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Strategy for a Large Scale Introduction of Solar Energy in Central Asia

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Abstract: In spite of the significant need for energy and the large power of solar radiation (insolation) available in Central Asia the use of solar energy is still in a starting phase. In this paper a strategy is lined out how this deficit may be overcome, start-ing from a large number of affordable small and medium-sized photovoltaic solar plants. Details for various types of multi-purpose and dedicated solar plants are explained. Investment costs may be significantly lowered by the assembly of solar panels and the production of connectors, wiring and special accumulators within Central Asia. PV solar panels produce a much lower amount of greenhouse gases than Diesel generators resulting in a significant contribution to cli-mate change mitigation.

Keywords: *solar energy, photovoltaic, insolation, multipurpose solar plants, dedicated solar plants, production within Uzbekistan, greenhouse gases, climate change mitigation*

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1. INTRODUCTION

In most places in Central Asia there is ample sunshine (http://solargis.com/products/maps-and-gis-data/free/overview/) that calls for an application in the generation of heat by solar heating and electrical power using the photovoltaic (PV) effect. PV solar elements are mass-produced using bulk monocrystalline, polycrystalline and amorphous silicon, also several thin-film combinations of semiconducting alloys are used in practice. Typical conversion efficiencies nowadays are in the range of 15 to 25 %.

When talking about large scale solar energy application two approaches can be chosen:

Top-down: Very large solar stations are constructed with one or several megawatt output power for a centralized electricity supply requiring a significant US$ investment that in Central Asia generally only can be implemented on a government-level or in government-dominated energy-supply corporations. Large-scale energy production requires a reliable and well-distributed supply grid that may not be available in many areas.

Bottom-up: A large quantity of smaller solar stations (5 to 50 kW_p) can be constructed by private business and distributed right at the locations of the end consumer. Using internet control these stations may be monitored as well as interconnected to larger local electricity grids (decentralized power grids). The investment per station naturally is much lower and in general can be afforded by the end consumer who receives an added value in his work. In other cases small credit schemes will be useful to spur investments.

2. CONFIGURATIONS OF SOLAR STATIONS

Photovoltaic power stations or shortly – PV solar stations – can be classified according to table 1:

According to this table station # 1 and # 2 feed the energy produced by the solar panels (yield) into the public grid. Additionally, type 2 also allows that part of the yield is diverted for customer use. The stand-alone station # 3 and # 4 operate independent of the public grid.

When calculating the cost of solar energy in relation to Diesel generators and the public grid two cases (I and II) have to be distinguished and to be compared with the energy from the grid (cases III and IV):

I. <u>100% efficiency.</u> The energy produced by PV solar stations or Diesel generators is totally exploited, i.e. the total energy produced (stand-by energy) is equal to the energy used by the customer. This is true for the following types of PV solar stations according to table 1:

  # 1: The total electrical energy produced is fed into the grid,
  # 2: Part of the electrical energy is used by the client, the rest is fed into the grid,
  # 5: The total electrical energy produced is used for operating water pump(s) or equivalent equipment.

Table 1. Types of solar stations.

- Configurations of solar stations -

Nr. #	PV Solar station technology	System components	% exploitation of solar energy	investment cost	Estimated cost per kWh solar energy (depending on configuration)	Flexibility of operation
1	Grid feed-in	• Solar panels • grid converter	100%	low ca. 1380 €/kWp	ca. 12 ct	low
2	Grid feed-in +self- consumption	• Solar panels • grid converter • user exit	100%	low ca. 1380 €/kWp	ca. 12 ct	high
3	Stand alone + large battery capacity	• Solar panels • DC/AC converter • many batteries • DC/AC converter • battery charge controller	100%	high >3000 €/kWp depending on battery capacity	> 25 ct depending on battery capacity	high
4	Stand alone + relative small battery capacity	• Solar panels • DC/AC converter • few batteries • DC/AC converter • battery charge controller	can be 100%, but also <<100%, depending on work cycle (i.e. energy mostly taken from batteries)	medium high ca. 3000 €/kWp	ca. 22 ct, can be higher when little use of direct solar energy conversion (i.e. energy mostly taken from batteries)	medium
5	**PV Solar technology for dedicated applications:** • irrigation • cooling • venting ... others	**Only solar panels plus** • water pump • cooling equipment • fans ... others	100%	low 1000-1500 €/kWp	≤ 12 ct	low

II. Efficiency less or only temporarily equal to 100%. This is the case when the stand-by energy is larger or only temporarily equal to the energy consumed. In practice this corresponds to the situation when the customer according to his needs applies variable loads to the generating system (PV solar, Diesel generator, or grid) any time of the day. Diesel generators have a stand-by energy that is related to the maximum power needed by the customer. When the load is smaller at various times of the customer work cycle a part of the stand-by energy is lost, leading to an efficiency that can be significantly lower than 100%. This case is typical for Diesel generators and naturally leads to high average prices per kWh consumed.

The stand-alone PV solar systems # 3 and # 4 in table 1 have the advantage of energy storage by batteries (accumulators): At day time they can deliver electric energy whenever the customer demands it, otherwise the energy produced is used for charging the batteries, from which energy can be extracted any time according to the work cycle of the customer. Energy can only be lost when at sunlight the batteries are already fully. This is why the cost of the energy extracted from stand-alone PV solar stations generally is lower than the energy produced by Diesel generators.

III. Energy from the grid: In most Central Asian countries the electricity price from the grid is heavily subsidized by the government to an amount as low as 0.03 € per kWh. This price tag cannot be equaled by Diesel generators or solar stations. But, due to the in many areas overaged public grid technology – stemming even from Soviet times – electricity supply often cannot be provided in a reliable way – leading to regular black-outs up to several hours a day: the latter is especially true in small villages and rural areas. This can lead to severe losses in work productivity of the end user that in many cases can compensate for the higher costs of PV solar energy.

IV. A different calculation has to be taken into account when the <u>consumer site is located far away from an access to the public grid</u>: From local sources a price tag of 8.382 € was given for a 1 km extension of a public grid power line, that may be written off in about 20 years. For a 5 km additional power line the cost of the public grid is not lower than that of PV solar stations of the type # 3 and # 4, and even much higher compared to the type # 5. If the present subsidized low electricity price of 0.03 €/kWh will not be maintained in the coming years the calculation will change even more in favor of solar systems.

3. SOLAR ENERGY APPLICATIONS SPECIFIC FOR CENTRAL ASIA

In Central Asia specific applications further support the exploitation of PV solar stations are:

1. In rural areas presently a large demand is expressed for water pumping in fertile (often virgin) land far away from farming villages: In mountainous areas the ground water is unsalted and may be used directly, while in the plains (typical for steppes) the ground water is often salty and cannot be exploited directly. In that case sweet water from rivers may be used exploiting the existing network of irrigation pipelines and canals. Calculations from farming experts show that the use of dedicated PV solar pumping stations can be highly profitable when valuable crops are grown that require a limited demand for irrigation like wine, nuts, pomegranates, and others. Of course, drip irrigation should be used as a standard in order to minimize water and energy consumption.

2. The mass application of PV solar-driven pumps (or equivalent equipment, see table 1) of the # 5 type is favored by the strongly reduced investment cost of dedicated PV solar stations. Solar stations of this type do not need inverters and batteries and hence are much less expensive than the other types of solar stations. Taking also into account that they do not require maintenance they are clearly superior to Diesel generators – especially in distant locations. In view of the large added value to agricultural production this application most likely will lead to the most strongly developing applications of PV solar energy in Central Asian countries.

3. Another important aspect is that much of the agricultural land presently used in Central Asia is contaminated already from Soviet times by salinization, caused by excessive irrigation, as well as of the remains of an intensive use of fertilizers, pesticides, and fungicides – all leading to reduced crops and an decreasing acceptance by the local consumers of the products. Fertile new land (virgin land) - when irrigated with the support of dedicated PV solar-driven water pumps - therefore is an attractive option for the near future.

4. The foregoing option opens the way even to agricultural technologies of *bioproduction* that are still underdeveloped in Central Asia: Taking into account the favorite climate of Central Asia for the production of high quality fruits and vegetables PV solar-irrigated virgin land can solve the imminent problem that in many cases neither fresh nor dried fruits and vegetables may be exported to Western countries due to the residual contents of fertilizers, pesticides, and fungicides exceeding the legal threshold limits. In Central Asia this could create new attractive options to increase the export market for ecologically clean grown or even biologically certified food products.

5. The demand for solar stations of the # 3 and # 4 type depends largely on the special situation at the place of the future customers: In areas with a fragile power supply by the public grid including total black-outs PV solar stations in many cases are obviously profitable. This concerns both high-productivity farming as well as small and medium-size enterprises that cannot work profitably without a reliable permanent power supply.

To sum up practically all Diesel engines so far installed and planned for the future can be replaced profitably by PV solar stations of the types # 3 and # 4. The limited life time of Diesel engines and the permanent need for maintenance and control generally favors this development.
There is a multitude of further applications, ranging from the power supply of remote relais stations for communication, especially in view of the quite developed mobile phone system in Central Asia, to public health institutions, police stations, as well as for all kinds of emergency facilities, and many other applications.
An argument against the introduction of PV solar equipment is the high investment cost for the acquisition of the PV solar system. PV stations require expensive high technology components that partly presently cannot be produced in a competitive way within the Central Asian countries. But (GHG) it is evident that, in principle, the investment costs can be cut nearly into half when a proportion of PV solar station components are produced within Central Asia by private business (mostly small and medium-sized enterprises), like:

- Assembly of solar panels
- Production of dedicated accumulators for PV stations using low-cost conventional lead technologies and possibly yearly maintenance cycles including repair and recycling. In this area practical experience still has to be acquired by the Uzbek companies – preferably in cooperation with European battery producers.
- Connectors and wiring
- Pavilions (housing) for PV solar stations

Of course, specific knowledge acquisition is necessary in every of these components.

Finally, financial support by foreign and/or Central Asian credit lines could significantly speed up the implementation of a large-scale introduction of solar energy in Central Asia.

4. CLIMATE PROTECTION

A very important aspect is the enormous impact of the large scale exploitation of PV solar energy in the climate change mitigation, as demonstrated by the fact that – taking into account all possible contributions starting from the production of the system to the operation up to the end of the anticipated life time of the equipment – the emission of greenhouse gases (GHG) is 17 times lower for PV solar stations in the range of 7 kWp in comparison to equivalent Diesel generators (Fig. 1 and 2).

For example, investigations have proven that the installation of a medium-sized stand-alone battery-supported photovoltaic (PV) system in Jizzakh, Uzbekistan, contributes to avoid greenhouse gas (GHG) emissions since the farm was fueled before by a diesel generator. For quantifying the respective GHG emission savings average emission factors from literature and the assumptions outlined in table 2 have been taken into account. The assumptions have been taken rather conservatively – especially the life time – because of the dusty conditions.

Table 2. Key figures of the PV-system.

Type of PV-system	Stand-alone, battery supported
Capacity	7 kWp
Lead-acid battery	10 kWh
Life time (estimated after [1])	20 years
Average annual global horizontal irradiance (GHI) [2]	1675 kWh/m2
Performance Ratio (according to [3])	90%

5. DESCRIPTION OF THE ANALYZED SYSTEM

For calculating the GHG emission factor all steps from cradle to grave of the PV system are considered. Contrary to electricity production from fossil fuel energy, where GHG emissions are released mainly during the operation phase, the main part of the emissions from PV power production occur during the production and construction phase. During ordinary operation the PV systems only very few GHG emissions (e.g. for maintenance purposes) are emitted. Therefore it is important to consider all steps during the life cycle of the PV system if GHG emission savings towards conventional energy provision systems are analyzed.

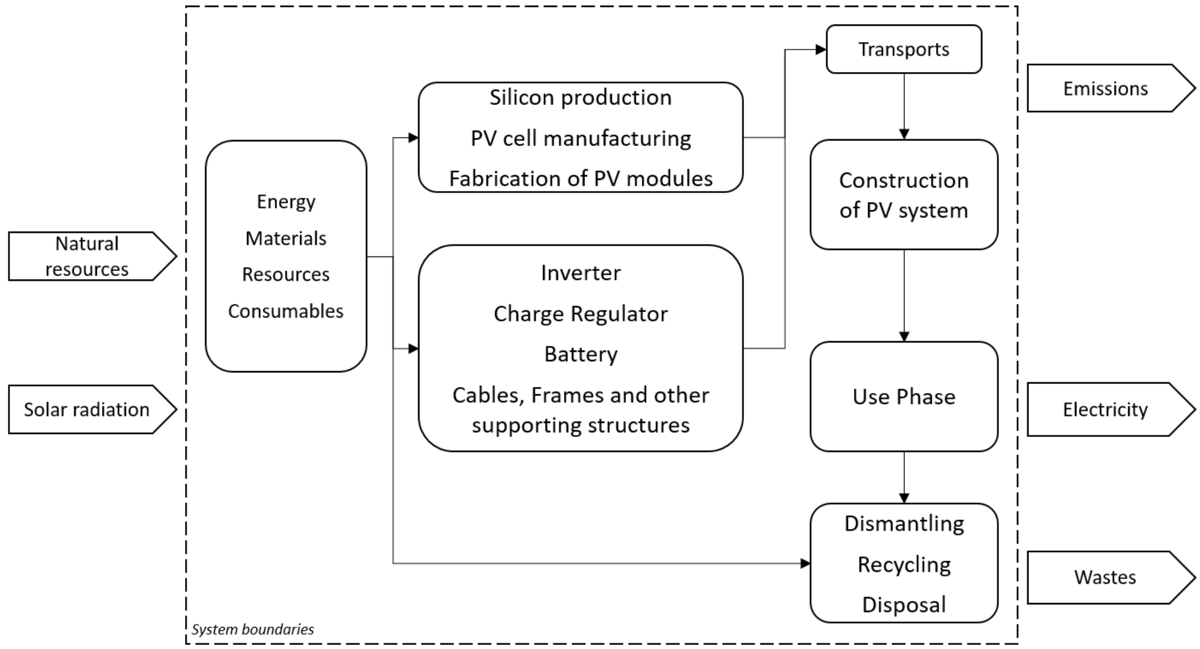

Figure 1. System boundaries of the analyzed PV-system

Like displayed in
Figure **1** all life cycle steps including silicon extraction, material production, PV module construction, use phase, dismantling and recycling or disposal of the PV system are considered here. As the functional unit 1 kWh of produced electricity is chosen.
The share of material production and construction of the photovoltaic modules related to the overall GHG emissions can be up to 90% [1]. This is mainly caused by silicon extraction, wafer, cell and module manufacturing which demand together up to 83% of the totally used energy.
The GHG emissions are therefore very much related to the energy mix of the respective PV-panels producer region. Here the PV panel's production is considered to take place in Central Europe.
Afterwards all the components have to be transported to Uzbekistan where they are used for the erecting of the overall PV system. Further the production, transport and use of a lead-acid storage battery is considered in the analysis (see Table).
Most important for the emission factor is the solar irradiance and the amount of electricity that can be produced during the life time of the PV system. Due to the very sunny conditions in Uzbekistan the specific electricity yield of the PV system is rather high (1485 kWh/kW). The greenhouse gas (GHG) emission factor not only takes CO_2 emissions but also other greenhouse gases like methane or nitrous oxide into consideration. Thus it is denoted with CO_{2e} (CO_2 equivalent).

6. RESULTS AND SAVINGS COMPARED TO DIESEL BASED POWER PROVISION

Greenhouse gas (GHG) emission factors for the production and construction of PV modules vary between 50 and 100 g CO2e/kWh$_{el}$ [1]. According to different studies [4, 5, 3, 6–8] a GHG emission factor of 55 g CO2e/kWh$_{el}$ was considered here for PV modules production, construction, use and dismantling. It is broken down on the individual production steps as follows in Table . Beside the PV panels the battery storage is considered with 20 g $CO2e/kWh_{el}$. Therefore, the overall GHG emission factor sums up to 75 g $CO2e/kWh_{el}$. Thus compared to electricity provision via diesel generator the PV system saves about 1.2 kg $CO2e/kWh_{el}$. Even though all the assumptions for GHG emissions from PV panel production and construction are made rather conservatively, the amount of saved greenhouse gases is considerable.

Table 3. Composition of the GHG emission factor of PV power production compared to power production via Diesel generator

Component	g $CO2e/kWh_{el}$	Reference
Total PV system	55	[1, 3, 4, 6–8]
Of which:		
Panels production	50	[1, 3]
Transport & construction of the system	1	[1, 3]
Use phase	4	[1, 3]
End of life	1	[1, 3]
Battery back up	20	[1]
Total	75	
Alternative:		
Diesel generator	1270	[6]
Savings	1195	

CONCLUSION

In Central Asia the conditions for a large-scale exploitation of PV solar energy are quite favorable: Small and medium-sized PV solar stations of are technically and economically feasible and prove to be significantly more cost-effective that the previously used Diesel generators. Necessary measures for a fast grow of the solar-energy application include an extensive training and know-how transfer, consulting and the start of “learning by doing” within Central Asia and the surrounding Central Asian countries.

PV solar technologies can spur the development of agricultural production in the direction of ecologically cleaner products, as well as the productivity of smaller and medium-sized companies – especially in areas with a limited public power supply.

The production of an increasing share of PV solar technology components in the country will also create high-tech working places as well as reduce investment costs for Central Asian solar energy users.

Finally the large-scale use of PV solar energy will give a significant contribution to the conservation of the surrounding environment and for an effective climate change mitigation – that is most urgent in regions like Central Asia.

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