Energy from the Desert

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Abstract

The key factors for the feasibility of very large-scale photovoltaic power generation (VLS-PV) systems up to the order of giga-watts have been identified by considering their socio-economical benefits to neighboring regions, as well as to the global environment. Then, Six desert first and then selected three were compared. Finally, three scenario studies have been performed to ensure sustainability. When considering world energy fundamentals in 21st century, this option should become one of essential solution for the people. As results, electricity costs of between 0.09 and 0.11 $/kWh are shown, depending mainly on annual irradiation level (module price 2 $/W, interest rate 3 %, salvage value rate 10 %, depreciation period 30 years). The life-cycle CO_2 emission is around 13 g-C/kWh, due mainly to manufacturing of the modules and arrays. I/O analysis shows that 25 000–30 000 man-years of local jobs are created per 1 km^2 of VLS-PV installed. To assure sustainable local economic growth, the first local PV module production facility supplies 5 MW for the construction of the local VLS-PV annually In subsequent years, plural or larger production facilities are brought into operation and replaced every 10 years, so that after approximately 40 years a 1.5 GW VLS-PV plant is in operation stably, assuming 30 year module life. In this way, local employment and economy will grow sustainably while VLS-PV produces energy from the desert.

Background and concept of VLS-PV

An intensive work has been made by Task VIII under IEA Photovoltaic Program(1). According to the present results(2) from the ongoing work, a very large-scale PV system is defined as a PV system ranging from 10 MW up to several gigawatts (0,1–20 km^2 total area) consisting of one plant or an aggregation of multiple units operating in harmony and distributed in the same district. These systems should be studied with an understanding of global energy scenarios, environmental issues, socio-economic impact, PV technology developments, desert irradiation and available areas:

- All global energy scenarios project PV to become a multi-gigawatt generation energy option in the first half of this century.
- Environmental issues which VLS-PV systems may help to alleviate are global warming, regional desertification and local land degradation.
- PV technology is maturing with increasing conversion efficiencies and decreasing prices per watt. Prices of 1.5 USD/W are projected for 2010, which would enable profitable investment and operation of a 100 MW plant.
- Solar irradiation databases now contain detailed information on irradiation in most of

the world's deserts.

- The world's deserts are so large that covering 50 % of them with PV would generate 18 times the world primary energy supply of 1995.

An example image is illustrated in Figure 1. VLS-PV array fields and agricultural development areas are distributed one after another. This combination allows to provide electricity enough for an entirely new type of agricultural development to keep fields sustainable.

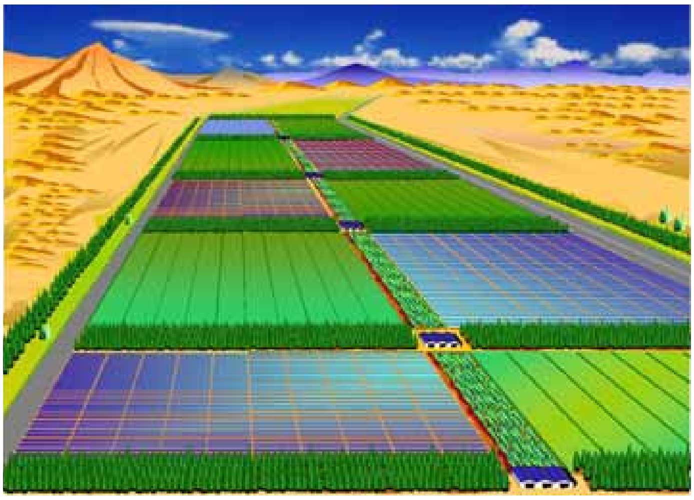

Figure 1 Image of a VLS-PV system in a desert area

VLS-PV Case Studies

Electricity generation costs of between 0.09 and 0.11 USD/kWh are shown, depending mainly on annual irradiation level (module price 2 USD/W, interest rate 3 %, salvage value rate 10 %, depreciation period 30 years) as shown in Figure 2.

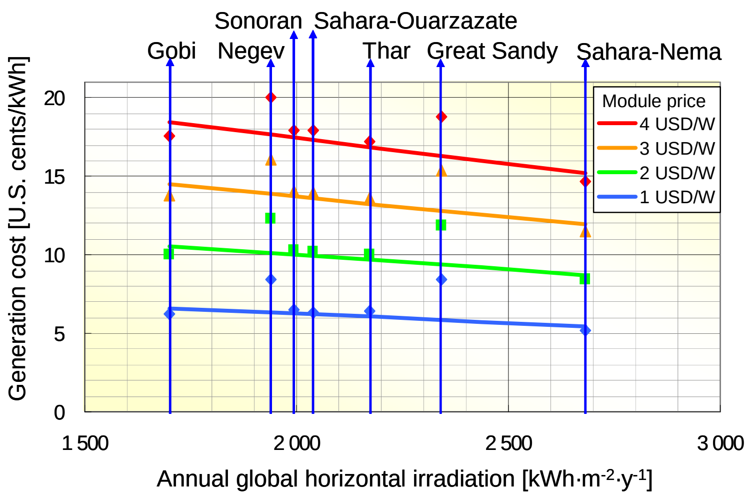

Figure 2 Best estimates of generation cost for each desert as a function of annual global horizontal irradiation

These costs can come down by a factor of a half to a quarter by 2010. Plant layouts and introduction scenarios exist in preliminary versions. I/O analysis shows that 25 000–30 000 man-years of local jobs for PV module production are created per 1 km2 of VLS-PV installed.

Other findings of the two flat-plate PV systems and one two-axis tracking concentrator PV are also given:

- The case study in the Gobi desert describes a VLS-PV system built of strings of 21 modules combined to arrays of 250 kW consisting of 100 strings. Two of these arrays are connected to an inverter of 500 kW. Two hundred of these sets of 2 arrays are distributed over an area of approximately 2 km^2. Total requirements for construction of the plant based on local module assembly are 848 485 modules, 1 700 tons of concrete for foundation and 742 tons of steel for the array support. The life-cycle CO_2 emission is around 13 g-C/kWh, mainly due to manufacturing of the modules and the array support.
- In the Sahara case study, several distributed generation concepts were compared to minimize transmission costs. A potentially attractive option is dispersed 300 plants of 5 MW PV systems, the total capacity of which is 1.5 GW, located along the coast of Northern Africa, connected to the grid by a single 1 - 10 km medium voltage line. A complete I/O analysis was also carried out resulting in 2 570 induced jobs by the operation of a 5 MW/y PV module production facility.
- In the Negev desert in the middle-east, a 400-sun concentrator dish of 400m^2 was evaluated. Simulations indicated that 16.5 % overall system efficiency is achievable, and an economic attractive operation with generation costs of less than 0.082 USD/kWh is possible.

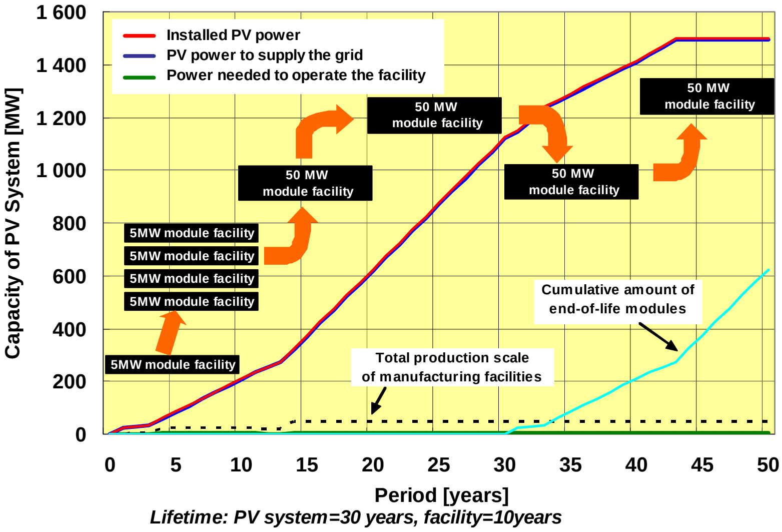

Figure 3 Sustainable scheme for VLS-PV development

Scenario Studies for Sustainability

Three sustainable scenario studies were developed showing that sustainable local economic growth, sustainable technological–environmental development and non-technological demonstration and sustainable financial (stakeholder) support are possible when a long-term perspective is developed and maintained:

- In the concept of sustainable local economic growth as shown in Figure 3, the first local PV module production facility has an annual output of 5 MW. This local production supplies for the construction of the local VLS-PV system. In subsequent years, three more 5 MW module production facilities are brought into operation, so that annually 20 MW is supplied to the local VLS-PV system. After 10-15 years, a module production facility of 50 MW is put into operation. Every 10 years this facility is replaced by a more modernized one. Thus after approximately, 40 years, a 1.5 GW VLS-PV plant is in operation, and the local production facility supplies for replacement only. Figure 4 shows a summary of the sustainable grows. This way, local employment, and thus, the economy, will grow sustainably.
- To reach the point of a 1 GW system, four intermediate stages are necessary: R&D stage, Pilot stage, Demonstration stage, and Deployment (commercial) stage. From stage to stage, the system scale will rise from 2.5 MW to 1 GW, module and the system cost will go down by a factor of 4. Production will be shifted more and more to the local economy. Technological issues to be studied and solved include reliability, power control, standards. Non-technical items include training, environmental anti-desertification strategies, and industrialization and investment attraction. These four stages have a total duration of 15 years.
- To realize the final commercial stage, a view to financing distribution is developed for all of the three previous stages, consisting of direct subsidies, soft loans, equity, duty reduction, green labels, and tax advantages. It is clear that direct subsidies will play an important role in the first three stages (R&D, pilot, and demonstration). Ultimately, in the commercial stage, enough long-term operating experience and track record are necessary to attract both the soft loans and equity for such a billion dollar investment.

The following scenario is also suggested to reach a state of large-scale PV introduction. At first, the bulk systems that have been installed individually in some locations would be interconnected with each other by power network afterwards, incorporated with regional electricity demand growth. Finally, such a district would become a large power source.

[stage 1] A stand-alone, bulk system is introduced to supply electricity for surrounding villages or anti-desertification facilities in the vicinity of deserts.

[stage 2] Remote, isolated networks germinate. Plural systems are connected by a regional grid. This contributes to load levelling and the improvement of power fluctuation.

[stage 3] The regional network is connected to a primary transmission line. Generated energy can be supplied to a load centre and industrial zone. Total use combined with other power sources and storage becomes important for matching to the demand pattern and the improvement of the capacity factor of the transmission line. Furthermore around the time stage 3 is reached, in the

case of a south-to-north inter-tie, seasonal differences between demand and supply can be adjusted. An east-to-west tie can shift peak hours.

[stage 4] Finally, a global network is developed. Most of the energy consumed by human beings can be supplied through solar energy. For the last stage, a breakthrough in advanced energy transportation will be expected on a long-term basis, such as superconducting cable, FACTS(flexible AC transmission system), or chemical media.

Understandings and Recommendations

From the perspective of the global energy situation, global warming, and other environmental issues as well as from the case studies and scenarios, it is apparent that VLS-PV systems can:

- contribute substantially to global energy needs.
- become economically and technologically feasible.
- contribute considerably to the environment.
- contribute considerably to socio-economic development.

To secure that contribution, a long-term scenario (10-15 years) perspective and consistent policy is necessary on technological, organisational, and financial issues. Action now is required to unveil the giant potential of VLS-PV in deserts. In such action, the involvement of many actors is needed. In particular, it is recommended that on a policy level:

- National governments and multinational institutions adopt VLS-PV in desert areas as a viable energy generation option in global, regional and local energy scenarios
- The IEA-PVPS community continues Task VIII for expanding the study and refining the R&D and pilot phase and for involving participation by desert experts, financial experts and for collecting further feedback information from existing PV plants.
- Multilateral and national governments of industrialised countries provide financing to generate feasibility studies in plural desert areas around the world and to implement the pilot and demonstration phase.
- Desert-bound countries (re-) evaluate their deserts not as potential problem-areas but as vast and profitable (future) resources for sustainable energy production. The positive influence on local economic growth, regional anti-desertification and global warming should be recognised.

Acknowledgements

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References

(1) IEA PVPS Programme: http://www.oja-services.nl/iea-pvps/tasks/index.htm/
(2) K. Kurokawa: Energy from the Desert, James & James, May 2003.