KfW Development Bank

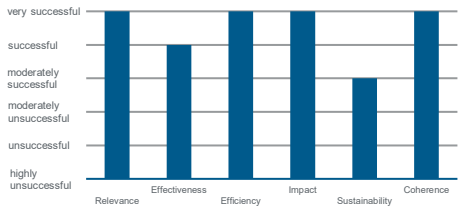
Ex post evaluation
NOOR I in Ouarzazate, Morocco

Title	Renewable Energies Fund – Ouarzazate solar power plant		
Sector and CRS code	Energy, CRS 23		
Project number	2009 66 838 and 2010 66 414		
Commissioned by	Federal Ministry for Economic Cooperation and Development (BMZ)		
Recipient/Project-executing agency	MASEN (Moroccan Agency for Sustainable Energy)		
Project volume/ Financing instrument	*EUR 100 million / FC loan*		
Project duration	*11/2011 (PV) – 11/2018 (FCOD NOORo I)*		
Year of report	2022	**Year of random sample**	2020

Objectives and project outline

The objective of the project at outcome level was to introduce efficient, environmentally and socially compatible generation of electrical energy and to introduce a technology of the future for climate change mitigation. For this purpose, NOOR I in Ouarzazate (NOORo I) used Concentrated Solar Power (CSP) technology. At impact level, the aim was to contribute to global climate change mitigation and economic growth in Morocco with the additional clean energy generated.

Overall rating:
successful



Key findings

The project was very relevant and very well integrated into the Moroccan solar plan. All donors worked very well together and implemented the project effectively and efficiently. NOORo I had a signalling effect for future projects inside and outside Morocco that use the same technology. However, sustainability is limited.

- The cooperation between the financial donors worked exceptionally well within a steering committee, and private capital was also integrated within the framework of a Public Private Partnership (PPP) model.
- All indicators were achieved and NOORo I produces more energy than planned. In addition, there was a positive signalling effect for follow-up projects in Morocco, such as NOOR Midelt.
- The developmental impacts occur at local, national and global level. For example, the construction of CSP plants in Dubai, South Africa or Chile is directly associated with the measure in Ouarzazate.
- The sustainability is the only aspect that is limited. Water loss in the El Mansour Eddahbi reservoir, where the water used to cool NOORo I is collected, has increased massively in recent years. The reasons for this are still unclear and beyond NOORo I's control, but the development of an emergency concept is important to ensure sustainable operation.

Conclusions

- An important success factor for the project was the integration of private capital via a PPP structure. This created a risk-adjusted investment climate for other private investors – despite the high technological risk associated with the project.
- The Moroccan state's ownership was essential for the implementation of the NOOR solar complex in Ouarzazate. Without this, a pilot project like this one would not have been possible using such new technology.

Rating according to DAC criteria

Overall rating: 2

General conditions and classification of the project

As a contribution to Morocco's ambitious solar plan, KfW provided the following financing contributions for the solar power plants in Ouarzazate:

Project	Technology	MW	ICOD	FCOD	EUR (million)	Type	Source	InPro No.
NOORo I	CSP (parabolic trough)	160	20 January 2016	30 November 2018	40	loan	BMZ (IKLU)	23164
					60	loan	BMZ (IKLU)	26291
					15	grant	BMU (IKI)	29669
NOORo II	CSP (parabolic trough)	200	24 April 2018	23 April 2021	330	loan	BMZ (IKLU)	27572
					33.44	grant	EU (NIF)	33293
NOORo III	CSP (tower)	150	20 October 2018	expected 2023	324	loan	BMU (DKTI)	27889
NOORo IV	PV	72	2 August 2018	1 August 2020	60	loan	BMZ (IKLU)	33475

The intention was to use these financial contributions to cover part of the investment costs of the individual power plants. In addition, residual funds of EUR 25 million (due to investment costs that were lower than anticipated) were reallocated to finance part of the common infrastructure of the Ouarzazate solar complex, in particular the water supply from the El Mansour Eddahbi reservoir to the solar complex, as well as the fencing, the electronic safety system and the erosion control measures on site. The power plants reached their first commercial operating date (ICOD) between January 2016 and October 2018. After successful trial runs and operational optimisation, NOORo I, II and IV reached their final commercial operation date (FCOD) between November 2018 and April 2021. NOORo III is expected to reach its FCOD by the end of 2023.

Although the assessment in this ex-post evaluation focuses on NOORo I, the other three power plants in the complex, namely NOORo II, III and IV, cannot be completely disregarded. They are therefore also mentioned in this report, when appropriate. MASEN, the state-owned development company for renewable energies, is responsible for the administration of all four power plants. In total, the NOOR solar complex has an installed capacity of around 580 MW, with output of NOORo I at 160 MW. The energy generated in the complex is fed into the national power grid. NOORo I has been in operation since January 2016 and, since November 2018, the company has been solely owned by a private project company in which MASEN holds shares.

Relevance

At the time of the project appraisal of the NOORo I solar power plant in 2011, Morocco's primary energy consumption was largely dependent on imports of fossil fuels. The country was considered the largest energy importer in the Middle East and North Africa. At the same time, Morocco has been in a phase of economic and population growth for several years. Overall, this resulted in an increase in energy demand

of approx. 7 per cent per year at the beginning of the 2000s. However, an increase in energy capacity with the energy mix at the time meant, on the one hand, greater political dependence on other countries, which also entailed higher costs for the government budget. On the other hand, increased demand for an energy mix dependent on fossil fuels would have exacerbated the problems of climate change even further.

Therefore, Morocco built on its considerable experience with renewable energy from the 1990s and 2000s with wind and hydropower projects and developed a national plan for solar energy in 2009. Various solar technologies were analysed for this purpose, including concentrated solar power (CSP) and photovoltaics (PV). One of the requirements of the Moroccan partners was to provide electricity even in periods without sunshine, in particular to help cover the evening peak loads. A storage option therefore also needed to be available. This storage in the form of batteries for PV systems of the required capacity and at a reasonable cost was not yet available at the time. For this reason, in particular, CSP with thermal storage was chosen (see also Efficiency criterion).

The intended impact chain of the project was as follows:

construction of NOORo I -> increase of sustainable energy production -> increased energy supply for households and companies -> economic growth with CO2 emission savings. At the same time, the expectation was that NOORo I would be seen as a pilot project for CSP technology. It was intended to contribute to further innovations in CSP technology at a macroeconomic level, to establish Morocco's own national solar industry and to lead to price degressions in CSP technology.

The results and planned activities of the project were largely in line with the national climate plans, energy sector strategies and policies, and the Sustainable Development Goals (SDGs). In 2009, Morocco adopted its national energy strategy, which aims to reduce the country's dependence on imports by 2020 through the expansion of renewable energies and improved energy efficiency. In concrete terms, this means that renewable energies (wind, solar and hydropower) should account for 42% of the total installed electricity generation capacity by 2020. The Moroccan solar plan (Plan Solaire Marocain, PSM), which implements the national energy strategy for solar energy, defined an expansion target of 2,000 MW for solar power plants by 2020 and 6,000 MW by 2030. The NOOR complex in Ouarzazate is an important building block. The strategy was embedded in the National Climate Change Plan. The project thus contributes directly to Moroccan national climate plans and energy sector strategies and makes a direct contribution to Sustainable Development Goals seven and nine.

The project idea met the needs of the target group. The project's target group was the entirety of all Moroccan electricity consumers connected to the general interconnected grid. Expressed in figures, the entire Ouarzazate complex, NOORo I to NOORo IV, could supply 400,000 households or 1.7 million people with the electricity generated. The intent was also for Moroccan companies and workers to participate intensively in the construction and operation of the power plant with the aim of building a Moroccan solar industry that is also internationally active with the experience gained from the project.

In summary, it can be said that the project, as a pilot project, was one of the basic building blocks for the implementation of the Moroccan solar plan, as the experience gained there can be used in corresponding follow-up projects. It addressed a relevant issue and made good use of Morocco's high solar radiation.

Relevance rating: 1

Coherence

Several actors in Germany's development cooperation (DC) were involved in the total financing of the NOOR complex in Ouarzazate. Both the Federal Ministry for Economic Cooperation and Development (BMZ) and the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) have financed parts of the complex. The promotion of the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) operated as part of the German Climate Technology Initiative (DKTI) and later the International Climate Initiative (IKI). The Gesellschaft für internationale Zusammenarbeit (GIZ) supported project preparation with sector analyses. Overall, the measures were conceived in a complementary manner within Germany's DC, and the various instruments of DC, i.e. technical and financial cooperation, also interacted sensibly.

Morocco adopted an ambitious strategy in 2009 with the aim of having approximately 42 per cent of the installed output in renewables – wind, solar and hydropower – by 2020. To achieve these goals, Germany's DC is supporting Moroccan partners with the Morocco wind programme and the Tanafnit El Bori run-of-river power plant. At the same time, the Moroccan government developed the NOOR ("light" in Arabic) solar plan. This includes the development of 2000 MW of capacity by 2020 and 6000 MW of capacity by 2030. In addition to the four power plants in Ouazarzate, there are also three other PV systems: NOOR-Boujdour, NOOR-Laayoune and NOOR-Tafilalet are currently being implemented but are not funded by German Financial Cooperation. The power plants in Ouazarzate are an integral part of achieving the partner objectives and cover around 500 MW of the targeted 2000 MW. NOORo I uses a parabolic trough concentrator for energy production, where the water vapour leaving the turbine is wet-cooled. The construction of this plant was the basis for further follow-up phases in which NOORo II was used to finance another CSP plant with parabolic trough concentrator and air cooling, and NOORo III was used to finance a CSP plant with solar tower and air cooling as well. NOORo IV consists of a photovoltaic system. All four projects as well as a transmission line feeding the energy produced in this way into the national grid and a common infrastructure together form the NOOR complex in Ouarzazate. As a result, NOORo I demonstrates clear coherence and is embedded in both previous and subsequent activities within German DC in terms of financing and the interaction between the various measures.

The financing of the entire NOOR solar complex in Ouarzazate was a project that consisted of many members of the international community. The financiers involved were the African Development Bank (AFDB), the Agence Francaise de Développement (AFD), the Clean Technology Fund, the European Investment Bank (EIB) and the World Bank. Not all financiers were involved in all components, i.e. NOORo I–IV. Nevertheless, all were members of the steering committee. Cooperation was very good and regular coordination meetings were held. Many steps in the process, for example awarding procedures, were discussed there and then standardised. This meant that MASEN, as the project-executing agency, was able to follow a uniform process and not different processes for the respective donors. This allowed the project-executing agency MASEN to adopt a uniform approach, created efficiencies and is a sign of strong and well-functioning donor harmonisation. At the same time, this two-stage process, firstly coordination in the steering committee and then uniform cooperation between the financiers and MASEN, ensured very good coordination between the national stakeholders. MASEN functioned as a central point of contact for coordinating implementation of the entire project. A significant part of the total financing from private donors was mobilised as part of a Public Private Partnership (PPP) structure.

In summary, it can be said that the project was very well coordinated within German DC. Coordination with other international donors via the steering committee functioned exceptionally well, and the embedding in a PPP structure also mobilised private capital.

Coherence rating: 1

Effectiveness

According to the project proposal, the objective of the project at outcome level was to introduce efficient, environmentally and socially compatible generation of electrical energy and to introduce a future technology for global climate change mitigation.

The target achievement of the project at outcome level can be summarised as follows:

Indicator	Target value	Actual value at EPE
(1) After the first two full years of operation, an average of over 370 GWh of electrical energy is generated annually	370 GWh p.a.	Achieved every year since commissioning. Average annual production since 2016: 424 GWh p.a.

(2) At least two solar power plants are under construction or in the pipeline three years after completion of the plant	-	Achieved with the construction of NOORo II–IV and the permit for Midelt.

Indicator (1): NOORo I was commissioned on 1 January 2016, which is close to 12 months later than planned. In the first year, annual production was 400 GWh, exceeding the target of 370 GWh per year two years earlier than planned. Since then, the target value has always been exceeded and in 2021, for example, production was 440 GWh. Over the period from 2016 to 2021, average annual production was 424 GWh. As a result, this indicator was achieved.

Indicator (2): The plan was that further solar-powered power plants would be built as a result of NOORo I. The introduction of CSP technology in Morocco was another motivation for the support of the project on the donor side. The construction of NOORo II, NOORo III and NOORo IV, all of which were also put into operation in 2018, has achieved this indicator. It is important to mention that NOORo II and NOORo III use CSP technology, while NOORo IV is a PV solar power plant. In addition to the other NOOR power plants in Ouarzazate, approval has also been granted for the construction of a solar power plant in the Midelt region, meaning that the indicator was exceeded.

Overall, it can be said that the indicators set for NOORo I were exceeded. More energy is being produced than planned and more solar power plants are being completed.

Effectiveness rating: 2

Efficiency

NOORo I was the first power plant in Morocco to use CSP technology. This was at a time when CSP plants and their technology were not particularly widespread around the world. In this respect, the costs at the time were slightly higher than for a photovoltaic system, and the costs for PV have also fallen even more sharply since then. At the same time, there was no other technology at the time that included a corresponding storage option and thus greater availability of solar energy at peak load times in the evening hours, as was the case with NOORo I.

Ultimately, the final costs remained below the estimated amounts – both for NOORo I and the other three power plants.

Total costs (EUR million)	NOORo I	NOORo II	NOORo III	NOORo IV
Planned costs	750	985	645	94.7
Actual costs	633.6	818.8	626.5	65.6
Difference	- 16 per cent	- 17 per cent	- 3 per cent	- 31 per cent

On the one hand, the lower current total costs in all four power plants are due to the fact that MASEN has generous “contingencies” planned in all its budget proposals. This was intended to prevent budget overruns. At the same time, focus was placed on obtaining as many parts as possible from local production during construction. Although this slightly delayed the original completion, it also created competition. This took place both in the delivery of small parts within Morocco and between larger companies that wanted to gain a foothold in the Moroccan market. At the same time, the Public Private Partnership structure reduced the risk for the companies, as the state and/or the donors took on corresponding risks. Ultimately, the private sector invested just under USD 126 million in NOORo I via the PPP structure. This made

NOORo I the largest PPP-financed solar power plant in Morocco and the entire MENA region at the time.[1] All this reduced the companies' ultimate bid prices for NOORo I and resulted in lower costs than planned. The other two NOORo II and NOORo III power plants benefited from technological progress and learning experiences from NOORo I. While NOORo I, for example, has a cooling system with high water consumption, NOORo II uses less water due to the use of air cooling (see also sustainability criterion). NOORo IV, which is a pure PV power plant, benefited the most from the price degression in the area of solar energy, meaning that the final total costs were more than 31 per cent lower than originally planned.

During implementation, there was an overall delay in the completion of NOORo I of just under a year. On the one hand, this was due to the complex awarding procedures, but on the other hand, also to problems during construction. For example, there were problems with the delivery of the components, such as the turbine or generator, as they had to be delivered with a heavy-duty transporter and there was no corresponding permit at the beginning. Strong winds and rains also slowed down the construction process.

The increased energy generation of NOORo I (see indicator 1, effectiveness criterion) and the lower costs have ensured that the project ultimately achieved macroeconomic profitability of 3.4 per cent compared to the 0.9 per cent originally targeted.[2] In addition to the purely economic perspective, the fact that NOORo I is now regarded worldwide as a positive example for CSP technology should not be underestimated (see Impact criterion).

In summary, it can be said that production efficiency was very high due to lower prices than originally assumed and the anticipatory course set with regard to competition was very high. This contributed significantly to a higher economic rate of return of 3.4 per cent.

Efficiency rating: 1

Impact

At the start of the project, the impact was defined as contributing to global climate change mitigation and economic growth in Morocco.

The contribution to global climate change mitigation was operationalised in the 230,000 tonnes of CO2 per year avoided two years after the power plant was commissioned. Assuming an emission factor of 0.63 tCO2/MWh, this indicator has been achieved since 2019, three years after commissioning. In 2018, the figure of 207,476 tonnes of CO2 per year was still just under the achievement target for the indicator.

Indicator	PA status	Ex post evaluation
The annual reduction of CO2 emissions two years after commissioning amounts to 230,000 tonnes of CO2 per year	-	2018: 207,476 2019: 238,132 2020: 300,854 2021: 266,208

Further developmental impacts materialised at three different levels:

Local level: According to a report by the World Bank, the project has been highly effective locally by raising the standard of living in general, improving the connection to other cities by building new roads and generating jobs.[3] In total, more than 1,900 people were employed during the construction of NOORo I, 1,500 of whom were Moroccans and 600 of whom were employed from the surrounding provinces. Even after construction work was completed, 61 people work for MASEN in NOORo I. Of these, close to half (27) are from the local communities of Ouarzazate and Ghassate, and eight of the employees are female. With regard to the entire NOOR Ouarzazate complex, 9,149 people were employed in the construction phase, and in the operating phase, approx. 250 people are now working directly to operate the power

[1] World Bank 2018. Implementation Completion and Results Report NOOR I.
[2] World Bank 2018. Implementation Completion and Results Report NOOR I.
[3] World Bank 2018. Implementation Completion and Results Report NOOR I.

plants, while approx. 200 people work for other companies on the NOOR Ouarzazate site. Although it cannot be precisely quantified, further positive impacts on employment and the local economy along the value chain are to be expected. In addition to effects on employment and the local economy, MASEN has also committed itself to contributing to more than 300 social projects in local communities. During the evaluation trip, for example, a solar power system on an orphanage, a solar-powered water pump and the support of a pre-school were reviewed.

National level: The project's target group was all Moroccans connected to the power grid. NOORo I has the capacity to supply 400,000 households with electricity. In addition to the users of the electricity grid, companies along the value chain in the solar industry are also economically significant. The solar industry in Morocco has grown significantly in recent years, which can be attributed in part to the NOOR complex in Ouarzazate. The role of NOORo I as a pilot project for CSP is also evident at national level. Shortly after piloting the solar complex in Ouarzazate, a similar solar complex with more output was planned in Midelt. Solar power plants with 800 MW were to be built there in two construction phases. The corresponding competitive bidding was designed to be non-technology-specific, which means that all solar and storage technologies can be offered and the price is decisive. A consortium with CSP and photovoltaics prevailed, with similar prices in the two technologies.[4] This shows that CSP technology can be competitively offered with photovoltaics. This is also due to the learning experience gained in Ouarzazate, which has led to a price degression in the sector.

Global level: The NOOR complex in Ouarzazate is known around the world, and developers and financiers visit each year to study the technology. MASEN itself organises conferences in which they share their knowledge with relevant stakeholders. In 2019, for example, there were 147 field visits with a total of 3,076 visitors. Of the 147 field visits, 82 were from the general public, 28 from project partners, 19 from politically high-ranking dignitaries, 13 from the press or film industry and five were other groups. As a result, according to the World Bank, the project also seems to have influenced other countries from the Middle East, such as the United Arab Emirates, Saudi Arabia, Tunisia, Lebanon, Jordan and Egypt, to consider CSP technology.[5] Specifically, the construction of a 700 MW CSP plant in Dubai's Mohammed bin Rashid Al Maktoum Solar Park, the 150 MW Aurora plant in South Australia and Chile's 110 MW Atacama solar tower is associated with the NOOR solar complex. Among other things, these construction projects in Dubai and South Australia benefited from the lower prices (approx. 10 US cents per kWh). NOOR Ouarzazate thus also had a global impact as a "role model".

NOORo I and the entire Ouarzazate solar complex have very positive effects at local, national and global levels. The project influenced future projects throughout the world. The overall impacts are therefore rated as very good.

Impact rating: 1

Sustainability

MASEN itself was founded in 2010 by royal decree to implement the renewable energy transition in Morocco. It is the implementing organisation to achieve the target of 2000 MW by 2020 and 6000 MW with renewable energy in 2030. Since its foundation, MASEN has grown continuously and gained a lot of experience in the area of renewable energy projects. They are currently responsible for almost 20 wind and solar power plants in Morocco. MASEN co-financed NOORo I at the time of the evaluation. NOORo I is managed by an operating company in which MASEN has a 25% share. This operating company has been supporting NOORo I independently and with great competence for more than three years. During the period in which the operating company provided support, the electricity generated increased and all problems that occurred as part of NOORo I, but also later, especially involving NOORo III, were solved professionally. There is no doubt that the operator is able to adequately operate the solar complex.

MASEN is not only a shareholder in the operating company, but also purchases electricity from the operating company. This is at a price higher than the national tariff. At the same time, MASEN continues to sell the electricity to the grid company at the national tariff. This results in annual losses of approx.

[4] Federal Ministry for the Environment, Nature Conservation and Nuclear Safety 2021. NOOR III evaluation report.

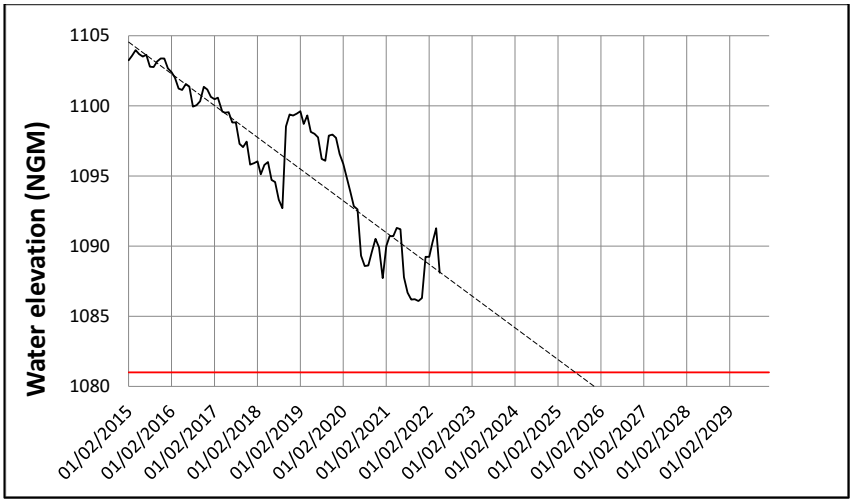
[5] World Bank 2018. Implementation Completion and Results Report NOOR I.

EUR 33 million. The Moroccan state covers this loss. All contracts are concluded for 25 years and provide the partners with corresponding security. For future projects, such as NOOR Midelt, production costs may be lower than the national tariff. Corresponding profits would then be directed to MASEN.

The land on which the NOOR Ouarzazate complex is built was purchased from the local community by mutual agreement. There were no complaints, and the contract was concluded as part of a land purchase plan between 2011 and 2013.

However, there are some remaining questions regarding the sustainability of NOORo I. NOORo I uses water cooling. The water is taken from the nearby El Mansour Eddahbi dam. This had a volume of approx. 420 million m³ at the time of the project appraisal. According to the agreement, MASEN has the right to use up to 6 million m³ per year for the entire solar complex. In recent years, water consumption has been reduced due to the installation of improved and water-saving systems, for example through evaporation loss reduction, improvements in cooling systems and the reuse of industrial waste water. In 2021, NOORo I, the power plant with the largest water consumption, extracted 1.63 million m³ from the reservoir. At the same time, however, there is a negative trend in the water volume of the El Mansour Eddahbi reservoir. Of a water volume of almost 420 million m³ in 2015, there were only just under 58.4 million m³ of water in mid-2022. Even the most negative scenarios from the water study had not foreseen this at the project appraisal. Figure 1 shows the water level of the reservoir and the lowest withdrawal level that MASEN requires for its water withdrawal. The trend of the water level to date has been extended using the dotted line. Assuming that the trend continues, MASEN would no longer be able to extract water from the reservoir from mid 2025, meaning that NOORo I would be inoperable.

Figure 1 El Mansour Eddhabi water level and MASEN water withdrawal



One explanation for the low water volume is that part of El Mansour Eddhabi's water volume is in the upstream Sultan Moulay Ali Cherif dam. According to MASEN, water could flow from there to the solar complex if necessary. At the same time, this dam was not depicted in the previous water concepts. It would therefore be urgently necessary for MASEN to draw up an updated strategy, including an emergency plan. If this is not possible, the sustainability of NOORo I would be severely endangered.

In summary, financial sustainability is secured for the coming years, but there are doubts about the water supplies that are absolutely necessary for the operation of NOORo I. The sustainability is rated as only just satisfactory.

Sustainability rating: 3

Notes on the methods used to evaluate project success (project rating)

Projects (and programmes) are evaluated on a six-point scale, the criteria being **relevance**, **coherence**, **effectiveness**, **efficiency**, **impact and sustainability**. The ratings are also used to arrive at an **overall rating** of a project's developmental efficacy. The scale is as follows:

Level 1	very successful: result that clearly exceeds expectations
Level 2	successful: fully in line with expectations and without any significant shortcomings
Level 3	moderately successful: project falls short of expectations but the positive results dominate
Level 4	moderately unsuccessful: significantly below expectations, with negative results dominating despite discernible positive results
Level 5	unsuccessful: despite some positive partial results, the negative results clearly dominate
Level 6	highly unsuccessful: the project has no impact or the situation has actually deteriorated

Rating levels 1-3 denote a positive assessment or successful project while rating levels 4-6 denote a negative assessment.

The **overall rating** on the six-point scale is compiled from a weighting of all six individual criteria as appropriate to the project in question. Levels 1–3 of the overall rating indicate a "successful" project, levels 4–6 an "unsuccessful" project. It should be noted that a project can generally be considered developmentally "successful" only if the achievement of the project objective ("effectiveness"), the impact on the overall objective ("impact") **and** the sustainability are rated at least "moderately successful"
(level 3).