Ex post evaluation – India

Sector: Solar energy (CRS code: 23230)
Project: PV solar power plant Sakri, India (BMZ no.: 2011 65 992*)
Implementing agency: Maharashtra State Power Generation Company Limited (Mahagenco)

Ex post evaluation report: 2020

		Planned	Actual
Investment costs (total)	EUR million	370.00	199.00
Counterpart contribution	EUR million	120.00	41.00
Funding	EUR million	250.00	158.00
of which BMZ budget funds	EUR million	35.00	27.30

*) Random sample 2019

Summary: The project involved the construction of a 125-MW large-scale photovoltaic power plant at the Shivajinagar site near Sakri in the Indian state of Maharashtra. The implementing agency Mahagenco is a state-owned energy provider that has strong roots in the energy market in Maharashtra.

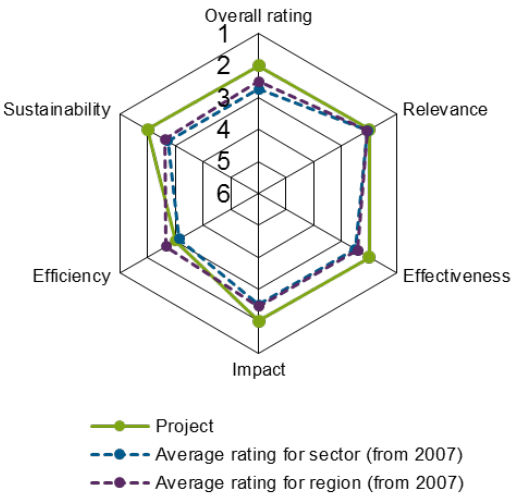
Development objectives: The overarching development goal of the FC measure was to contribute to the further expansion of solar power, and thus to an ecologically sustainable and climate-friendly energy supply in India (impact). The measure aimed to support the restructuring of the energy supply in the State of Maharashtra towards an increased use of solar power (outcome) by implementing the first major grid-connected photovoltaic project (output).

Target group: The measure's target group was users of electrical power in the State of Maharashtra. The project benefited all users connected to the grid and therefore all grid-connected households in equal measure.

As a result of the project, roughly 100 direct jobs were to be created for the plant's maintenance. Other target groups were the implementing agency, as well as the entire solar industry and the financial sector. The goal was to benefit these groups through the transfer of technology and knowledge.

Overall rating: 2

Rationale: The project made an important contribution to the restructuring of the Indian energy system towards renewable energy sources. In the first six years of operation, the photovoltaic power plant's energy production quantity was around 8% higher than the indicator of 180 GWh p.a. defined ex ante. The implementing agency runs the facility in a very efficient and profitable manner. No negative social or environmental impacts were observed. The additionality and model nature of the project are very high. Upon commissioning, the solar farm was the first in India to have a capacity of over 100 MW and also one of the largest in the world. The plant was built during an early stage in the market launch process and therefore had a significant impact on the further development of the market. In view of the current project pipeline, there now also appears to be a general change in strategy in the State of Maharashtra and at the implementing agency, shifting more towards increased use of solar power. Since the solar farm was commissioned, however, the implementing agency has also expanded coal-based power plant capacity on a large scale, which makes it more difficult to attribute the change in strategy to the FC measure.



Highlights: In India, the trend towards increasingly large solar power plants continues unabated. The approach has proven effective: three of the six largest photovoltaic power plants in the world at present were built in India.

Rating according to DAC criteria

Overall rating: 2

Ratings:

Relevance	2
Effectiveness	2
Efficiency	3
Impact	2
Sustainability	2

Relevance

At the time of the project appraisal (2011), India was experiencing very dynamic economic growth. This resulted in a growing demand for plants to generate power: between 2011 and 2018, gross domestic product (GDP) rose by an average of 7.0%[1] per year, with energy consumption increasing by roughly 7.5%.[2] The core problem in the Indian energy sector at the time of the programme proposal was the huge "gap in energy", in other words, the lack of power plant capacity in relation to energy consumption. In 2010, the World Bank estimated that the shortage of energy was costing the country around seven percentage points of its gross domestic product.[3] This problem also applied to the State of Maharashtra, India's most heavily industrialised state. The peak load deficit in Maharashtra in the 2010/11 financial year was around 23%, which means that peaks in consumption could not be covered by the available energy production capacity.[4] In view of this situation, the expansion of energy production capacity, 66% of which was attributable to fossil-fuel-based power plants at that time, was a key starting point for improving the country's energy supply and, with it, its development prospects. This statement remains true from today's perspective. As the first large power plant of its kind, and as such a specific case study, the aim of the Sakri solar power plant was to demonstrate the potential of renewable sources of energy for energy production in India in terms of their ability to cover growing demand for energy.

The objectives were as follows: the ultimate objective (impact) as per the programme proposal was to "contribute to the further expansion of solar power and thus to an ecologically sustainable and climate-friendly energy supply". The project objective (outcome) was "to support the restructuring of the energy supply in the State of Maharashtra towards an increased use of solar power by implementing the first major grid-connected photovoltaic project". The project's results chain – implementing the first major grid-connected photovoltaic project in order to contribute to the further expansion of solar power in India – is plausible, even from today's perspective.

The measure's target group was defined as users of electrical power in the State of Maharashtra, so according to the programme proposal, all users connected to the grid and therefore all households as well.

The measure was embedded in the objectives of German and international cooperation and corresponded to the strategies pursued by the Indian partner institutions.

It was part of the fields of assistance and technologies in the Energy sectoral policy document of the Federal Ministry for Economic Cooperation and Development's (BMZ), as valid at that time. In particular, the project targeted the fields of "Renewables" and "Expansion of local capacities" for the planning and operation of sustainable energy systems. Furthermore, the topic of energy was and still remains an agreed focus area of bilateral cooperation between India and Germany.[5] The particular importance of the energy sector in bilateral development cooperation is underlined by the creation of the Indian-German Energy

[1] World Bank Data 2020: GDP growth (annual %) - India, https://data.worldbank.org/country/india

[2] DES 2020: Economic Survey of Maharashtra, https://www.maharashtra.gov.in/Site/upload/WhatsNew/ESM_2019_20_Eng_Book.pdf

[3] World Bank 2010: India's Power Sector, https://www.worldbank.org/en/news/feature/2010/04/19/india-power-sector

[4] DES 2012: Economic Survey of Maharashtra, https://mahades.maharashtra.gov.in/files/publication/esm_2011-12_eng.pdf

[5] BMZ 2007: "Sustainable Energy for Development" sectoral policy document, https://www.bmz.de/de/mediathek/publikationen/reihen/strategiepapiere/konzept145.pdf

Forum (IGEF) in 2006. One of the priorities of the Energy Forum's work is the promotion of large-scale renewable energy technologies.

In view of the Millennium Development Goals (MDGs), the project can be allocated to MDG 7, ensuring environmental sustainability and the associated indicator 7.2 "CO2 emissions".

Furthermore, the project was heavily aligned with the partner country's strategies. With the launch of the Jawaharlal Nehru National Solar Mission (JNNSM) in January 2010, the Indian central government set itself the goal of building an additional 20 GW of photovoltaic capacity by the year 2022. During the first phase of the mission, ending in March 2013, the government planned to build 1,000 MW of grid-connected solar power plants.[6] In 2015, the JNNSM's target was raised to 100 GW of installed photovoltaic capacity by 2022.[7] In the State of Maharashtra, construction on the first megawatt-range photovoltaic plants began in 2010, with projects in the double-digit megawatt range following in 2013. Since then, the expansion of renewable energy sources in the state has been supervised and promoted by the Maharashtra Energy Development Agency (MEDA) at institutional level.

During the project implementation period, organisations including the Agence Francaise de Developpement (AFD) were active in the Indian solar power sector; in 2010 and 2013, the AFD provided the Indian Renewable Energy Development Agency (IREDA) with a total of EUR 110 million, primarily for the development of solar power plants in various states.[8] The World Bank financed projects for promoting new business models, mainly in the related area of grid-connected rooftop photovoltaic systems.

Relevance rating: 2

Effectiveness

The programme objective (outcome) was "to support the restructuring of the energy supply in the State of Maharashtra towards an increased use of solar power by implementing the first major grid-connected photovoltaic project". The achievement of the objectives at outcome level can be summarised as follows:

Indicator	PA target value	Ex post evaluation
(1) Annual **production of electrical energy** by the Sakri solar power plant	180 GWh p.a.	196 GWh p.a. (Average April 2013–March 2019)
(2) The State of Maharashtra's policy-based requirement to increase the **share of purchased energy generated from solar power to 0.25%** of the purchase of fossil energy sources by 2013 is **achieved by at least 50%**.	**Financial year 2010/11:** Solar requirement: 0.25% Target: 259 GWh photovoltaic Actual: 1.1 GWh photovoltaic **Achievement rate: 0.4%**	**Financial year 2013/14:** Solar requirement: 0.5% Target: 589 GWh photovoltaic Actual: 311 GWh photovoltaic **Achievement rate: 53%**

[9]Sources: (1) Mahagenco, internal project monitoring. (2) MEDA 2014: DISCOM Cumulative Report of FY 2010-14.

All of the indicator target values set out for the project were achieved in full. The indicator for produced energy defined in the programme proposal was achieved; in the first six years of operation, the average quantity of energy produced was 196 GWh p.a., thus around 8% above the value of 180 GWh p.a. defined

[6] Renewable Energy World 2010: India Approves Solar Implementation Plan https://www.renewableenergyworld.com/2010/01/13/india-approves-solar-implementation-plan/#gref

[7] Renewable Energy World 2015: The Dark Horse in the Global Solar Race: India's 100-GW Solar Ambition, https://www.renewableenergyworld.com/2015/04/15/the-dark-horse-in-the-global-solar-race-indias-100-gw-solar-ambition/

[8] AFD 2013: Combating Climate Change through the Promotion of Renewables, https://www.afd.fr/en/carte-des-projets/combating-climate-change-through-promotion-renewables

ex ante. These good energy production values for the photovoltaic farm emphasise that the technical availability of the photovoltaic farm and power grid must be rated as positive. According to the information from the implementing agency, there was no curtailment of the solar farm's feed-in power due to a lack of power grid capacity. There were only individual cases of grid disconnections related to maintenance and grid expansion work. According to the final review, power is fed directly into the high-voltage grid by a switchboard plant installed especially for the solar power plant and an overhead line measuring around 60 km in length. Since Maharashtra is the most heavily industrialised state with a high level of regional energy consumption, it experiences fewer of the bottlenecks typical at the high-voltage level, which often result from the addition of renewable energy sources in remote regions with good wind or solar potential but a low regional load.

A further indicator targets the political requirements regarding the proportion of solar energy in the quantity of power purchased in Maharashtra. Even though the political target was doubled in comparison to the programme proposal, half of this increased value was achieved, meaning that the indicator was met.

The good yield data for the photovoltaic power plant underline the positive impression that the plant is operated properly. The FC measure also had positive effects on employment. Around 200 people work at the plant in total, roughly 40 of whom are engineers and technicians and 160 work in roles that require training. The latter type of role has brought particular advantages to the surrounding villages, which are inhabited predominantly by the Adivasi, a socially and culturally disadvantaged group.

Overall, the project objective was achieved in full and support was provided to improve the power supply in Maharashtra. Solar power now plays a more important role in Maharashtra's energy supply, though conventional energy sources continue to dominate the state's power generation mix.

Effectiveness rating: 2

Efficiency

The project measures were implemented cost-efficiently. The results were achieved with a comparatively low use of funds (production efficiency):

- The total costs were around EUR 200 million. At the time of the project appraisal, the total costs of the power plant were estimated at around EUR 370 million. The actual costs were thus around 46% below the budgeted figure. This can be attributed mainly to the price decrease for photovoltaic modules between 2010 and 2012.
- Using the project's residual funds, the implementing agency was able to build another solar farm with a capacity of 50 MW in 2014/15 (Baramati, BMZ no.: 2014 68 636).
- The unit costs for the photovoltaic farm with a capacity of 125 MWp were EUR 1.6 million/MWp (EUR 1.6/Wp). At the point when construction began in September 2012, this system price was certainly typical for the market. In the lead market of Germany with a corresponding competition structure, the prices for free-standing photovoltaic plants was around EUR 1.51/Wp in August 2012.[10]

The project was also largely appropriate regarding the use of funds at the micro- and macroeconomic level (allocation efficiency):

- The feed-in tariffs for the solar power plant were INR 15.61/kWh. This corresponds to an average of around EUR 0.20/kWh for the operating years 2013–2019.[11] This remuneration rate was agreed for a term of 25 years under a power purchase agreement with the distribution grid operator, which is also state-owned. A brief assessment of the electricity generation costs during the ex post evaluation based on the system price, the irradiation data and the capital costs results in a levelised cost of electricity (LCOE) of around INR 8.66/kWh, which is equivalent to around EUR 0.11/kWh. Operating the solar farm must therefore be highly profitable for the operator, but the operator has not provided the actual producing costs.

[10] Photon Consulting. 2012. Market price and volume data. 2012.

[11] ECB 2020: Indian Rupee/Euro, https://sdw.ecb.europa.eu/quickview.do?SERIES_KEY=120.EXR.Q.INR.EUR.SP00.A

- In view of the amount of power generated, the project's macroeconomic efficiency is rather low; this is mainly due to the high feed-in tariffs in contrast to the producing costs for fossil-based power of around EUR 0.05/kWh. Even the internalisation of negative external effects, such as the savings in carbon emissions and the fuel cost savings, are not able to redress the balance. However, the strong trend towards multi-megawatt plants on the Indian photovoltaic market emphasises the project's positive spill-over effect for the introduction of climate-friendly technology. In a recent photovoltaic auction round in India, the lowest hammer price was EUR 0.028/kWh and therefore significantly below the producing costs for conventional power plants.[12]

Since large-scale photovoltaic power plants were only in their market-launch phase in India at the time of the project appraisal and implementation, there were no alternative sources of financing for a solar farm of this size. Until the 125 MW solar power plant in Sakri was connected to the grid, an 8.5-MW farm connected in the previous year (2012) was the largest photovoltaic farm in Maharashtra.[13] Indian banks had very little experience with the financing of solar power plants, which is why the investment risks were regarded as high for what was new technology in India at the time.

Overall, the objectives of the project were achieved economically. From the microeconomic perspective of the implementing agency, the project is classed as highly profitable. By contrast, the macroeconomic efficiency is lower in view of the high feed-in tariffs.

Efficiency rating: 3

Impact

According to the impact objective, the aim of the measure was to contribute to the further expansion of solar power, and with it to an ecologically sustainable and climate-friendly energy supply in India. The achievement of the objectives with reference to the impact-level objective can be summarised as follows:

Indicator	Status PA	Ex post evaluation
(1) Within the first **three years** after commissioning (May 2013), **another even larger solar power plant** enters the construction phase in India.	0	**February 2014**: Commissioning of the **130 MW Welspun** solar power plant in Madhya Pradesh
(2) Within the first **five years** after commissioning, the **proportion of renewable energy sources in the power generation mix** in Maharashtra and India increases to at least ten percent.	**Maharashtra 2010/11:** **6%** share of renewables in power generation mix **India 2010:** **4%** share of renewables in power generation mix	**Maharashtra 2018/19:** **11%** share of renewables in power generation mix **India 2018:** **9%** share of renewables in power generation mix
(3) **Prevention of CO_2** emissions	155,000 t p.a.	162,000 t p.a. (Mean value April 2013–March 2019)

[12] PV Magazine 2020: Rekordverdächtige Photovoltaik-Ausschreibung könnte Indien für ausländische Investitionen öffnen, https://www.pv-magazine.de/2020/07/01/rekordverdaechtige-photovoltaik-ausschreibung-koennte-indien-fuer-auslaendische-investitionen-oeffnen/

[13] MEDA 2020: List of Grid Connected Solar Power Projects Commissioned in Maharashtra State, https://www.mahaurja.com/meda/data/grid_solar_power/SPPCommissioned.pdf

(4) The **peak load deficit in the energy sector** in Maharashtra is lower (new indicator)[14]	n/a	2010/11: -3,882 MW (-22.6%) 2018/19: + 1336 MW (+7.2%)

Sources: (1) The Hindu 2014: India's largest solar plant in MP, Modi calls it 'saffron revolution'. (2) Economic Survey of Maharashtra 2011-12 and 2019-20. IEA Data and Statistics. (3) Calculations during the EPE based on power production. (3) Economic Survey of Maharashtra 2011/12 and 2019/2020.

The first impact indicator relates to the implementation of similar projects in India and, as such, to the FC measure's exemplary nature. Between the full commissioning of the power plant in May 2013 and the end of 2016, at least seven further large photovoltaic power plants with a capacity of over 100 MW were connected to the grid in India.[15]

The Sakri photovoltaic power plant is an important reference plant in India as it was the first to have a capacity of > 100 MW and was built during an early stage of the launch of photovoltaic technology onto the market. At the time, it was one of the largest photovoltaic plants in the world. In the years that followed, further solar parks of this magnitude were commissioned in India, the largest of which was located in the State of Rajasthan and has a capacity of 2,245 MW.[16] It can be assumed that the measure was an important factor for the expansion of solar power in India and had an impact on raising the JNNSM's level of ambition from 2015 onwards. The reason is that the country's first large-scale plants emphasised the performance capacity of photovoltaic technology under the local climate and energy-related conditions.

At state level, the use of photovoltaic technology has also been significantly expanded in Maharashtra, though the state is behind other states like Karnataka and Rajasthan in this regard. As large net power importers with a large amount of available space, these states had more of an incentive than Maharashtra to introduce a proactive renewable energy policy with ambitious target quotas. Nevertheless, solar power has since become established in Maharashtra: the cumulative installed photovoltaic capacity in the segment rose from 35 MW at the end of 2012 to 1,116 MW at the end of 2019 from a plant size of 0.5 MW.[17] Furthermore, at the end of 2019, the state had one of the largest photovoltaic project pipelines out of all Indian states.[18]

As an additional indicator, the comparison of the development of the renewable energy share in the total energy production mix in Maharashtra and India was added during the ex post evaluation. In both cases, this proportion rose in equal measure; on the whole, Maharashtra was above the national average, mainly due to the expansion of wind power. In India, the target value of 10% was narrowly missed in the 2018/19 financial year.

The carbon emissions prevented as a result of the solar power production are calculated on the basis of the emission factor in the Indian energy system in the average amount of 0.82 t CO2/MWh between 2013/14–2018/19.[19]

The development of the peak load deficit in Maharashtra was defined as an additional indicator during the ex post evaluation (EPE). This indicator can be used to measure the quality of the power supply as it quantifies the capacity to supply sudden increases in power consumption, which occur, for example, in the ramp-up of production systems, in heating industrial enterprises or during pumping processes. If these diverging, higher consumers cannot be serviced, loads are rejected, i.e. power cuts take place. In

[14] The peak load deficit is a proxy for the development of the main problem in the Indian energy sector at the time of the project proposal. Even though the rectification of the peak load deficit can mainly be attributed to the addition of conventional sources of energy, the measure also had a positive effect on this development.

[15] PV Resources 2019: Large-Scale PV Power Plants - Top50, http://www.pvresources.com/en/pvpowerplants/top50pv.php

[16] Mercom India 2020: With 2,245 MW of Commissioned Solar Projects, World's Largest Solar Park is Now at Bhadla, https://mercomindia.com/world-largest-solar-park-bhadla/

[17] MEDA 2020: List of Grid Connected Solar Power Projects Commissioned in Maharashtra State, https://www.maharja.com/meda/data/grid_solar_power/SPPCommissioned.pdf

[18] Bridge to India 2019: India Solar Map, https://bridgetoindia.com/report/india-solar-rooftop-map-december-2019/

[19] CEA 2018: CO2 Baseline Database for the Indian Power Sector, http://www.cea.nic.in/reports/others/thermal/tpece/cdm_co2/user_guide_ver13.pdf

Maharashtra, the peak load deficit was closed by the large-scale expansion of power production capacities; the available production capacity is currently 7.2% above the peak load.[20] The addition of photovoltaic plants plays a secondary role in this development as mainly coal-based and wind power plants were added. Around 70% of the capacity added in Maharashtra between 2010/11 and 2018/19 can be attributed to coal-based power plants and around 30% to renewable energy sources (including 6.2% to photovoltaic plants). The proportion of renewable energy in the state's power production mix rose from 6% to 11% in the same period.

In view of potential environmental impacts, it became clear during the implementation of the project that part of the area was declared as forest even though the rocky ground did not allow any trees to grow.[21] During the EPE, the implementing agency stated that 3,000 trees had been planted on the plant's premises and there were currently no problems concerning use of the land.

The indicators defined ex ante regarding the measurement of target achievement at impact level were achieved in full. The project provided important momentum for the large-scale expansion of solar power in India and was the proof of concept for photovoltaic power plants in the multi-megawatt class.

Impact rating: 2

Sustainability

From today's perspective, the continued operation of the solar farm seems to be ensured, primarily due to the high level of professionalism demonstrated by the implementing agency and the company contracted to operate and maintain the plant. According to sensitivity calculations, the photovoltaic farm will be paid off from the eighth year of operation, i.e. from the Indian financial year 2020/21. As such, economic operation is also assured in the event of a failure of one part of the installed components. Relevant reserves for the potential replacement of components during the project term can be set aside thanks to the project's profitability, with producing costs of EUR 0.11/kWh and an agreed feed-in tariff of EUR 0.20/kWh over a period of 25 years (see Efficiency above).

The stability of the implementing agency is regarded as positive: on the one hand because it is a state-owned company, and on the other hand due to its assets and yield data. The implementing agency's capacity to operate and maintain the plant has risen sharply as a result of the FC measure. For instance, in-house and external engineers and technicians are regularly trained at the plant; furthermore, the senior management team visited Germany in 2018 to learn about the latest developments in the field of digital O&M (operation and management) for photovoltaic plants.

An estimate based on the annual reports leads to a generally positive assessment of the implementing agency's financial soundness. Microeconomic risks stem from the important role of coal-based power plants in the implementing agency's portfolio as these investments have lower load factors due to the excess capacity in the energy sector and are increasingly affected by the stricter environmental requirements regarding emission protection. A further risk is the unstable financial situation of the Indian distribution grid operators, who are responsible for allocating costs to the power plant operators for the quantity of power supplied. Due to these structural problems, the state-owned distribution grid operator Maharashtra State Electricity Distribution Company Limited (MSEDCL) has accumulated arrears in the amount of EUR 1.7 billion towards the implementing agency MAHAGENCO, which is also state-owned. Despite these outstanding payments, the implementing agency's results have been mainly positive in recent years.

Even though the implementing agency has not commissioned any more photovoltaic multi-megawatt plants since 2014, it has since built up a concrete project pipeline of at least 187 MW. Furthermore, the implementing agency has announced the construction of two large-scale solar power plants in the multi-megawatt range.[22] As such, there are signs that the implementing agency has at least recently initiated a

---

[20] DES 2020.

[21] DownToEarth 2015: Sakri solar power plant may not be shifted after all, https://www.downtoearth.org.in/news/sakri-solar-power-plant-may-not-be-shifted-after-all--34409

[22] Mercom 2019: Mahagenco Seeks Landowners for Development of 600 MW of Solar Projects, https://mercomindia.com/mahagenco-landowners-development-solar-projects/

change in strategy away from coal power towards the increased use of solar power. The now increasing expansion of solar power in Maharashtra underlines that the project is continuing to have an impact.

Sustainability rating: 2

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, effectiveness, efficiency** and **overarching developmental impact**. The ratings are also used to arrive at a **final assessment** of a project's overall developmental efficacy. The scale is as follows:

Level 1	Very good result that clearly exceeds expectations
Level 2	Good result, fully in line with expectations and without any significant shortcomings
Level 3	Satisfactory result – project falls short of expectations but the positive results dominate
Level 4	Unsatisfactory result – significantly below expectations, with negative results dominating despite discernible positive results
Level 5	Clearly inadequate result – despite some positive partial results, the negative results clearly dominate
Level 6	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.

Sustainability is evaluated according to the following four-point scale:

Sustainability level 1 (very good sustainability): The developmental efficacy of the project (positive to date) is very likely to continue undiminished or even increase.

Sustainability level 2 (good sustainability): The developmental efficacy of the project (positive to date) is very likely to decline only minimally but remain positive overall. (This is what can normally be expected).

Sustainability level 3 (satisfactory sustainability): The developmental efficacy of the project (positive to date) is very likely to decline significantly but remain positive overall. This rating is also assigned if the sustainability of a project is considered inadequate up to the time of the ex post evaluation but is very likely to evolve positively so that the project will ultimately achieve positive developmental efficacy.

Sustainability level 4 (inadequate sustainability): The developmental efficacy of the project is inadequate up to the time of the ex post evaluation and is very unlikely to improve. This rating is also assigned if the sustainability that has been positively evaluated to date is very likely to deteriorate severely and no longer meet the level 3 criteria.

The **overall rating** on the six-point scale is compiled from a weighting of all five individual criteria as appropriate to the project in question. Rating levels 1-3 of the overall rating denote a "successful" project while rating levels 4-6 denote 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 ("overarching developmental impact") and the sustainability are rated at least "satisfactory" (level 3).