ENABLING PV in Angola

Supported by

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Status: 30.09.2019

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list of abbreviations

AHK	Chamber of Commerce Abroad
BAI	Banco Angolano de Investimentos
BFA	Banco de Fomento Angola
BIC	Banco BIC Angola
BPC	Banco de Poupança e Crédito S.A.R.L. (Savings and Credit Bank)
BNA	National Bank of Angola
BSW	German Solar Industry Association
FATF	Financial Action Task Force
IMF	International Monetary Fund
INE	institutes of statistics
IVA	Value added tax
kV	kilovolt
kWh	kilowatt hour
MINEA	Angolan Ministry of Energy and Water
MW	megawatt
MWh	megawatt hour
PHOTOVOLTAICS	photovoltaics
SADC	Southern Africa Development Community
SEZ	Special Economic Zone

preliminary remark

The "ENABLING PV in Angola" project aims to identify applications for the use of photovoltaic (PV) and PV diesel hybrid solutions in Angola.

The following steps have been implemented for this purpose:

Firstly, it was investigated whether and how Angolan production facilities, which today use diesel generators to generate electricity, can use PV solutions to supplement or replace electricity generation. This report summarises the results of the investigations.

Secondly, a training course and workshop were organised in the Angolan Ministry of Energy MINEA in Luanda: The training in November 2018 explained the various photovoltaic solutions and their potential for power generation in Angola. The workshop in March 2019 presented results of profitability calculations of selected case studies for the use of photovoltaics in Angolan production facilities.

Thirdly, a freely accessible website with sample projects and an integrated calculation tool for modelling the profitability of PV diesel hybrid plants was set up.

The project was supported by the Federal Foreign Office and implemented by eclareon with the support of the Delegation of the German Economy in Angola (AHK Angola), the German Solar Industry Association (BSW-Solar) and some of its member companies.

1. summary

The current economic situation in Angola is difficult. The oil price crisis of recent years has had a considerable impact on Angola's economy, which is heavily dependent on oil. The Kwanza has been devalued and the inflation rate has risen to more than 20%. For this reason, the Angolan government has introduced various reforms to stabilise the country. Part of these reforms is the diversification of the economy to make it more resistant to crises. The new democratically elected government wants to dismantle economic barriers that, for example, will lead to Angola's 173th place out of 190 in the *Ease of Doing Business* Ranking in 2019. In addition, corruption is to be combated. Among other things, these measures led to a continuous decline in the inflation rate, which had fallen below 17% at the time of the editorial completion of this study (August 2019).

Projects such as the Luanda-Bengo Special Economic Zone (SEZ) facilitate private sector investment in Angola through secure infrastructure and good business conditions. Nevertheless, entrepreneurial activity in large parts of the country is hampered by a weak infrastructure.

The Angolan energy sector is currently undergoing major changes, inspired by the energy plan of the government of *Angola Energia 2025*. In order to electrify large parts of the country, the energy supply is to be significantly expanded. For this reason, the Angolan Government is proposing three areas which it intends to focus on:

- Expansion of existing electricity grids
- Development of regional island networks
- Construction of mini grids for individual villages

In addition, the security of energy supply of the existing networks is to be improved. The main source of energy to ensure this is hydropower. According to government targets, the installed PV capacity is to be increased to 100 MW by 2025. In Angola there are no additional government loans or funds to promote environmentally friendly projects such as the use of renewable energies. In addition, as non-English companies are required to make payments in local currency and carry out all transactions with domestic banks, financing PV projects in Angola is difficult.

Although the country's natural solar radiation would encourage the development of the PV sector, low electricity prices and the fact that government plans are based on other technologies make it difficult to implement PV projects. Only the implementation of off-grid systems to replace diesel generators has the potential to be cost-effective at current system prices. However, as fossil fuel subsidies are gradually phased out and electricity and diesel prices rise, the use of PV in Angola is expected to increase over time. If the government continues to invest in infrastructure and facilitate the entry of international companies into the market, Angola's enormous potential for solar power generation can be exploited.

2. about Angola

2.1 Geography and Demography

2.2.1 Area and population density

With an area of 1,246,700 km², Angola is one of the larger countries on the African continent. It is characterized by a highland in the center and south of the country and a long coastline. Angola is located in the southwest of Africa and borders on the Atlantic Ocean, Botswana and Namibia in the south, Zambia in the east and the Democratic Republic of Congo in the north and east. (DLA Piper, 2018).

Figure 1: Geographic map of Angola (wikimedia.org)

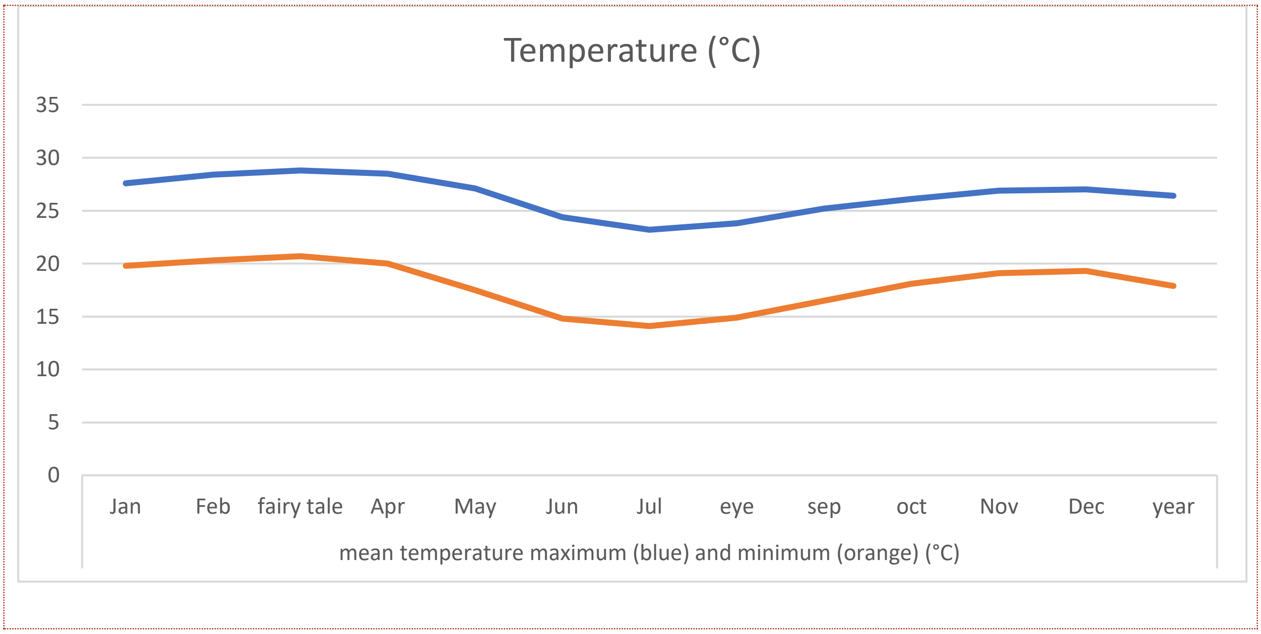
The country has a total of 30.13 million inhabitants (IMF). The official language is Portuguese, other national languages are Umbundu, Kimbundu, Kikongo, Tschokwe and Ovambo. (DLA Piper, 2018).

2.2.2 Climate

Angola has a temperate tropical climate with an average annual temperature of 24,7°C. In general, two tropical seasons can be distinguished: the dry Cacimbo and the warm rainy season. The first cool season lasts from June to September, while the rainy season lasts from October to May and is characterised by a warm and humid climate.

The country is divided into several climate zones according to its geographical characteristics: the coastal region on the Atlantic Ocean, the highlands and the south of the country. The coastal region is relatively humid with about 600 mm annual precipitation, with precipitation decreasing from north to south. Angola's annual rainfall is approximately 1638 mm. The tropical north of the country is rainy and has the highest average annual temperature. The plateau enjoys high average temperatures during the Cacimbo and lower around 18°C during the rest of the year due to the altitude (1,000 - 1,800 m above sea level). Due to the geographical proximity to the Kalahari Desert with low temperatures in the warm season, the southwestern part of the country is semi-dry due to the influence of continental tropical air masses and the cold Benguela current. (Government of Angola, 2011).

The consequences of climate change (as in all sub-Saharan African countries) also affect Angola. The average temperature rose by about 1.5°C between 1960 and 2006. An upward trend of 0.47°C can be observed per decade (C. McSweeney & Lizcano). This increase in temperatures decreases with the decrease in annual precipitation by about 2 mm per month per decade (1960-2006). This leads to an increased risk of extreme weather events such as droughts and floods. Coupled with Angola's low climate adaptation capacity, the 2013 drought, which was the most devastating of the last 30 years, led to the involuntary migration of over 1.5 million people. (Carvalho, Santos, & Pulquério, 2016).



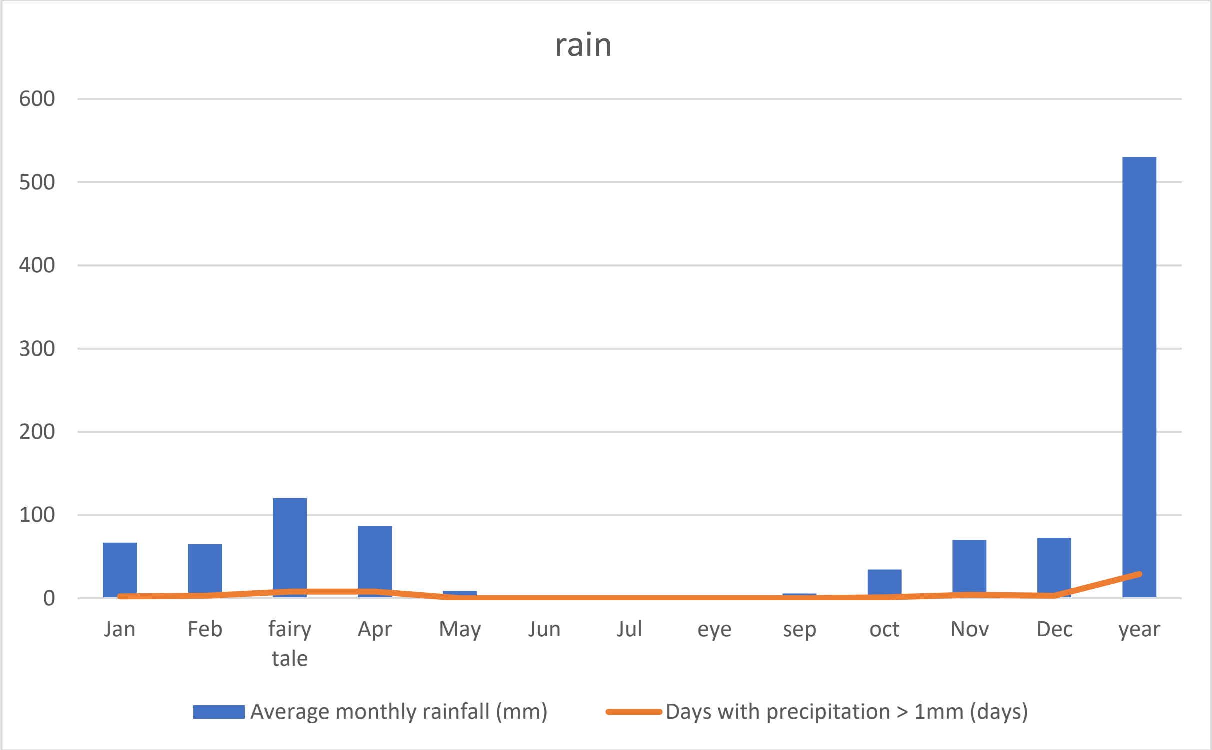


Figure 2: Average temperatures in °C and precipitation in mm for Angola (wetter.de, 2019*Fehler! Verweisquelle konnte nicht gefunden werden.***)**

2.2.3 Age structure and urbanity

Angola's population has risen sharply in the last decades following the civil war. With a growth rate of around 3.3%, this trend will continue in the future. Moreover, Angola's average population is very young. About 48% of the 30 million Angolans are under the age of 14, 28% are 15-24 years old and only about 6% of the population are over 55 or older. (GTAI, 2019).

Most Angolans, about 65%, live in urban areas. Angola's rural population, on the other hand, lives mainly in the highlands, the Bié Plateau, and along important watercourses. In the south settlements are sporadically distributed due to traditional nomadic cattle breeding. (Britannica, 2019).

Angola's high urbanization rate is mainly due to the civil war, which forced many people to migrate to cities to escape the struggles in the countryside. For example, the capital Luanda, which still had 500,000 inhabitants in 1975, has grown into one of the most expensive metropolises in Africa in the wake of Angola's economic growth in recent years, and is now home to 27% of all Angolans. Other important urban centres are Benguela/Lobito, Huambo and Lubango, Soya and Cabinda, the latter being important hubs for the national oil industry. (US Commercial Service).

2.2.4 Education

Angola's education system has suffered greatly from decades of civil war. Not unexpected is the literacy rate of 66%[1]. About 85% of all school-age children attend school for an average of only 5.1 years. This is compulsory and free of charge for children between the ages of seven and eleven up to the 4th school year. The secondary school, which lasts eight years, is only completed by 10% of all Angolan children. The lack of access to education is compounded by the inadequate infrastructure and equipment of many educational institutions. The country's 17,000 teachers are mostly underqualified and too few to fill the education gap - according to the Angolan government, an additional 200,000 teachers would be needed to meet the country's minimum education requirements. (Ministry of Education Angola, 2018). Despite reforms by the Ministry of Education, the shortage of teachers and the educational infrastructure were not remedied in 2004. This is particularly problematic in view of the growing population.

It is unclear how many Angolans have access to higher education institutions such as universities. The figures vary from 0.7% to 4%. The country has several state, private and church universities. The Universidade Agostinho Neto in the capital Luanda is one of the oldest state institutions of higher education dating back to colonial times. In the meantime, the university has scattered about 40 institutions throughout the country. Among the well-known private universities are the Universidade Jean Piaget de Angola in Luanda and Benguela. In addition, an Islamic university with grants from Saudi Arabia is currently being completed. However, many wealthy families send their children abroad to study.

Due to Angola's young population structure, youth unemployment is one of the country's biggest problems. In 2018, 19% of all young people aged 15-24 were unemployed. (UNDP, 2018). This figure has fallen slightly compared to previous years due to Angola's interpretation of industrialisation and large-scale vocational training reforms. Since 2004, 450 decentralised vocational training centres have been set up under the direction of the Ministry of Public Administration, Employment and Social Security (MAPESS) to provide young people with the necessary qualifications for integration into the labour market within a short period of time. (FormPRO, 2019). However, these short-term training centres, often run in collaboration with international partners, are not a long-term solution to Angola's educational gap and youth unemployment.

2.2.5 Income and employment

Angola occupies one of the last places in the Human Development Index Ranking (147th out of a total of 189). Despite rich natural resources and gas and oil reserves, the country's wealth is very unequally distributed, so that only a small elite benefits. Massive corruption not only hampers the generation of sufficient government revenue, but the dysfunctional administrative apparatus also hampers the distribution of these into publicly necessary services, such as the education or health system. Coupled with Angola's rapid population growth and limited public resources, it is hardly surprising that more than half of all Angolans are considered poor (55.3%). (UNDP, 2018).

Almost one third of the population lives below the poverty line. The rural population is particularly hard hit. About 94% of the rural population is considered poor (The Borgen Project, 2016). Agriculture accounts for about 11% of Angola's gross domestic product and employs

[1] Due to differing information from NGOs and the government, this figure is unfortunately not reliable.

about half the population. (UNDP, 2018). Other industries are the service sector, in which about 40% of all employees work and the industrial sector with 8.7% of all employees. (World Bank, 2016). The poverty rate of 55% is surprising given the relatively low unemployment rate (excluding youth unemployment) of 8.2%. However, about 60% of the working population is considered to be "working poor". One measure to remedy this was to raise the minimum wage by 30% to a maximum of 32.181 Kwanzas (USD 102.5) per month in raw material extraction and trade. (ANGOP, 2019). However, in view of the complex link between the marauded education system, the high population growth rate and the dysfunctional corrupt state and administrative apparatus, it remains to be seen whether this reform can bring about lasting change.

2.2 Political change and economic development

Angola's civil war broke out immediately after Angola's independence in 1975. The socialist MPLA (People's Movement for the Liberation of Angola), supported by the Soviet Union and Cuba, was able to win the war in 2002 after the death of the UNITA leader (National Union for Angola's Independence), supported by South Africa and the U.S., however, and has since profited from its position as a ruling party, through advantages in campaign financing or the general strong power of the executive branch.

With the enactment of the third constitution in 2010 and the peaceful presidential elections in 2017, the country is now experiencing a democratic change that offers new opportunities for freedom. (US Commercial Service). With a GDP of 105.9 (2018) billion US dollars, Angola is now one of the larger economies in sub-Saharan Africa.

However, macroeconomic analysis considers Angola to be one of the least competitive countries in Southern Africa. There are many reasons for this, including the fact that many sectors are dominated by mostly monopolistic companies that are closely linked to the country's political elite. Another reason is the above-mentioned massive corruption, which hampers the sustainable development of the country. The NGO Transparency International annually assesses corruption in Angola and ranked the country at the bottom of the *Corruption Perception Index*. The country occupies 165th place out of 180 countries. (Transparency International, 2018). The Angolan government has also introduced numerous reforms to combat corruption. The Financial Action Taskforce, an independent body for monitoring compliance with money laundering and counter-terrorism measures, has already acknowledged Angola's progress and has not been active in the country since 2016. However, additional measures to reform the Angolan banking sector and make it less vulnerable to corruption have been neglected.

Another problem of the Angolan economy is its dependence on the oil industry. Oil accounts for more than 95% of Angolan exports (DLA Piper, 2018)contributes 50% of GDP, and accounts for 75% of government revenue. (US Commercial Service). However, this has led the country to become highly dependent on commodity prices. Since 2014, Angola has faced a significant economic downturn, mainly due to the international decline in oil prices and the associated sharp decline in foreign currencies in the country. This entailed high national debt, budget cuts by the state, devaluation of the national currency Kwanza, high inflation rates and lower import rates.

It is questionable whether this recession is not also a consequence of Angola's necessary adaptation to the international economic system. What is certain, however, is that the government has introduced a large number of reforms. For example, it is committed to economic diversification and the development of national production capacities. (US

Commercial Service). Since 2016, inflation has also risen from 32% to 16.94% in June 2019. (BNA, 2019) and is thus the lowest rate since 2015. (Trading Economics, 2019). However, Angola's reference rate remains high, at 15.5% in July 2019 (BNA, 2019).

Angola's industrial sector (according to the Angolan Institute of Statistics, INE) is divided into four sectors: the commodity sector (oil, diamonds and others), the manufacturing sector and the production and distribution of electricity and water. Electricity and water are considered here as two separate areas. Table 2 shows the growth of the most important industrial sectors from 2014 to 2017 (AHK, 2018).

Industrial sector (in %)	2013	2014	2015	2016	2017
raw material extraction	0.3	-2.4	7.7	-2.9	-5.4
Processing industry	0.9	10.2	1.9	-3.5	5.6
Energy	33.6	16.8	7.2	12.9	1.1
Water	-0.5	10.3	4.9	-0.6	6.7

Table 1: Overview of industrial sectors (AHK, 2018)

As Table 2 shows, the slump in growth in the sectors in 2014 as a result of the international decline in oil prices is clearly visible (AHK, 2018). This trend has been reversed since 2017. Several manufacturing sectors grew, such as beverages and tobacco (3.2%), textiles (2.6%), printing and paper (5.2%), machinery and equipment (4.8%) and furniture (9.5%). (AHK, 2018). Although oil exports will continue to be an important source of foreign exchange in the future, their share of the overall economy is expected to decline steadily, while other sectors are developing. (PwC).

However, an institutional framework is still lacking to promote the diversification of the economy. As a result, diversification is slow. In addition, a weak business climate is hampering industrial growth (PwC) (for more information see chapter 2.3).

Another obstacle to investment in sectors other than the oil industry is the poor quality of the country's transport infrastructure. This was either severely damaged during the civil war or was affected by the periodic floods of the rainy season. Angola is one of the few African countries to have no major infrastructure financing gap, mainly due to its large oil reserves. However, reconstruction is progressing only slowly. This is primarily the result of mismanagement, such as overambitious goals, unrealistic planning and budgeting, and corruption. In addition, the pro-cyclical financing of projects led to an increase in public debt.

The Luanda-Bengo Special Economic Zone (SEZ), established in 2009, is an exception to the Angolan business climate and infrastructure restrictions. It offers tax incentives to 20 resident companies through a legal basis to simplify private investment. Other benefits include a more reliable electricity and water supply and better access to transport infrastructure. (US Commercial Service).

One focus of the Angolan government is the energy industry. With regard to industrial competitiveness, the Angolan Government has set itself the following energy targets for 2025 (Ministério de Energia e Aguas de Angola , 2018):

- Improve the efficiency of public utilities,
- Introduction of a new market system that allows cost savings, and

- Develop a new regulatory model that promotes efficiency.

The government is also organising a number of events aimed at promoting national energy production and facilitating business relations between companies from different sectors. One of these events was the *Expo-Indústria, which took* place from 14 to 17 November 2018 in Luanda. More than 300 exhibitors took part in the fair, who want to promote the economic and industrial potential of the country, which will also help to create jobs and reduce imports.

2.3 Inflation and interest rates

Angola's inflation rate is very high. Since 2015, the national currency has lost its value as the National Bank of Angola (BNA) has been asked to stabilise Angola's economy. Inflation was 20.46% in 2018, compared with 29.84% in 2017. (Statista, 2019).

In 2016, the *Financial Action Task Force (FATF)* acknowledged Angola's progress in combating money laundering and terrorist financing and lifted its monitoring of the country. Nevertheless, BNA had difficulty in carrying out a reform of the Angolan banks. (US Commercial Service).

2.4 market access

Angola is a signatory of SADC, a regional economic community with 16 member states[2]. Founded in 1992, SADC is committed to regional integration and poverty reduction in Southern Africa through economic development and peace and security. (SADC, 2019). The SADC has also established a free trade area to which Angola could belong in the future. In January 2019, the Minister of Trade of Angola expressed the intention to take steps to fulfil the necessary conditions for entry. Moreover, Angola's only important cooperation in the SADC zone is currently limited to the Trans-Cunene Corridor and the Cunene Basin project with Namibia.

Angola's growth is hampered by the country's weak business climate. In 2019, the World Bank updated its *Ease of Doing Business* Ranking for 190 countries worldwide that were evaluated in various business areas. Angola was ranked 147th in the ranking (World Bank, 2019). Some of the reasons for this position are poor performance of contracts, inefficient tax bureaucracy and difficulties in starting a business. The authorisation to start a commercial activity can take up to 45 days. (Doing Business 2020, 2019). Here, too, numerous government reforms were introduced from 2018 to 2019 to improve the business climate. Among other things, however, this has resulted in increased requirements for the documentation of import and export transactions.

Angola's main trading partners are China and the USA, followed by France and South Africa. (PwC). Angola is also Germany's fifth largest trading partner from sub-Saharan Africa. Direct participation of German small and medium-sized enterprises is rare and works, if at all, via a local sales partner. (AHK, 2018). Companies that already have experience in Africa could have advantages when entering the Angolan market. However, according to AHK, a lot of time and financial resources have to be invested in order to be successful in the country, as the business environment is still considered difficult. Portuguese companies that have been active in Angola for a long time are an opportunity for cooperation. In addition, an established Angolan business

[2] These include Angola, Botswana, the Comoros, the Democratic Republic of Congo, Eswatini, Lesotho, Madagascar, Malawi, Mauritius, Mozambique, Namibia, the Seychelles, South Africa, Tanzania, Zambia and Zimbabwe.

partner who is familiar with local business processes is critical to business success. (US Commercial Service).

3. market potential for solar energy

3.1 Energy Strategy Angola Energia 2025

Angola is a resource-rich country in the field of power generation. In addition to fossil fuels and large hydroelectric power plants, the country has so far used small capacities of renewable energies from biomass, solar and wind energy and small hydroelectric power plants.

The "Angola Energia 2025" government's energy plan and strategy published in 2016 is a roadmap for Angola's energy sector until 2025. The goal is to meet the country's energy needs by 2025 through efficient resource distribution while maximizing people's well-being. According to the *Angola Energia 2025* Plan, the electricity mix for 2025 should be designed taking into account energy security, regional development, economic and environmental criteria. (Ministério de Energia e Águas de Angola, n.d.).

According to this energy plan, energy demand is expected to more than quadruple by 2025, from 1.6 GW in 2013 to 7.2 GW. The growth drivers for the rising energy demand are expected to be a significant increase in the rate of electrification among the rural population, an increase in electricity consumption in private households, further industrialisation of the country and growth in the service sector. (Ministério de Energia e Águas de Angola, n.d.).

On the generation side, the government accordingly plans to increase capacity from 4.7 GW in 2019 to 7.5 GW in 2022 by 2025. Of the 7.5 MW, 800 MW are to be generated with renewable energies. (Ministério de Energia e Aguas de Angola , 2018).

According to the energy strategy, by 2025 6.5 GW (66%) will be generated from hydropower and 1.9 GW (19%) from natural gas. (Ministério de Energia e Águas de Angola, n.d.). With a total of 159 identified sites for large hydropower plants, Angola has very good location factors for this type of power generation. The country also has a high potential for solar energy generation, but plans to install only 100 MW of solar capacity by 2025 (see section 3.2 for details).

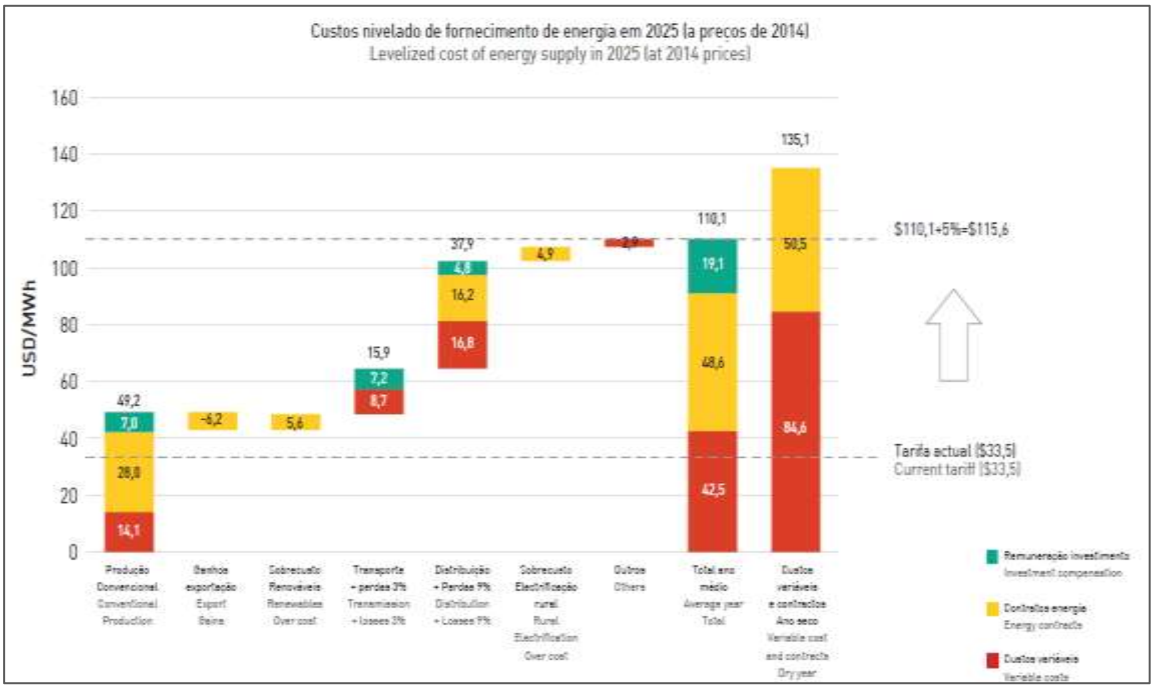
As part of the expansion of power plant capacities, the government plans to lay more than 2,500 kilometers of new power lines by 2025, expand substations in the transmission grid and develop international connections in the transmission grid in order to be able to export electricity. In addition, it has set itself the goal of rehabilitating distribution networks and connecting more than 1.5 million new consumers. A medium-term goal is to connect more than 1 million people (200,000 per year) to the distribution network between 2018 and 2022, with a focus on provincial capitals, outlying areas and municipal capitals. (Ministério de Energia e Aguas de Angola , 2018). However, investments in grid development should not be made in remote locations where high investment provides a negative cost-benefit ratio or where competitive small hydropower plants are possible (see Section 3.3 for details). (Ministério de Energia e Águas de Angola, n.d.).

One of the most pressing issues in Angola is rural electrification, as the current rate of electrification (2018) is only about 38% and the energy strategy is to raise it to 60% by 2025. (Ministério de Energia e Águas de Angola, n.d.). To this end, an agency will be set up to launch strategic policy measures. Rural electrification is to take place primarily with renewable energies. The government expects the private sector to play a large part in this. For example, electrification programmes with solar energy through so-called "solar villages" alone are expected to generate around USD 219 million in private investment (see Section 3.3.3 for more details). (Ministério de Energia e Águas de Angola, n.d.).

Another important planned measure for the successful implementation of the energy strategy is the adjustment of electricity tariffs. According to the energy plan, the currently still high energy subsidies are to be reduced, above all for urban energy supply, since the majority of electricity consumers in conurbations have sufficient income to pay non-subsidised electricity prices. And urban areas are expected to account for 90% of total consumption by 2025. (Ministério de Energia e Águas de Angola, n.d.).

Figure 1 from the Energy Strategy shows the expected costs for Angola in 2025 for the generation, transport and distribution of electricity without subsidies. The calculations show that an average tariff of 38.6 AOA/kWh or 7 €cent/kWh (exchange rate: 1:0.00181 (AOA/€) (conversion at 30.08.2019) would be sufficient to cover the total costs of electricity generation.

Figure 3: Levelled costs of energy supply in Angola in 2025



(Ministério de Energia e Águas de Angola, n.d.)

In the first four months of 2019, the subsidised electricity price in Angola averaged 11.8 AOA/kWh or 2.14 €cent/kWh ((exchange rate: 1:0.00181 (AOA/€) , conversion as of 30.08.2019). Compared to that: Most electricity consumers in surrounding African countries pay between 10 and 20 €cent/kWh. The *Decree Executivo n.°122/19* of 24 May 2019, issued by the Ministry of Finance of Angola, began to reduce subsidies for the price of electricity. Since then, prices for electricity from the grid have risen to up to 14.74 AOA/kWh (2.675 €cent/kWh) (exchange rate: 1:0.00181 (AOA/€)). According to the energy strategy, the companies and experts surveyed within the framework of the project expect a further reduction in subsidies and thus a further increase in grid electricity prices. In addition, despite the currently stable diesel prices of around 135 AOA/litre (34.22 €cent USD/litre, (exchange rate: 1:0.901 US$/€) as of 30 August 2019), the AHK expects a reduction in subsidies for diesel fuel and a concomitant increase in diesel prices in the near future.

3.2 Ressure potential

As mentioned above, the energy plan envisages installing a total capacity of 800 MW of renewable energy by 2025. Of this, 100 MW of solar energy is to be added. In 2018, the plan was once again adjusted from MINEA to 200 MW by 2025. (Ministério de Energia e Aguas de Angola , 2018).

The average horizontal global radiation in Angola is 2,160 kWh/m2/year, which is twice as much as the value of Germany. Solar energy thus offers the best conditions for decentralised power generation. (Ministério de Energia e Águas de Angola, n.d.).

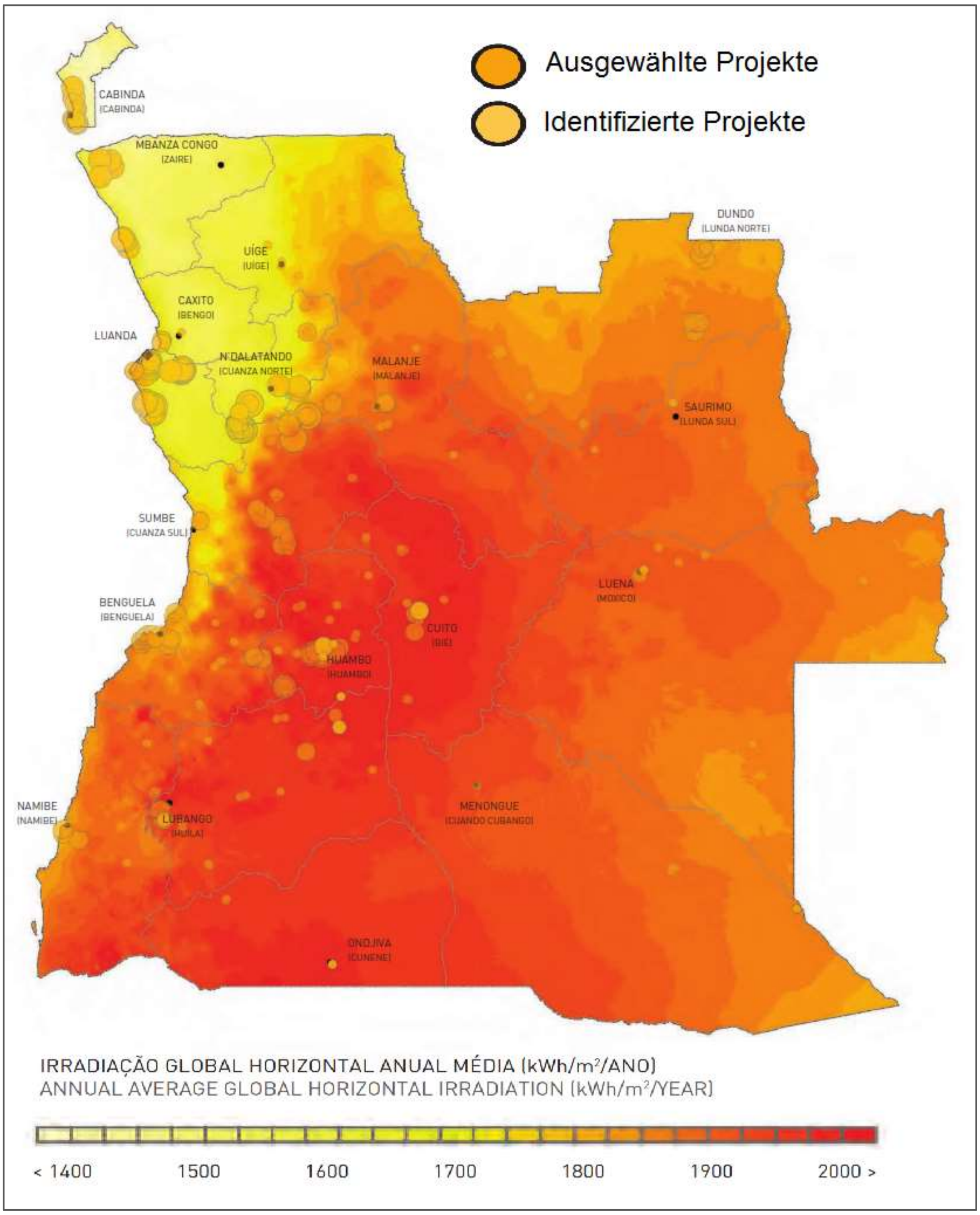


Figure 4: Solar resources, identified and selected projects to achieve the 100 MW target (Ministério de Energia e Águas de Angola, n.d.)

According to the plan, photovoltaic (PV) systems in combination with diesel generators should significantly reduce the consumption of fossil fuels, as these have already been identified as an economic alternative in calculations for the energy plan. The use of electricity storage systems would make diesel generators completely superfluous, but would also significantly increase the investment costs for the PV system. Therefore, according to the plan, storage tanks are to be used primarily for smaller applications in areas that are difficult to access, where the costs for transporting the fuel and thus the production costs of diesel electricity are very high, i.e. economical application of the solutions is also possible with storage tanks. (Ministério de Energia e Águas de Angola, n.d.). In addition, the plan assumes that prices for PV components will continue to fall over the years in Angola.

In the field of rural electrification, a potential of 22 MW was identified for PV systems: Of these, 10 MW will be provided by so-called "solar villages" with mini grids (see also Chapter 3.3.2), another 10 MW with PV diesel hybrid systems in cities and 2 MW at PV installations in Rivungo, a small town in the southeast of the country.

3.3 Expansion of the electricity grid infrastructure

The feeding of electricity from decentralised renewable energies such as solar energy into the existing electricity distribution network has not been regulated in Angola to date. For the use of solar energy, the government focuses instead on the above-mentioned rural electrification and its strategy for this is based on economically viable solutions and the socio-political approach of reducing regional differences and directing investments in such a way that a uniform level of development can take place in the country. Currently, the income gap between Luanda and other larger cities and the rest of the country is very large.

Since Angola's electrification requires large financial resources, the government says the investments must be distributed and used efficiently and effectively. The expansion of the network is therefore geared to consumers.

- Demand determination: Identification, geographical classification and characterisation of all populated places and industrial areas according to their current and future electricity consumption;
- Electrification planning: All sites to be connected to the grid after expansion were identified. Places that are not connected to the grid are to be electrified by off-grid decentralised generation systems;
- Electrification models: Three models have been proposed to prioritise investment and electrification by 2025, taking into account the country's electrification target of 60%. These three models are described below (see sections 3.3.1, 3.3.2 and 3.3.3).

3.3.1 Rural electrification with grid expansion

This rural electrification strategy takes into account existing distribution networks outside large urban areas. The further expansion of the national transmission grid is expected to reach 174 sites by 2025, covering around 5% of the Angolan population (equivalent to approx. 1.5 million inhabitants). The following figure shows all municipalities that are to be connected to the national grid. This significantly reduces the costs of operating the distribution networks, which in turn can facilitate the involvement of the private sector. It is planned to build 60 kV substations from existing or planned 220 kV substations, usually located in the municipalities mentioned above.

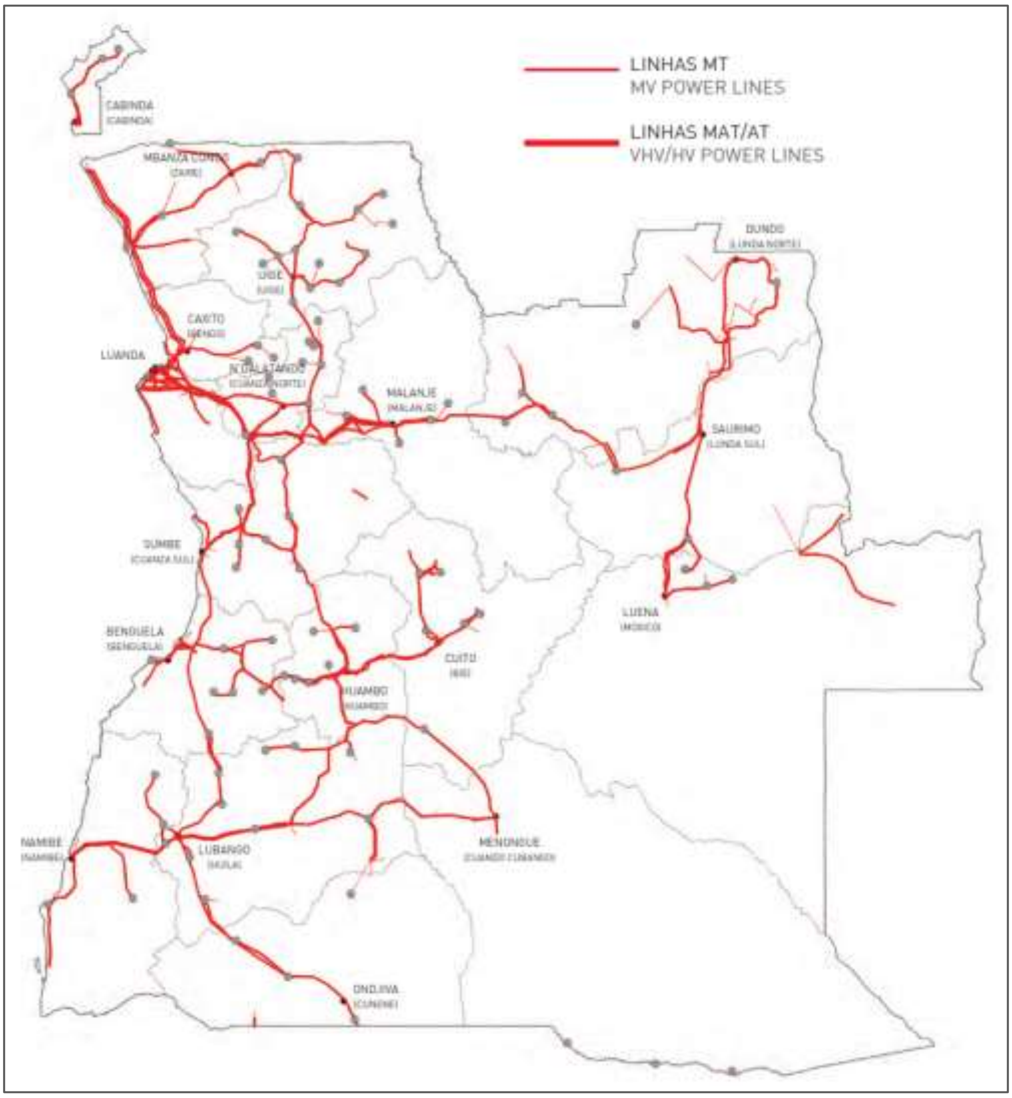


Figure 5: Electrification of communities outside large urban areas through the expansion of the national electricity distribution grid (Ministério de Energia e Águas de Angola, n.d.).

3.3.2 Rural electrification with mini grids

For other regions with too high grid expansion costs due to too great distances to the power distribution grid, the government will pursue decentralized solutions for power supply. The energy plan considers 31 locations (around 1% of the population) that can be supplied with small hydropower, diesel or PV solutions. Municipalities located in the vicinity of competitive small hydropower plants have hardly any advantages by being connected to the national power grid, so it is economically unattractive to connect such locations centrally. Instead, small hydropower plants with the lowest generation costs are to be re-dimensioned and networked with mini grids, taking into account the load of nearby villages and rural grids. In the process, seven small hydropower plants were identified in nine municipalities (see Figure 6 below). In addition, a site was identified for a hydroelectric power plant on the Cuango River, which could supply four other communities with around 300,000 inhabitants.

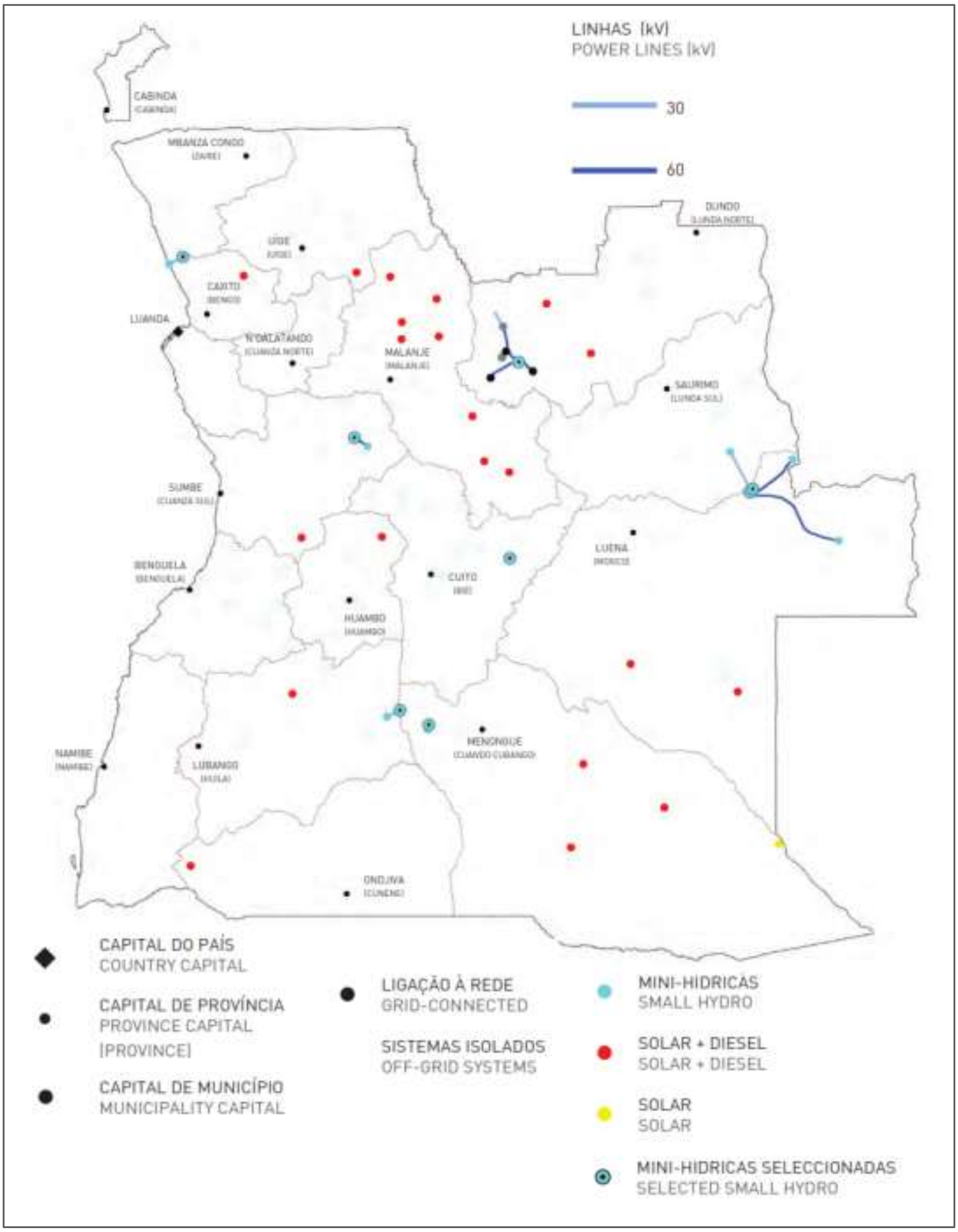


Figure 6: Off-grid supply systems (Ministério de Energia e Águas de Angola, n.d.)

For 21 municipalities, the grid connection costs are so high that they are to be electrified using PV diesel hybrid solutions and mini grids. Ten of the planned mini grids are listed in Table X below.

One city from the list was chosen because of the very high diesel costs to be supplied with 100% solar power: the capital of the Rivungo region in Cuando Cubango. If successful, this approach will be extended to other remote and solar resource-rich communities in Angola.

province	district	Capital of the district
bengo	ambiance	ambiance
beer	Cuemba	Cuemba

Cuando Cubango	Cuchi	Cuchi
Cuando Cubango	Rivungo	Rivungo
Cuanza Sul	must end	must end
Huíla	cuvango	cuvango
Luanda Sul	muconda	muconda
moxico	Alto Zambeze	Cazombo
moxico	Luacano	Luacano
moxico	luau	Luao

Table 2: Electrification projects with off-grid renewable energy systems in district capitals by 2025 (Ministério de Energia e Águas de Angola, n.d.)

3.3.3 Rural electrification with solar villages

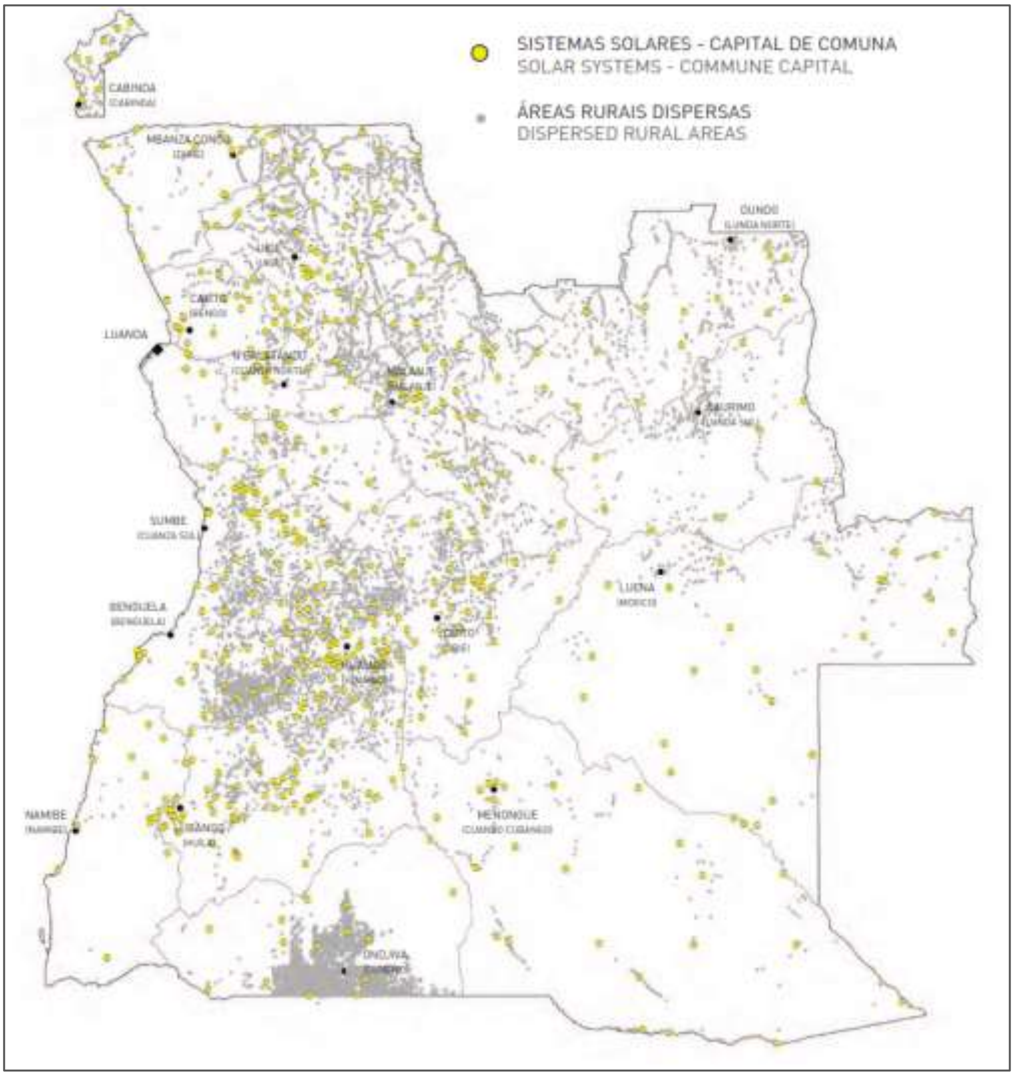


Figure 7: Proposed locations for solar villages and remote rural areas (Ministério de Energia e Águas de Angola, n.d.)

This plan provides for the creation of solar villages with small local networks in municipalities with more than 3,000 inhabitants. This will supply electricity to public institutions such as schools, health centres and public lighting. This could be developed and financed by the private sector. Even remote locations could benefit from solar lanterns and stoves.

The Angola Energia 2025 Energy Plan aims to realize a total of 500 such solar villages by 2025. The following map shows some site proposals for the implementation of 500 solar villages and other remote locations where connection to the central network or the installation of mini grids is not considered economical (see Figure 7).

3.4 Financial framework for investments in solar energy

There are currently no loans or funds in Angola to support environmental technologies or renewable energy projects. (DLA Piper, 2018)

There are 28 registered commercial banks in Angola, operating mainly from Angola, Portugal and South Africa. Five of these banks - Banco Angolano de Investimentos (BAI), Banco Economico, Banco de Fomento Angola (BFA), Banco BIC Angola (BIC) and Banco de Poupança e Crédito S.A.R.L. (BPC) - control more than 80% of total bank balances, deposits and loans. Angolan banks offer few unsecured loans and require substantial amounts (125%) of collateral from the borrower in the form of real estate or dollar deposits. Trade credits are still limited. Some loans are denominated in foreign currencies, but are then weighted at 130% for the calculation of risk-weighted assets. (US Commercial Service).

Companies operating in Angola must make payments in local currency (Kwanza) and through local banks, including payments to suppliers and contractors located outside Angola. The purpose of this law is to strengthen the demand for Kwanza and thus expand the performance of the Angolan financial sector. (US Commercial Service).

4. three case studies for PV applications in Angola

In August 2019, eclareon calculated the profitability of three different PV application cases on the basis of the above studies on the current investment framework for PV in Angola:

1. Grid-connected PV system for self-supply
2. PV diesel hybrid system without accumulator
3. PV diesel hybrid system with storage tank

The profitability of these projects was calculated using cash flow modelling. The necessary information was collected during the preparation of this study and through additional interviews with the German Chamber of Foreign Trade in Angola, the German Embassy in Luanda and two companies with experience in the implementation of PV hybrid systems in sub-Saharan Africa.

4.1 PV system for self-supply

A profitability analysis for a grid-connected PV system for self-consumption with diesel backup unit is presented below.

PV Project		
PV System Size	kWp	852,00
Specific System Cost	AOA/kWp	585.000
PV Battery Size	kWh	-
Specific Battery Costs	AOA/kWh	-
Total System Cost	AOA	498.420.000
Fixed Operation Costs	AOA p.a.	7.476.300
Variable Operation Costs	AOA/kWh	-

PV Generation		
Global Tilted Irradiation (GTI)	kWh/qm/a	2.313
Performance Factor	%	80%
Specific Yield	kWh/kWp/a	1.850
Degradation	% p.a.	0,70%

Investment			
Project Duration		Years	20
Equity		AOA	498.420.000
Debt (Gearing)	-	AOA	-
Loan Tenor		Years	10
Interest Rate		%	17%
Discount Rate		%	18%
Inflation Rate		%	17%

PV Business Model		
PV Self-Consumption	%	80%
Grid Electricity Price	AOA/kWh	12,82
Backup Diesel Replacement	%	15%
Diesel Generation Costs	AOA/kWh	45,00
Price Escalation (Fuel/Grid)	% p.a.	16%

Results		
Net-Present Value	AOA	(26.678.601)
Project IRR	%	17,34%
Equity IRR	%	17,34%
Payback Period	Years	-
LCOE (no subsidy)	AOA/kWh	78,63
Min DSCR**	x	-
Min LLCR***	x	-

* LCOE: Levelized Cost of Electricity
** DSCR: Debt Service Coverage Ratio
*** LLCR: Loan Life Coverage Ratio

Figure 8: Project overview - PV system for self-sufficiency without memory (eclareon; 2019)

suppositions

As mentioned in Chapter 3.3, there is no regulation in Angola for the feeding of privately produced electricity from solar energy into the electricity grid. Therefore, no income from electricity fed into the grid is taken into account in the present case. The defined input parameters represent an industrial system that supplies a large industrial load with a diesel backup system that ensures uninterrupted supply in the event of power failures. The PV system generates savings by replacing mains power and reducing the power requirement of the diesel generator. 80% of the PV electricity generated is consumed on site and 15% is used in the event of power outages. The last 5% is considered a loss that occurs, for example, when the PV system generates electricity but cannot be used efficiently due to the lack of electricity consumption. This assumption requires very professional PV system planning. According to *Decree Executivo n.°122/19, the* grid electricity price for the industrial sector is set at 12.82 AOA/kWh and the cost of diesel at 45 AOA/kWh, assuming an annual cost increase of 20% in the first five years and 16% after five years. These high growth rates are linked to the high inflation rate in Angola, which is expected to start at 17% (2019) and fall to a lower level of around 12% by 2022, following the current trend, where it stagnates until the end of the asset's useful life. The diesel price increase is always set above the inflation rate, based on the government's plans to cut subsidies.

Although the PV modules have a lifetime of 25 years, their economic use is set at 20 years. A longer observation period does not apply due to the high inflation rates. Here, too, solar radiation of 2,313 kWh/m2/year is assumed. The project is financed entirely with equity capital.

outcomes

As Figure 7 shows, even with the best possible solar irradiation conditions in Angola and professional PV system planning and installation, the initial investment will not be written off within 20 years. This is mainly due to the currently still very low grid electricity price for industrial consumers. The cash flow for the case is as follows:

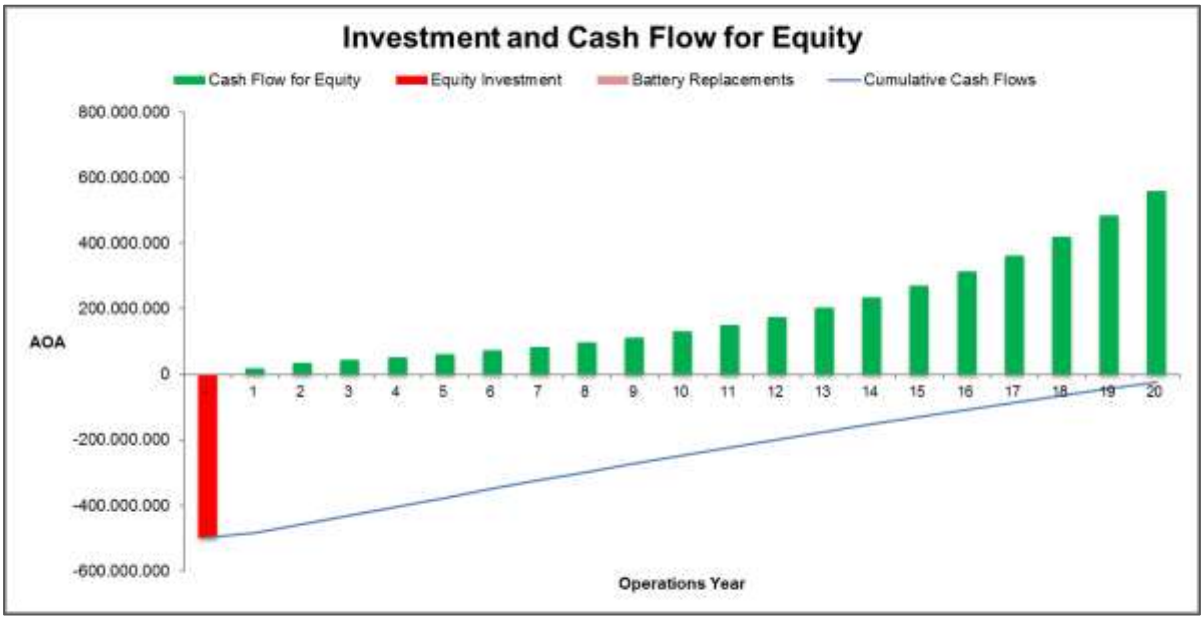


Figure 9: Equity capital cash flows - grid-connected PV system for self-sufficiency without storage (eclareon, 2019)

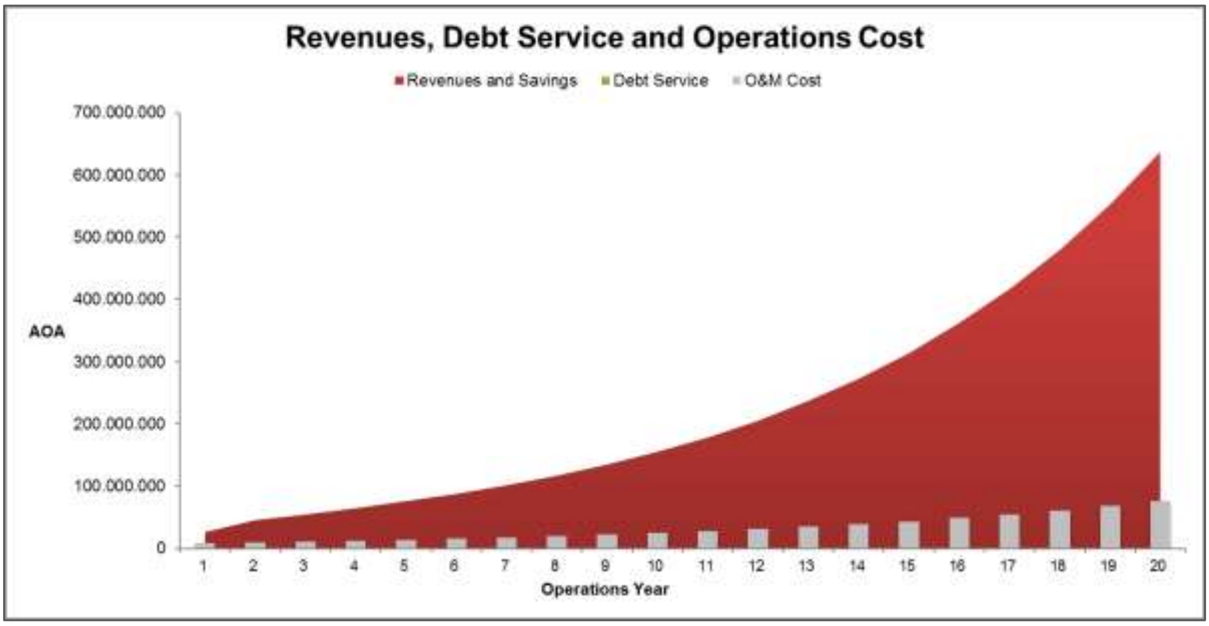


Figure 10: Project cash flows - grid-connected PV system for self-sufficiency without storage (eclareon; 2019)

External financing was not taken into account in this case because of the unfavourable economic situation. The assumed revenues from savings and operating costs increase over time at a comparable rate due to the inflation rate.

sensitivity analysis

The analyses show how the two economic indicators for the investment, the amortization period (amortization) and the internal rate of return on equity (equity IRR) change when certain parameters in the framework conditions change. It becomes clear which changes in the individual assumptions have a particularly strong influence on the profitability of the investment (high sensitivity). This has to be considered carefully during the investment.

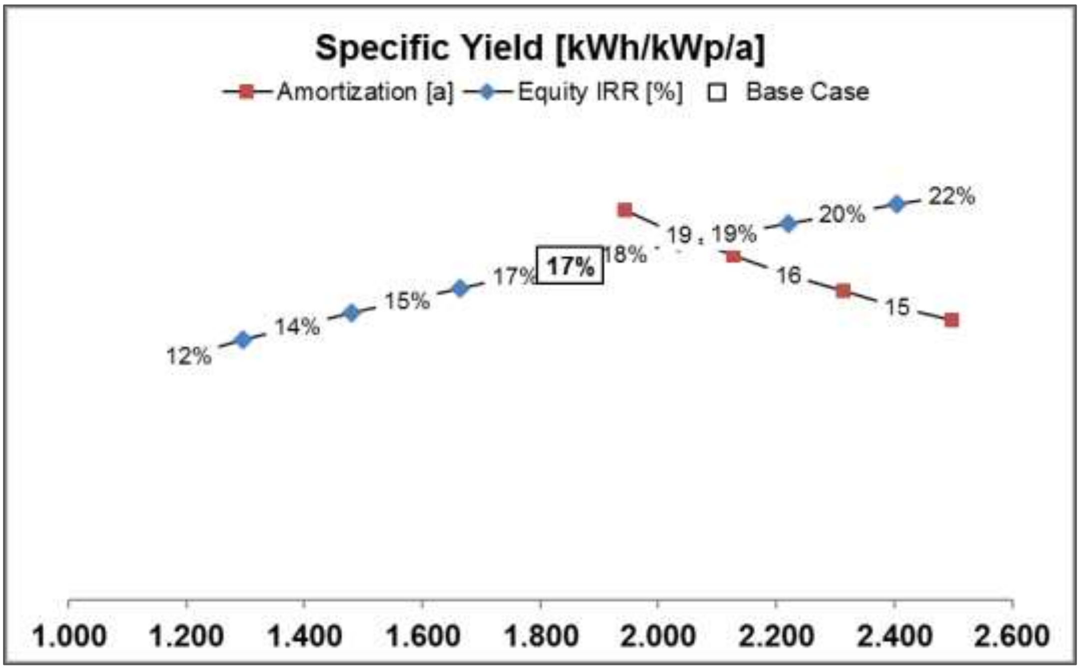


Figure 11: Sensitivity analysis: Yield - grid-connected PV system for self-sufficiency (eclareon; 2019)

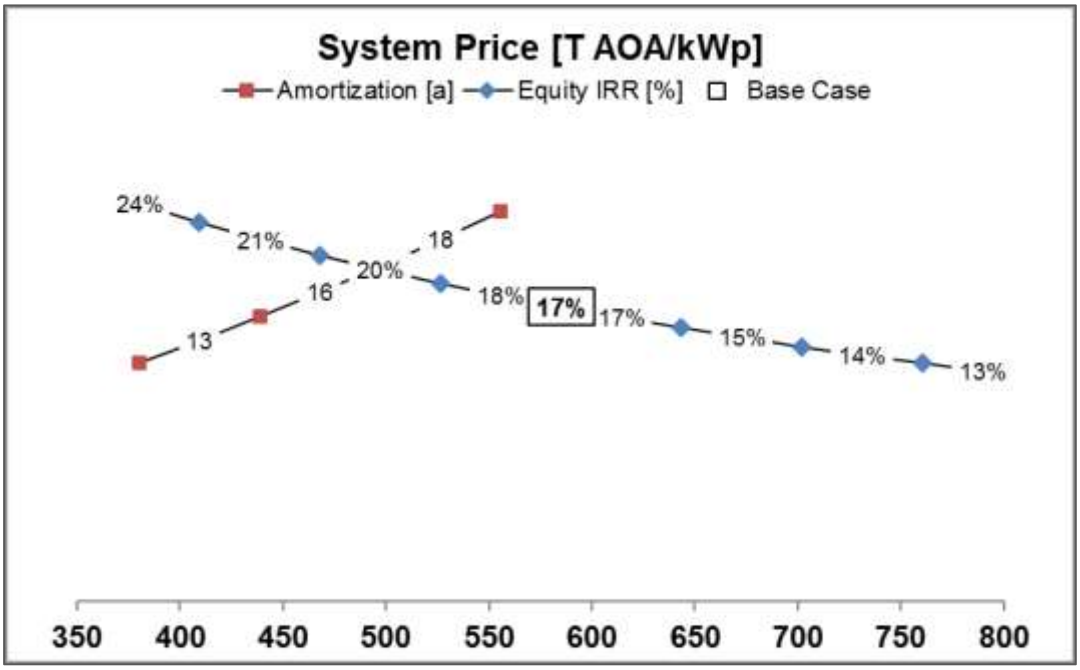


Figure 1: Sensitivity analysis: System price - grid-connected PV system for self-sufficiency (eclareon; 2019)

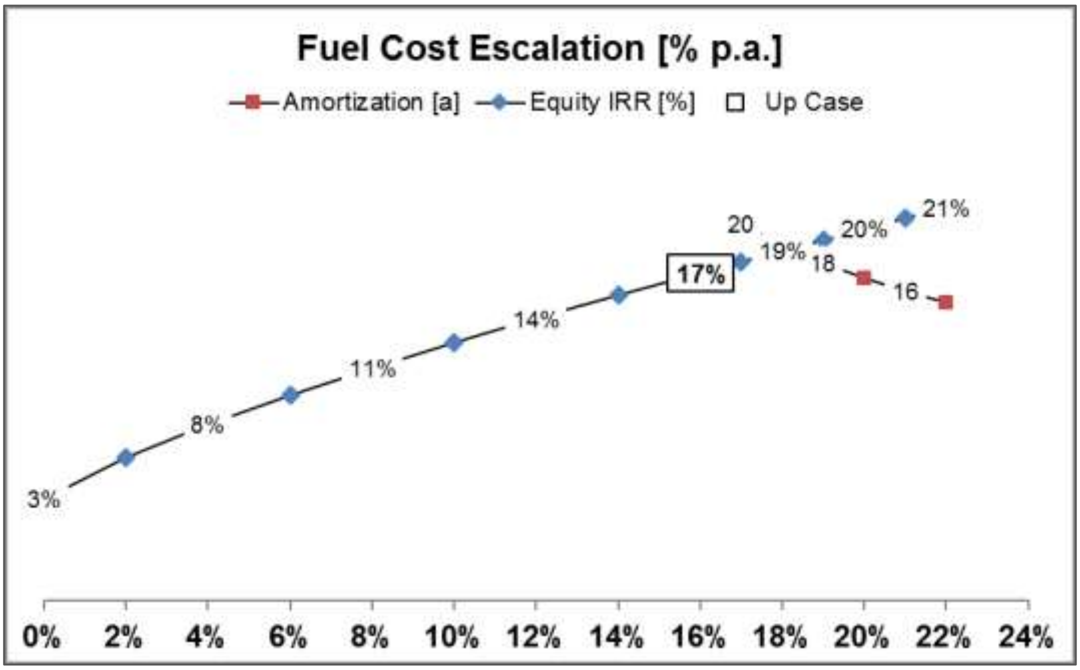


Figure 13: Sensitivity analysis: Fuel cost increase - grid-connected PV system for self-sufficiency (eclareon; 2019)

3.2 PV diesel hybrid system without storage tank

A profitability analysis for a PV diesel hybrid system without storage (battery) based on diesel savings is presented below. The system is designed exclusively for captive use.

PV Project			
PV System Size		kWp	380,00
Specific System Cost		AOA/kWp	750.000
PV Battery Size		kWh	-
Specific Battery Costs		AOA/kWh	-
Total System Cost		AOA	285.000.000
Fixed Operation Costs		AOA p.a.	4.275.000
Variable Operation Costs		AOA/kWh	-
PV Generation			
Global Tilted Irradiation (GTI)		kWh/qm/a	2.313
Performance Factor		%	80%
Specific Yield		kWh/kWp/a	1.850
Degradation		% p.a.	0,70%
Investment			
Project Duration		Years	20
Equity		AOA	216.290.324
Debt (Gearing)	25%	AOA	71.250.000
Loan Tenor		Years	7
Interest Rate		%	18%
Discount Rate		%	20%
Inflation Rate		%	17%

PV Business Model		
Direct PV Consumption	%	95%
PV Consumption via Battery	%	-
Battery Losses	%	-
Diesel Generation Costs	AOA/kWh	45,00
Price Escalation (Fuel/Grid)	% p.a.	20%
Results		
Net-Present Value	AOA	77.691.657
Project IRR	%	23,16%
Equity IRR	%	23,68%
Payback Period	Years	12,26
LCOE (no subsidy)	AOA/kWh	99,83
Min DSCR**	x	1,66 x
Min LLCR***	x	2,65 x

* LCOE: Levelized Cost of Electricity
** DSCR: Debt Service Coverage Ratio
*** LLCR: Loan Life Coverage Ratio

Figure 14: Project overview - Captive PV diesel hybrid system without memory (eclareon; 2019)

Assumptions for this PV business model

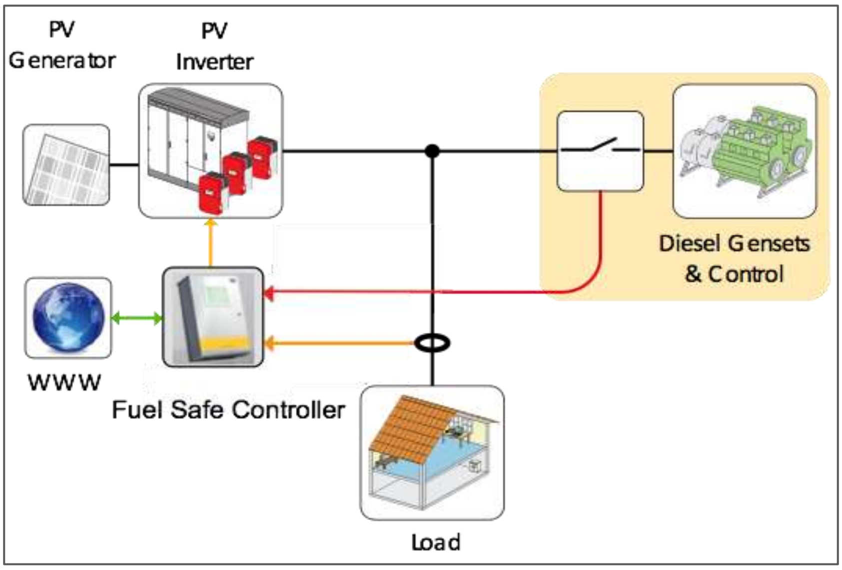


Figure 15: Intelligent and fast interface between load, generator and PV inverter - Fuel Save Controller (SMA Solar Technology)

Together with the connected current collector, the diesel generator forms the higher-level system and builds the electrical grid. This also applies if the PV electricity is fed into the grid. PV electricity production can be considered a negative load. The fuel economy regulator does not control the generator, but the PV power system to keep the generator within fuel-saving operating conditions.

Diesel generators must be operated with at least 30% of the installed power in order to avoid inefficient use. In addition, the generators in this business model would have to run 24 hours a day, 7 days a week. A sufficient load profile during the day (sunshine) is assumed to reduce fuel consumption. In general, a 60% PV share with fuel economy regulator is recommended if no storage is planned.

The useful life of the system was again (conservatively) set at 20 years. A longer observation period does not make sense due to high inflation rates. Here, too, solar radiation is estimated at 2,313 kWh/m2/year. This example generates revenue through savings in diesel fuel consumption. As in the first case, it was assumed that 95% of the electricity generated by the PV system can be used productively, while 5% is lost.

After the analysis of the diesel prices for the target groups of this business model, a price of 45 AOA/kWh generation costs with conventional diesel generators was assumed. The increase in fuel costs in the first five years is 20%, due to an expected price increase due to new legislation in Angola and a reduction in subsidies. After five years, a lower price increase, linked to inflation, is assumed. This option takes into account a leverage ratio of 25% at an interest rate of 18% (due to the high inflation rate).

Furthermore, this business model does not take into account any savings in maintenance costs for the running diesel generators. The cost savings could be considered in favour of the profitability of the PV system, as obsolete diesel generators have a high maintenance requirement. However, it could also be argued that the shortened running times and lower load increase the wear of the generators.

outcomes

As can be seen from Figure 13, the payback period under the best possible solar irradiation conditions in Angola is 12 years and the internal rate of return on equity is 24%. The *Debt*

Service Coverage Rate DSCR is 166% and offers a rate high enough to attract institutional funds, but again only at a debt ratio of 25%. This exemplary project can be regarded as the most economically viable option. The business model of a PV diesel hybrid system for self-sufficiency without storage should be taken into account when selecting future PV projects in Angola. The cash flows are as follows:

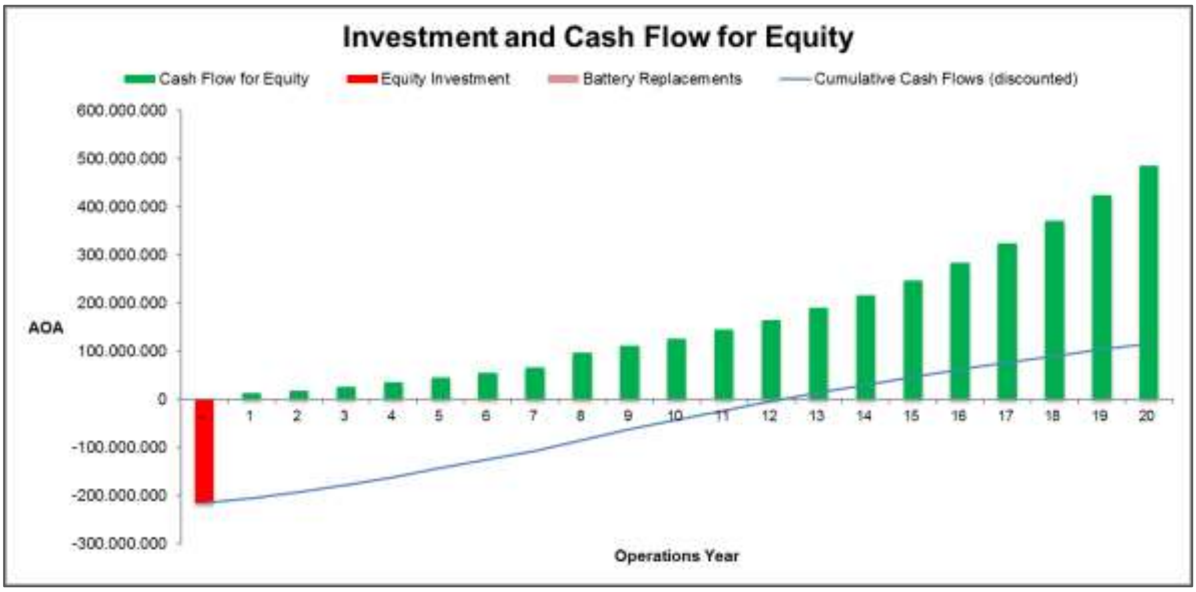


Figure 16: Equity capital cash flows - PV diesel hybrid system for self-sufficiency without storage (eclareon; 2019)

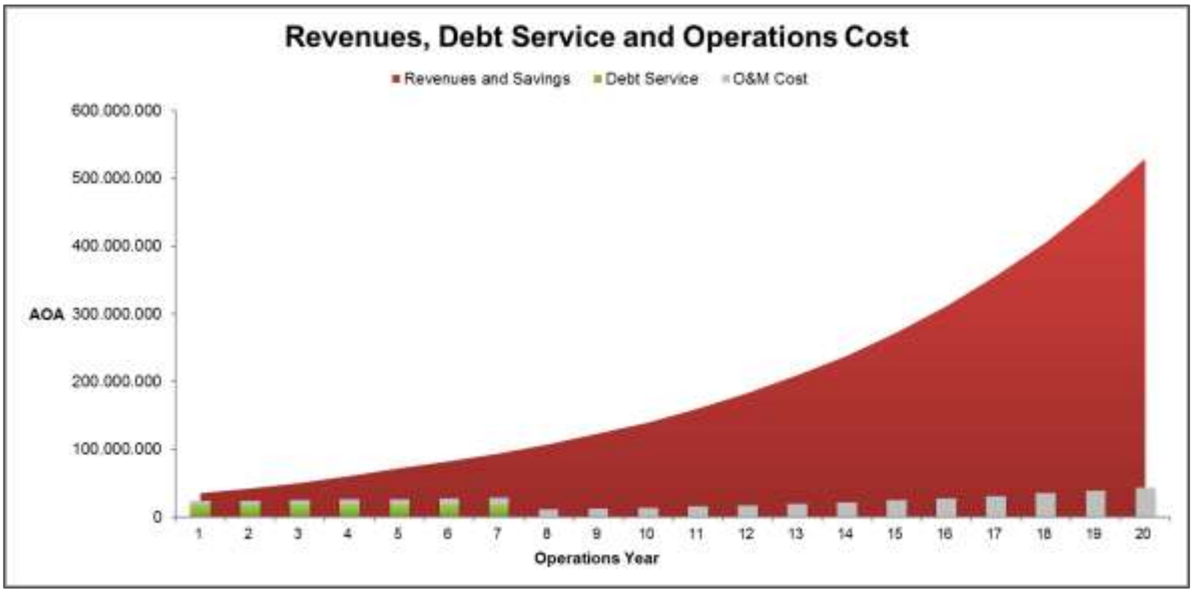


Figure 17: Project cash flows - PV diesel hybrid system for self-sufficiency without storage (eclareon; 2019)

sensitivity analysis

The following graphs show how the two economic indicators for the investment, the amortization period (amortization) and the internal rate of return on equity (equity IRR) change when certain assumptions about the investment conditions are changed.

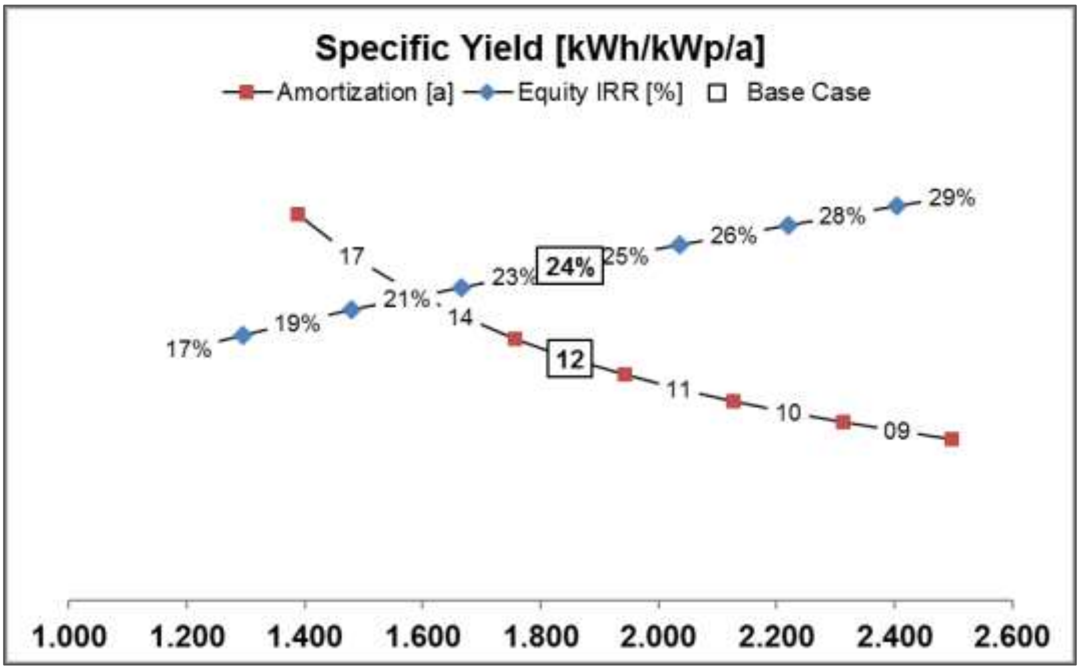


Figure 18: Sensitivity analysis: Yield - PV diesel hybrid system for self-supply without storage (eclareon; 2019)

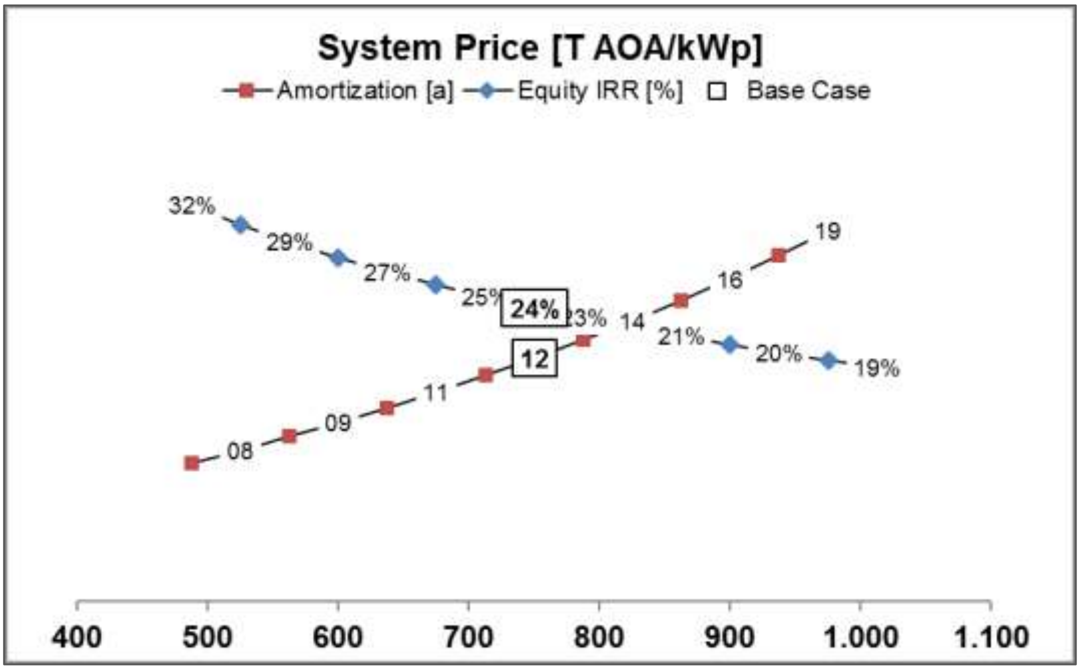


Figure 19: Sensitivity analysis: System price - PV diesel hybrid system for self-sufficiency without storage (eclareon; 2019)

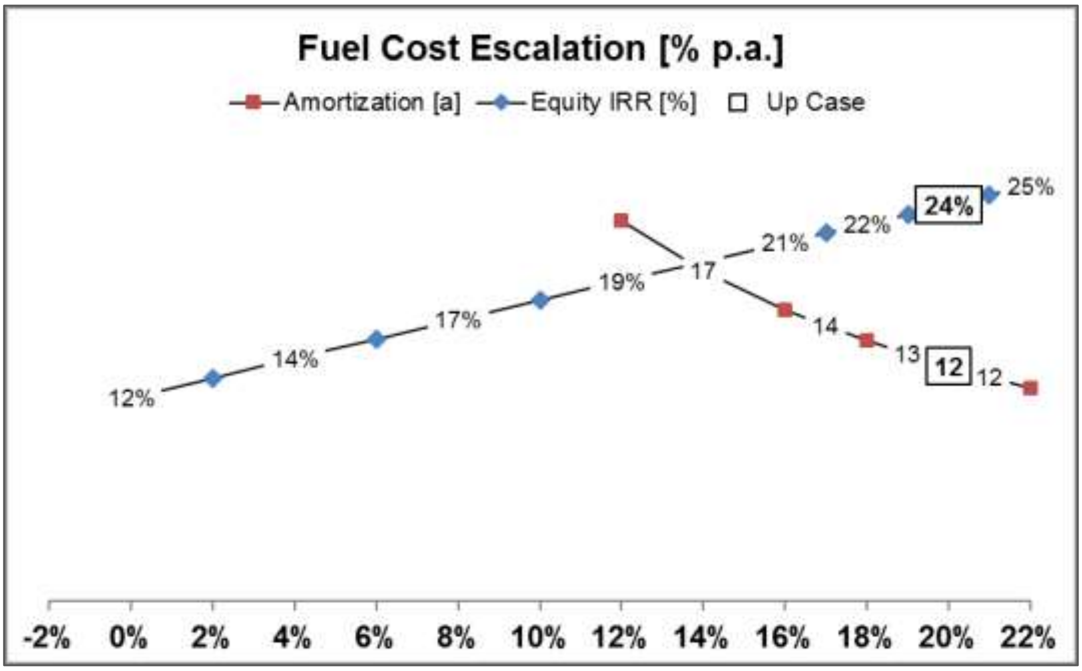


Figure 20: Sensitivity analysis: Fuel cost increase - PV diesel hybrid system for self-supply without storage (eclareon; 2019)

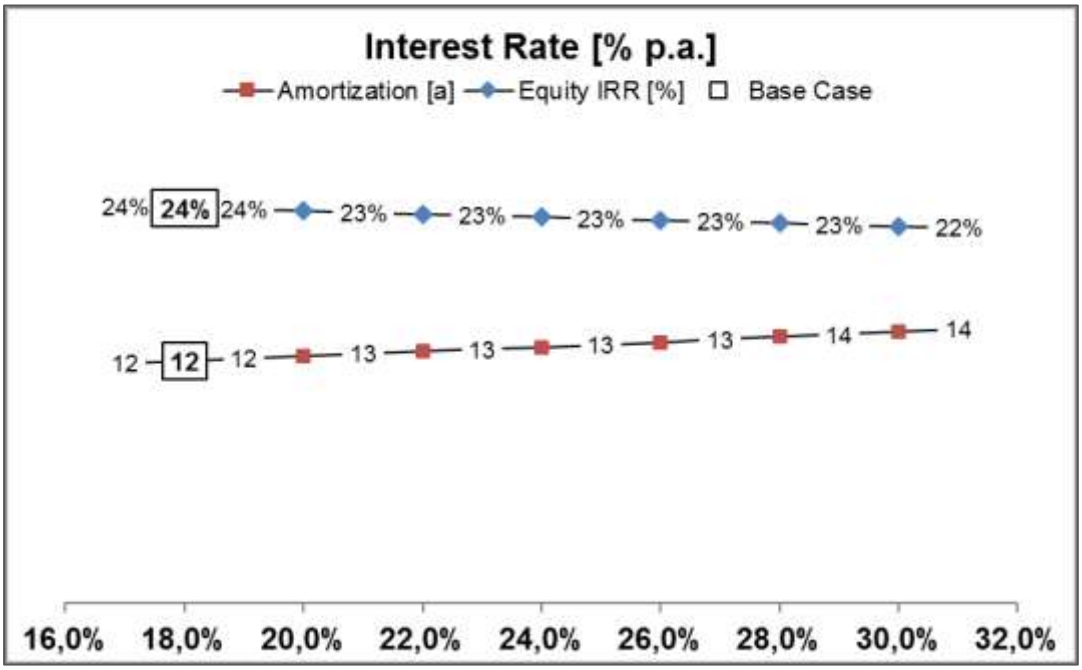


Figure 21: Sensitivity analysis: Interest rate - PV diesel hybrid system for self-sufficiency without storage (eclareon; 2019)

3.3 PV diesel hybrid with accumulator

Option 3 presents an exemplary profitability analysis for a PV diesel hybrid project with storage based on diesel savings.

PV Project		
PV System Size	kWp	75,80
Specific System Cost	AOA/kWp	700.000
PV Battery Size	kWh	150
Specific Battery Costs	AOA/kWh	300.000
Total System Cost	AOA	98.060.000
Fixed Operation Costs	AOA p.a.	1.470.900
Variable Operation Costs	AOA/kWh	-

PV Business Model		
Direct PV Consumption	%	50%
PV Consumption via Battery	%	50%
Battery Losses	%	10%
Diesel Generation Costs	AOA/kWh	45,00
Fuel cost escalation first 5 years	% p.a.	20%
Fuel cost escalation after 5 years	% p.a.	17%

PV Generation		
Global Tilted Irradiation (GTI)	kWh/qm/a	2.313
Performance Factor	%	80%
Specific Yield	kWh/kWp/a	1.850
Degradation	% p.a.	0,70%

Investment			
Project Duration		Years	20
Equity		AOA	98.060.000
Debt (Gearing)	-	AOA	-
Loan Tenor		Years	10
Interest Rate		%	20%
Discount Rate		%	18%
Inflation Rate		%	17%

Results		
Net-Present Value	AOA	(8.576.681)
Project IRR	%	17%
Equity IRR	%	17%
Payback Period	Years	-
LCOE (no subsidy)	AOA/kWh	178,62
Min DSCR**	x	-
Min LLCR***	x	-

* LCOE: Levelized Cost of Electricity
** DSCR: Debt Service Coverage Ratio
*** LLCR: Loan Life Coverage Ratio

Figure 22: Project overview - PV diesel hybrid system with storage (eclareon; 2019)

suppositions

The integration of a storage system reduces the operating time of the diesel generator and thus fuel consumption. The memory guarantees the power quality and grid stability (voltage, frequency, reactive power) and can replace the reserve and no-load operation of the generator.

The PV penetration and storage capacity can be expanded to the economic optimum and a diesel off mode can be supported. The power distribution between the generation units can help to cover the load demand in the most economical way. An additional control unit is required for this purpose.

Option 3 is calculated using new storage technology (lithium) with a high degree of efficiency and a long service life. This example assumes a battery change after 16 years, with lower reinvestment costs. The assumptions about the increase in fuel prices, the inflation rate or the average irradiation correspond to those in examples 1 and 2. In contrast to option 2, no debt ratio was assumed.

outcomes

As Figure 21 shows, no amortization has yet been achieved at the end of the useful life. This is mainly due to high battery costs and low diesel prices in Angola. The cash flow for this option is as follows:

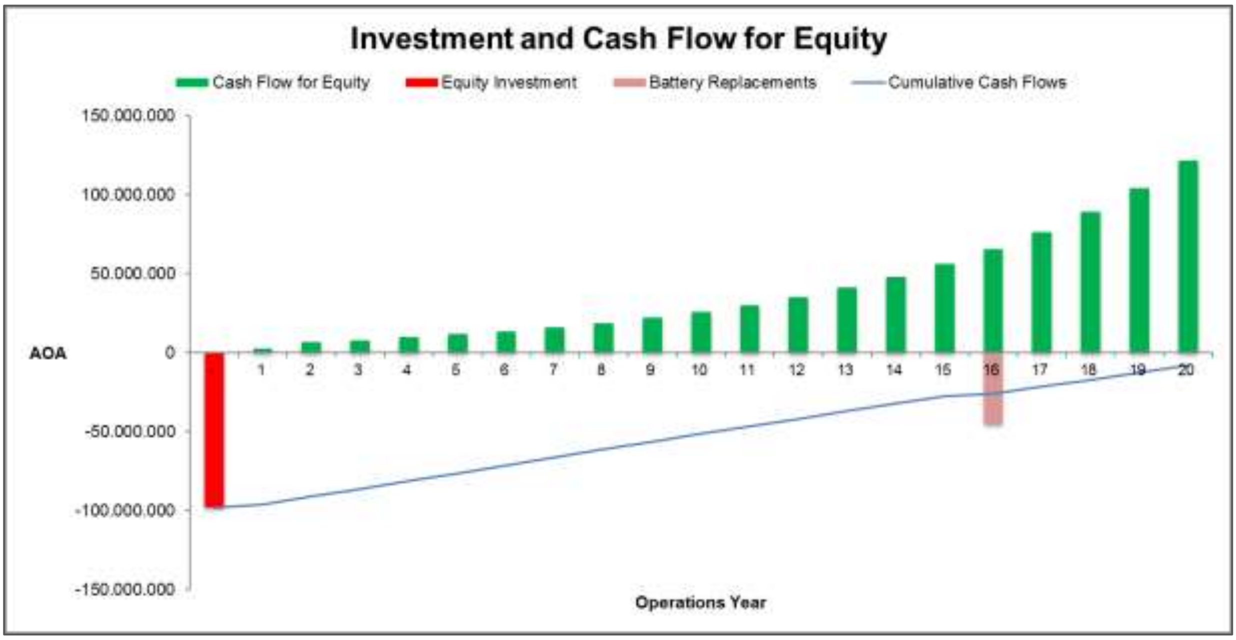


Figure 23: Equity capital cash flows - PV diesel hybrid system for self-sufficiency with storage (eclareon; 2019)

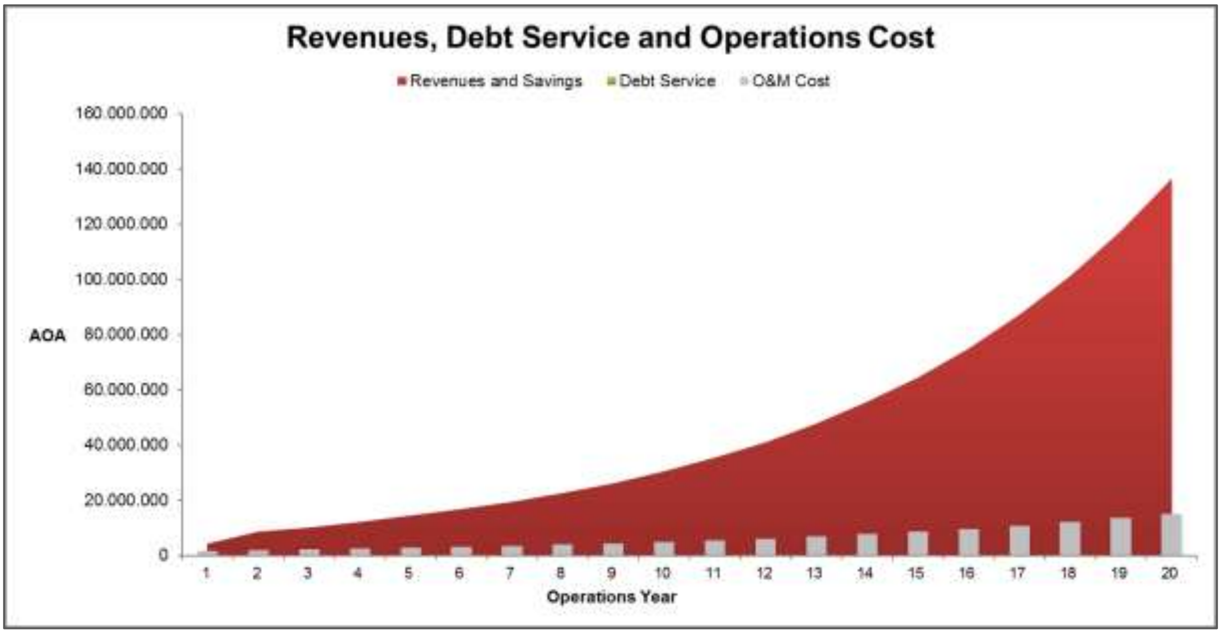


Figure 24: Project cash flows - PV diesel hybrid system for self-sufficiency with storage (eclareon; 2019)

sensitivity analysis

The following graphs show how the two economic performance indicators for the investment, the amortization period (amortization) and the internal rate of return on equity (equity IRR) change when certain assumptions regarding investment conditions change. As Figures 22 to 24 show, revenue and system price have a very strong impact on the profitability of the business model studied. The same applies to the increase in the price of diesel during the useful life of the PV system.

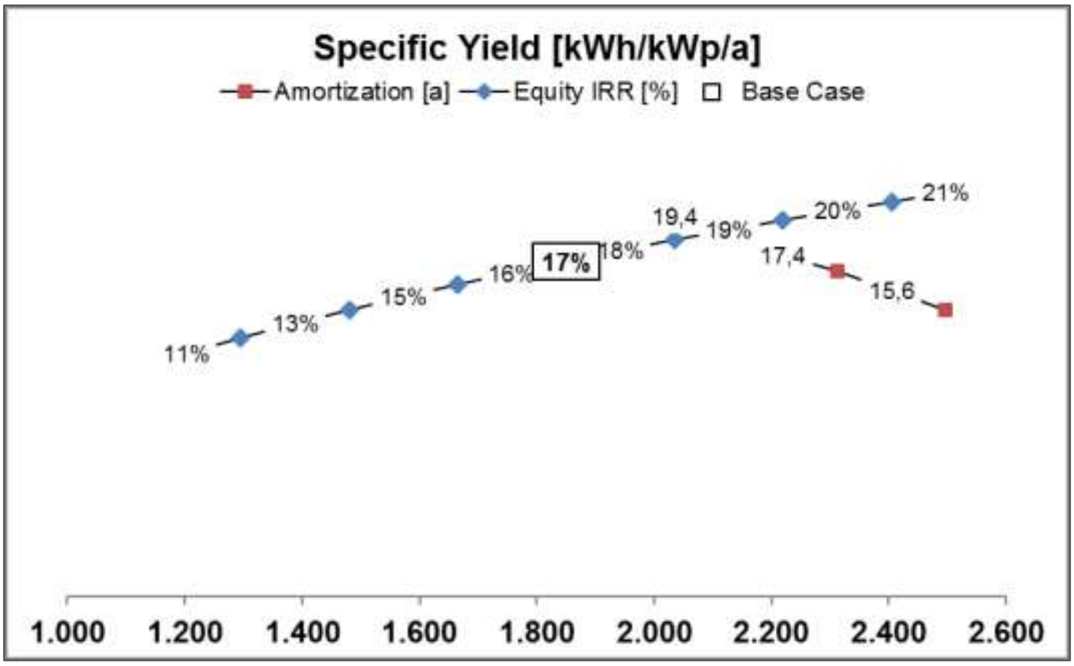


Figure 25: Sensitivity analysis: Yield - PV diesel hybrid system for self-supply with storage (eclareon; 2019)

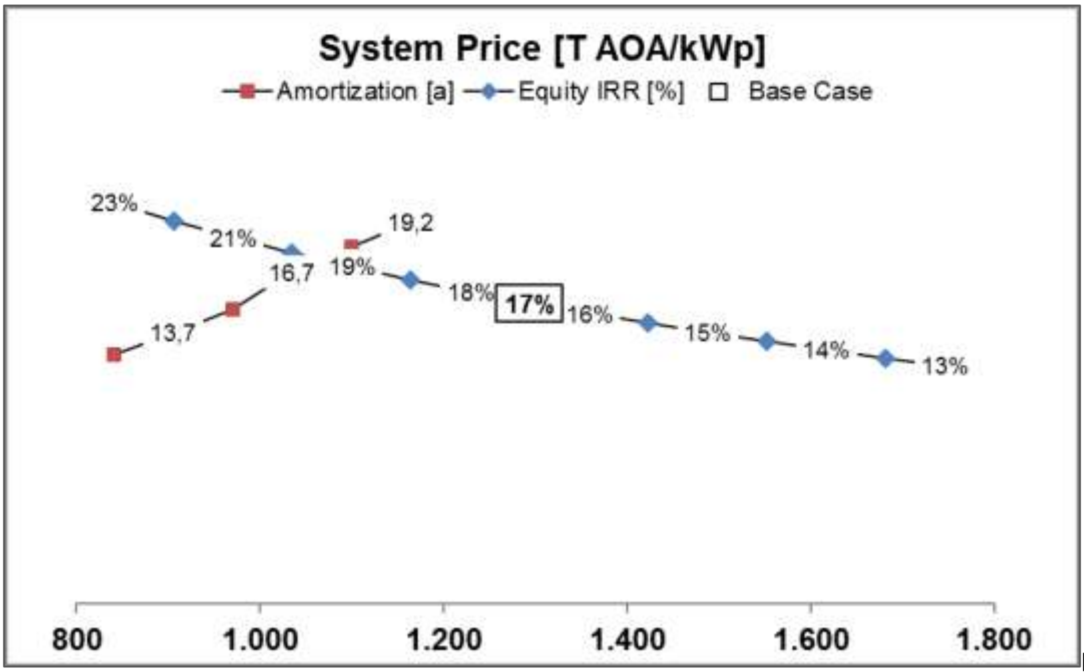


Figure 26: Sensitivity analysis: System price - PV diesel hybrid system with memory (eclareon; 2019)

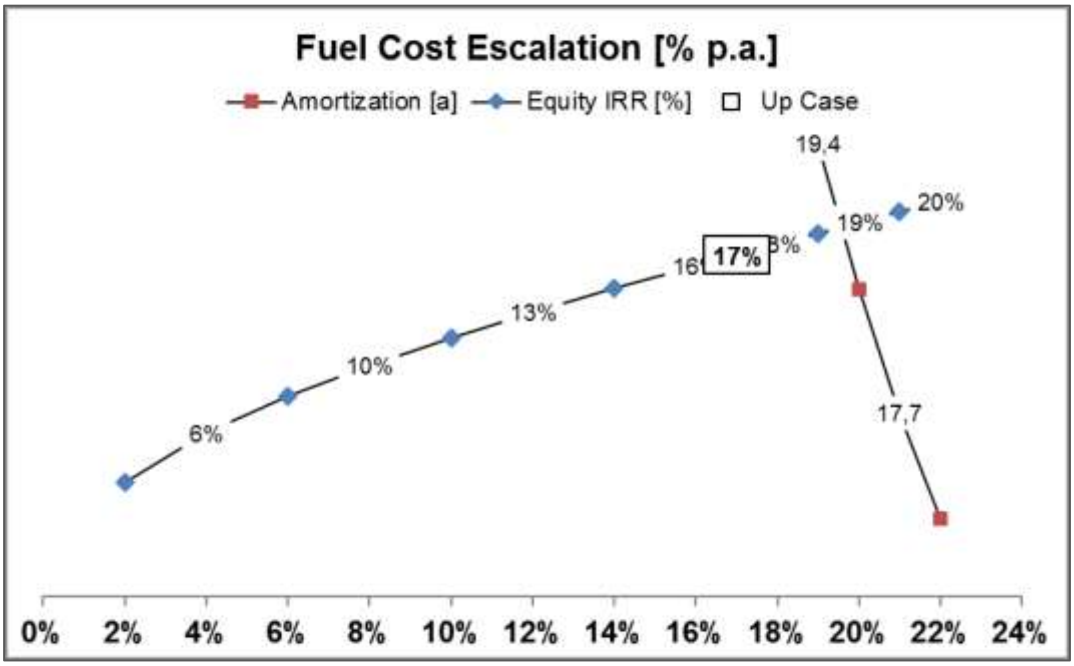


Figure 27: Fuel cost increase sensitivity - PV diesel hybrid system with memory (eclareon; 2019)

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