# Very Large Scale PV Power Generation for Shifting to a Renewable Energy Future

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In order to meet the environmental challenge in the 21st Century, renewable energy must play an important role. PV is one of the most promising renewable energy technologies. It may be no exaggeration to say that we're now coming to the stage of energy transition by PV power plants. PV power plants came on the market first in the latter half of 2000s. Since then, a capacity of the largest PV power plant in the world has been broken every year. In 2014, some PV plants over 500MW started operation. Currently, a share of PV power plants will be 15% or more of the total PV installation in the world. The technical and economic feasibility of the large scale PV power plants are already proven, and the environmental and socio-economic benefits can make the project more attractive. To deploy large scale PV power plants as a major power source, the feasibility and expected benefits of PV power plants are analysed, as well as a potential for global energy system.

Keywords: VLS-PV, Large Grid-connected PV systems, Sustainable

## I. INTRODUCTION

In order to meet the environmental challenge in the 21st Century, renewable energy must play an important role. PV is one of the most promising renewable energy technologies. It may be no exaggeration to say that we're now coming to the stage of energy transition by PV power plants.

PV power plants came on the market first in the latter half of 2000s. Since then, a capacity of the largest PV power plant in the world has been broken every year, and some PV plants over 500MW have already started operation. Currently, a share of PV power plants will be 15% or more of the total PV installation in the world. The technical and economic feasibility of the large scale PV power plants are already proven, and the environmental and socio-economic benefits can make the project more attractive.

To deploy large scale PV power plants as a major power source, under the framework of the IEA PVPS [1] and Task8 [2]-[6], we analysed the feasibility and expected benefits of PV power plants, as well as a potential for global energy system

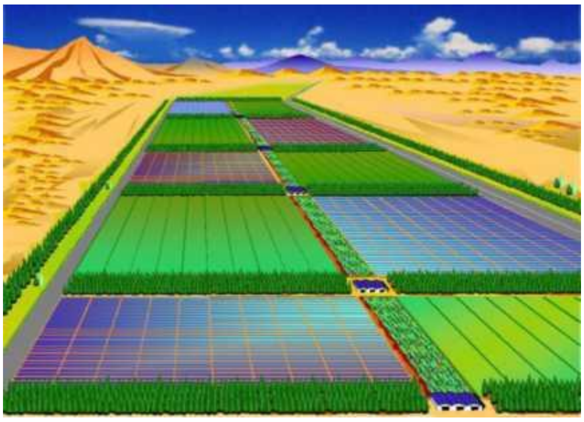

*Figure 1. Image of VLS-PV on a desert area*

## II. FEASIBILITY AND BENEFITS OF PV POWER PLANTS

### A. Technical feasibility

PV power plants with several hundred MW scales are already in the commercial stage and technically feasible, as shown in Fig.2. In 2014, some PV plants over 500MW started operation. It may be reasonable to expect that GW- scale PV power plants will come on the market in near future. CPV is another promising technology with options suitable in the desert environment, and some large-scale projects are implemented.

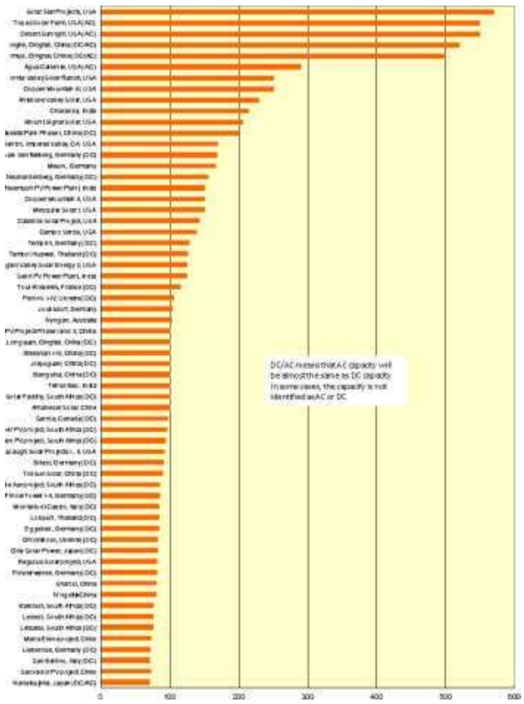

*Figure 2. Examples of existing large scale PV power plants in the world*

PV power plants in the desert have to endure the severe environmental conditions, such as soiling. A degree of soiling and its impact is depending upon surrounding environments and meteorological conditions of the site. Cleaning option of the PV plants can be justified if the cost for cleaning is lower than the income generated by the solutions (see Fig.3). In general, a cost for cleaning is heavily depending upon the local cost of labour and water.

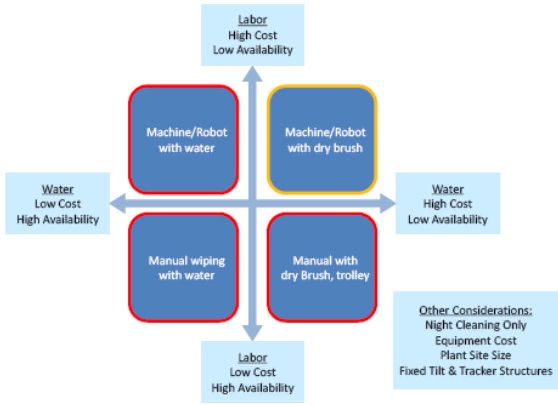


*Figure 3. Classifications of cleaning method [6]*

Besides soiling, sand storm and particles, high temperature and large temperature difference between day and night, exposure to intense ultraviolet irradiation, etc. are the significant and special issues for PV power plants in the deserts environment. Recently, importance and necessity of evaluating capability and performance of PV modules under the desert condition is widely accepted. Evaluation method for those issues are not standardised internationally yet, and further discussions are needed.

### B. Economic feasibility

Initial cost for PV installation has been decreasing. In some regions, LCOE of PV technology is already reached to the level of retail electricity tariff. According to the IEA PV technology roadmap [7], initial cost for utility-scale PV system will be 1.5-3 MUSD/MW in 2015, and reached to approximately 1 MUSD/MW and 0.7 MUSD/MW in 2030 and 2050 respectively. If the indicated costs are achieved, the LCOE of PV power plants will be able to compete with conventional power plants.

Fig.4 represents the expected LCOE of 1 GW PV power plants assuming some desert areas, as a function of global horizontal annual irradiation.

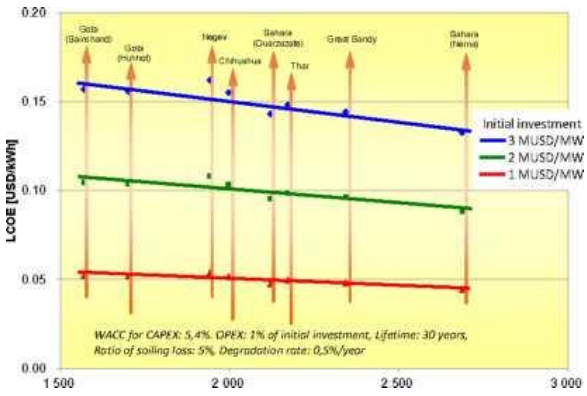


*Figure 4. Expected LCOE of PV power plants [6]*

When it comes to the PV power plant in the desert environment, the LCOE is already low even, 0.1 USD/kWh, with the current module price level. In the near future, PV power plants will become more competitive against conventional power plants; their production costs in tendency are steadily increasing.

## C. Environmental benefits

PV technology is one of the promising technologies for climate change mitigation, as the Energy Pay-Back Time is very short and the CO2 emission rate is very small. The Energy Pay-Back Time and CO2 emission rate of the VLS-PV plants are within the ranges of 1 to 3 years and 30 to 70 g-CO2/kWh respectively, depending on the type of PV module (efficiency mainly) and location of installation (irradiation and array manufacturing electricity mainly).

Assuming 30 years life-time, the plants can produce 10 to 30 times more energy than the total energy consumed throughout the life-cycle. Similarly, the CO2 emission rate will be one-tenth or one-twentieth of average CO2 emission rate in China or Africa. This means that 90 to 95 % CO2 emissions for power generation can be reduced by substituting new fossil fired power plants with the VLS- PV plants.

As relative indicator, the Ecological Footprint (EF) is there, which is one of the indicators to monitor the effects of CO2 on the environment. The EF is expressed by the capability of ecosystem required to purify, absorb and mitigate the impact of human activities. Capability of ecosystem is called bio-capacity (BC). The earth is sustainable while the EF is smaller than the BC, but if the EF is higher than the BC, the earth is regarded as unsustainable.

The EF and BC in the Northeast Asian region can be balanced by installing the 1,000 GW VLS-PV plants in the Gobi desert covering China and Mongolia. The Area required for the VLS-PV plants is only 1 to 2 % of the Gobi desert. It should be noted that, this calculation considers the effects of CO2 emissions reduction only. The environmental effect can be further exploited if the development is coupled with afforestation and agricultural development in the surrounding area.

Without VLS-PV

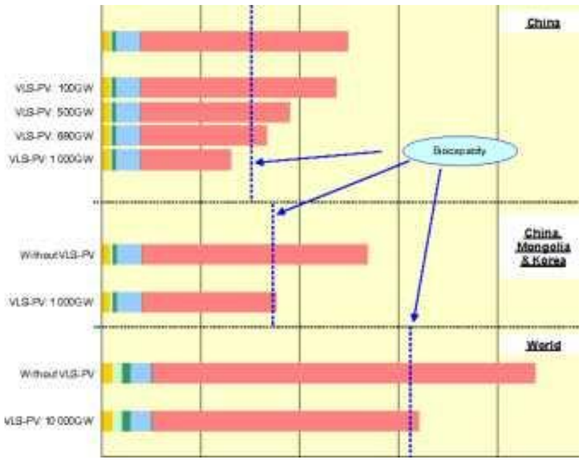


*Figure 5. Ecological impacts by VLS-PV project on the Gobi desert [4]*

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Figure 6 shows an example of study on life-cycle water use for electricity generation. Conventional power plants such as fossil power and nuclear power consume much water for cooling. The plants locating inland are generally using ground water. On the other hand, PV technologies consume water at the production stage to some extent, but little during their operation. Clearly, PV power plants will contribute to saving ground water use by substituting conventional power plants inland.

## D. Social benefits

A construction of GW-scale PV power plant will create substantial and stable demand for PV system components as well as employment for construction if the construction is managed in an appropriate manner. Figs.7 and 8 show one of our scenarios we proposed for GW- scale PV plant with sustainable social development.

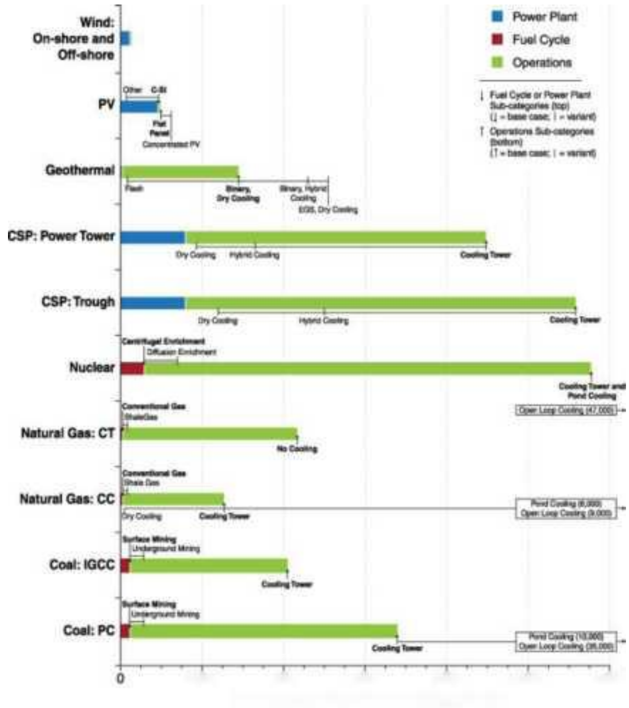


*Figure 6. Life cycle water withdrawal [8]*

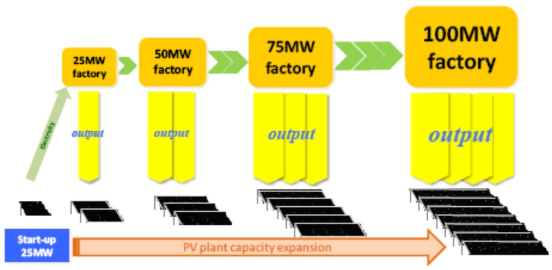


*Figure 7. Conceptual view of a sustainable scheme [6]*

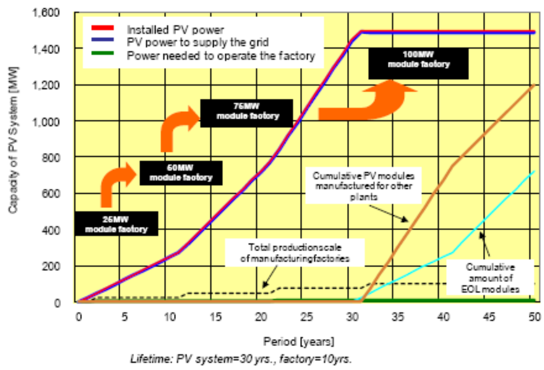


*Figure 8. Sustainable scheme for VLS-PV development [6]*

Under the scenario, approximately 9 thousand jobs are created during the projected period, and approximately 400 stable jobs are created annually (see Fig.9). It should be noted that, the simulation only includes direct employment. If it is coupled with indirect employment in the supply chain, the impact of VLS-PV on sustainable job creation can be doubled.

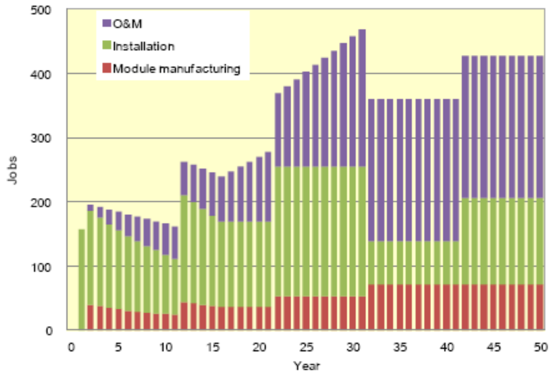


*Figure 9. Expected direct employment by VLS-PV project with productivity improvement [6]*

## III. PV POWER PLANTS AS A MAJOR POWER SOURCE

The cross-border supply networks for electricity are the prerequisite for the mass deployment of PV power plants as a major power source. Global deployment of PV power plants will be accelerated by developing energy supply system combined with other renewables and energy storage technologies.

For Northeast Asia it is proposed that the excellent solar and wind resources of the Gobi desert could be utilized for load centers in China, Korea and Japan as a contribution to the energy transformation ahead. The area is composed by regions, which can be interconnected by a high voltage direct current (HVDC) transmission grid. Our precise study such as Fig.10 revealed that 100% renewable energy system in Northeast Asia is reachable. PV will play an important role although wind energy may dominate the region. Main electricity exporters are Northwest, North and Central China.

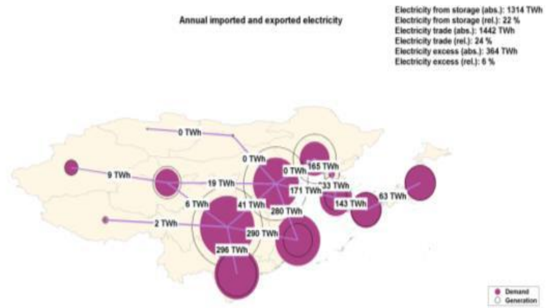


*Figure 10. Annual generation and demand for area-wide open trade scenario for Northeast Asia and reference year 2030 [9]*

The renewable energy can also be used to produce gaseous and liquid fuel when the power supply surpasses the demand. One of the advantages of this technology is that such fuel can be used for non-electricity energy demand such as heat or vehicle fuel. Although there are technical and economic barriers to be solved for the renewable-based fuel production system, low carbon energy system with 100 % renewable energy is certainly possible in the future.

It will be difficult, of course, to immediately start a super grid project, including construction of hundreds of GW of PV power plants. However, socio-economic benefits as well as environmental value of a concept of a VLS-PV supergrid should be seriously taken into account from a long-term viewpoint.

In order to achieve the goal, technical and institutional issues for international grid connection should be addressed and discussed in a more intensive manner.

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