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Concentrated Solar Power Plant – Noor-I, Draa-Valley, Morocco

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3.3 Concentrated Solar Power Plant – Noor-I, Draa-Valley, Morocco

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3.3.1 General overview of the case study

Especially in the arid areas of the Middle East and North Africa (MENA), water availability plays an important role in the expansion planning of industrial-scale solar power plants. Although power plants may account for only a very small portion of local water demand, competition for water with other sectors is expected to increase when water resources are insufficient for meeting local needs. This can lead to conflicts between different users (such as communities, farmers, tourism, businesses and utilities). Despite the increasing attention on the water–energy nexus, comprehensive studies analysing the interdependencies and potential conflicts between energy and water at the local level are absent.

To examine the linkages between water resources and energy technologies at the local level, this case study was selected because Morocco is one of the countries most affected by water scarcity and, at the same time, it is also one of the most promising countries in North Africa for the development of renewable energies and offers excellent conditions for solar and wind power plants. Nevertheless, the country's electricity system is still largely based on conventional energy sources, and the country is more than 95% dependent on energy imports. To strengthen the country's energy security and reduce the financial burden associated with energy imports, Morocco is pursuing an ambitious renewable energy expansion strategy: by 2020, around 42% of the national electricity demand should be met by renewable energies. In view of Morocco's ambitious plans, it is particularly important to identify the potential conflicts and synergies resulting from the expansion of renewable energies in relation to the water sector.

One of the most ambitious renewable energy projects is the solar complex NOOR$_o$ (Light), in Ouarzazate in the Drâa-Tafilalet region in southern Morocco (Figure 3-26). The arid environment and the high solar radiation provide ideal conditions for the solar complexes with a total capacity of around 580 MWp. The complex, which was completed in 2019, consists of four power plants, three concentrated solar power (CSP) blocks, of which two are parabolic trough systems (NOOR$_o$ I and II) and one is a solar tower (NOOR$_o$ III), and a solar photovoltaic plant (NOOR$_o$ IV). Particularly, CSP technologies can require significant amounts of water, depending on the cooling technology applied. While NOOR$_o$ II and III were already built with dry cooling technologies, which need only minimal water, NOOR$_o$ I, utilises a wet cooling system with significant water requirements. In addition, water is required for cleaning the parabolic mirrors and solar PV panels. In Ouarzazate, this water demand is covered by the only available water reservoir in the province, the El Mansour Eddahbi Reservoir. This water reservoir is also the source of water for the population and local agriculture, which is the main source of income in the province of Ouarzazate. Rather than being discharged continuously, water from the reservoir is supplied in larger quantities, known as 'lâchers', about seven times a year, with varying quantities of water also being supplied to the southern downstream oases (Heidecke 2009). However, currently, the water demand of the solar power plant is only marginal, with a share of about 0.8% of the reservoir water compared to the 96% of the water used for agriculture, 2.2% for the residential sector in Ouarzazate and 0.9% for the tourism sector (own calculations based on Heidecke, 2009; Busche, 2012; Wuppertal Institute and Germanwatch, 2015; Karmaoui et al., 2016). However, analyses have shown that the effects of climate change will likely negatively impact the water supply in the future (Diekkrüger, 2010, 2012). Presently, Ouarzazate is one of the driest regions in Morocco, with water availability of approximately 360 m^3 per capita per year, which is far below the internationally specified critical limit of 1,000 m^3 per capita per year.

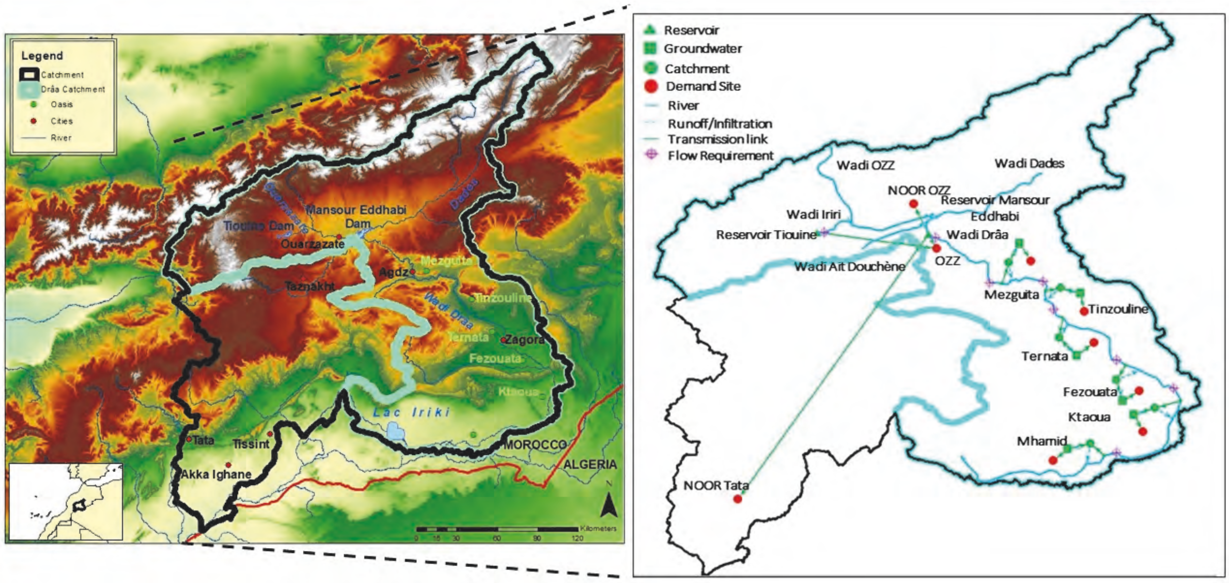

Figure 3-26: Overview of the catchment area of the Middle Drâa Valley (Ersoy et al., 2020)

Although preliminary analyses of water supply and demand exist, a systematic approach is non-existent. While existing climate models provide information on the future availability of water in the region and numerous technical developments to reduce the water demand of CSP power plants are already being researched, hardly any systematic analyses are available so far regarding the future socio-economic developments of the region and the resulting water consumption. Furthermore, the indirect impacts of the energy system on water resources have not been studied. Addressing these research gaps, the case study investigated how water availability and, as a consequence of socio-economic developments, water demand in the region will develop in the future against the background of climate change, what indirect impacts on water resources stem from the energy system and how strategies could be designed to address negative developments.

To involve local stakeholders, three workshops were conducted in the case study region in April and December 2018 as well as in October 2019. For all three workshops, representatives of local farmers, civil society groups and local and regional administration were invited. The objective of the first workshop was to develop socio-economic water demand scenarios for the Middle Drâa Valley together with the local stakeholders. The second workshop aimed to discuss water conservation measures to avoid critical water demand developments and evaluate the measures against selected criteria. The third workshop discussed governance strategies for implementing the selected water-saving measures. Figure 3-27 gives an overview of the applied methods and the stakeholders' participation in the different steps.

Figure 3-27: Overview of the research approach and stakeholder participation

3.3.2 Local water demand scenarios

To identify the key factors that influence future water demand and supply in the Middle Drâa Valley, the complex interlinkages between the surface and groundwater systems and the energy, agricultural, economic and residential sectors were mapped (Figure 3-28).

Given the complex interrelationships between the agricultural sector and water supply and demand shown in the system map, the agricultural sector is one of the key links influencing future water demand. Further aspects that are not explicitly shown in the system map but can influence the different elements of the system and thus the future water supply and demand structures are changes in the political framework conditions and potential infrastructure developments such as the construction of access roads or further dams.

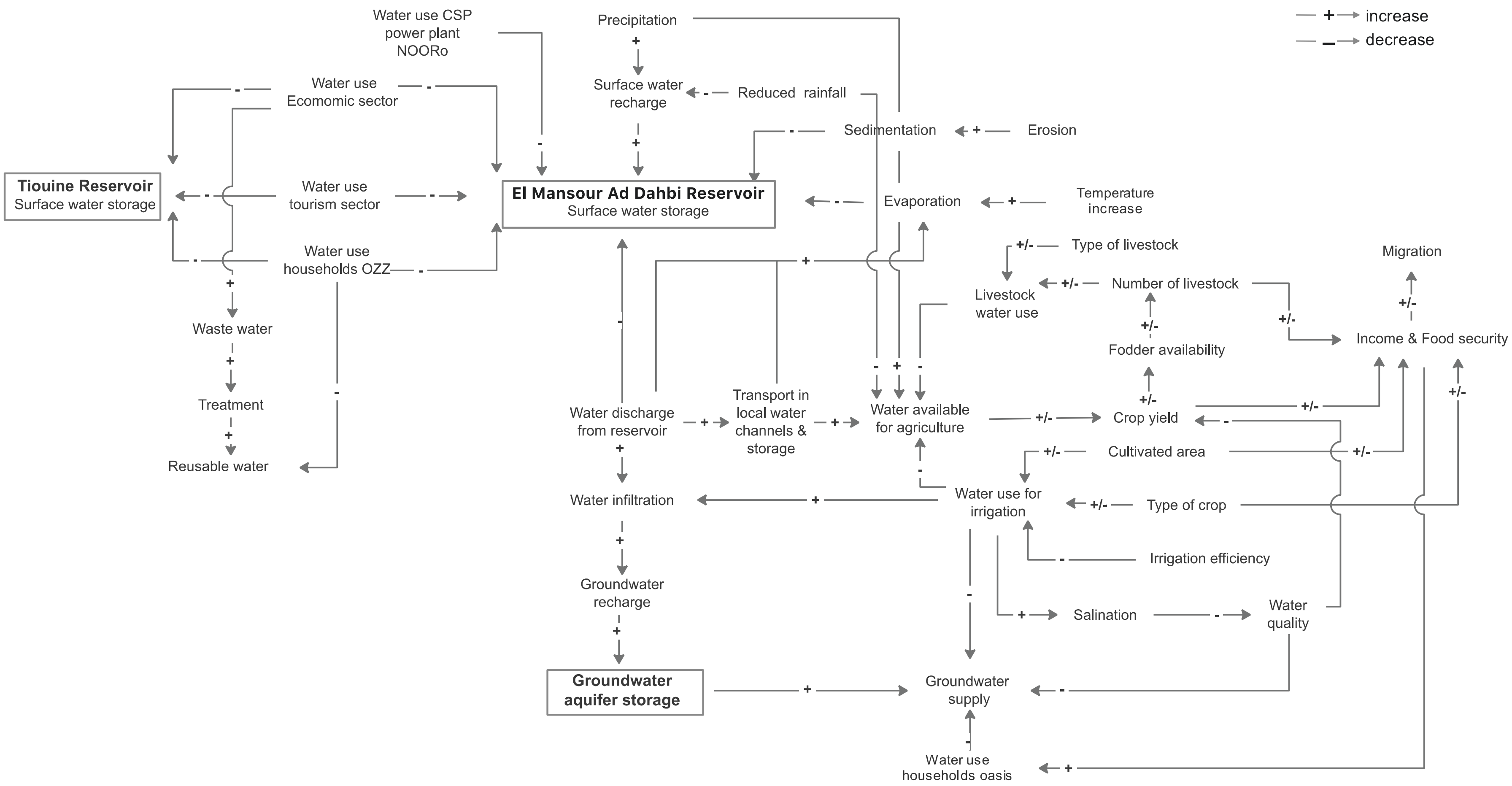

Figure 3-28: System map of water supply and demand of the Middle Drâa Valley (Terrapon-Pfaff et al., 2021)

The most critical factors influencing future water demand, derived from the system map and prioritised with the local stakeholders, include the cultivated area, choice of crop types, irrigation with groundwater, water quality, population development and tourism sector development. By linking the potential development trajectories of these factors, three scenario narratives were drafted during the first workshop by local stakeholders: one business-as-usual scenario (S1: BAU) and two more extreme but possible scenarios describing, on the one hand, an economic development scenario that is associated with the overexploitation of water resources (S2: Economic growth first) and, on the other hand, development in the direction of sustainability (S3: Growing sustainability). The drafted scenario storylines were further developed into three consistent narratives underpinned by quantitative details and data points for quantifying the future water demand and water supply implications. The water demand of these socio-economic scenarios in combination with the water demand of the solar power plant NOOR$_o$ was modelled using the WEAP software (Figure 3-29).

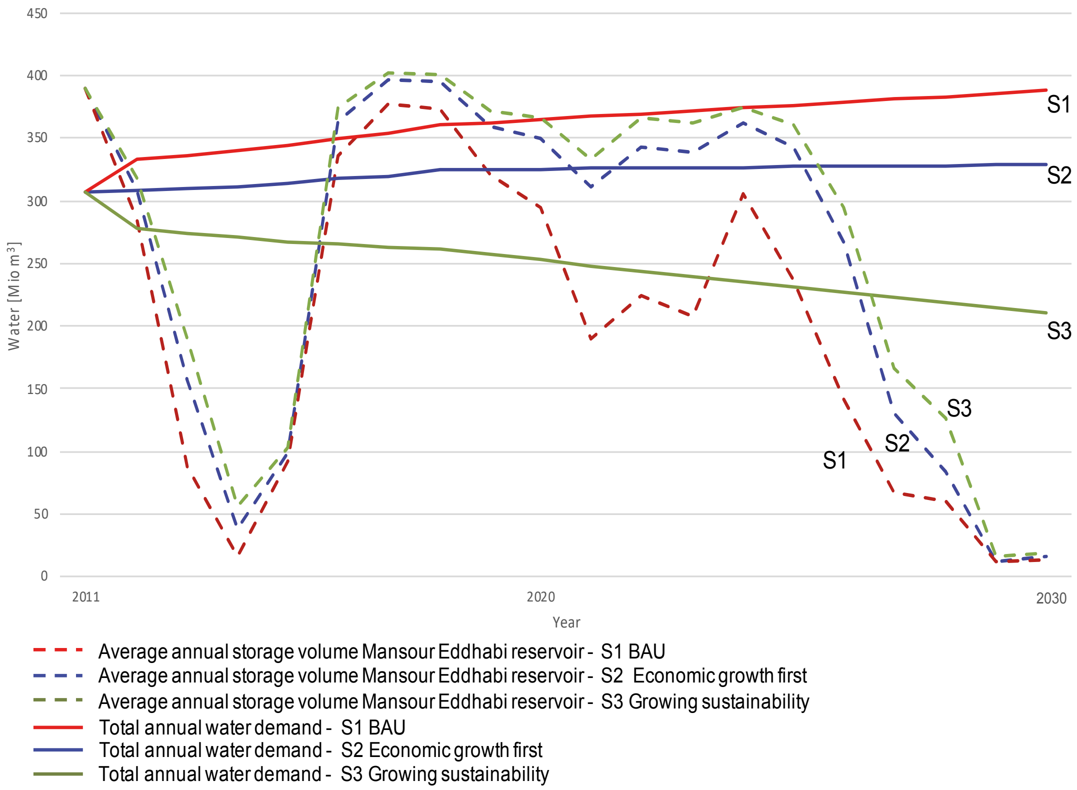

Figure 3-29: Modelling of water demand scenarios for the Middle Drâa Valley (Terrapon-Pfaff et al., 2021)

In terms of water supply, the simulation shows a general negative trend due to changes in precipitation patterns, discharge reduction, and sedimentation levels in the Mansour Eddahbi reservoir. In terms of water demand, Figure 3-29 shows a steady increase up to 2030 for the scenarios S1 'BAU' and S2 'Economic growth first'. In contrast, S3, 'Growing sustainability', indicates a decrease in water demand. In considering the water demand in the scenarios in relation to the development of water availability, it is clear that the water demand is not being met in drought years. However, in the case of S3, water demand can be met in most of the modelled years. The results show that even a transition towards sustainability, as illustrated in S3, cannot prevent water shortages in drought years, but it still offers the possibility of meeting the socio-economic water needs and NOORo power plant demand in most years. Although these scenarios and their quantification are based on several assumptions and are, therefore, subject to a range of uncertainties, the overall direction of the water demand developments is clear. Despite the apparent long-term inevitability of water scarcity in the region, measures should be taken to counteract the critical scenario developments, at least partially.

The developed scenarios illustrate that the development of water supply and demand turns out to be the more critical component in the analysed water–energy nexus context. Water becomes the limiting factor for the other sectors. In contrast, presently, water use by the $NOOR_o$ solar power plant is not critical. However, it is shown that the power plant itself may be affected by water scarcity in the future.

3.3.3 Direct impacts of the energy system on water resources

The total WSF_{quan} of the CSP in Morocco is 0.22 m^3 kWh^{-1}, with most of it associated with the operation phase (Table 3). The contributions from the operation phase are 100% direct and are associated with water requirements for cooling purposes and solar panel cleaning (details of the calculation see Appendix A). This also appears as an on-site hotspot of the WSF of the CSP (black circle around the case study location in Figure 3-30). The total WSF_{qual} is approximately 1.3 m^3 kWh^{-1} higher, with most of it being attributable to the construction phase (Table 3-3). The contributions are 100% remote and will be described further in the next section.

3.3.4 Indirect impacts of the energy system on water resources

Apart from the WSF_{quan} of the operation phase, all other contributions to the WSF come from the upstream supply chain (Table 3-3) and are therefore associated with indirect impacts. The WSF_{quan} of the construction phase is predominantly related to upstream processes that provide energy carriers, mainly hard coal and lignite, and electricity, mainly from hard coal. This indicates a large dependence of the CSP supply chain on fossil energy. At the same time, water consumption is high here. Additionally, ammonia production is represented here. As the chemical industry's demand for ammonia is generally high, ammonia production is therefore often represented in upstream supply chains. Therefore, this is not a special feature of the case study.

As for the other case studies, the WSF_{quan} of the construction phase is small compared to the operation phase. However, although the WSF_{qual} of the construction phase is high, it can be neglected for the operation phase. Treatment of hard coal ash in Switzerland and Spain, natural gas production in the US and treatment of lignite ash in Greece and Germany are responsible for 53% of the contribution to WSF_{qual}. Keeping in mind those processes without a specific location (the so-called 'global' or 'rest-of-world' ones that have been excluded from the hotspot analyses), the share from such processes that have a connection to coal combustion and natural gas production would increase to 81%. This also confirms the supply chain's dependence on fossil energy and highlights the associated high-water consumption. To improve the hotspot analysis, a better regionalisation of this upstream chain is desirable. Such high impacts associated with processes from the upstream supply that are only indirectly linked to the case studies and can hardly be touched can only be decreased by reducing the demand for resources in construction and operation and using raw materials from recycling or reuse.

Table 3-3: Cumulative LCIA indicator results for case study 3 – concentrated solar power in Morocco. For further explanations, see the caption of Table 3-1.

	Construction			Operation			Total
	total	direct [%]	indirect [%]	total	direct [%]	indirect [%]	
WSF_{quan}	4.52E-03	0	100	2.16E-01	100	0	2.20E-01
WSF_{qual}	1.25E+00	0	100	4.31E-02	0	100	1.30E+00
CED_{fo}	2.48E-01	0	100	1.35E-01	0	100	3.83E-01
CED_{re}	1.27E-02	0	100	4.00E+00	100	0	4.01E+00
EDP	1.10E-02	0	100	1.02E-04	0	100	1.11E-02
GWP100	9.98E-02	0	100	2.90E-02	0	100	1.29E-01
RMI	1.41E-01	0	100	1.24E-02	0	100	1.53E-01
TMR	1.82E-01	0	100	1.34E-02	0	100	1.95E-01
ECO	2.39E-03	0	100	5.22E-04	0	100	2.92E-03
HuHe	4.53E-03	0	100	9.31E-04	0	100	5.46E-03

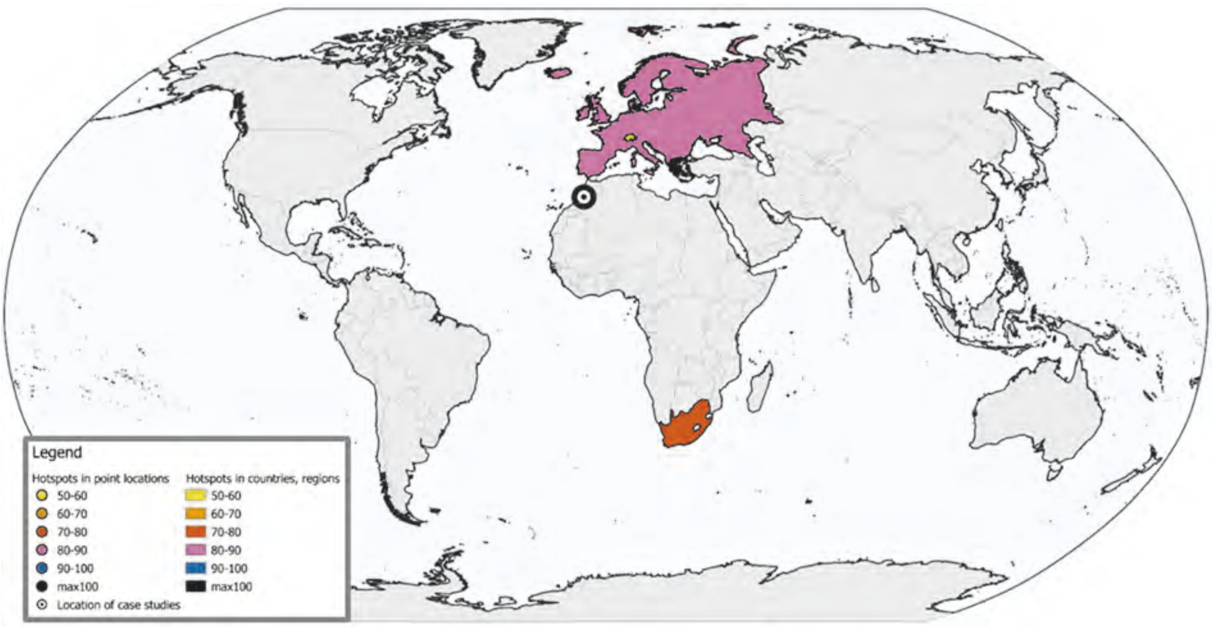

Figure 3-30: Hotspot analysis of the indicators WSF_{quan} and WSF_{qual} for case study 3 – concentrated solar power in Morocco. Further explanations, see the caption of Figure 3-2.

The WSF hotspot analysis identifies the direct water use as hotspot for the WSF_{quan} (Figure 3-30, black circle around case study location) and Switzerland, Greece, Europe and South

Africa as hotspots of the WSF_{qual} (Figure 3-30). The latter is associated with the mining of platinum group metals that are needed in the supply chain of the construction phase, while the others are related to the treatment processes described above.

3.3.5 Direct and indirect impacts of the energy system on the environment

In 2012, a Specific Environmental and Social Impact Assessment (SESIA) was implemented by 5 Capitals Environmental & Management Consulting (5 Capitals, 2012a) before the construction of Noor I. This assessment was based on various technical and scientific investigations offering information on different aspects that need to be dealt with in the ESA for this case study. Decisive information has either been considered in the LCIA indicators or is complemented as follows.

In the non-technical summary (5 Capitals 2012b) 5 Capitals pointed out that the biodiversity of the occupied land was low and 'would not be significantly impacted by the development of the proposed project.' Furthermore, no endangered species were encountered.

Regarding the impact on the landscape, the only anthropogenic elements on-site were 'a small camp for road construction and the tarmac road that is being built to connect the village of Tasselmant with the N10 and for site access'. Near the road, there were two widely visible telecommunication antennas with a negative impact on the natural character of the landscape. In contrast, the site of Noor I is visible only from a short distance of approximately 5 km along the N10 road and cannot be seen from any village or town due to the landscape's topography. As these populated areas are the most sensitive areas and the natural character along the road is already disturbed by the mentioned telecommunication antennas, the overall impact of Noor I on the landscape is neutral and negligible.

Looking at the ESA indicators, only CED_{re} reveals direct contributions. This corresponds to the result for the hydropower plants on the Danube (Section 3.2.5). Here, too, the energy input is described, but this time by the sun and not by an environmental impact. For the construction phase, the cumulative results of CED_{fo}, CED_{re}, EDP, GWP100, RMI and TMR are higher than for the coal power plant, while the results of GWP100, RMI and TMR are comparable to those of the hydropower plants. The contributions to CED_{fo} are mainly from fossile energy production around the world and to CED_{re} from forestry and hydropower globally. EDP is also associated with forestry and GWP100 with material supply from mining and the chemical industry. Especially in the latter case, however, the upstream chain is hardly regionalised, which weakens the informative value of the hotspot analysis. The contributions to RMI and TMR are predominantly from gravel and sand, hard coal and iron ore mining as well as potassium chloride production. The supply chains of hard coal and iron ore have been regionalized in the course of this project and the impacts can be assigned to the countries Australia, Brazil and China. For the other raw materials, no specific location can be identified. Regionalization of supply chains assigned to raw materials is an ongoing task of the LCA community. The indicator results for ECO and HuHe are smaller and the contributions from the construction phase are related to a variety of processes belonging to the chemical industry, material supply and fossil energy production in general. Except for CED_{fo}, the indicator results of the operation phase are throughout smaller. CED_{fo}, GWP100, RMI and TMR are to a large extent associated with natural gas production and similar processes in Russia and China, but mostly without knowing the specific location. These processes are also the largest contributors to the indicators ECO and HuHe in the operation phase, although their overall results are rather small.

The ESA hotspot analysis shows a multitude of midpoint hotspots (Figure 3-31a), also in comparison with the other case studies. Hotspots from natural gas production in the USA and Russia, forestry in Germany, solar energy from South Africa, petroleum production in the Middle East and hard coal mining in Chinese mines are linked to the construction phase of the CSP. The operation phase also holds shares on the hotspots from natural gas production in the USA and Russia and is responsible for the on-site hotspot in Morocco due to solar energy demand. This is not a hotspot of environmental impacts as pointed out at the beginning of this section. The on-site hotspots in Figure 3-31a (black circle around case study location) also comprises shares from the indicator EDP because the CSP occupies large areas of land. This is also the reason behind the on-site hotspot in Figure 3-31b from the indicator ECO, as both indicators assess land occupation (details see Section 2.2). However, both indicators can only assess the amount of occupied land here and do not include quality aspects. As the occupied land type is desert the environmental impact can still be estimated as low here.

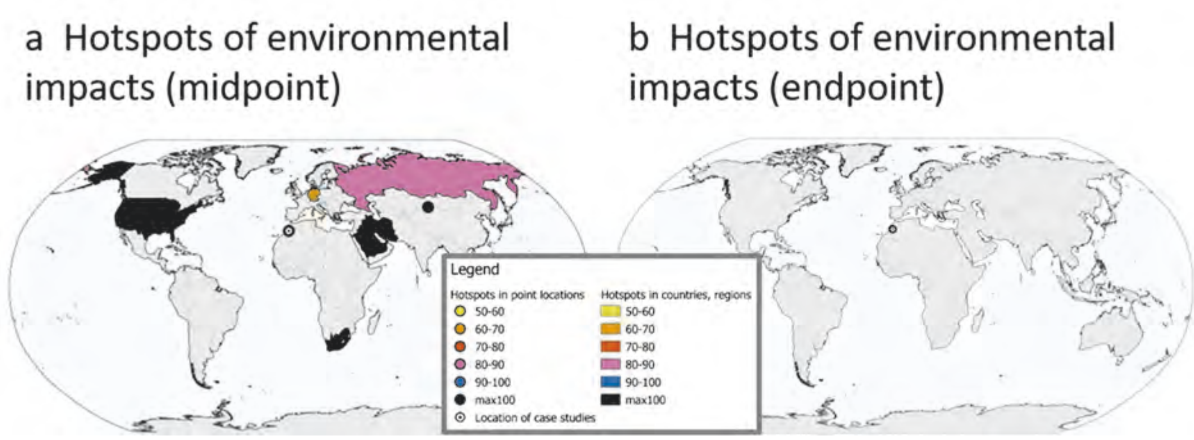

Figure 3-31: Hotspot analysis of the ESA indicators for case study 3, concentrated solar power in Morocco. Midpoint environmental impacts (CED, EDP, GWP100, RMI, TMR and WSF) and endpoint environmental impacts (ECO and HuHe) are shown separately (a and b). Further explanations, see the caption of Figure 3-2.

3.3.6 Design of instruments to address impacts

To illustrate how the most critical developments in the scenarios could be mitigated, water-saving measures, both in the energy sector and others, were evaluated against a set of sustainability criteria integrating the preferences of local stakeholders. Based on the results, governance strategies for implementing these water-saving measures were subsequently identified.

The objectives of the implementation of water-saving measures are primarily combating water scarcity and water stress and protecting surface and groundwater bodies to increase water security and enable sustainable agriculture and rural development. To achieve these objectives, as many water-saving measures as possible must be taken to at least partly mitigate the expected negative developments described by the scenarios. However, implementing these measures requires different stakeholders to become active either by, for example, changing their habits, making investments, designing regulations or building capacities. Not all water-saving measures are equally effective and feasible, and stakeholders might differ in their preferences for certain measures. Accordingly, strategic decisions on water conservation measures require – alongside the consideration of a range of technical, environmental, social, and economic issues – considering the stakeholder interests and perspectives. To this end, a participatory multi-criteria analysis approach (MCA) was applied. The approach is based on the quantitative principles of multi-criteria decision analysis in combination with participatory elements, which are integrated into the overall structure of the MCA process. To this end, the different water-saving measures (Table 3-4) were evaluated against the set of criteria (Table 3-5) by applying different weighting sets representing the attitudes of different stakeholder groups (Table 3-6).

Table 3-4: Water-saving measures (Terrapon-Pfaff et al., 2021)

Category	Measure		Short description
Water conservation measures	M1	Crop choice	Simulates a change in cropping patterns towards less water-intensive crops (e.g. arboriculture).
	M2	Irrigation practice	Describes the change in irrigation patterns from day-time to night-time irrigation, which can reduce the evaporation water loss
Water efficiency measures	M3	Irrigation efficiency	Assumes an improvement in the irrigation efficiency by applying drip irrigation
	M4	Conveyance efficiency	Covers improvements in conveyance efficiency from current open channel networks (60% efficiency) to lined channels (80% efficiency) or pipes (95% efficiency)
	M5	Precision agriculture	Covers the implementation of precision agriculture on a large scale, thereby increasing the water efficiency in the agricultural sector from the current relatively low levels
	M6	Desalination	Aims at the installation of desalination units, as the high salinity of water in the Drâa Valley is impeding agricultural production. Desalinated water can be used for irrigation to improve water productivity or drinking water quality
	M7	Wastewater treatment	Describes the reuse of treated wastewater as an alternative source of irrigation and drinking water
	M8	Rainwater harvest	Covers the harvest of rainwater for irrigation purposes and as a domestic water source
	M9	Water savings in urban households	Assumes water savings in the growing urban population, by installing water-saving appliances
	M10	Water savings in the tourism sector	Aims to reduce per capita water use by the tourism sector
Water policies	M11	Aligning national water & agriculture strategies	Aims to eliminate inconsistencies or contradictions between the 'Plan Maroc Vert' and the national water policies.
	M12	Regulatory interventions	Designates regulatory changes for either legally limiting the cultivation of water-intensive crops or providing subsidies for the cultivation of less water-intensive crops
	M13	Information campaign	This measure aims to increase the information and knowledge on water-saving technologies to allow users to make informed decisions regarding investments in technologies
	M14	Conservation-oriented water prices	This measure aims at introducing water prices to lower agricultural water use
Technical measures solar power plant	T1	Conversion NOOR 1 to Wet/Dry Hybrid	Simulates the introduction of a novel hybrid dry/wet cooling technology, which could save up to 80% of water compared to wet-only cooling, without compromising performance
	T2	Reducing cleaning water consumption NOORo I-IV	Covers the optimised cleaning schedules and implementation of devices that cut water consumption for cleaning
	T3	Maximal reduction of water consumption cooling and cleaning	Describes the maximum reduction of water consumption in the solar power plant through the application of the latest technological innovations in both cooling and cleaning as well as an additional reduction through internal reuse of water

Table 3-5: Criteria set (Terrapon-Pfaff et al., 2021)

Category		Criterion	Short description
Environment	C1	Water savings	Estimates the amount of water that could potentially be saved (including conservation and efficiency measures) by the chosen alternative if it were implemented on a large scale. The higher the potential, the more preferable the option
	C2	Water quality	Refers to the estimated impact on water quality by the chosen alternative, i.e. the ability of the option to improve water quality. The higher the potential, the more preferable is the option
	C3	Sustainability of water use	Takes the different sustainability degrees of each alternative into account. In particular, the alternatives that do not involve groundwater overexploitation but favour the use of renewable water resources are preferred
Technology	C4	Technical and operational suitability	Relates to the suitability of the technology or political instrument for implementation in the Middle Drâa Valley. The higher the suitability (feasibility and viability), the more preferable the option is
Economic	C5	Investment cost	Corresponds to the estimated initial investment for implementing an alternative. The lower the cost, the more preferable the option
	C6	Operation & maintenance costs	Captures the ongoing expenses that a measure entails, for example, for maintenance. The lower the cost, the more preferable the option
	C7	Economic benefit	Measures the ongoing beneficial effects of the measure, for example, through profits from the export of cash crops or money saved through less water consumption
Social	C8	Social acceptance	Estimates the level of social acceptance and willingness to support the chosen alternative and compatibility with traditional practices

Table 3-6: Preference weights (Terrapon-Pfaff et al., 2021)

Criteria		Average	Farmers group	Civil society group	Local administration
C1	Water savings	0.16	0.08	0.11	0.34
C2	Water quality	0.19	0.11	0.15	0.08
C3	Sustainability of water use	0.12	0.15	0.21	0.03
C4	Technical and operational suitability	0.11	0.05	0.05	0.21
C5	Investment cost	0.09	0.34	0.08	0.15
C6	Operation and maintenance costs	0.10	0.03	0.03	0.11
C7	Economic benefit	0.12	0.02	0.02	0.05
C8	Social acceptance	0.12	0.21	0.34	0.02

The results of the MCA calculations for this average weighting of preferences across stakeholders (Figure 3-32) show that the most recommendable alternatives are water conservation measure M1, which proposes a change in cropping patterns towards less water-intensive crops (e.g. arboriculture), and the efficiency measure M3, which aims at water savings by improving irrigation efficiency. Taking a closer look at the criteria scores, it can be seen that both alternatives perform particularly well in the environmental criteria categories, including contribution to water savings, water quality and the sustainability of water use. However, both alternatives do not come off well in terms of the investment costs. In this regard, the alternatives ranked third and fourth, M4 (proposing a change in irrigation patterns from day-time to night-time irrigation) and M2 (focusing on improving the conveyance efficiency by changing from currently dominating open earth channels networks to lined channels or pipes), perform better. All these measures are directed at the agricultural sector, which is not surprising, as this sector uses the majority share of the available water resources. In comparison, the technical alternatives for saving water in the solar power plant NOOR$_o$ (T1 – T3) are the least recommendable, as compared to the other alternatives, these measures do not contribute much to water savings and water quality in total and have high investment costs. Likewise, the alternatives M8 (harvesting rainwater for irrigation or domestic purposes) and M9 (water savings in urban households) received lower scores, mainly because these alternatives performed much lower in terms of water savings and water quality improvements than the other alternatives.

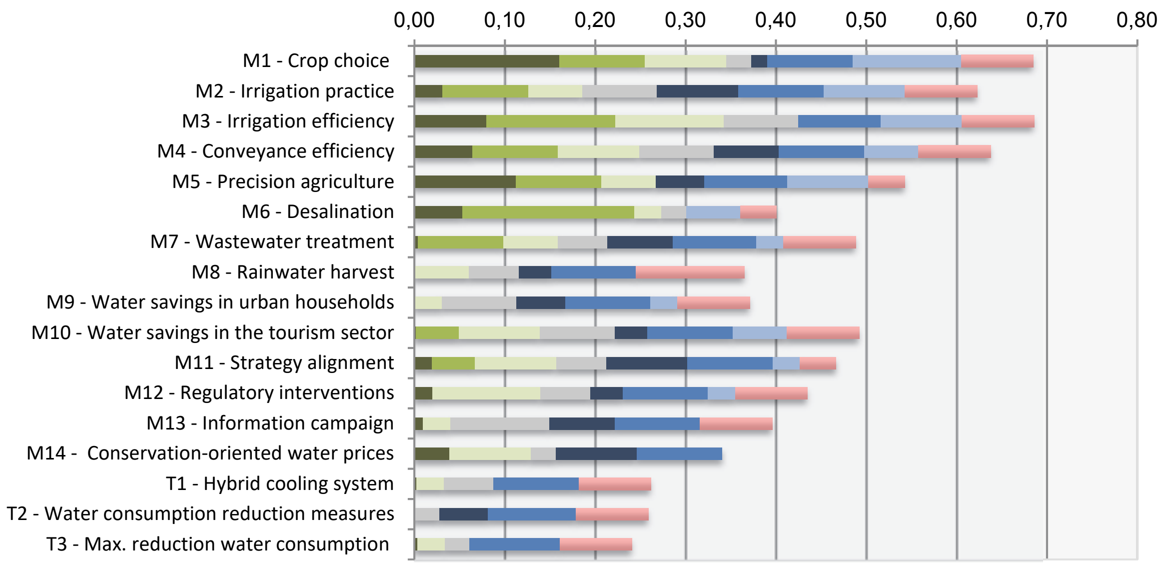

Figure 3-32: Ranking of water-saving measures (Terrapon-Pfaff et al., 2021)

In terms of the implementation of the alternatives ranked highest across preference weightings, it is to be noted that the water-saving measure that would save the highest amount of water, M1 (changing crop choices), would necessitate major changes in the agricultural practices and require a longer implementation. Measures that could be implemented more quickly but also require significant funds are improvement in irrigation efficiency (M3) and conveyance efficiency (M4). Furthermore, measures that would require changes in traditional workflows might not be easily adapted by the local communities. And although numerous barriers still exist for the preferred measures for their wide-scale implementation, it needs to be noted that the realisation of these measures can only be the starting point. To increase resilience towards the expected negative developments described by the scenarios, even the water-saving measures that were ranked lowly will need to be considered – but their implementation might be more challenging.

Table 3-7: Governance strategies discussed in the water-energy nexus context

	Strategy	Brief Description	Applied Use Case	Source/Reporting
S1	Best Practice Guides	Best practice guides summarize the possible and optimal range of activities under a given legal set.	South Africa	South African Sugarcane Institute (2019)
S2	Benchmarking	Benchmarking entails a comparative analysis of the performance based on pre-defined indicators	South Africa	South African Sugarcane Institute (2019)
S3	Intermunicipal Contracting	A flexible intermunicipal contract is a written voluntary-based co-operation agreement	Upper Franconia; Germany	Region Bayreuth (2019)
S4	Intermunicipal Cooperation	The formation of a body for intermunicipal cooperation is generally a response to capacity / resources bottlenecks.	Valle del Nalon, Spain	O'Keeffe (2011)
S5	Interdepartmental Offices	An office or council under the auspices of one ministry or department, which brings together representatives from different ministries/departments	Jordan	Breulmann (2018)
S6	Organization Culture Transformation	Interventions of organization culture change entail a management restructuring, explicit values, and new roles and practices.	Queensland, Australia	Förster (2005); Conner et al. (2016)
S7	Platform Creation with Explicit Inclusion of Traditional Methods/Leaders	A coordinating platform forms a multistakeholder board that addresses the implementation and discussion of regional issues like of e.g. a river basin plan or a lake protection plan, in this case with explicit implementation of traditional methods/leaders.	Minnesota, USA; Ontario, Canada	Coté (2016)
S8	Water Withdrawal Charges	System that charges withdrawal of water from a region's/country's water resources.	Federal States; Germany	Grawel (2012); Neumüller (2000)

Against the backdrop of these multi-layered challenges and governance strategies for implementing the measures, further research and discussions with the local stakeholders on governance strategies were conducted. This further research is in line with the call of Hoff et al. (2019) that nexus analysis should go beyond mere identification of technical solutions and provide accompanying institutional and policy-relevant recommendations.

During the third workshop in Morocco seven governance strategies (Table 3-7) were discussed and elaborated together with the local stakeholders (not counting strategy 8 (S8), which was treated separately). The strategies were pre-selected based on already existing applications and their potentially pragmatic and participatory character. In doing so, the workshop followed Hagemann and Kirschke (2017)'s call to implement and adapt already known WEF challenge strategies, to fortify and deepen systemic interdisciplinary governance research. On the other hand, top-down(-like) policies and strategies, such as those of the Green Morocco Plan, were not introduced. However, participants were given several opportunities to freely mention, discuss and attribute strategies (and top-down plans) that appealed to them.

The multi-attribute analyses revealed a stakeholder preference for S2 – Benchmarking, S7 – Tradition, Including Platform Creation and S1 – Best Practice Guides with regard to the strategies' benefit for sectors and the application of the desired measure. Furthermore, the evaluation of governance strategies for the implementation of the selected water-saving measures showed that targeted education and information of citizens should be the first step towards the introduction of water-saving measures. Furthermore, efficient assistance in the implementation of technical solutions on site was defined as a prerequisite. Likewise, it was suggested that measures from other regions of the world be combined with traditional working methods to discover new ways to counteract water scarcity.

The results of the case study can be used to support decision-making regarding energy and water development in the region.

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