, from which Morocco is suffering. While agreement was generally high on the importance of the top four criteria, controversies remained on their order with numerous movements back and forth in the ranking. Direct employment opportunities were regarded as a direct result of the local value chain integration and thus ranked in the center and equal to electricity prices. The environmental criteria on land, air, waste, and climate change

¹⁷ The boundaries of the categories are: Least importance: ≥ 2.36 - < 6.13 ; Moderate-low importance: ≥ 6.13 - < 9.91 ; Moderate importance: ≥ 9.91 - < 13.68 ; High-moderate importance: ≥ 13.68 - < 17.45 ; High importance: ≥ 17.45 - ≤ 21.23 .

were again ranked as being of rather low importance. Yet, contested views were held in regard to climate considerations: Given that Morocco is a developing country with marginal GHG emissions and little historic responsibility, most of the participants were in favor of a “development first” approach in national electricity planning. Nevertheless, others argued that the mitigation of climate change should also be prioritized by the *GoM* due to the kingdom’s high vulnerability to the impacts of climate change.

Young Leaders

The ranking of the group “Young Leaders” had a standard deviation of 4.14. The group ranked the criteria in the following order¹⁸:

- \ High importance: “Use of domestic energy sources” (15.09), “Technology and knowledge transfer” (15.09), and “Electricity system costs” (15.09);
- \ Moderate importance: “Pressure on local water security” (9.43), “Non-emission hazardous waste” (9.43), and “Safety” (9.43);
- \ Moderate to low importance: “Local air pollution and health” (6.29), “Pressure on land resources” (6.29), and “Global warming potential” (6.29);
- \ Least importance: “Domestic value chain integration” (3.77) and “On-site job creation” (3.77);

In the ranking of the group “Young Leaders” 55 per cent of the weightings were placed on national criteria and 45 per cent on local. Compared to the 45/55 ratio of equal weights, this clearly indicated the high priority assigned by this group to the national dimension in electricity planning. Despite the final result, the achieved ranking was highly debated and included several contested criteria. In particular the criteria ranked as being of top priority in the final ranking were characterized by frequent vertical movements. Throughout the open discussion participants stated that affordable electricity prices, decreased energy import dependence, as well as technology and knowledge diffusion should be considered as “enablers” for other criteria and thus were found on top of the final ranking. In line with this argumentation, industry integration and direct employment were placed last. Furthermore, participants agreed that the criteria “Pressure on local water security”, “Non-emission hazardous waste”, and “Safety” are important and belong to “one group” as poor performance within these criteria will negatively impact people’s lives. However, while participants agreed in general to that evaluation, some participants men-

¹⁸ The boundaries of the categories are: Least importance: $\geq 3.77 - < 6.04$; Moderate-low importance: $\geq 6.04 - < 8.30$; Moderate importance: $\geq 8.30 - < 10.57$; High-moderate importance: $\geq 10.57 - < 12.83$; High importance: $\geq 12.83 - < 15.09$.

tioned that they would add “Local air pollution and health” as well as “Pressure on land resources” to that group of criteria, also mentioning that water and land are equally important and mandatory for life.

National NGOs

The ranking of the group “National NGOs” had a standard deviation of 7.27, which was the highest standard deviation of all groups, showing a relatively unequal distribution of the weights. The group ranked the criteria in the following order¹⁹:

- \ High importance: “Pressure on local water security” (29.44);
- \ Moderate importance: “Use of domestic energy sources” (14.38);
- \ Moderate to low importance: “Pressure on land resources” (12.31);
- \ Least importance: “Non-emission hazardous waste” (7.19), “Technology and knowledge transfer” (7.19), “Local air pollution and health” (7.19), “Domestic value chain integration” (5.65), “Global warming potential” (5.65), “Safety” (5.65), “Electricity system costs” (2.68) and “On-site job creation” (2.68).

In the ranking of “National NGOs” 35 per cent of the weightings were placed on national criteria and 65 per cent on local. Compared to the 45/55 ratio of equal weights, this clearly indicated the high priority assigned by this group to the local dimension in electricity planning. While agreement on the importance of water considerations in electricity planning was achieved early in the process of “silent negotiation” the ranks of the remaining criteria were more contested and marked by vivid discussions among the group. Most noticeably, environmental criteria, such as land, air, and waste received rather high ranks compared to the other stakeholder groups’ rankings. In contrast, socio-economic criteria were ranked significantly lower with employment and electricity prices placing at the bottom of the ranking. The argumentation here was that without a clean environment, sustainable growth would not be possible. Interestingly, mitigating climate change was understood as an international task and thus not considered as of great importance for participants—despite being representatives of mostly environmental NGOs. An exception was marked by the high priority given to reducing the country’s energy import dependence which was understood as a key necessity for decreasing the national trade deficit and enabling investments in social infrastructure and services. The low concerns over safety issues in electricity planning were explained by participants in such a way that Morocco has yet not suffered from any major accident in the energy sector. Nevertheless, participants emphasized that their ranking would significantly

¹⁹ The boundaries of the categories are: Least importance: $\geq 2.68 - < 8.03$; Moderate-low importance: $\geq 8.03 - < 13.38$; Moderate importance: $\geq 13.38 - < 18.73$; High-moderate importance: $\geq 18.73 - < 24.08$; High importance: $\geq 24.08 - \leq 29.44$.

change if nuclear energy would become a realistic option in Morocco's electricity future.

Local Communities

The ranking of the group "Local Communities" had a standard deviation of 4.31. The group ranked the criteria in the following order²⁰:

- \ High importance: "Pressure on local water security" (20.73);
- \ Moderate importance: "Global warming potential" (10.36), "Technology and knowledge transfer" (10.36), "Pressure on land resources" (10.36), and "Electricity system costs" (10.36);
- \ Moderate to low importance: "Safety" (7.77), "Use of domestic energy sources" (7.77), and "On-site job creation" (7.77);
- \ Least importance: "Domestic value chain integration" (5.53), "Local air pollution and health" (5.53), and "Non-emission hazardous waste" (3.45).

In the ranking of the group "Local Communities" 45 per cent of the weightings were placed on national criteria and 55 per cent on local. Compared to the 45/55 ratio of equal weights, this indicated that both national and local aspects were generally considered equally important (as there are five nationally and six locally relevant criteria). Nevertheless, the distribution of weighted scores showed that the group expressed particularly high preferences for environmental criteria concerning water, land, and climate. Participants explained their preferences by referring to many real cases where the siting of power plants has deprived adjacent communities of their land and water use and has frequently resulted in substantial ramifications of peoples' livelihood security (see also Chapter 4.1.3). Climate change was considered a threat to rural populations in particular and therefore placed relatively high in the ranking as well. Affordability of electricity was perceived to be of rather high importance especially for poor households that are mostly located in the rural areas of Morocco. While technology and knowledge diffusion was discussed as a key cornerstone of sustainable economic growth by the group, other predominantly national criteria, such as the integration of domestic industries and energy import dependence were perceived to be of lower importance compared to other stakeholder groups' priorities. The argumentation here was that local communities would not be affected directly by the latter two criteria, whereas know-how and technology diffusion could help rural people out of poverty and reduce rural exodus. Although relatively low weightings were assigned to air pollution and safety issues, the ranking

²⁰ The boundaries of the categories are: Least importance: ≥ 3.45 - < 6.91 ; Moderate-low importance: ≥ 6.91 - < 10.36 ; Moderate importance: ≥ 10.36 - < 13.82 ; High-moderate importance: ≥ 13.82 - < 17.27 ; High importance: ≥ 17.27 - ≤ 20.73 .

was rather contested with several participants wanting them placed higher due to the many recorded cases of human health problems stemming from the pollution of fossil fuel power plants (see also Chapter 4.1.3).

4.3.4.1.1 Synthesis of individual stakeholder group weightings

To identify the main trends in the distribution of weightings assigned by all six stakeholder groups during the individual workshops, the arithmetic mean and the average standard deviation were calculated as sums for all criteria. The average standard deviation across all stakeholder group rankings was 3.64.

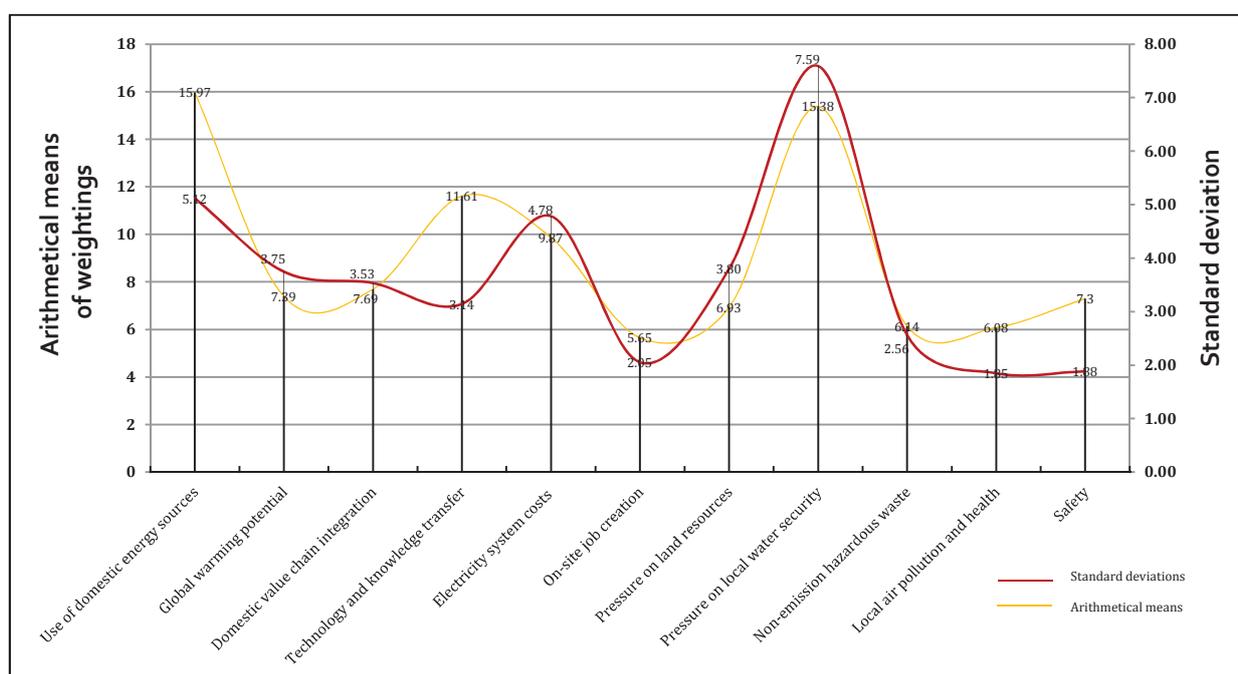


Figure 4: Distribution of weightings based on the arithmetical means (yellow) and the standard deviations (red) calculated for all stakeholder groups' individual results.

Based on the results illustrated in Figure 4, the following general conclusions can be drawn on the importance of criteria and their contestation in the ranking²¹:

- \ High importance: "Use of domestic energy sources" (15.97) and "Pressure on local water security" (15.38), both of which are also marked by high outliers or extreme values that pull the mean weight of these criteria at a higher level;

²¹ The boundaries of the categories are: Least importance: ≥ 5.65 - < 7.71 ; Moderate-low importance: ≥ 7.71 - < 9.79 ; Moderate importance: ≥ 9.79 - < 11.84 ; High-moderate importance: ≥ 11.84 - < 13.91 ; High importance: ≥ 13.91 - ≤ 20.73 .

- \ Moderate importance: “Technology and knowledge transfer” (11.61) and “Electricity system costs” (9.87);
- \ Moderate to low importance: “Domestic value chain integration” (7.69), “Global warming potential” (7.39), and “Safety” (7.30);
- \ Least importance: “Pressure on land resources” (6.93), “Non-emission hazardous waste” (6.14), “Local air pollution and health” (6.08), and “On-site job creation” (5.65);
- \ Contestation of criteria: The standard deviation was used as a simple measure of the level of convergence between weights. A large standard deviation indicates that the weightings are spread far from the mean and a small standard deviation indicates that they are clustered closely around the mean. In this study, a standard deviation above the mean standard deviation of 3.64 was regarded as an indicator for contradictory preferences or a “polarization of opinions” (Garmendia and Gamboa, 2012, p. 116). This is also indicated in the boxplot of Figure 3 by rather unbalanced boxes and a large scatter of weightings with extreme minima and maxima. The criteria that were characterized by contradictory preferences—lowest convergence—with standard deviation values well above the mean encompassed “Pressure on local water security” (7.59), “Use of domestic energy sources” (5.12), and “Electricity system costs” (4.78). A couple of outliers for these three criteria increased the standard deviation. “Pressure on land resources” (3.80) and “Global warming potential” (3.75), “Domestic value chain integration” (3.52) and “Technology and knowledge transfer” (3.14) were less contested with standard deviations almost equal to the mean of 3.64. In contrast, “Safety” (1.89), “Local air pollution and health” (1.85), “On-site job creation” (2.05), and “Non-emission hazardous waste” (2.56) had low standard deviations with less scattered weightings, indicating more consensus among the different groups on the importance of these criteria. Furthermore, for the five criteria with an above average standard deviation, “National NGOs” and “Finance and Industry” were each at a rather extreme position on the spectrum in three instances (either assigning a criterion with the lowest or highest weight compared to all groups). For two criteria, “Electricity system cost” and “Pressure on land resources”, these two groups were at the opposite ends of the spectrum.

Based on the arithmetical mean calculated for all individual stakeholder group results, 53 per cent of the weightings were placed on national criteria and 47 per cent on local. Compared to the 45/55 ratio of equal weights, this indicated the high priority assigned by the majority of stakeholder groups to the national energy planning objectives whereas the local dimension was considered as of relatively less im-

portance. Despite this general agreement, differences were observed: “National NGOs” and “Local Communities” put more emphasize on locally relevant criteria (“National NGOs”: 65 per cent; “Local Communities”: 55 per cent), whereas all other stakeholder groups emphasized more the national dimension (“Young Leaders”: 55 per cent “Policy-makers”: 58 per cent; “Academia”: 60 per cent; and “Finance and Industry”: 62 per cent). This difference was most pronounced for the two locally relevant criteria “Pressure on local water security” and “Pressure on land resources” where “National NGOs” as well as “Local Communities” assigned considerably higher weights on these criteria. Both groups weighted also the nationally relevant criteria “Domestic value chain integration” in similar ways and below the arithmetic mean compared to all other groups. However, criteria that received the highest preferences were at the same time almost always the criteria with the highest standard deviation. On the other hand, criteria ranked as being of relatively low importance in electricity planning were more consistent across all groups. As the low standard deviations on these criteria point out, local issues—except for the criterion “Pressure on local water security”—are thus more promising for a robust “compromise solution” to be reached.

4.3.4.1.2 Similarities and differences: Cluster analysis of individual group weightings

Although the analysis of individual stakeholder group weightings provided insights on different stakeholder preferences, this data was analyzed further in order to reveal conflicting or common interests as similarities and differences between stakeholder groups.

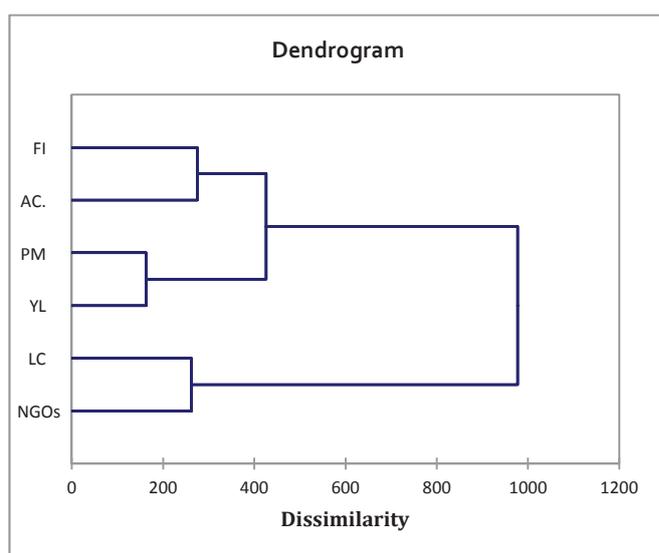


Figure 5: Hierarchical clustering analysis using Ward's method for the 6 stakeholder groups and all 11 criteria.

In this regard, a cluster analysis on the individual stakeholder group weightings was facilitated (see Chapter 3.3.1 for details about the method). The horizontal axis of the dendrogram represents the distance or dissimilarity between clusters. Each fusion of two clusters is represented on the graph by the splitting of a horizontal line into two horizontal lines. The horizontal position of the split, shown by the short vertical bar, gives the distance (dissimilarity) between the two clusters. The higher the distance value (the height of the vertical lines) between two joining clusters, the higher their dissimilarities.

According to the cluster analysis depicted in Figure 5, three clusters occur. Two of these clusters merge at about the same horizontal distance. The closest preference structures in regard to their weightings are between “Policy-makers” and “Young Leaders” who fuse in the earliest cluster (farthest to the left), meaning that those two groups have the lowest dissimilarities in their individual group weightings. The next cluster is formed by “Local Communities” and “National NGOs” which merge at a similar distance as the third cluster between “Finance and Industry” and “Academia”. In addition, a wider cluster consisting of “Finance and Industry”, “Academia”, “Policy-makers”, and “Young Leaders” fuses before all stakeholder groups join into one cluster at a much higher distance.

Furthermore, a cluster analysis between the national and the local criteria subgroups was conducted to deepen the understanding of differences and similarities between the group weightings. The results are illustrated in Figure 6 and herewith described briefly.

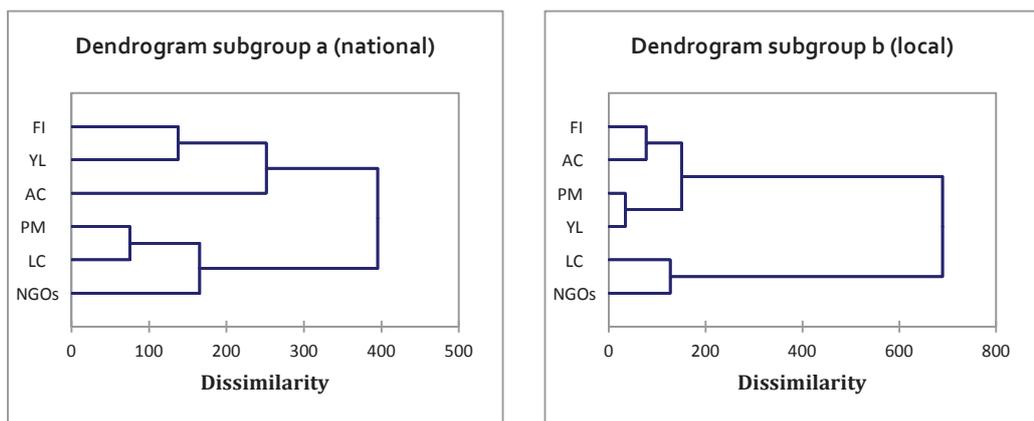


Figure 6: Cluster analysis results of the two subgroups.

- \ Subgroup a (national): Interestingly, the cluster with the lowest dissimilarities at the national level is fused between “Policy-makers” and “Local Communities”, while later “National NGOs” merge with this cluster. “Finance and Industry” and “Young Leaders” also form another cluster to which later “Academia” is added.
- \ Subgroup b (local): The results of the local analysis mirror the results from the overall cluster analysis illustrated in Figure 5, with “Policy-makers” and “Young Leaders” fusing in the earliest cluster, followed by the second cluster of “Finance and Industry” and “Academia” as well the third of “Local Communities” and “National NGOs”. While the first two clusters merge together relatively early, the last cluster fuses at a relatively great distance, indicating the large dissimilarities between “Local Communities” and “National NGOs” with the other four stakeholder groups in regard to locally relevant criteria.

Four conclusions can be drawn from the cluster analysis of the individual stakeholder group weightings: Firstly, “Local Communities” and “National NGOs” had relatively few differences in their rankings and generally fused with other stakeholder groups at a large distance. Especially in regard to predominantly local criteria, the coalition between these two groups and the opposition to the other groups was significant. Secondly, compared to all other stakeholder groups “Policy-makers” and “Young Leaders” were characterized by the smallest differences with regard to their preferences across all 11 criteria. Yet, the degree of their coalition was mostly influenced by their strong similarities in the weighting of locally relevant criteria, whereas their similarities in the subgroup of nationally relevant criteria were not as pronounced. Thirdly, “Finance and Industry” and “Academia” shared similar views across all criteria and especially in the subgroup of locally relevant criteria. Lastly, in the majority of cases “Policy-makers”, “Young Leaders”, “Finance and Industry” and “Academia” fused at a relatively short distance, whereas “National NGOs” and “Local Communities” merged with the others at a relatively large distance, meaning that their differences with the other groups were rather strong.

4.3.4.2 Description of the compromise solution weightings

The ranking of the “compromise solution” had a standard deviation of 4.28. The participants of the final stakeholder workshop ranked the criteria in the following order²²:

- \ High importance: “Use of domestic energy sources” (16.62) and “Technology and knowledge transfer” (16.62);
- \ High to moderate importance: “Domestic value chain integration” (11.08), and “Pressure on local water security” (11.08);
- \ Moderate importance: “Global warming potential” (8.31), “Electricity system costs” (8.31), and “On-site job creation” (8.31);
- \ Moderate to low importance: “Local air pollution and health” (6.23) and “Pressure on land resources” (6.23);
- \ Least importance: “Safety” (4.43) and “Non-emission hazardous waste” (2.77).

Most noticeably, all national criteria were found in the top ranks of the overall ranking. In fact, 60 per cent of the weights developed as the “compromise solution” were put on the national dimension, compared to the 45 per cent which would have been

²² The boundaries of the categories are: Least importance: ≥ 2.77 - < 5.54 ; Moderate-low importance: ≥ 5.54 - < 8.31 ; Moderate importance: ≥ 8.31 - < 11.08 ; High-moderate importance: ≥ 11.08 - < 13.85 ; High importance: ≥ 13.85 - ≤ 16.62 .

achieved if all weights would have been equal (five national criteria, six local criteria). In contrast, almost all locally relevant criteria were ranked as being of rather low importance during the final workshop, meaning that the most preferred technology mix would favor national objectives over local impacts. Interestingly, the result of the participatory negotiated “compromise solution” showed similar weighting patterns as the mathematically calculated distribution of arithmetic means described in Chapter 4.2.1.7, meaning that both rankings were alike and that the negotiated “compromise solution” was almost equal to the mathematical compromise (see also Figure 3). On the one hand, “Use of domestic energy sources”, “Pressure on local water resources”, and “Technology and knowledge transfer” placed in the top three of both rankings. On the other hand, the cluster of predominantly local criteria “Local air pollution and health”, “Pressure on land resources”, “Safety” and “Non-emission hazardous waste” was characterized by relatively low preferences both times. Yet one notable finding was that the majority of national criteria were ranked higher in the “compromise solution” compared to the arithmetical mean results, whereas the opposite was observed in regard to the local dimension. This was also mirrored in the comparison of the ratios of both dimensions: “compromise solution” 60/40, arithmetic mean 53/47. One outlier in this context though, was marked by the criterion “On-site job creation” which was ranked higher in the “compromise solution” than in the arithmetic mean calculated across all stakeholder groups.

4.3.4.2.1 Robustness of the compromise solution

The development of a “compromise solution” inevitably involved negotiations between stakeholder groups. The robustness of the result, and thus its acceptance, therefore inherently depended on the preferences and interests among the different stakeholder groups. In this regard, the interplay between the different stakeholder groups and the individual trade-offs made during the negotiation process of the “compromise solution” shed light on its robustness in two ways. On the hand, the behavior of the different stakeholder groups, i.e., the criteria movements made during the process of “silent negotiation”, allowed for the identification of criteria that are procedurally stable/contested, thereby revealing potential lines of coalition/conflict with regard to the importance attached to the criteria by the different stakeholder groups. On the other hand, a comparison of the individual group weightings to the weightings negotiated as “compromise solution” showed the representation of the different stakeholder groups within the “compromise solution” and whether the final result was biased towards certain stakeholder groups at the expense of others.

Robustness with regard to the criteria movements

Figure 7 illustrates that the total number of moves made for each criterion during the four consecutive rounds of negotiations varied significantly across the 11 criteria, with "Global warming potential" (30 moves) and "Non-emission hazardous waste" as well as "Safety" (2 moves) positioned on the extreme ends of the spectrum.

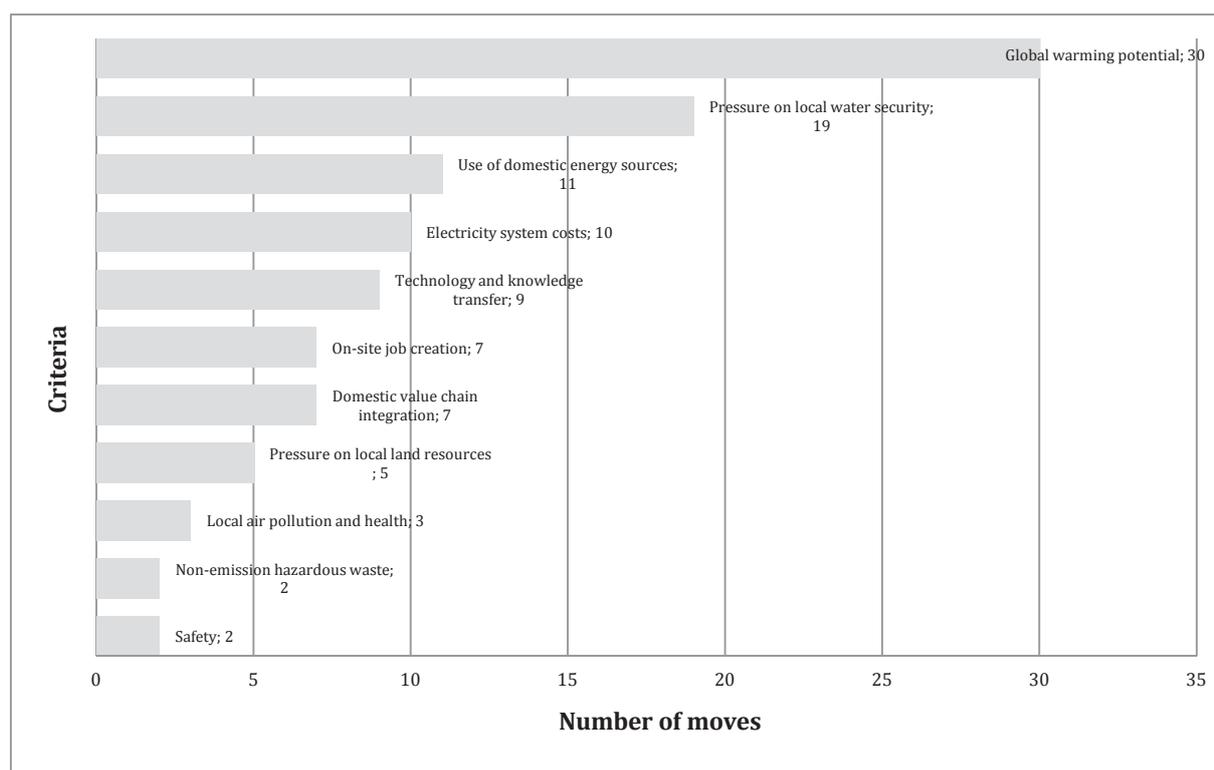


Figure 7: Total moves for each criterion during the four rounds of negotiating the "compromise solution".

However, a high number of moves does not necessarily relate to the contestation of a criterion and thus needs to be interpreted with caution. This is because some criteria were constantly moved unidirectional in the ranking (up OR down) and, thus, resulted in a relatively high number of moves, while others were rather ambivalent with a high number of bidirectional moves (up AND down). Therefore, two additional data sets helped to analyze the robustness of the "compromise solution" in regard to the criteria movements. Figures 8 and 10 depict the movements (direction as well as number of moves) made for each criterion and each round of the "silent negotiation".

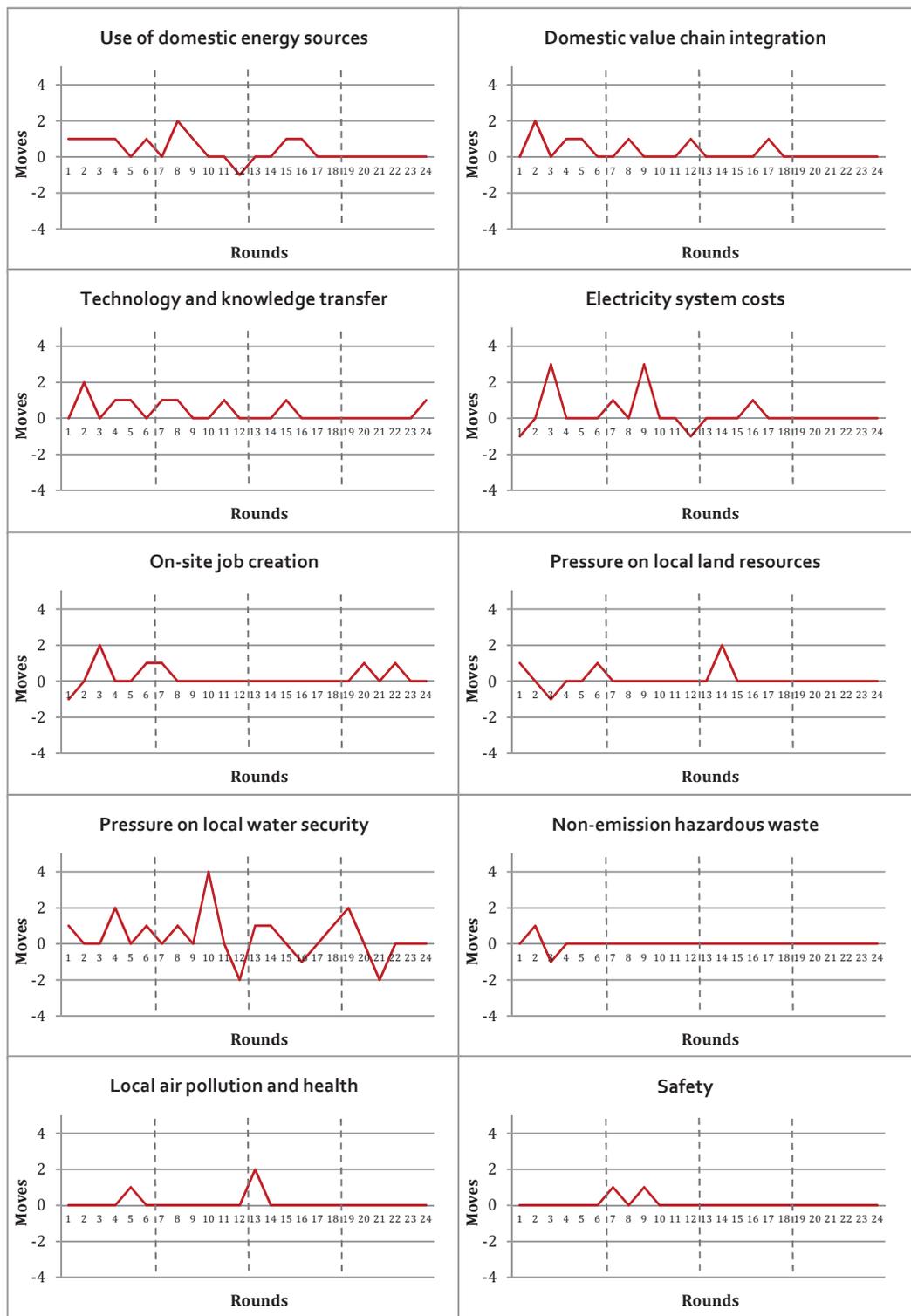


Figure 8: Criteria movement tracking for the four rounds of negotiating the “compromise solution” (for criterion “Global warming potential” see below).

Figure 9 shows two additional elements: a) the standard deviation of the individual group weightings (yellow line; as described in Chapter 4.2.1.7), and b) the standard deviation of the criteria movements made in “silent negotiation” during the final workshop (red line). The assumption here was twofold: Firstly, if both standard deviations were below their arithmetical mean, the “compromise solution” for the respected criteria can be considered as relatively stable, whereas standard deviations above the arithmetical mean pointed towards contestation or a “polarisation of opinions” (Garmendia & Gamboa, 2012, p. 116). Secondly, if the standard deviation of a criterion in the “compromise solution” was below/above the arithmetical mean, while it is above/below in the individual group weightings, participants of the final stakeholder workshop have shown willingness/resistance to compromise compared to their individual group weightings. It was striking to see that both standard deviations follow almost a similar pattern.

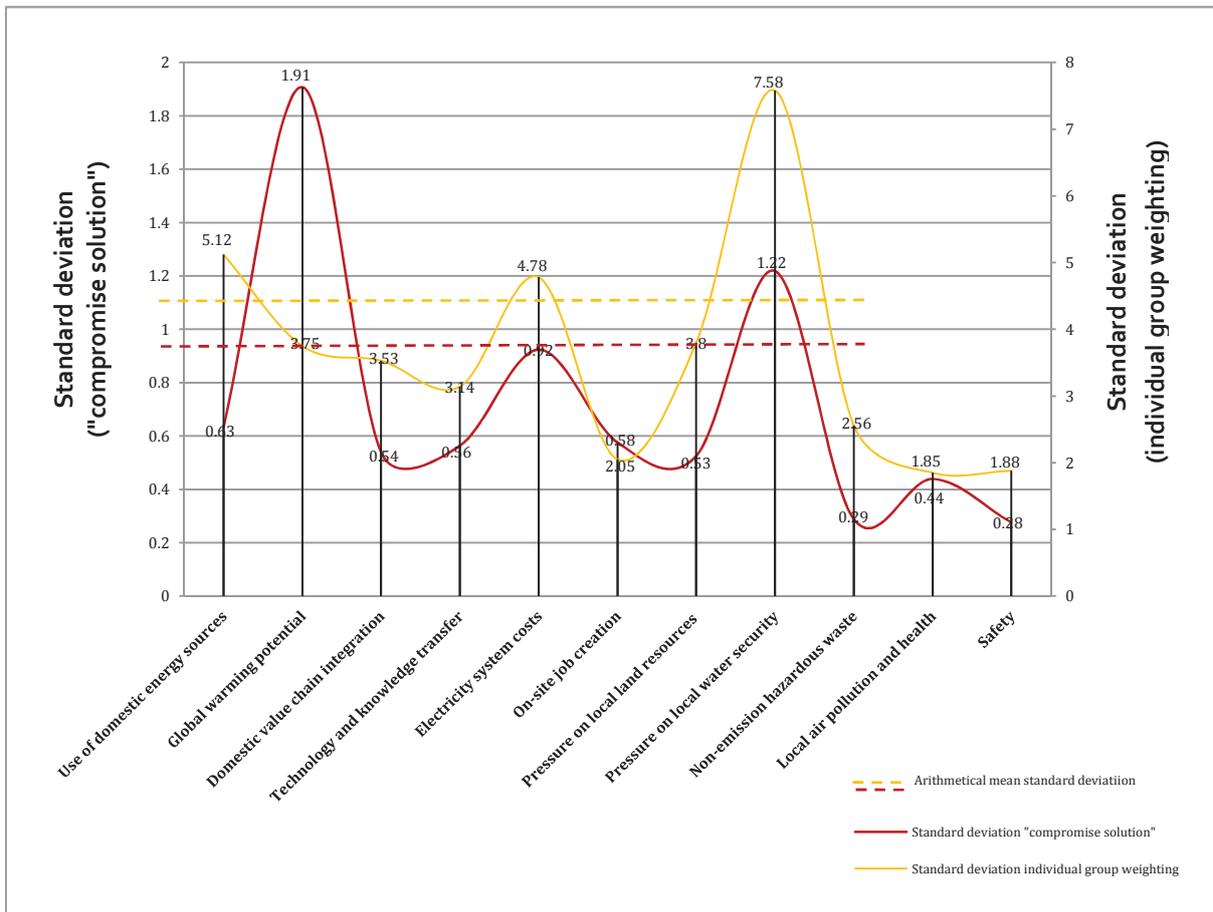


Figure 9: Standard deviation for the criteria movements made during the four rounds of negotiating the “compromise solution” and standard deviation of the individual group weightings.

The robustness of the result was interpreted based on these three figures (7 to 9), which together illustrate the interplay and behavior between the different stakeholder groups during the negotiation process of the “compromise solution”:

- \ Procedurally stable/uncontested criteria in the “compromise solution”: Criteria that were characterized by unidirectional movements with standard deviations below the arithmetical mean of 0.71 for the criteria movements as well as 3.64 for the individual group weightings can be considered as stable in the “compromise solution”. Criteria of this group encompass “Domestic value chain integration”, “Technology and knowledge transfer”, “Local air pollution and health” as well as “Safety”.
- \ Procedurally relatively stable/uncontested criteria in the “compromise solution”: Despite bidirectional movements the criteria “Non-emission hazardous waste” and “On-site job creation” were comparably stable with only limited deviations in their vertical order and standard deviation values below the arithmetical mean values of 0.71 and 3.64. In addition it was noteworthy that the criteria “Use of domestic energy sources” and “Pressure on local land resources”, both marked by comparably high standard deviation values in their individual group weightings (above the arithmetical mean value of 3.64), were at the same time characterized by low standard deviation values in regard to their movements and only limited bidirectional deviations in their order²³. This finding pointed towards a mutual learning process among participants that led to a higher willingness to compromise and transformed previously contested criteria into relatively robust criteria in the final workshop.
- \ Procedurally contested criteria in the “compromise solution”: Criteria that were characterized by frequent bidirectional movements with standard deviation values above the arithmetical means of 0.71 and 3.64 can be considered as contested in the “compromise solution”. Criteria in this group encompassed “Electricity system

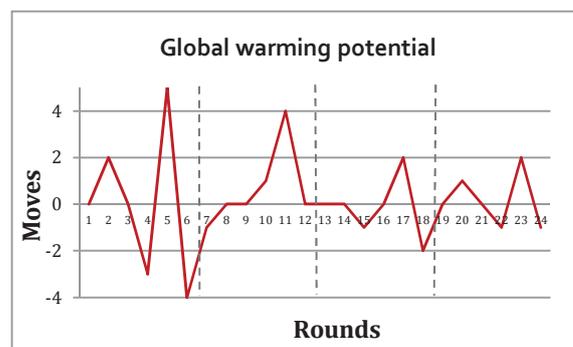


Figure 10: Criteria movement tracking of “Global warming potential” during the “compromise solution” negotiation.

²³ With the exception of “National NGOs” (2nd rank; ranking category: high to moderate) and “Local communities” (3rd rank; ranking category: moderate) all other stakeholder groups placed the criterion “Use of domestic energy sources” on the 1st or highly important rank of their individual group rankings. This means that—despite the high standard deviation of the individual group weightings—the two groups “National NGOs” and “Local Communities” were willing to compromise during the final workshop.

costs”, “Pressure on local water security”, and especially “Global warming potential”. As Figure 10 illustrates the latter was highly conflictual and characterized by significant bidirectional movements during the negotiations process of the “compromise solution”. This result was mirrored in the individual group weightings and became apparent in heated debates especially between “Academia” and “Policy-makers” during the final workshop.

Robustness with regard to the representation of stakeholder groups

Furthermore, as a proxy for determining the representation of the different stakeholder groups within the “compromise solution”, the level of compromise each group made was calculated by cumulating the distance from the compromise weightings to the individual group weightings for each stakeholder group (arithmetic mean: 41.75). Table 5 illustrates the cumulative distances of the “compromise solution” compared to the individual group weightings for the stakeholder groups (see Chapter 3.3.1), whereas the boxplot diagram of Figure 3 depicts this graphically. Respective dispersion diagrams for all stakeholder groups can be found in Annex 5 in suppl. material.

	PM	FI	AC	YL	NGOs	LC
Use of domestic energy sources	2.67	6.76	4.61	1.53	2.24	8.85
Global warming potential	5.64	2.60	5.95	2.02	2.66	2.05
Domestic value chain integration	2.94	2.75	3.66	7.31	5.43	5.55
Technology and knowledge transfer	2.67	8.29	1.88	1.53	9.43	6.26
Electricity system costs	0.17	8.17	1.82	6.78	5.63	2.05
On-site job creation	3.66	1.33	0.29	4.54	5.63	0.54
Pressure on land resources	1.91	4.11	3.88	0.06	6.08	4.13
Pressure on local water security	2.94	1.30	3.66	1.65	18.36	9.65
Non-emission hazardous waste	5.37	0.64	3.72	6.66	4.42	0.68
Local air pollution and health	1.91	0.75	3.88	0.06	0.96	0.71
Safety	0.22	5.35	2.05	5.00	1.22	3.34
Cumulative distance per group (Ø 41.75)	30.09	42.05	35.39	37.12	62.05	43.80

Table 5: Distance of the individual group weightings to the weightings of the “compromise solution” (less/more than the compromise in red/green).

The cumulative distance of each stakeholder group between their individual group weightings and the “compromise solution” allowed for two interpretations in regard to the degree the different stakeholder groups are represented in the compromise ranking:

- \ High representation in the “compromise solution”: Among the stakeholder groups that were characterized by a cumulative distance value well below the

arithmetic mean of the cumulative distance per group and that were, thus, more dominantly represented in the “compromise solution” than others, were “Policy-makers” (30.09), “Academia” (35.39) and “Young leaders” (37.12).

- \ Low representation in the “compromise solution”: In contrast, “National NGOs” (62.05) lost significant ground in the “compromise solution” and can, therefore, be considered as comparably underrepresented in the compromise result. The remaining two groups, “Local Communities” (43.80) and “Finance and Industry” (42.05) reached a more balanced compromise compared to their individual group weightings but still at higher expenses compared to the highly represented groups. It was noteworthy that these groups made their highest concessions on the criteria ranked on top of the “compromise solution” (because of rather extreme positions in their individual group weightings compared to the spectrum of all groups) and thus made significantly higher sacrifices than all other groups in regard to divergent but lower ranked criteria.

4.3.5 Comparison of stakeholder preferences based on ranks

Arguably, an analysis of the stakeholder preferences purely based on the surrogate weights calculated is limited as the stakeholders did not state these values directly during the workshops. Rather, these preferences are subject to mathematical calculations, i.e., the CAR method. With this limitation being taken into consideration, the stakeholder preferences were also analyzed with regard to the ranking positions of the criteria. However, an analysis of the ranking positions of the criteria is difficult as there was no restriction on how many ranks the stakeholder could “define” during the “silent negotiation”. As a result, the individual group rankings have different number of ranks ranging from three to eleven ranks (including white cards). For this reason, the approach already described in Chapter 3.3.1 was used which results in five different importance categories based on Table 6 in order to make the individual group rankings comparable.

Number of ranks								
1	1	1	1	1	1	1	1	1
2	2	2	2	2	2	2	2	2
3	3	3	3	3	3	3	3	3
	4	4	4	4	4	4	4	4
		5	5	5	5	5	5	5
			6	6	6	6	6	6
High				7	7	7	7	7
High-moderate					8	8	8	8
Moderate						9	9	9
Moderate-low							10	10
low								11

Table 6: Determination of ranking categories based on the different number of ranks (for details see Annex 8 in suppl. material).

As a first step for analyzing the individual group rankings, Table 7 gives an overview about the importance categories of the individual group ranks.

	Use of domestic energy sources	Global warming potential	Domestic value chain integration	Technology and knowledge transfer	Electricity system costs	On-site job creation	Pressure on land resources	Pressure on local water security	Non-emission hazardous waste	Local air pollution and health	Safety
<i>PM</i>	high	high	moderate	high	moderate	least	moderate	moderate	moderate	moderate	least
<i>F&I</i>	high	moderate-least	moderate	moderate	high	moderate	least	moderate	least	moderate	moderate
<i>AC</i>	high	least	high	high	moderate-least	moderate	least	high	moderate-least	least	moderate-least
<i>YL</i>	high	moderate	least	high	high	least	moderate	moderate	moderate	moderate	moderate
<i>NGOs</i>	high-moderate	moderate-least	moderate-least	moderate-least	least	least	moderate	high	moderate-least	moderate-least	moderate-least
<i>LC</i>	moderate	moderate	moderate-least	moderate	moderate	moderate	moderate	high	least	moderate-least	moderate

Table 7: Comparison of ranking categories of all stakeholder groups.

According to Table 7, the criteria “Use of domestic energy sources” (appears four times on the top of the rankings), “Pressure on local water security” (2), and “Technology and knowledge transfer” (2) were all placed multiple times on top of the individual group rankings. The criteria “Global warming potential” as well as “Electricity system costs” were placed one time on top of the rankings. The criteria “On-site job creation” (3), “Pressure on land resources” (2) and “Non-emission hazardous waste” (2) were placed multiple times on the bottom of the individual group rankings. The criteria “Global warming potential”, “Domestic value chain integration”, “Electricity system costs”, “Local air pollution and health”, and “Safety” were all placed at least one time on the bottom of the ranking.

Secondly, in order to account for the differences within the ranking categories, the following numbers were attached to each importance category (see Table 8):

- \ High importance = 5;
- \ High to moderate importance = 4;
- \ Moderate importance = 3;
- \ Moderate to low importance = 2;
- \ Least importance = 1.

	Use of domestic energy sources	Global warming potential	Domestic value chain integration	Technology and knowledge transfer	Electricity system costs	On-site job creation	Pressure on land resources	Pressure on local water security	Non-emission hazardous waste	Local air pollution and health	Safety
<i>PM</i>	5	5	3	5	3	1	3	3	3	3	1
<i>F&I</i>	5	2	3	3	5	3	1	3	1	3	3
<i>AC</i>	5	1	5	5	2	3	1	5	2	1	2
<i>YL</i>	5	3	1	5	5	1	3	3	3	3	3
<i>NGOs</i>	4	2	2	2	1	1	3	5	2	2	2
<i>LC</i>	3	3	2	3	3	3	3	5	1	2	3
Total	27	16	16	23	19	12	14	24	12	14	14

Table 8: Comparison of ranking categories of all stakeholder groups converted into numbers (last row shows the sum for each criterion).

Based on Table 8, three observations can be made:

- \ The three most important criteria are “Use of domestic energy resources” (27 points), “Pressure on local water security” (24), and “Technology and knowledge transfer” (23), whereas the least important criteria are “On-site job creation” (12), “Non-emission hazardous waste” (12), “Local air pollution and health” (10), and “Safety” (10) (see last row in Table 8).
- \ On four occasions, between “Policy-makers” / “Academia” concerning the criterion “Global warming potential”, between “Finance and Industry” / “National NGOs” concerning the criterion “Electricity systems costs”, between “Academia” / “Young Leaders” concerning the criterion “Domestic value chain integration”, and between “Young Leaders” / “National NGOs” concerning the criterion “Electricity system costs”, the highest difference can be observed between the ranking categories, i.e., one group placed the criterion on the top of their ranking (high importance) while the other placed the criterion on the bottom (least importance). This indicates a potential for conflict between these groups and the respected criteria. At least the conflict between “Policy-makers” / “Academia” was observed during the “silent negotiation” within the negotiation of the “compromise solution” (see Chapter 4.1.4.2.1).
- \ If all groups are compared with another with regard to the differences between their individual importance categories (see Annex 8 in suppl. material for a comparison of all groups / criteria) the highest differences can be found between “Academia” / “Young Leaders” (19 differences importance categories) and “Policy-makers” / “Academia” (17). On the other hand, the lowest differences can be found between “Policy Makers” / “Young Leaders” (8) and “National NGOs” / “Local Communities” (9). This result is in line with the cluster analysis (see Chapter 4.1.4.1.2).

In a last step, an additional ranking has been developed. This ranking is based on the cumulative value for each criterion developed in tab. 8, which is the sum of the numbers attached to each importance category for each criterion (e.g., for “Use of domestic energy resources” the cumulative value is 27; see tab. 8 last row). This additionally developed ranking is a proxy for what a combined ranking of all individual group rankings, such as the “compromise solution”, should look like if it was based only on the importance categories. The ranking order of the criteria is as follows:

\ “Use of domestic energy sources” > “Pressure on local water security” > “Technology and knowledge transfer” > “Electricity system costs” > “Global warming potential” = “Domestic value chain integration” > “Pressure on land resources” = “Local air pollution and health” = “Safety” > “Non-emission hazardous waste” = “On-site job creation”.

The additionally developed ranking has seven different ranks. Consequently, the criteria fall within the following importance categories:

- \ High importance: “Use of domestic energy sources”;
- \ High to moderate importance: “Pressure on local water security” and “Technology and knowledge transfer”;
- \ Moderate importance: “Electricity system costs”;
- \ Moderate to low importance: “Global warming potential”, “Domestic value chain integration”, “Pressure on land resources”, “Local air pollution and health”, and “Safety”;
- \ Least importance: “Non-emission hazardous waste” and “On-site job creation”.

Table 9 illustrates a comparison of the importance categories of the additionally developed ranking and the ranking of the “compromise solution” based on the ranks.

	Use of domestic energy sources	Global warming potential	Domestic value chain integration	Technology and knowledge transfer	Electricity system costs	On-site job creation	Pressure on land resources	Pressure on local water security	Non-emission hazardous waste	Local air pollution and health	Safety
<i>Add. ranking</i>	5	2	2	4	3	1	2	4	1	2	2
<i>Compromise</i>	5	3	4	5	3	3	3	4	1	3	2
Difference	0	+1	+2	+1	0	+2	+1	0	0	+1	0

Table 9: Comparison of the additional ranking and “compromise solution”.

When the importance categories of the additionally developed ranking are compared with the ranking of the “compromise solution”, it can be stated that especially two criteria (“Domestic value chain integration” and “On-site job creation”) are two categories higher in the “compromise solution” than in the additionally developed

ranking, while four criteria are only one importance category higher. For five criteria exactly the same importance categories in both rankings can be observed.

These results can be interpreted in such a way that the “compromise solution” is relatively robust as overall only minor changes (a difference of none or only one importance category for nine criteria) in the importance categories occurred. These changes can be interpreted as mutual learning effects during the “silent negotiation”. Furthermore, this result is found in general to be in line with the analysis based on the weightings in the previous Chapters.

4.3.6 Concluding remarks on stakeholder preferences

Given that different electricity pathways based on different electricity generation options could be selected in Morocco for fulfilling the kingdom’s growing energy needs, the research of Chapter 4.1 maps out the wide array of multidimensional perspectives and the preferences of different Moroccan stakeholder groups in regard to future technologies choices aimed towards a sustainable and socially robust energy future. Albeit in a limited manner (see Chapter 5), the results showed that there were both converging as well as conflictual stakeholders’ views on many aspects of electricity decision-making and the desired future electricity system.

At the vision’s level, the visions of the different stakeholder groups were very much alike and indicated a general agreement on the GoM’s policy framework towards low-carbon development and its corresponding policies to promote economic prosperity, good governance, and environmental protection. However, when stakeholders were asked how electricity generation technologies could either foster or hamper the achievement of their visions, some differences among stakeholder groups emerged. These differences became most apparent between two stakeholder clusters: On the one side, “Policy-makers”, “Finance and Industry”, “Academia” and “Young Leaders” argued in favor of a “development first approach” by prioritizing nationally relevant, technical, and economic issues and emphasizing electricity generation as an “enabler” for achieving national development objectives and further socio-economic trickle-down-effects. On the other side, “National NGOs” and “Local Communities” put considerably more emphasis on locally relevant and environmental aspects and frequently referred to existing cases where the implementation of power plants had either positive or negative impacts on local environments and communities. The patterns of the individual criteria rankings of all stakeholder groups and the cluster analysis further emphasized the similarities among the stakeholder groups on both sides as well as the differences between the two clusters.

Although the “polarisation of opinions” between the two groups also resulted in heated debates during the final workshop, a “compromise solution” on a final criteria ranking was eventually achieved and approved by all stakeholder groups. The result of the participatory negotiated “compromise solution” showed similar weighting patterns to the “mathematical solution” based on the arithmetic means of all individual stakeholder group rankings. Most noticeably, all national criteria were found in the top ranks of the overall ranking while almost all locally relevant criteria were ranked as being of low-moderate importance during the final workshop. As striking as this might appear, it could be misleading to think that a) the most preferred technology mix would favor national objectives over local impacts and that b) the prevailing development model in the minds of Moroccan society would follow a “grow first, clean up later” attitude (in which environmental degradation could potentially be improved and reversed when a certain threshold of welfare and education is reached). Instead the robustness of the “compromise solution” was challenged along two axes of conflict. Firstly, because “National NGOs” and “Local Communities” lost significant ground in the “compromise solution” and made higher sacrifices on their environmental and local preferences than all other stakeholder groups to reach the final result. Secondly, due to the contestation of three criteria that are characterized by polarized viewpoints in both the “compromise solution” and in the comparison of all individual stakeholder weightings, namely “Global warming potential”, “Pressure on local water security” and “Electricity system costs”.

All in all the stakeholder groups shared similar visions for how they wanted their country to be by the year 2050, but differed in their priorities and interests on how the development of new electricity infrastructures should be geared towards achieving their visions. That is why planning Morocco’s electricity future requires not only careful considerations of conflict lines but also increased efforts towards an inclusive multi-stakeholder dialogue to find trade-off solutions that are supported by all relevant stakeholder groups.

4.3.7 Analysis of procedural and distributive justice

As utility-scale power plants are not located in empty territories but mostly on lands that have economic and cultural value for local communities, outcomes of a project may either threaten or enhance the livelihood situation and sense of place of communities. Therefore, the participation of local communities in technology decision-making as well as the perceived fairness by which adverse and beneficial project outcomes are allocated among the local population are widely recognized prerequisites for achieving community approval and project legitimacy (Pasqualetti, 2011; Strachan & Jones, 2012). In this regard, the need for granting procedural and dis-

tributive justice to local communities located in the vicinity of power plants was judged similarly across all stakeholder groups. However, actors estimated this need differently for each electricity generation technology based on the varying perceptions on the transformative characteristics of different power plants.

Procedural justice: All stakeholder groups related the need to have local communities participate meaningfully in the design, the siting, and the operation of electricity generation technologies to two aspects. On the one hand, technologies that were associated with substantially negative environmental and socio-economic implications at the local level, such as nuclear, coal, oil, and natural gas, were ranked highest and seen as most critical for community engagement. The reasoning here across all stakeholder groups was that allowing local citizens to have a say in the decision-making over these technologies could make the mitigation and management of environmental and social impacts more efficient and thereby protect local livelihoods more effectively. In addition, the involvement of local citizens was also regarded important for enhancing the positive outcomes of technologies and for tailoring the project design to local context specifics. Although ranked lower than their fossil fuel and nuclear counterparts, utility PV, CSP, onshore wind, and utility hydro-electric were seen as more beneficial at the local level and thus still considered important in regard to the need of community engagement.

Distributive justice: The distribution of benefits and burdens stemming from a specific electricity generation project were discussed in similar veins as the need of procedural justice. Participants across all stakeholder groups agreed that the spatial pattern of utility-scale power plants falls unequally on the Moroccan society and on disadvantaged regions that have suffered historically from high levels of environmental deprivation or geographic isolation. In this regard, the need to provide local communities with legal means for grievance resolution and compensation of adverse impacts was considered highest for fossil fuel and nuclear technologies. The reasoning provided here was that fossil fuel and nuclear power plants are mainly sited in the proximity of already heavily industrialized areas and thus require effective measures that enable local communities to resolve project-related disputes and claim remedies where disproportionately high and adverse impacts are threatening their livelihoods or cultural values. In contrast, the need to share a reasonable amount of benefits with local communities was regarded highest for renewable energy technologies. The arguments provided here were twofold: First, utility-scale RE plants were perceived to generate more socio-economic prospects than non-renewable options at the local level. Second, because most of the RE power plants are located in remote areas characterized

by political and economic neglect in Morocco, participants rated the necessity to provide benefits from these technologies higher.

In addition to the technology-dependent evaluation, all stakeholder groups regarded the meaningful involvement of local citizens in the planning and deployment of electricity generation technologies as well as fairness in the distribution of benefits and burdens as a prerequisite of socially robust electricity planning. This result was reflected in the overall ranking in which all stakeholder groups placed “procedural justice” mostly on top of all other 11 criteria and “distributive justice” among the top three criteria.

4.4 MCDA technology evaluation

This chapter combines the information about the performance of the 8 different electricity generation technologies across the 11 criteria (scores developed in the attribute matrix Table 1) with the stakeholder preferences about the relative importance of the evaluation criteria (weights) by applying the MCDA software Decide-IT 2.82. The result was an overall ranking of the electricity generation technologies based on their specific performance characteristics and a) equal weights as well as b) the weights established as “compromise solution” in the final workshop (see Chapter 4.1.4).

4.4.1 Overall ranking based on equal weights

To understand the effect of stakeholder preferences on the final ranking of the 8 examined electricity generation technologies, the performance of the technologies was first assessed against the 11 criteria and the respective 20 indicators by setting all weights equal. Figure 11 presents the resulting ranking of the technologies and reveals the patterns of the attribute matrix depicted in Table 1 and described by Schinke et al. (2017).

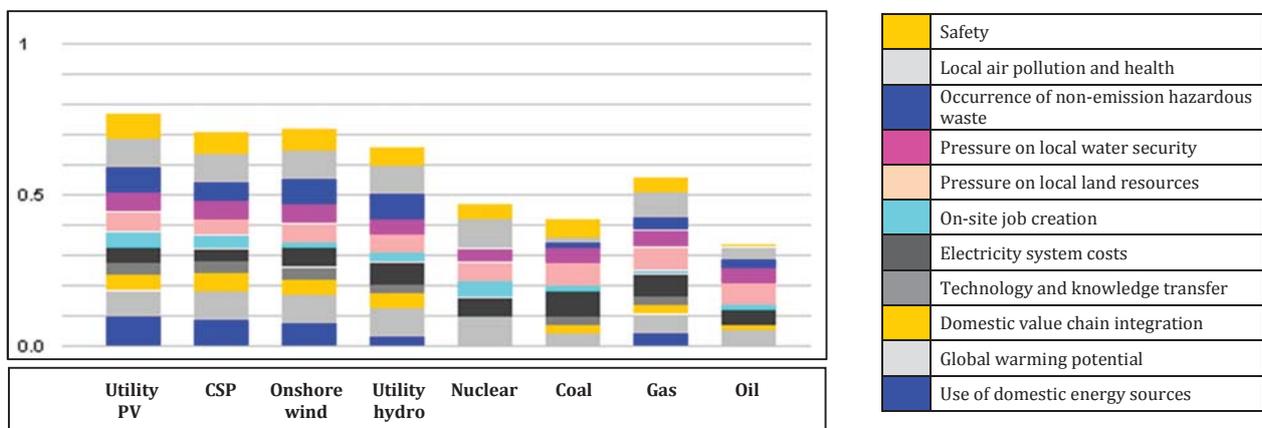


Figure 11: Technology ranking based on equal weights.

The bar representation enables prospective impact variations of a technology to be illustrated in a single figure and thereby avoids both a fragmentation of information (such as in Table 1) as well as an oversimplification (such as in Figure 12). It is based on the “most likely point,” which is either the arithmetical mean (for all quantitative criteria) or the median (for all qualitative criteria) and presents the final score of each alternative, which has been standardized on a scale from 0 to 1 and multiplied by the criteria weights (in this case equal weights). The colored segments of each bar indicate the contribution of the performance in each of the 11 criteria to the final score.

When all criteria were considered equally important, the RE technologies turn out as the best four options while the fossil fuel and nuclear alternatives mark the bottom of the ranking. Although the exact order of the ranking may be slightly different, this outcome was consistent with the findings of previous national MCDA studies in which utility PV, onshore wind, CSP, and utility hydro-electric electricity generation options were also generally found on top of the rankings (Chatzimouratidis & Pilavachi, 2009; Stein, 2013; Hirschberg et al., 2014; Cartelle, et al., 2015; Grafakos et al., 2015).

In order to shed additional light on the overall ranking, Figure 12 presents the distribution of the different technologies across the nationally and locally relevant criteria.

The illustration shows that all RE technologies place in the top right quadrant and, hence, provide the most benefits and have the lowest adverse impacts across the national and local dimension. Together they form a technology cluster which is significantly better than their fossil fuel and nuclear counterparts of which natural gas marks an outlier with superior performance characteristics at both levels than the others. In contrast, all fossil fuel and nuclear alternatives fall in the bottom left quadrant meaning that their performance is lower than the mean performance value for all technologies considered.

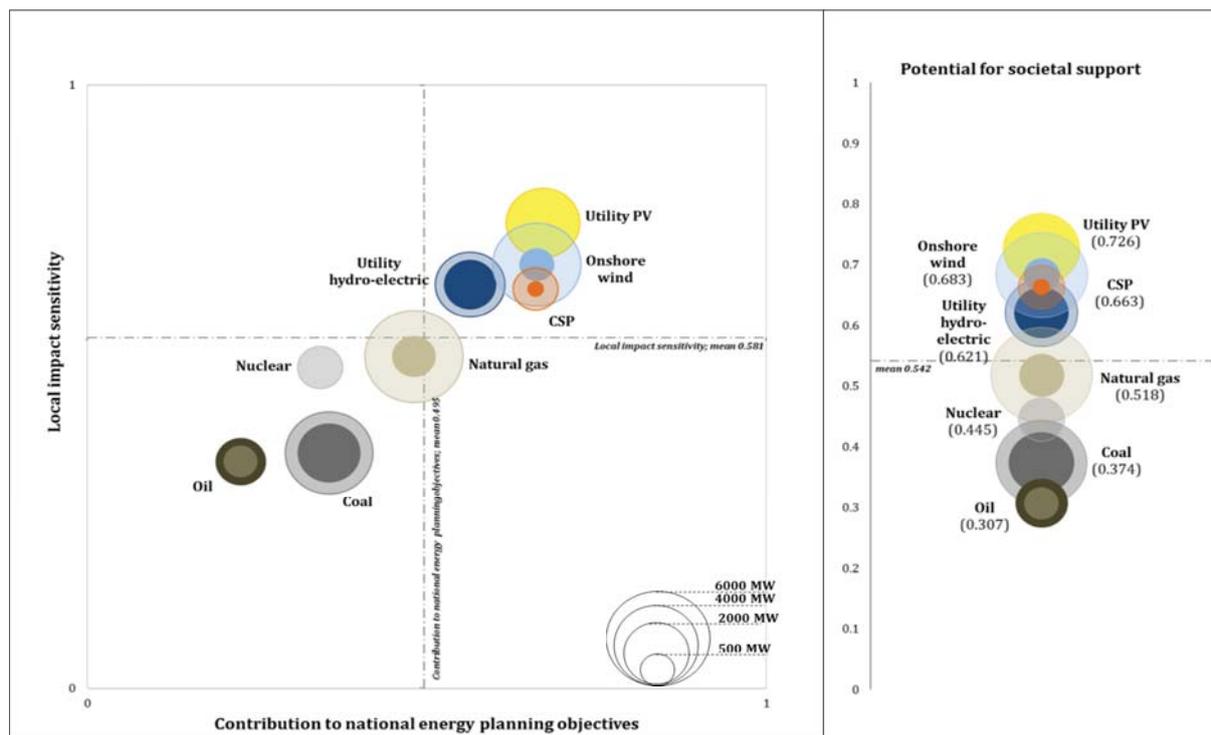


Figure 12: Technology performance in the context of Morocco's national energy planning objectives and local impact sensitivity with equal weights. The bubbles' diameter is proportional to the installed (filled) and planned capacities in MW (shaded). Left: On the horizontal axis is the index of the five criteria that are predominantly related to the objectives of the National Energy Strategy, whereas on the vertical axis the index of the six predominantly local criteria is plotted. Boundaries of the four quadrants are defined by the mathematical mean calculated for all eight technologies along the two criteria indices.

Contribution to national energy planning objectives: At the national level, utility PV performed best with the highest contribution to national energy planning objectives due to its high potential use of domestic energy sources, low life-cycle GHG emissions, as well as moderate economic prospects in terms of industry integration and technology transfer. Yet, the high integration costs of utility PV weakened the overall result despite that the LCOEs of PV plants are now almost cost competitive with coal and gas in Morocco. Onshore wind and CSP technologies were almost identical in second and third with the former having a higher potential to integrate domestic industries and profit from technology transfer, whereas the latter's system costs are comparatively lower. Although characterized by low electricity system costs, their rather low economic benefits and geographically limited capacities explained why utility hydro-electric facilities ranked fourth. Of all the conventional technologies natural gas-fired power plants ranked the best but still considerably lower than their RE alternatives. This was particularly due to their higher GHG emissions, low contribution to energy independence, and relatively low economic prospects in terms of domestic

value chain integration and technology transfer. Nevertheless, the electricity system costs of natural gas-fired power generation are cheaper. While uncertainties still remain about the future exploration of domestic gas reserves, coal-fired power generation has no potential to reduce Morocco's energy import dependence. It also contributes significantly to global warming and thus ranked in sixth position despite having the cheapest electricity system costs in Morocco as of today. Nuclear was characterized by a rather ambivalent performance on the national level: it placed second to last as a strong performer regarding GHG emissions, but with low performance for the remaining nationally relevant criteria. As the worst climate polluting and most expensive technology, oil was ranked in last position.

Local impact sensitivity: At the local level, utility PV received the highest index with particularly strong performances in regard to on-site job creation, human health, and safety. Onshore wind, utility hydro-electric, and CSP technologies took up the next three positions with almost identical scores. While onshore wind was characterized by considerably lower direct employment effects and higher numbers of severe accidents, CSP would have performed equal to utility PV if it was not for its higher land and water requirements as well as waste generation in particular. The favorable ranking of hydro-electric facilities, however, should be treated with caution. This is because the applied range of attribute values for land and water consumption was based on the average values of the other technologies due to multiple purpose use and uncertainties in the scientific data on water and land requirements, resulting in a methodological artifact (for more information, see Schinke et al., 2017, p. 70). Among all conventional technologies natural gas technologies placed best and were ranked fifth at the local level, mainly due to relatively low values on air pollution, waste, and safety risk as well as favorable values for land requirement. Nuclear power plants on the other hand performed favorably under the criterion on-site job creation but suffered from radioactive waste and safety risks, thus resulting in rank six. At the bottom of the ranking, coal and oil-fired power plants were by far the worst performers in regard to the six locally relevant criteria and received unfavorable values across almost all categories.

The overall performance across all 11 criteria mirrored the technologies' positions in the quadrants. The ranking indicated that all RE technologies, and especially utility PV and onshore wind, have a higher potential to be socially supported than the fossil fuel and nuclear options. This in turn suggested that the deployment of oil, coal, and nuclear in particular could be faced with opposition at the national as well as at the local level.

4.4.2 Overall ranking based on stakeholder weights

In contrast to Chapter 4.2.1, this part of the technology evaluation examines stakeholder’s preferences in regard to their influence on the overall performance characteristics of the 8 electricity generation technologies against the 11 criteria. Hence, while the underlying attribute values are the same as in Chapter 4.2.1, the weights changed from equal weights to the weights derived as the “compromise solution” (see Table 4 and Figure 3). The results can be seen in Figure 13 and 14. In comparison to Figure 11, Figure 13 shows that the overall ranking of the eight electricity generation technologies almost stays the same: The four RE-based technologies continued to perform better than their fossil fuel and nuclear-fired alternatives. Yet slight changes were also seen. Onshore wind was no longer the second best alternative, because CSP’s performance increased slightly. In contrast, the performance of utility hydro-electric decreased slightly. The ranking did not change for conventional alternatives. However, based on the weights of the “compromise solution”, the score of nuclear decreased nearly to the low level of coal. Moreover the distance between coal and oil increased slightly, because coal gained some points while oil decreased, making oil with greater distance the worst performing alternative at the bottom of the ranking.

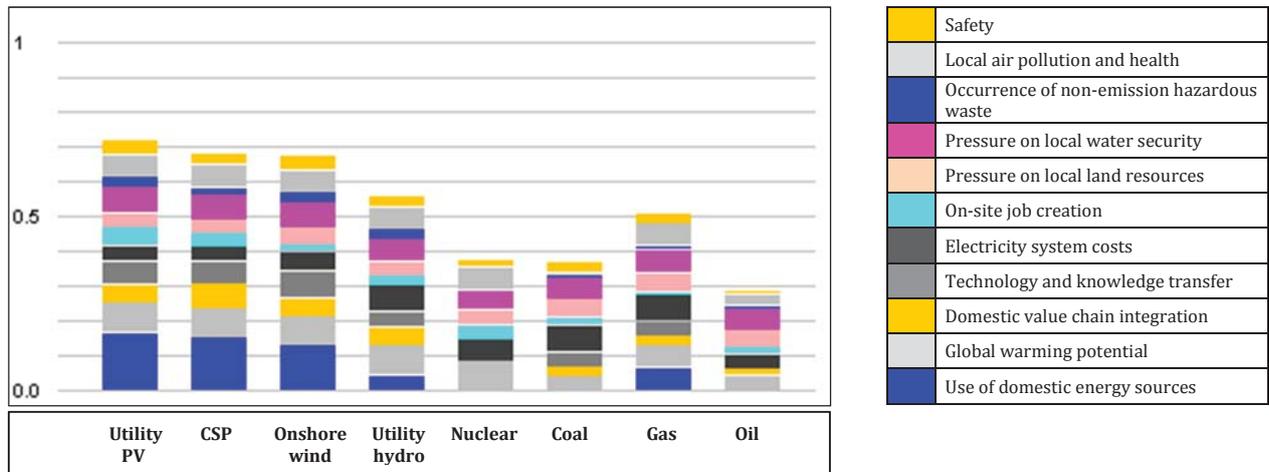


Figure 13: Technology ranking based on the weights of the “compromise solution”.

The gap between utility hydro-electric and natural gas was not as pronounced anymore due to the weaker performance of utility hydro-electric compared to the ranking based on equal weights. Additionally, it was interesting to note that, while the ranking of the eight alternatives changed only on one occasion in comparison to the ranking based on equal weights, the structure of the underlying performance characteristics changed considerably: Especially the criteria “Use of domestic energy sources” and “Technology and knowledge transfer” gained significantly in their weightings compared to an equal weighting. At the same time, the criteria “Safety” and “Non-emission hazardous waste” decreased in their importance. Consequently, alternatives that have high/low attribute values for these criteria were able to increase/decrease their performance. For example, the nuclear alternative benefited indirectly from a lower weighting for the criterion “Non-emission hazardous waste” as it has low performance for this criterion, while for utility PV, CSP, onshore wind, and utility hydro-electric, the lower weighting for this criterion resulted in considerable losses. By contrast, nuclear did not benefit from the weight increase for the criterion “Use of domestic energy sources,” which increased the overall performance especially of utility PV, CSP, onshore wind, and natural gas. Figure 14 shows the distribution of the different technologies across the nationally and locally relevant criteria based on the weights of the “compromise solution.” While the performance characteristics of the eight electricity generating technologies at the national and the local level followed broadly the same patterns (see Figures 12 and 14), some differences were notable with regard to the national and local dimension based on the weights of the “compromise solution”.

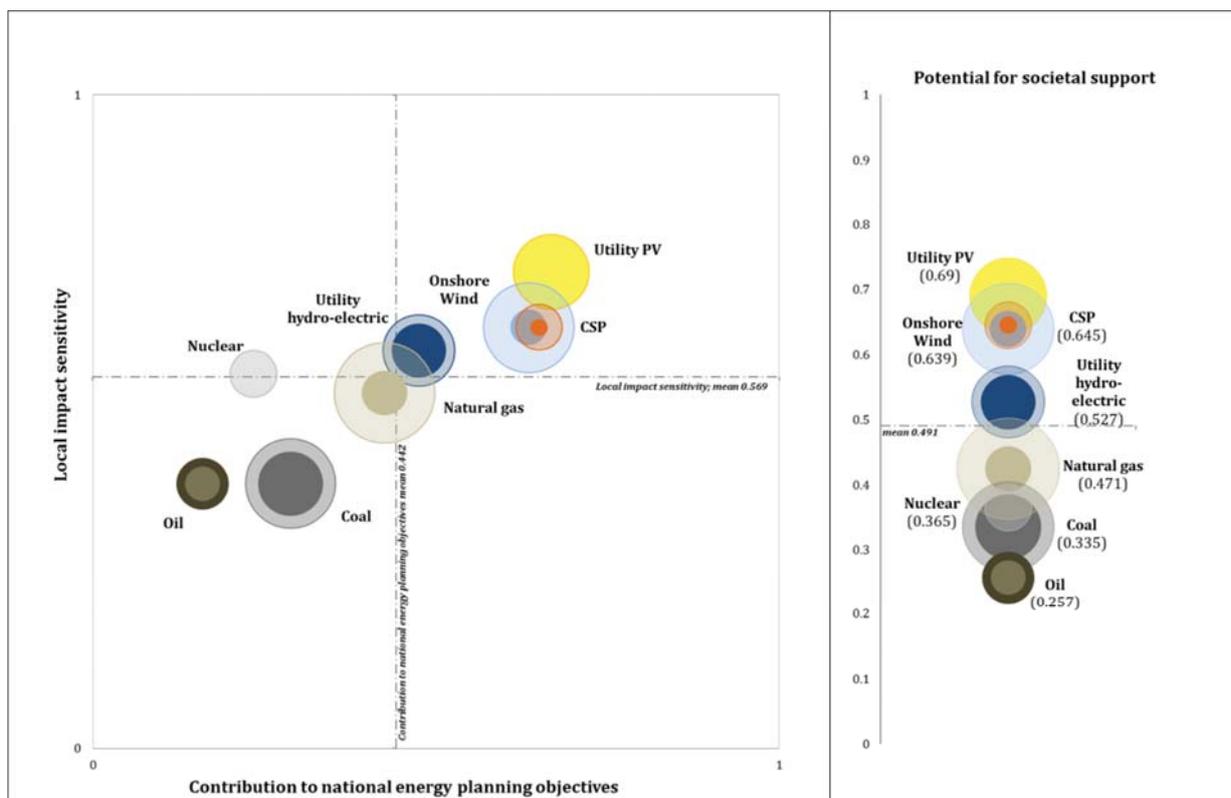


Figure 14: Technology performance in the context of Morocco’s national energy planning objectives and local impact sensitivity based on the weights of the “compromise solution”. The bubble diameter is proportional to the installed (filled) and planned capacities in MW (shaded). Left: On the horizontal axis is the index of the five criteria that are predominantly related to the objectives of the National Energy Strategy, whereas on the vertical axis the index of the six predominantly local criteria is plotted. Boundaries of the four quadrants are defined by the mathematical mean calculated for all eight technologies along the two criteria indices.

Contribution to national energy planning objectives: With the exception of utility PV, all alternatives lost in comparison to an equal weighting with regard to the national dimension²⁴. However, CSP—despite a negligible loss—performed almost equally, while the overall performance of onshore wind slightly decreased. Furthermore, the alternatives nuclear and utility hydro-electric lost considerably. This can be explained by the relatively poor performance of both alternatives with regard to criteria that gained significantly in importance, i.e., “Use of domestic energy sources” and “Technology and knowledge transfer” and to criteria where both alternatives show a relatively good performance, i.e., “Global warming potential” and “Electricity system costs”, but which lost in importance.

²⁴ With regard to Figures 12 and 14, it should be mentioned that the two means (national and local dimension, depicted as the two dotted lines in each of the figures) are different.

Moreover, the loss in importance of the criterion “Electricity system costs” affected the coal alternative the most and decreased its performance.

Local impact sensitivity: With regard to the local level, the changes of the weights resulted in a more mixed picture compared to the national dimension: The alternatives nuclear, coal and—to a lesser extent—natural gas benefited from a lower weighting of the criteria “Non-emission hazardous waste” as well as “Safety” and, to some extent, also from a lower weighting of the criterion “Local air pollution and health” (especially coal). On the other hand, the performance of RE-based alternatives decreased overall as they show in general relatively good performance with regard to the underlying attribute values within these criteria that are now weighted lower. Most affected from the weighting changes was the alternative onshore wind, which lost especially with regard to the criteria “Non-emission hazardous waste” and “Pressure on land resources”. The slightly higher importance of the criterion “Pressure on local water security” was not able to fully compensate for these losses. Additionally, the overall performances of the alternatives utility PV, CSP, and utility hydro were also negatively affected by the lower importance of the criterion “Non-emission hazardous waste”, while this effect was not as pronounced for CSP as for the other RE-based alternatives.

Compared to the MCDA results based on equal weights, the results based on the “compromise solution” showed that all RE alternatives are still to be found in the top right quadrant whereas all fossil-fuelled alternatives are in the bottom left quadrant. The exception was nuclear, which moved up into the top left quadrant.

4.4.3 Sensitivity analysis

A sensitivity analysis was conducted in order to factor in the uncertainty of the underlying data with regard to the ranges of the attribute values and to explore potential “what-if?” scenarios. The sensitivity analysis consisted of two parts: Firstly, the embedded tools and capabilities of the DecideIT 2.82 software were used. In conducting this part of the sensitivity analysis, the authors followed an approach similar to that taken by Danielson et al., 2007, Larsson et al., 2011 and Mihai et al., 2015, who also used the DecideIT 2.82 software and its embedded tools and capabilities to conduct a sensitivity analysis with regard to uncertainties embedded in the underlying attribute values. Secondly, the weights were also altered manually based on the results of Chapter 4.1.4 and associated uncertainties stemming from the weight ranges.

Sensitivity analysis with regard to attribute values

The underlying data for the attribute values within this study were subject to uncertainties expressed by ranges in the attribute values (for details about the attribute values, see Schinke et al., 2017). The DecideIT 2.82 software takes into account these uncertainties by using the concept of contraction (see info box). Consequently, the results of the performance of the 8 electricity generation technologies across the 11 criteria were—in some instances—not as clear cut as is shown in Chapters 4.2.1 and 4.2.2.

DecideIT 2.82 and the concept of contraction

Within the DecideIT 2.82 software it is possible to include data ranges for a given criterion. In other words, it is possible to include not only *one* value, e.g., € X, but to include a *range*, e.g., from € X to € XX, for a given criterion. Additionally, it is possible to state a “most likely” focal point within this range. As the software calculates the expected value for each criterion and aggregates it into a weighted sum of expected values, one can determine the degree to which the underlying attribute value *ranges* should be taken into account. This is realized through the concept of contraction, where the user can determine the extent to which values *around* the “most likely” point should be included in the analysis. For example, if the contraction level is set to 100 per cent, only the most likely point will be taken into account, meaning that the user is very certain that only the most likely point has to be taken into consideration and values above / below the most likely point can be omitted. The results gained will be relatively clear cut, but also the underlying uncertainty with regard to potential attribute values above/below the most likely point is neglected. On the other hand, if the contraction level is set to 0 per cent, the whole range of attribute values will be taken into account resulting in largely overlapping bar graphs (for more information on the concept of contraction within DecideIT, see Danielson et al., 2007).

As a first step, the cardinal ranking option within DecideIT was used, which served to provide an overview of the expected value ranges within the analysis. A contraction level of 85 per cent (Mihai et al., 2015) and the weights gained in the “compromise solution” were chosen. The resulting bar graphs are shown in Figure 15. Despite the overlaps of the bar graphs in Figure 15 between some alternatives, one can identify groups of alternatives that are superior to other alternatives—even if uncertainty in the underlying attribute values is acknowledged.

Hence, the following four groups of alternatives can be identified: a) utility PV, CSP, and onshore wind as the first and superior group; b) utility hydro-electric and natural gas; c) nuclear and coal; and d) oil as the worst performing alternative²⁵ (see Annex 6 in suppl. material for results with a contraction level of 80 per cent).

The final step for comparing the alternatives within DecideIT 2.82 was to conduct a pairwise comparison of alternatives indicating the exact strength of one alternative over another (Danielson et al., 2007).

²⁵ Depending on how one chooses to define the boundaries of the groups, other combinations of alternatives are possible. Here, the authors chose to group alternatives that have relatively high overlaps among each other.

The pairwise comparison showed the exact contraction intersection point: the lower this point, the higher the confidence that an alternative is better than another. For example, if two alternatives are compared that show high overlaps in Figure 15, the intersection point will be relatively high. This result would mean that these alternatives perform almost equally and that one can say only with very low confidence that one alternative is better than the other (see Figure 16).

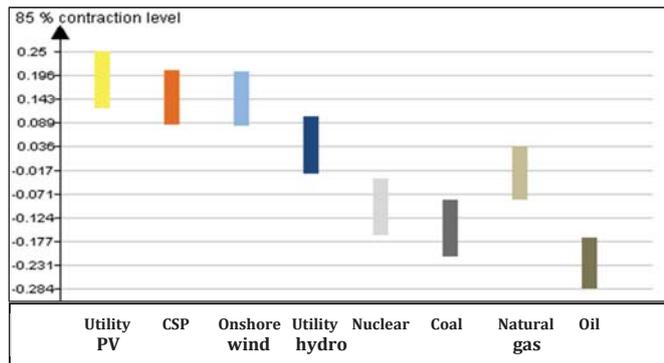


Figure 15: Cardinal ranking with an 85 per cent contraction level.

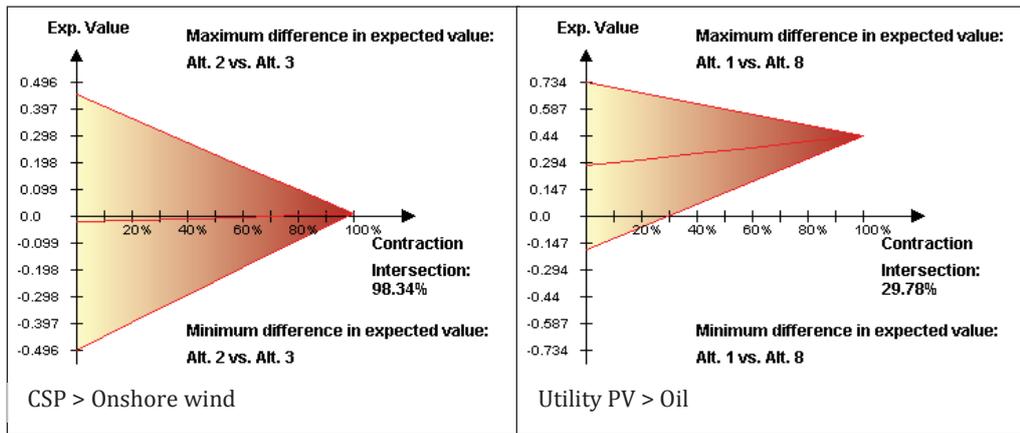


Figure 16: Pairwise comparison of CSP and onshore wind (left) and of utility PV and oil (right). Alternatives CSP and onshore wind perform almost equally (contraction intersection very high), meaning that there is only very low confidence that CSP is better than onshore wind. Alternative utility PV performs significantly better than oil with high confidence (very low contraction intersection).

For a systematic pairwise comparison, the best performing alternative within the groups identified above (a, b, c, and d) were compared with the best performing alternative in the next best group as well as the best/worst alternative within the groups (see Figure 17 and Table 10).

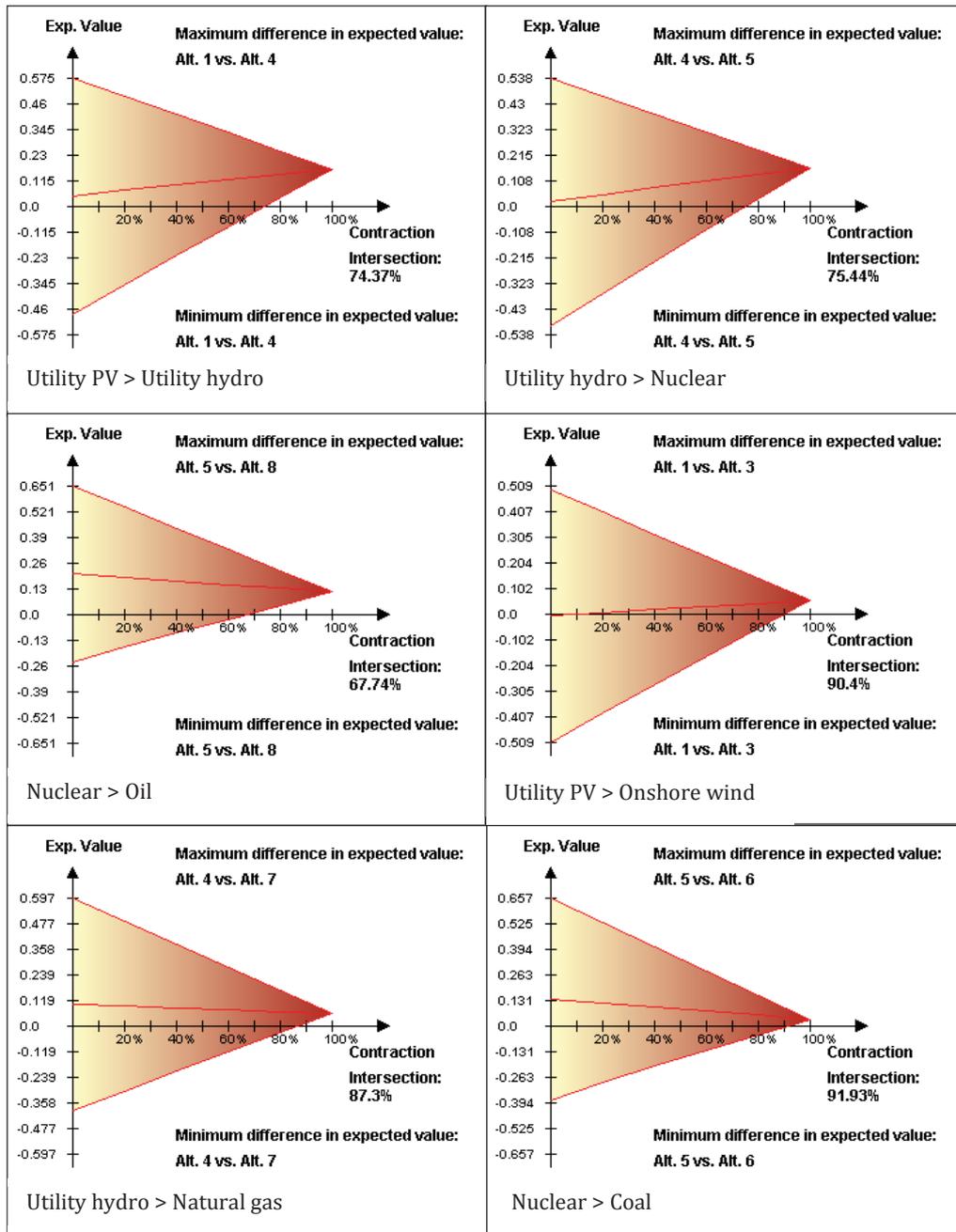


Figure 17: Results of the systematic pairwise comparison of the eight alternatives.

Based on the pairwise comparison (Figure 17, Table 6, and Annex 6 in suppl. material) it can be stated with confidence that even the worst performing RE-based alternative (utility hydro-electric) is better than all the conventional alternatives—even when uncertainty about the underlying attribute values is taken into account. An exception was natural gas, where there only exists mild confidence. For coal and oil,

the superior performance of all RE technologies of the first group (utility PV, CSP, and onshore wind) was highly confident.

Alternatives compared	Contraction intersection point	Confidence level
Utility PV > Utility hydro	74.37	Confident
Utility hydro > Nuclear	75.44	Confident
Nuclear > Oil	67.74	Confident
Utility PV > Onshore wind	90.4	Not confident
Utility hydro > Natural gas	87.3	Mildly confident
Nuclear > Coal	91.93	Not confident

Table 10: Summary of the pairwise comparison of the alternatives (confidence levels are based on the DecideIT software; for a comparison of all pairs see Annex 6 in suppl. material).

Furthermore, it can be stated with confidence that the alternative nuclear performed better than oil and that there was no confidence in the statement that nuclear performed better than coal.

Sensitivity analysis with regard to weights

Aside from the associated uncertainties of the underlying attribute values, uncertainties might also exist with regard to the weights. Therefore, in a first step, all weight ranges resulting from the individual group weightings were factored into the analysis. The lowest/highest weight stated in any group for a criterion marked the lower/upper boundary of the range. The arithmetic mean²⁶ was chosen as the “most

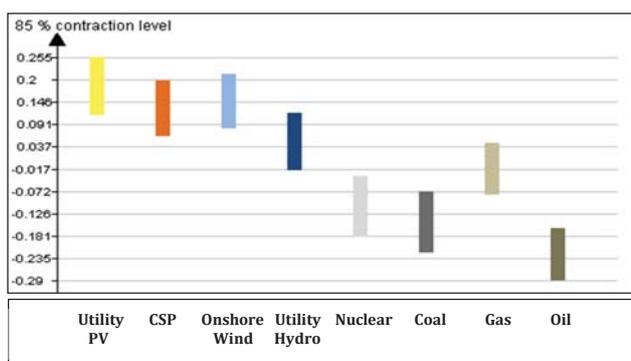


Figure 18: Cardinal ranking with weight ranges of all individual group weightings.

likely” point. In the second step, the criteria and associated weights that are contested within the “compromise solution” were also changed manually to see what effect the changes have on the performance of the alternatives. In a third step, all individual group weightings were then used separately to observe the effects on the overall result (see Annex 6 in suppl.

²⁶ Arguably, the better “most likely” points would have been the results of the “compromise solution”. However, as there was no limitation for the weightings within the final workshop, some weights of the “compromise solution” were below/above the lowest/highest weight of the individual group weightings. This made them unsuitable for the implementation in DecideIT 2.82 when using weight ranges.

material for results). A contraction level of 85 per cent was chosen for all following tests.

The acknowledgement of the weight ranges of all individual group weightings resulted in more uncertainties. Hence, the bar graphs in Figure 18 are longer compared to Figure 15. Overall, the effect of the weight ranges on the results was not significant insofar as the RE-based alternatives still performed better than their conventional alternatives with the exception of natural gas, which overlapped slightly more with utility hydro-electric. The difference between CSP and onshore wind was more pronounced, while the differences between nuclear, coal, and oil were less pronounced than before.

As a result of Chapter 4.1.4.2.1, three criteria were contested: “Global warming potential”, “Electricity system costs” and “Pressure on local water security”.

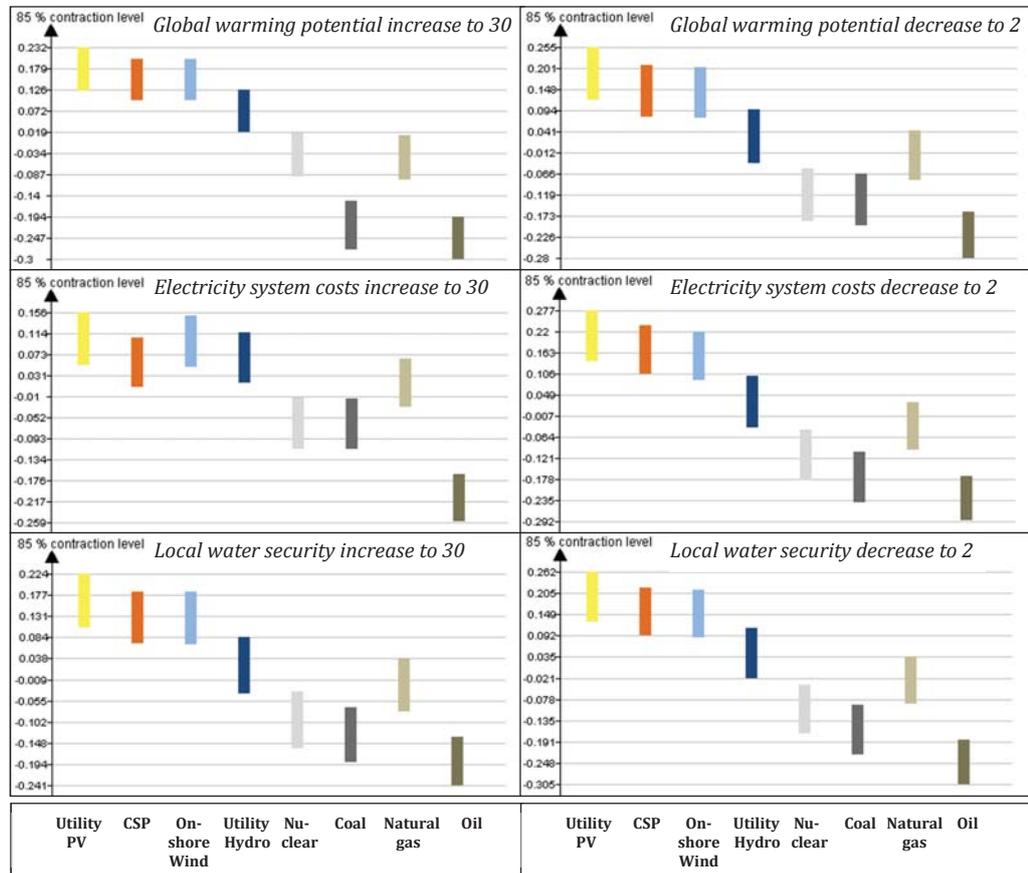


Figure 19: Influence of weight changes on the result.

Figure 19 shows the results if the weights of these criteria are changed manually²⁷ (weight increase/decrease for each criterion to 30 per cent/2 per cent separately). While especially drastic weight changes affected the overall result, the four principal groups stated above—a) utility PV, CSP, and onshore wind; b) utility hydro-electric and natural gas; c) nuclear and coal; and d) oil—did not change significantly. The most obvious changes were observed among conventional alternatives. For example, if the importance of “Global warming potential” is increased to a rather extreme value of 30 per cent, alternatives nuclear and natural gas, on the one hand, as well as coal and oil, on the other hand, perform almost equally with huge overlaps. In contrast, if “Electricity system costs” is increased to a value of 30 per cent, coal performs almost equally to nuclear, and natural gas outperforms both. The RE-based alternatives still were at the top of the ranking, however (see Annex 6 in suppl. material for further information on the results based on all six individual group weightings).

A striking result of the sensitivity analysis, even when different weight combinations were used, was that the alternatives utility PV, onshore wind, and—in most cases—CSP were still always on top of the ranking. In the same vein, the alternatives coal and oil always stayed at the bottom of the ranking. The alternatives utility hydro-electric and natural gas overlapped to varying extents depending on the weights chosen, as did natural gas and nuclear. In most instances, the alternative utility hydro-electric did not perform as good as utility PV or onshore wind, and sometimes had no overlaps at all with these alternatives. However, if rather extreme weights were chosen utility hydro-electric performed almost equally as CSP.

5 LIMITATIONS

Due to the rather explorative character, the results achieved in this study should be treated with caution. The following limitations should be taken into account when interpreting the results and could be overcome in future research activities:

- \ Stakeholder selection: In transdisciplinary research the selection of stakeholder groups has great influence on the scientific outcomes. This means that in other circumstances, e.g., other stakeholder groups or another composition of work-

²⁷ If one weight is changed, all other weights have to be changed, too, because the total weight of all criteria must always add up to 100. However, the proportions of the weights that are not changed manually are kept the same with the weights of the “compromise solution” as the initial point of departure (see suppl. material Annex 6 for the new weight tables). Furthermore, the rather extreme values of 30 and 2 were chosen as they represent the highest/lowest overall weights stated in any stakeholder group.

shop participants, other results with regard to stakeholders' preferences would be possible. However, the research team oriented the selection of stakeholder groups as well as participants towards a meaningful representation of different social backgrounds and perspectives in order to achieve an approximation of different societal views.

- \ Technology focus: This analysis is specific to utility-scale electricity generation technologies, whereas small-scale or decentralized distributed generation options may have very different results. Also, this study does not investigate any subject related to energy efficiency measures.
- \ Country focus: The results of this study are specific to Morocco at the national level and may not be applicable at a global scale, to other countries, or for local or regional decision-making within Morocco. However, a similar methodology employed with more location-specific input data may in combination with specific case-studies, i.e., projects that currently in the planning or construction phase, could be useful in decision-making at all these stages.
- \ Data uncertainties: With regard to the data used for this study, it must be noted that data input for certain criteria and indicators is subject to uncertainties—an issue which was addressed due to the usage of attribute value ranges, which leads to results that are also subject to uncertainty and lower confidence levels (see Chapter 4.2.3). On a similar token, the input data are also subject to a moment of subjectivity as some criteria and indicators are based on expert judgment and/or are of qualitative nature.
- \ Pre-selection of criteria: The criteria used within this study were pre-defined by the research team and no stakeholders were included in the selection process (see Chapter 3.1.2). This procedure was necessary for methodological, but mostly for practical reasons (as, for example, the time in the field and for the workshops was limited). This approach represents a certain deviation from the spirit of transdisciplinary projects and/or methodology. However, the research team attempted to counteract this deviation by using an extensive gap analysis with regard to criteria within the workshops (see Chapter 3.2.3). Moreover, the criteria selection did not include technical criteria, but focused on socio-economic, environmental, as well as developmental criteria as this was the focal point of this research. Additionally, this study focused on the operational phase of utility-scale electricity generation technologies while not addressing the decommissioning phase. These limitations (predefined criteria, no technical criteria, no criteria related to the decommissioning phase) must be taken into account with regard to the interpretation of the results as adding/removing any criterion would change the results.

- \ Methodological restrictions: The method of “silent negotiation”—while proving very capable of achieving a group compromise on the preferences regarding the different criteria and also giving enough room for mutual-learning and discussions—has the weakness of resulting in cardinal weights, which have to be transformed into so-called surrogate weights (see Chapter 3.3.1). However, due to this transformative step, the weights used within the analysis do not represent real numerical values stated by the participants. Instead they are also an approximation of those values. Furthermore, a greater number of rounds and moves within “silent negotiation” that have been prescribed by the research team for the participants of the workshop (see Chapter 3.2.4) may have yielded other results. However, a meaningful solution had to be found between time spent on this task and practical time constraints as well as stakeholder fatigue. In addition, the starting / ending position within the “silent negotiation” was perceived either as a strategic advantage / disadvantage from different participants. Therefore, drawing lots was found to be the most fair and practical solution for this issue (see Chapter 3.2.4).

Nonetheless, the research team believes that this research is an inspiring starting point for future research addressing the complexity of the integration of different stakeholders’ perspectives into future energy planning in Morocco. Future (re-search) projects should build on the data base developed in the MENA Select project and further strengthen the data input (see Schinke et al., 2017). The authors are confident that future transdisciplinary research with more location-specific input data, additional criteria and broader stakeholder participation could yield to highly valuable results in regard to energy policy-making in Morocco.

6 CONCLUSIONS

Morocco’s electricity consumption is projected to increase more than five times by 2050. At the same time, the total power generation capacities required to address the increasing electricity demands are estimated to rise from today’s 8 GW to 25 GW by 2030 and up to 93 GW by 2050 (Schinke et al., 2016, p. 24). Aware of the country’s energy stakes, the GoM presented a new National Energy Strategy (NES) in 2015 to take up these challenges. Despite being widely known for its ambitious RE roll-out (10,100 MW of additional capacity by 2030), the NES envisions conventional energy carriers to be an important pillar in the country’s future electricity mix as well (around 6,400 MW additional capacity by 2030). While its pioneering efforts to establish a legal, institutional, and financial framework for RE is a promising approach to unleashing Morocco’s domestic RE potential, the two-track energy policy of pursuing RE and conventional energy in parallel contradicts the national vision of

achieving “a low-carbon and climate change resilient development” (MEMEE, 2014a, p. 18) and the recently declared commitment to “meet 100 per cent domestic renewable energy production as rapidly as possible” (CVF, 2016). Nevertheless, the major part of electricity infrastructures needed to respond to the increasing electricity demands is still to be built and substantial investments in additional power generation capacities are yet to be made. Therefore, the exact mix of technologies along with respective electricity pathways still remains uncertain and is yet to be decided (IEA, 2016, p. 36).

As a consequence, the GoM currently puts a lot of effort in designing a possible energy future based on technological system optimization and least-cost evaluation models (Kern et al., 2016). However, electricity systems are not developed in isolation from a country’s development challenges and its society. Rather they develop in continuous interaction with social, economic, and environmental dimensions at the national and local level. This challenge is further aggravated by the fact that different societal actors might have different preferences as to which electricity future is desirable and what trade-offs are acceptable. Considering Morocco’s development needs, setting the national energy future on a path towards sustainable development, therefore, needs to be viewed not only as a cost minimization and system optimization problem, but also as a multiple criteria decision-making problem that accounts for advantages and drawbacks of different technology choices as well as societal preferences.

By assessing the performance of the most prominent utility-scale electricity generation technologies against sustainability objectives on the one hand, and against people’s preferences in electricity planning on other hand, the results of this transdisciplinary study provide scientifically sound and stakeholder-based guidance on how to expand Morocco’s future electricity generation capacities in sustainable and socially robust ways. The assessment was done by ranking the performance of four RE and four conventional electricity generation technologies across 11/20 sustainability criteria/indicators within a MCDA based on the software DecideIT 2.82 using objective performance characteristics derived from a desktop analysis (Schinke et al., 2017) and subjective stakeholder preferences developed during a series of seven workshops.

Even though the study may not provide a definitive representation of Moroccan society and has excluded technical criteria²⁸, the finding that all RE technologies

²⁸ As seen in the sensitivity analysis, the results are not rigid because small variations in its parameters cause only slight changes in the ranking of alternatives. Yet, major trends or additional (technical) criteria may alter the reality of input values in the future (e.g., the introduction of a carbon tax), making it necessary to modify the assessment.

proved to be significantly superior in their compatibility with sustainable development and better reflect the preferences of Moroccan stakeholders than their conventional alternatives leads to the following three conclusions.

Conclusion I: *National criteria should have priority in electricity planning, but meaningful community engagement is key at the local level*

The results indicate that Moroccan stakeholders generally place high priorities on nationally relevant criteria, whereas locally relevant aspects are mostly found at the bottom of their criteria rankings—except with issues related to local water security. However, as indicated by the cluster analysis of the individual stakeholder group weightings as well as robustness of the “compromise solution”, potential conflict lines emerge along the priorities of “National NGOs” and “Local Communities”. These two stakeholder groups emphasized the significant relevance of the local dimension in national electricity planning and raised concerns about following a “grow first, clean up later” attitude. In spite of these diverging views, all stakeholder groups highlighted the utmost importance of meaningful stakeholder involvement in the planning and deployment of electricity generation technologies as well as the fairness in the distribution of benefits and burdens for achieving legitimacy of national energy policy-making in communities adjacent to power facilities. Furthermore, as neither RE nor conventional electricity generation technologies can be regarded free from ambivalent impacts, planning Morocco’s electricity future requires not only careful considerations of conflict lines but also increased efforts towards an inclusive multi-stakeholder dialogue to find trade-off solutions that are supported by all relevant stakeholder groups—especially in local communities that usually bear much of the socio-environmental externalities and see little of the benefits.

Conclusion II: *RE technologies are most promising for reaching societal support and contribute to sustainable development at the national and local level*

When stakeholder preferences derived as a “compromise solution” are combined with the performance characteristics of each technology, the final ranking obtained from the MCDA technology assessment shows that RE options not only outperform their fossil fuel and nuclear counterparts in their contribution to sustainable development, but are also characterized by a higher potential to be socially supported²⁹. With utility PV, CSP, and onshore wind taking the top three spots in the overall ranking, Morocco’s Solar Plan and Integrated Wind Program, which aim to install up to 4,560 MW and 4,200 MW of new capacities respectively by 2030, are well positioned

²⁹ Furthermore, the results of the sensitivity analysis show that even if uncertainties of the underlying attribute values and different preferences in the form of different weight distributions are taken into consideration, the overall result always stays the same.

to reach widespread support among Moroccan society and can truly be regarded a stimulus for the country’s move towards sustainable development. Furthermore, the expected increase of 1,330-MW hydro-electric capacities by 2030 appears to be favorable according to the fourth rank of this technology. The wide difference in the sustainability index, which measures the contribution of each technology to sustainable development between the RE and the conventional electricity generation technologies, therefore, lends support for even more ambitious RE targets beyond the 52 per cent installed RE capacities by 2030 (see Figure 20).

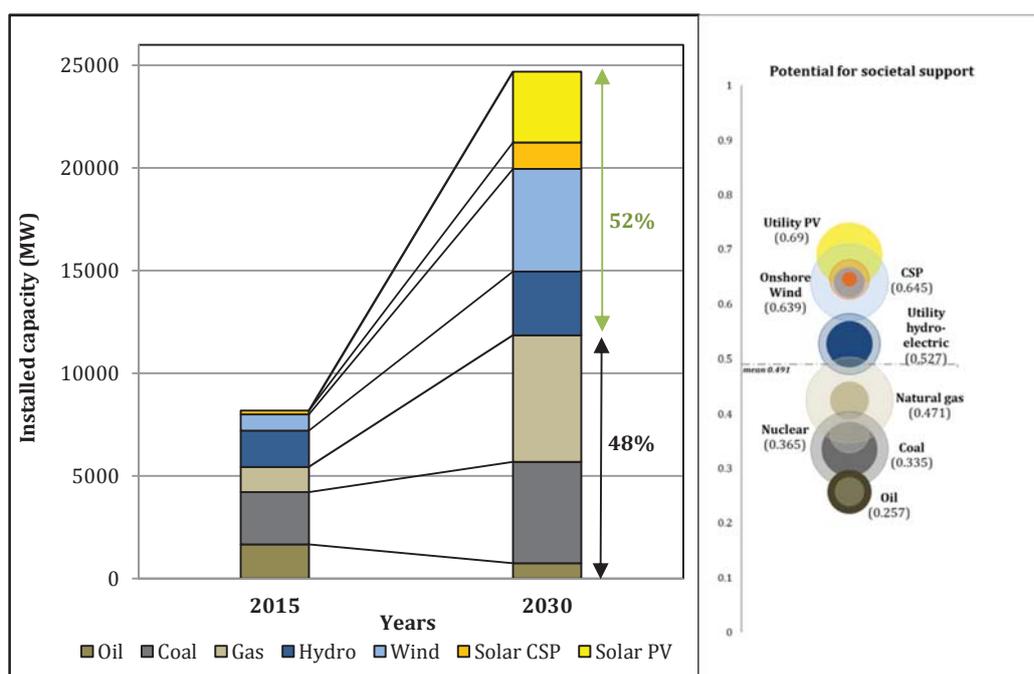


Figure 20: Total installed and assumed capacity in Morocco for 2015 and 2030 (based on Schinke et al., 2016) and technology ranking based on the weights of the “compromise solution.” The bubbles’ diameter is proportional to the installed (filled) and planned capacities in MW (shaded).

In line with Berg et al. (2016) and Garcia and Leidreiter (2016) who outlined the technical feasibility as well as framework conditions for an electricity system based on 100 per cent RE in Morocco, these results encourage accelerated investments in RE through policy incentives and private sector finance (e.g., green bonds) in order to achieve the national low-carbon development objectives as well as society support for future electricity technology choices.

Conclusion III: *Fossil fuel and nuclear technologies pose the risk of an unsustainable lock-in and could face opposition at the national and local level*

In contrast to the favorable sustainability positions of all RE technologies in the MCDA assessment, natural gas, nuclear, coal, and oil-fired power plants form the bottom of the ranking. Notwithstanding that the country's efforts to diversify away from unsustainable oil-fired electricity generation are commendable according to the study's findings, the paradox spending of Morocco—the internationally praised climate and renewable energy poster child—on new coal (e.g., in Safi and Nador) and nuclear power plants (in Sidi Boulbra) for providing baseload electricity generation should be reconsidered in the kingdom's NES and post-2030 energy plans. This is because both their sustainability drawbacks and low compliances with societal preferences not only pose significant risks of locking-in the power sector in less sustainable (or unsustainable) technology pathways, but could also result in intense opposition at the national and local level. This conclusion is well in line with international experts who argue for more flexible and quickly dispatchable options as alternatives to inert baseload power generation³⁰ in order to complement higher shares of RE in national electricity systems and avoid excessive capacity of coal and nuclear power plants to become costly stranded assets (IRENA, 2015). Although the relatively high ranking of natural gas does give some credence to the kingdom's National Liquefied Natural Gas Plan as a “bridging” strategy for transitioning into an electricity future based on high levels of intermittent RE penetration, its significant deployment should be reconsidered carefully and assessed against feasible alternatives (e.g., based on the availability of sites with sufficient geographic conditions). In this regard and despite geographical limitations to expanding their capacities significantly, CSP and utility hydro-electric plants with storage provide more socially accepted alternatives in Morocco: dispatchable resources that could quickly be ramped up to accommodate fluctuations from intermittent power and ensure system stability, as well as greater contributions to sustainable development.

³⁰ In addition to grid expansion, this includes increasing storage capacities as well demand-side management and enhanced coordination or forecasting of power plants.

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