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Republic of Uzbekistan: Solar Energy Development

Roadmap to Solar Energy Development

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Revisions

Revision	Date	Comment	Signatures		
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LIST OF ACRONYMS

ADB	Asian Development Bank
AS	Academy of Sciences
BO	Build and Operate
BOS	Balance of System
BOT	Build, Operate and Transfer
CAC	Central Asia Countries
CAPEX	Capital Expenditure
CCGT	Combined Cycle Gas Turbine
CSP	Concentrated Solar Power
DBO	Design Build and Operate
DNI	Direct Normal Irradiation
EOI	Expression of Interest
GHI	Global Horizontal Irradiation
GW	Gigawatt
HPP	Hydro Power Plants
IEE	Initial Environmental Examination
IPP	Independent Power Producer
ISCC	Integrated Solar Combined Cycle
ISEI	International Solar Energy Institute
JCS	Join Stock Company
JICA	Japan International Cooperation Agency
KWh	Kilowatt-hour
MW	Megawatt
MWAR	Ministry of Water and Agriculture Resources
O&M	Operation and Maintenance
PPA	Power Purchase Agreement
PV	Photovoltaic
RES	Renewable Energy Source
SJCS	State Join Stock Company
SPV	Special Purpose Vehicle
TA	Technical Assistance
TES	Thermal Energy Storage

TPP	Thermal Power Plant
TW	Terawatt
TWh	Terawatt hour
UFRD	Fund for Reconstruction and development of the Republic of Uzbekistan

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1 SCOPE OF THE ROADMAP

The Government of Uzbekistan has a commitment to develop solar energy and to become the regional knowledge hub for solar technologies. In response to the Government's request, the Asian Development Bank (ADB) launched a small-scale capacity development technical assistance (S-CDTA) for the 'Design/Foundation and Strengthening of the International Solar Energy Institute' and a policy and advisory technical assistance (PATA) to assist in the promotion of solar energy development.

This Roadmap: identifies barriers and risks; proposes actions and sets priorities to reach plausible solar development goals and targets for Uzbekistan taking into account the main stakeholders involved. An action plan up to 2030 is proposed.

2 ROADMAP RATIONALE

Republic of Uzbekistan produces 89% of power by means of Conventional Thermal Power Plants powered by natural gas, coal and fuel oil. Over 50% of that energy is generated in power plants built before 1982 and, just 10%, it is generated by means of power plants built after 1997 (1).

The fact that fossil fuel scarcity will start suffocating Uzbekistan in 10 to 12 years for oil reserves; 28 to 30 years for natural gas reserves and 150-200 years for coal reserves jointly with the need to update several existing power plants opens and opportunity for finding alternative solutions to supply energy (2).

The development of solar energy-based production plants is an option which would contribute to sustainability, to liberate national natural gas for other higher value added uses (exports or natural gas chemistry) and to future country energy security of supply.

Roadmaps, in the energy sector, are a recognized instrument to define technology portfolios and guide on how problems could be solved taking into account country's ecologic and resource limitations.

Roadmaps' methodology provides a tool not only to present possible, plausible, development alternatives in a graphic way, but also it is an aid in the decision making at different stakeholders' level.

By itself, the roadmap preparation process provides: a verification of the existing potential, an identification of the weak/strong points, growth scenarios analysis and validation, and natural resources availability review. A roadmap is meant to serve as an improvement tool for the Administration and as a guide for national and foreign investors.

The present roadmap aims to identifying gaps which have to be addressed to enable conditions under which solar energy can be developed in Uzbekistan in agreement with the country and government vision of sustainability. Targets and actions are set and prioritized for the different stakeholders.

3 OVERVIEW OF SOLAR ENERGY

3.1 SOLAR ENERGY WORLDWIDE

Scarcity of fossil fuel combined with its increasing demand has contributed to the search of new sources of energy and to research and development in the area of renewable sources of energy. As an answer to these efforts, a fast increase in the use of all renewable energies along with reduction of its costs has taken place and among them two stand out: Photovoltaics (PV) and Concentrated Solar Power (CSP).

3.1.1 Photovoltaics

Photovoltaics is a commercially available technology which has the potential to be implemented in nearly any country (3). The 100MW PV power plant currently under development in Samarkand, Uzbekistan, is an example. It will be owned by State Join Company Uzbekenergo and financed by Asian Development Bank (ADB) and Uzbekistan Fund for Reconstruction and Development. The PV plant will rank among the 10 biggest photovoltaic power plants in the world. The technology to be implemented is crystalline with no tracking.

The basic building block of a PV system is the PV cell, which is a semiconductor layer that converts solar energy into direct current electricity. PV cells are interconnected to form a PV module, typically up to 50-200 Watts (W). The PV modules combined with a set of additional application-dependent system components (e.g. inverters, batteries, electrical components, and mounting systems), form a PV system. PV systems are highly modular, i.e. modules can be linked together to provide power ranging from a few watts to tens of megawatts (MW).

R&D and industrialization have led to a portfolio of available PV technology options at different levels of maturity. Commercial PV modules may be divided into two broad categories: wafer based crystalline silicon (c-Si) and thin films:

- Crystalline silicon (c-Si) modules
    - Single-crystalline silicon (sc-Si)
    - Multi-crystalline silicon (mc-Si)
- Thin Film (TF) modules:
    - Amorphous (a-Si) and Micromorph (μc-Si) silicon
    - Cadmium-Telluride (CdTe)
    - Copper / Indium Sulfide (CIS) and Copper / Indium / Gallium di-Selenide (CIGS)

Although Thin Films are relatively new to the PV industry, they are reaching noticeable market share. Their raise has been slowed down in recent years due to a decrease in silicon prices, but they have kept a stable market share despite the PV market growth.

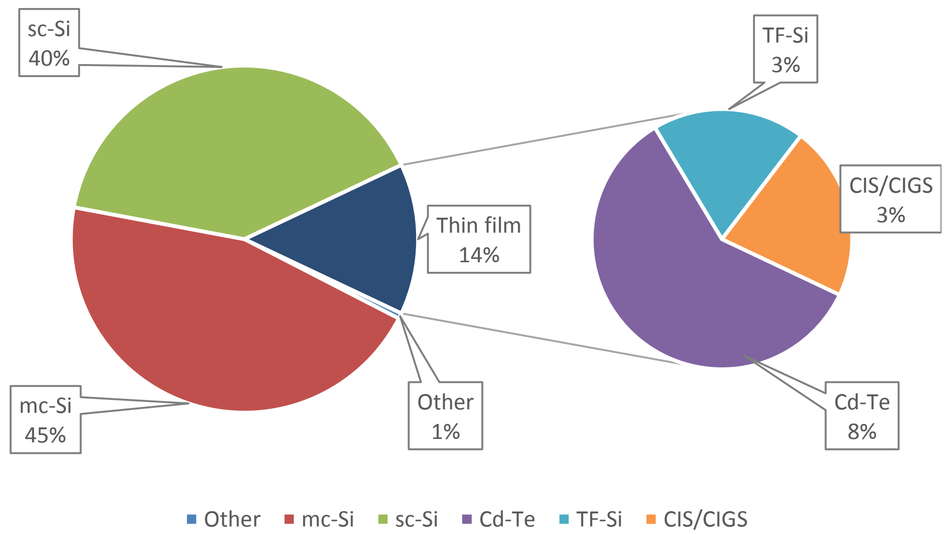

Figure 1. Market share of the different PV technological approaches as per 2011. Source: Own elaboration based on (4).

Conversion efficiency, defined as the ratio between the produced electrical power and the amount of incident solar energy per second, is one of the main performance indicators of PV cells and modules. The following table provides the current efficiencies of different PV commercial modules[1].

Crystalline silicon (c-Si)		Thin Film (TF)		
sc-Si	**mc-Si**	**a-Si / µc-Si**	**CdTe**	**CIS/CIGS**
14-20%	13-15%	6-9%	9-11%	10-12%

Table 1. Conversion efficiencies of different PV commercial modules. Source: (3).

The large variety of PV applications allows for a range of different technologies to be present in the market, with a direct relation between cost and efficiency. Note that the lower cost (per watt) to manufacture some of the module technologies, namely thin films, is partially offset by the higher area-related system costs (support structure, required land, wiring, etc.) due to their lower conversion efficiency.

Chips for electronic devices share many of the resources and manufacturing processes with PV elements, especially if silicon-based, although the purity level required for solar cells is "five nines" (99.999% Si), while electronic-grade silicon must be "nine nines".

In 2012, PV technology global installed capacity was around 100GW (5), being able to produce at least 110TWh electricity.

[1] This is the range of optimum values, influence of angle, temperature and diffuse direct irradiation share must be compared when selecting a technology, a one year simulation of the system is recommended.

As per 2012, the ten most important solar cell manufacturers in the world were (6):

- **Suntech Power Co. Ltd. (China).** With a manufacturing volume of 2,066MW and a shipping volume of 2,096MW in 2011. Annual manufacturing capacity of Suntech Power increased to 2.4GW at the end of the same year. The company did not plan to further expand its capacity during 2012.
- **First Solar LLC. (USA/Germany/Malaysia).** One of the few companies that manufactures Thin Film CdTe modules. Had a capacity of 2.38GW at the end of 2011. That year the production was 1.98GW.
- **JA Solar Holding Co. Ltd. (China).** Had a capacity of 2.8GW for cells, 1.2GW for modules and 1GW for wafers in 2011. An increase in module manufacturing capacity up to 2GW was expected for 2012.
- **Yingli Green Energy Holding Company Co. Ltd. (China).** With a 1.85GW capacity in 2011, that number increased up to 2.45GW in August 2012.
- **Trina Solar Ltd. (China).** According to the company, manufacturing capacity was 1.2GW for ingots and wafers and 1.9GW for cells and modules in 2011. An expansion to 2.4GW was planned for cells and modules in 2012. Shipping volume was 1.51GW in 2011.
- **Motech Solar (Taiwan/China).** Manufacturing capacity was 1.5GW at the end of 2011.
- **Canadian Solar Inc. (China).** Had a 228MW capacity for ingots and wafers, 1.5MW for cells and 2.1MW for modules in 2011. That year, the company informed of a sales volume of 1.32GW. There is no information about cell sales volume although it is thought to be lower. External reports give a number of 1.05GW.
- **SunPower Co.** (USA/Philippines/Malaysia). The company has two manufacturing facilities: one in the Philippines (600MW capacity) and the other in Mexico (500MW capacity). Modules are also assembled by third-party contract manufacturers in China, Poland and the USA. Total capacity in 2011 was 922MW.
- **Gintech Energy Co. (Taiwan).** In 2011, manufacturing capacity was 882MW.
- **Sharp Co. (Japan/Italy).** In 2011, manufacturing capacity was 1,07GW and the shipping volume was 857MW (637MW c-Si and 220MW Thin Film).

3.1.2 Concentrated Solar Power

CSP technology can provide renewable energy generation in countries with clear skies. CSP uses only direct solar irradiance. Not only clouds drop generation but also dust or high humidity in the atmosphere as they scatter the sun’s irradiation reducing the direct fraction. There are areas in Uzbekistan which fulfill these requirements.

CSP technology can supply base or pick loads by means of thermal energy storage, the plant is able to operate in a similar manner as a conventional thermal power plant during cloudy periods or at night time. CSP is able to follow demand supply ancillary services and stabilize the grid, complementing PV.

The different approaches to CSP technology are:

- Parabolic trough systems
- Power tower systems

- Linear Fresnel systems
- Dish/engine systems

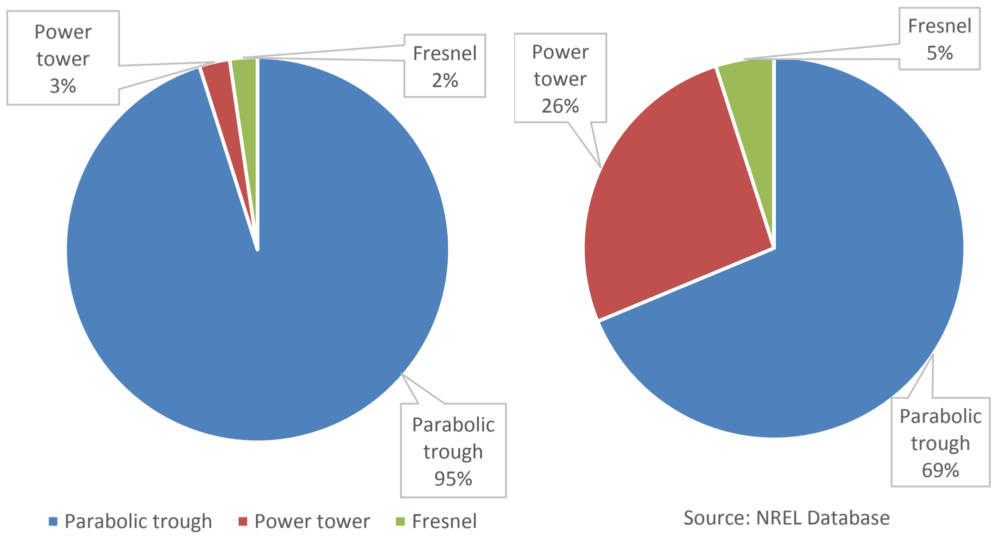

Figure 2. Market share of the different CSP technological approaches, both operating (left) and under construction (right) as per 2012. Source: Own elaboration based on (7).

In early 2012 the global CSP capacity installed reached up to 2 GW (8). CSP projects that are now in development or under construction are located in a dozen countries including China, Morocco, India, Spain and the United States (9).

3.1.2.1 Parabolic Trough systems

The parabolic trough is today considered a commercially mature technology, with thousands of megawatts already installed in commercial power plants, mainly in the US and Spain. As seen in Figure 2, Parabolic Trough copes around 95% of total CSP installed capacity as per 2012.

Parabolic Trough is a 2D, two dimensions, concentrating system in which the incoming direct solar radiation is concentrated on a focal line by one-axis tracking, parabola-shaped mirrors. They are able to concentrate the solar radiation flux from 30 to 80 times, heating the HTF up to 393 ºC (a different approach, using molten salts as HTF, can reach up to 530 ºC, but it is not commercially proven yet). The typical unit size of these plants ranges from 30 MWe to 80 MWe (megawatt-electric), and therefore, they are well suited for central generation with a Rankine steam turbine/generator cycle able to supply energy on demand if thermal storage is used to decouple solar daily cycle/electricity production.

Figure 3. Parabolic Trough collectors installed at Plataforma Solar de Almería (Spain). Photo courtesy of PSA-CIEMAT.

A Parabolic Trough solar field comprises a variable number of identical “solar loops”, connected in parallel. Each loop can rise the temperature of a certain amount of HTF from the “cold” to the “high” operation temperature (typically from 300 to 400 ºC). The loops contain from 4 to 8 independently-moving sub-units called “collectors”. The main components of a parabolic trough collector are:

- **HTF Thermal oil**: a synthetic oil is used as heat transfer fluid in all commercial Parabolic Trough CSP plants actually in operation. The most common oil used is a eutectic mixture of biphenyl and diphenyl oxide, although other fluids (such as silicone-based fluids) are under development and testing.

- **Mirror**: used to reflect the direct solar radiation incident on it and concentrate it onto the Receiver placed in the focal line of the parabolic trough collector. The mirrors are made with a thin silver or aluminum reflective film deposited on a low-iron, highly transparent glass support to give them the necessary stiffness and parabolic shape.
- **Receiver** or absorber tube: it consists of two concentric tubes; the inner tube is made of stainless steel with a high-absorptivity, low emissivity coating, and channels the flow of the HTF; the outer tube is made of low-iron, highly transparent glass with an anti-reflective coating; vacuum is made in the annular space. This configuration reduces heat losses, thus increasing overall collector performance.
- **Structure & Tracker**: the solar tracking system changes the position of the collector following the apparent position of the sun during the day, thus allowing concentrating the solar radiation onto the Receiver. It consists of a hydraulic drive unit that rotates the collector around its axis, and a local control that governs it. The structure, in turn, must keep the shape and relative position of the elements, transmitting the driving force from the tracker, and avoiding deformations caused by their own weight or other external forces such as the wind.

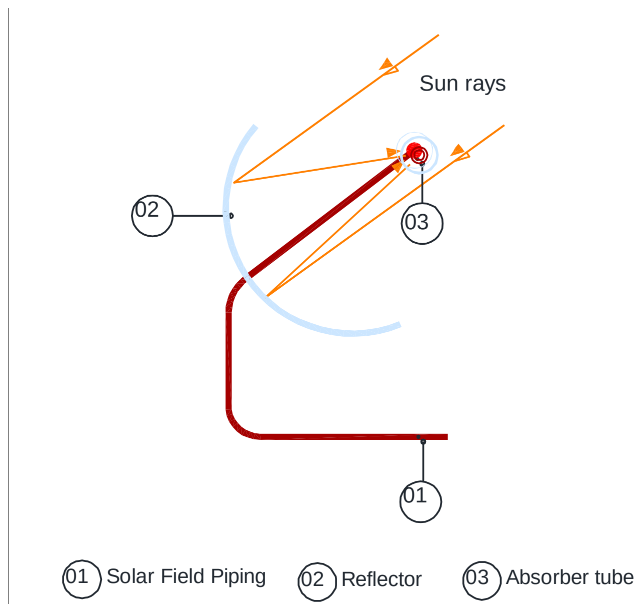

Figure 4. Schematics of a Parabolic Trough collector.

The power block of a Parabolic Trough CSP plant resembles a conventional Rankine-cycle power plant. The main difference is that, instead of combustion or nuclear process, the heat used to generate superheated steam is collected in the solar field and transferred using a heat transfer fluid. The main components of the power block are:

- **Condenser**: although it is also a heat exchanger, its design is more complex, and it affects the overall performance of the plant more than the other heat exchangers in the plant because it modifies the discharge pressure of the turbine. Being so, the Turbine manufacturer could try to limit the possible suppliers in order to give a performance guarantee, or even include it in its own scope of supply.

- **Electrical generator**: within the generator, the rotary movement from the Turbine is transmitted to a series of coils inside a magnetic field, thus producing electricity due to electromagnetic induction. The design and manufacturing of a generator requires special materials and alloys and a highly specialized workforce, only available to a limited amount of companies around the world. Carbon steel, stainless steel and special alloys are required for their manufacture, as well as copper and aluminum in smaller amounts.
- **Heat exchanger**: two different sets of heat exchangers are required in the power block. First, HTF-water heat exchangers (usually referred to as SGS or Steam Generation System) are required to generate the high-pressure and temperature steam that will drive the Turbine. Second, water-water heat exchangers are used to recover the heat from turbine bleeds, in order to preheat the condensate or feed water, thus increasing the Rankine cycle efficiency. If a TES system is included, a reversible, molten salt-HTF heat exchanger is also necessary. Carbon steel and stainless steel are required for their manufacture, as well as copper and aluminum in smaller amounts.
- **HTF Pumps**: the materials commonly used in joints for the range of temperatures and pressures required for this application are not compatible with the chemical composition of the HTF oil. Thus, specific designs and materials, mostly derived from the petrochemical industry, are necessary.
- **Pumps**: several sets of pumps are required within a Parabolic Trough CSP plant: feed water pumps, cooling water pumps, condensate pumps, and other minor pumps for dosing, sewage, raw water and water treatment purposes. If a TES system is included, molten salt pumps are also necessary. Carbon steel and stainless steel are required for their manufacture, as well as copper, aluminum and other materials in smaller amounts.
- **Steam turbine**: the expansion of the steam inside the turbine will cause the motion of the rotor blades, and this movement will be transmitted to the Electrical generator in order to produce electricity. The design and manufacturing of a turbine requires special materials and alloys and a highly specialized workforce, only available to a limited amount of companies around the world. Carbon steel, stainless steel and special alloys are required for their manufacture.
- **Storage tanks**: a large amount of tanks and pressure vessels are required in a Parabolic Trough CSP plant. This includes raw and treated water storage tanks, the deaerator, the steam drum, and the condensate tank for the Rankine cycle, the HTF storage, expansion and ullage vessels and other minor tanks for sewage, water treatment intermediate steps, etc. If a TES system is included, molten salt “hot” and “cold” storage tanks are also necessary. Carbon steel and stainless steel are required for their manufacture.

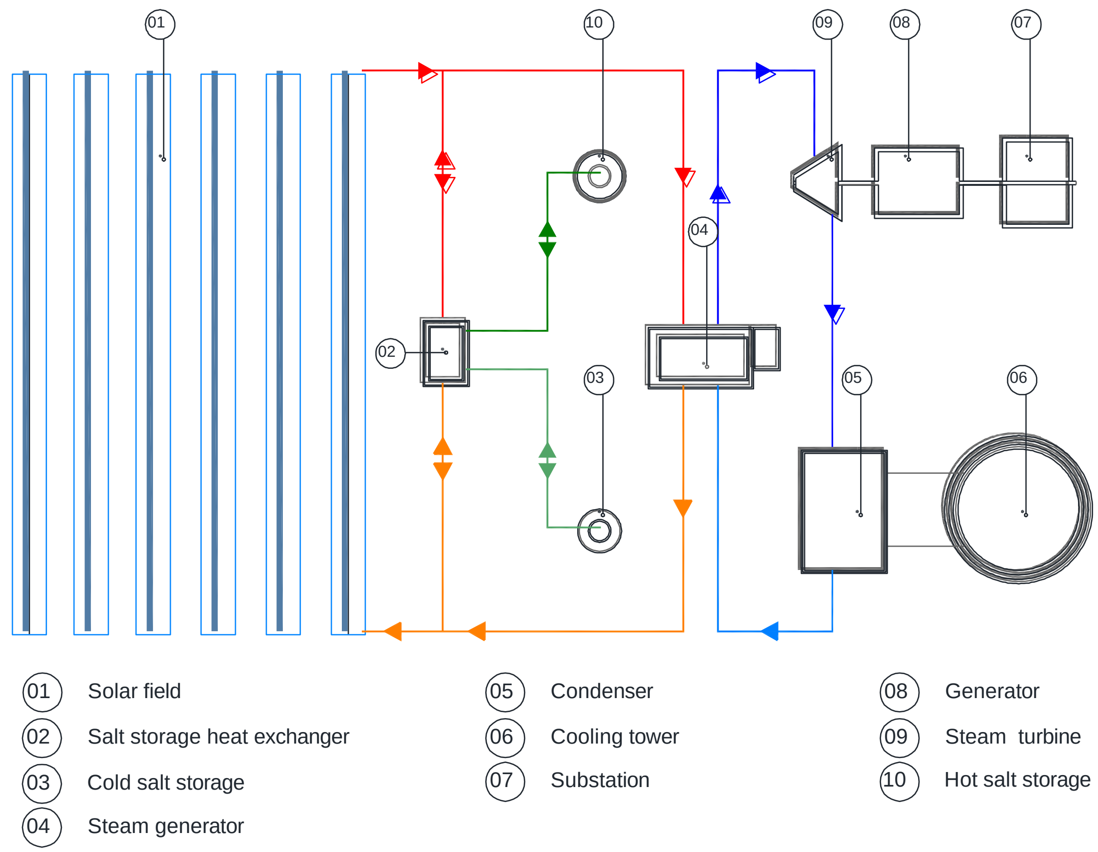

Figure 5. General schematics of a Parabolic Trough CSP plant with thermal energy storage.

The state of the art in the field of thermal energy storage (TES) is to use molten salts. The most common mixture used for this purpose is referred to as "**Solar salt**", and is composed by sodium nitrate ($NaNO_3$) and potassium nitrate (KNO_3). As described above, this salt is stored in two tanks (one "cold" and one "hot"), and a reversible heat exchanger is used to move energy from the solar field and to the power block.

Other elements are also necessary, such as piping, insulation, and either flexible piping or rotating joints in order to connect adjacent collectors, as well as electric switchgear, water treatment equipment, etc. However, these elements are either unspecific of CSP technology or, in the case of flexible piping or rotating joints, pose a minor fraction of the investment costs and are a highly specialized component, and thus have been omitted from this report.

3.1.2.2 Power Tower systems

The Power Tower systems, also known as Central Receiver systems, have more complex optics than the systems showed before as it is a 3-D concentration concept. A single solar receiver is mounted on top of a tower and sunlight is concentrated by means of a large paraboloid that is discretized in a field of heliostats. Multi-tower systems are also under development. As seen in Figure 2, Power Tower systems currently represent 3% of total CSP installed capacity, although this number is expected to increase in the near future as its share in the pipeline is higher than that.

Concentration factors for this technology range are between 200 and 1,000. Plant unit sizes could range between 10 and 200 MW and are therefore suitable for dispatchable markets. Integration into advanced thermodynamic cycles is also feasible.

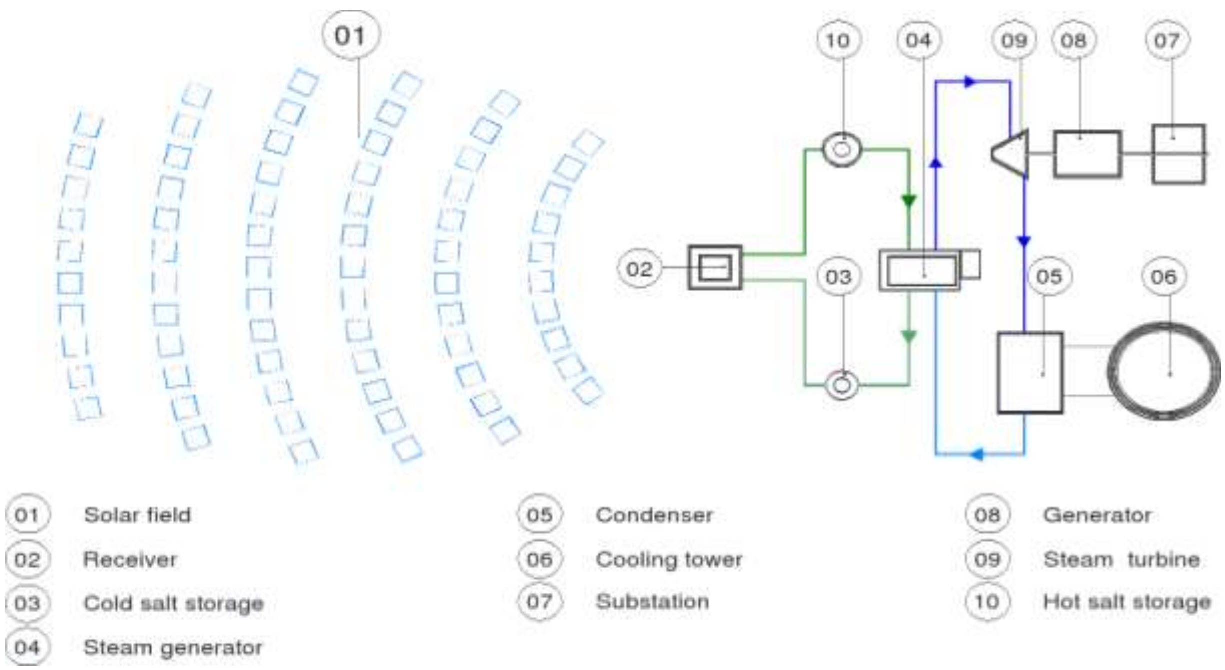

Figure 6. Functional scheme of a power tower system, using molten salt as HTF, with TES.

Although less mature than the parabolic trough technology, after a proof-of-concept stage, the power tower is currently taking its first steps into the market with three commercial plants in operation in southern Spain: PS10 & PS20 (11 and 20 MWe, using saturated steam as heat transfer fluid) and Gemasolar (17 MWe, using molten salts as HTF). Sierra SunTower, a 5 MWe plant in Lancaster, California (US) started operation in 2009 using a multi-tower solar field.

To this day, more than 10 different experimental power tower plants have been tested worldwide, generally small demonstration systems between 0.5 and 10 MWe, most of them operated in the 80's. During the last years, commercial power tower plants have been developed with a design power output higher than 100MWe, being the most representative the following projects:

Project Name	Location	Country	Power	Status
Ivanpah Solar	Mojave Desert, Nevada	USA	392 MW	Operational
Crescent Dunes	Tonopah, Nevada	USA	110 MW	Under construction
Cerro Dominador	Atacama Desert, Antofagasta	Chile	110 MW	Project awarded and approved

Table 2. Commercial Solar Power Plant Projects with power outputs higher than 100MWe. Source: (10).

A wide variety of heat transfer fluids like saturated steam, superheated steam, molten salts, atmospheric air or pressurized air can be used, and temperatures vary between 200 ºC and 1,000 ºC.

Falling particle receiver and beam-down receiver are other promising technologies, but farther from the market.

A Power Tower solar field comprises a variable number of identical heliostats, which reflect the sunlight towards the Receiver. The heat transfer fluid temperature will reach 250 to 700 ºC, depending on whether the HTF used is air, steam, molten salt, etc. The main components of a Power Tower solar field are:

- **Mirror**: used to reflect the direct solar radiation incident on it and concentrate it onto the Receiver, they are sometimes referred to as “facets”. The mirrors are made with a thin silver or aluminum reflective film deposited on a low-iron, highly transparent glass support to give them the necessary stiffness. They are almost identical to the mirrors for Parabolic Trough, differing only in size and shape. Although small heliostats can be made of flat glass, a slight curvature is necessary[2] for larger sizes.
- **Receiver**[3]: collects the radiation reflected by the heliostats and transfers it to the HTF in the form of heat. It is the real core of a power tower system and the most technically complex component, because it has to absorb the incident radiation under very demanding concentrated solar flux conditions and with the minimum heat loss. Receivers can be classified either by their configuration, as flat or cavity systems; or by their technology, as tube, volumetric, panel/film and direct absorption systems. Super Alloys or ceramics are the usual material for receivers.
- **Structure & Tracker**: the solar tracking system changes the position of the Mirrors on the heliostats, following the apparent position of the sun during the day and allowing concentrating the solar radiation onto the Receiver. Each heliostat performs a two-axis tracking with a drive that rotates the Mirrors, and a local control that governs it. The structure, in turn, must keep the shape and relative position of the elements, transmitting the driving force from the tracker, and avoiding deformations caused by their own weight or other external forces such as the wind.

[2] Due to non-ideal optics, as the Sun is not a point focus.

[3] The Receiver has been included in the solar field so as to keep an analogous structure for all CSP technologies, although in Power Tower systems it is physically within the power block.

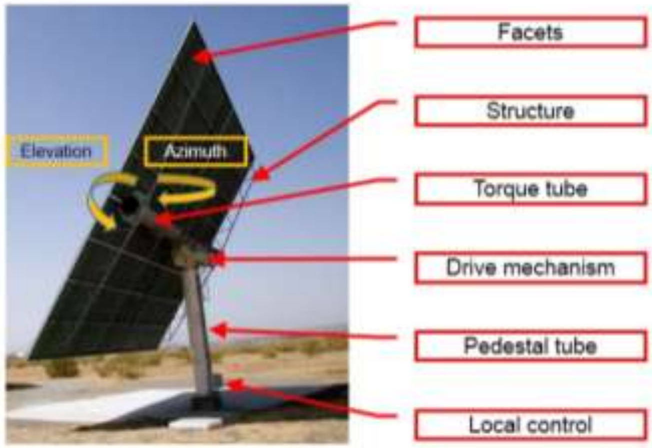

Figure 7. Main components of a heliostat. Photo courtesy of PSA-CIEMAT.

The power block of a Power Tower CSP plant resembles that of a Rankine-cycle power plant. The main difference is that, instead of a combustion or nuclear process, the heat used to generate superheated steam is collected in the solar field and transferred using a heat transfer fluid. The main components of the power block are:

- **Condenser**: it is analogous to the equipment described for Parabolic Trough plants.
- **Electrical generator**: it is analogous to the equipment described for Parabolic Trough plants.
- **Heat exchanger**: two different sets of heat exchangers are required in the power block. First, HTF-water heat exchangers (usually referred to as SGS or Steam Generation System) are required to generate the high-pressure and temperature steam that will drive the Turbine; this set will not be necessary if steam is used as HTF. Second, water-water heat exchangers are used to recover the heat from turbine bleeds, in order to preheat the condensate or feed water, thus increasing the Rankine cycle efficiency. If a molten salt TES system is included, a reversible, molten salt-HTF heat exchanger is also necessary, unless the very molten salt is used as HTF. Carbon steel and stainless steel are required for their manufacture, as well as copper and aluminum in smaller amounts.
- **Pumps**: it is analogous to the equipment described for Parabolic Trough plants.
- **Steam turbine**: it is analogous to the equipment described for Parabolic Trough plants.
- **Storage tanks**: it is analogous to the equipment described for Parabolic Trough plants.

The state of the art in the field of thermal energy storage (TES) is to use molten salts. The most common mixture used for this purpose is referred to as "**Solar salt**", and is composed by sodium nitrate ($NaNO_3$) and potassium nitrate (KNO_3). As described above, this salt is stored in two tanks (one "cold" and one "hot"), and a reversible heat exchanger is used to move energy from the solar field and to the power block. This heat exchanger is not necessary if the molten salt is directly used as HTF

Other elements are also necessary, such as piping, insulation, electric switchgear, water treatment equipment, etc. However, these elements are either unspecific of CSP technology or pose a minor fraction of the investment costs, and thus have been omitted from this report.

3.1.3 Institutes and agencies

In Europe, Plataforma Solar de Almería, CIEMAT, Spain www.psa.es is a leading R&D Center in concentrated solar energy, German Aerospace Center (Deutsches Zentrum für Luft- und Raumfahrt; DLR) is involved in the research and certification of different solar technologies and the Fraunhofer Insititute for Solar Energy Systems (ISE) conducts research on solar technologies and provides know-how and technical facilities as services. In U.S.A., NREL and DOE carry out research both in CSP and PV.

Figure 8. P.S.A. aerial view.

3.2 SOLAR ENERGY IN THE COMMONWEALTH OF INDEPENDENT STATES (CIS)

Given the differences in annual solar insolation among the countries of the Commonwealth of Independent States (CIS) and their different natural resources, the grade of development of solar energy varies from one country to another.

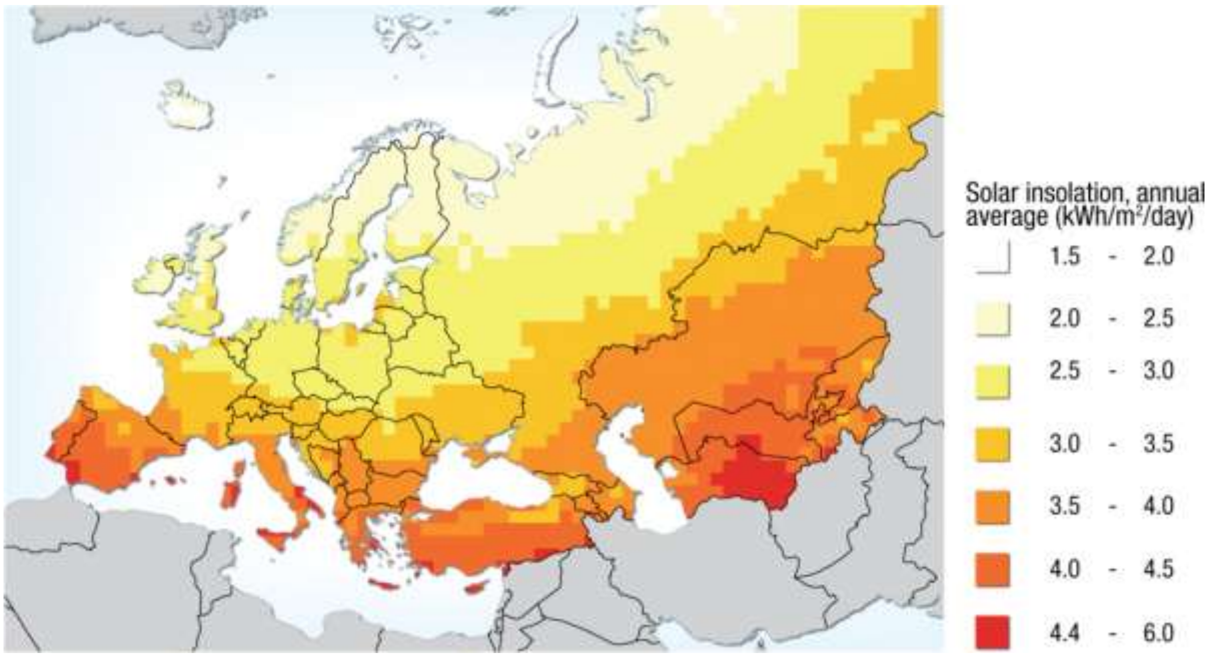

Figure 9. Annual average of solar insolation for Europe and Central Asia. Source: (11).

Figure 9 shows the annual average solar insolation for Europe and Central Asia. The countries of the CIS with a higher insolation average are located in Central Asia and the Caucasus.

3.2.1 Armenia

The average solar insolation over the country is 1.700kWh/m^2 per year, yet solar technology remains underdeveloped in Armenia. Estimated potential for solar thermal and PV exceeds 1,000MW (12). As per 2010, installed power was 0.1MW for PV and 0.25MW for solar thermal.

3.2.2 Azerbaijan

Azerbaijan relies heavily on its oil and gas reserves. This acts as a disincentive for the promotion and development of renewable energy sources. Solar insolation is similar to that of Armenia, 1,715kWh/m^2 per year. The recently approved plan “National Strategy for the Development of Alternative and Renewable Energy Sources in 2012-2020” aims at 290MW installed capacity for 2015 and 600MW for 2020 (13).

3.2.3 Georgia

Solar insolation in Georgia varies from 1,250 to 1,800 kWh/m^2 per year (14). Despite its potential, solar technology remains behind hydroelectric and thermal technology. The first accounts for over 85% of the electricity produced in the country (12).

3.2.4 Kazakhstan

Kazakhstan is rich in oil and gas, which has prevented the development of a market for renewable energy. Nevertheless, the country has embarked on a strategy and passed legislation to promote renewable energy resources targeting a 5 % share in the energy balance by 2024 (15). Solar potential in Kazakhstan is 6.7 million GWh/year (16) and the country has between 2,200 and 3,000 sunshine hours annually (17). Annual solar insolation varies between 1,300 and 1,800kWh/m^2 (17).

The presence of large reserves of high-purity quartz may further contribute to the development of solar energy in Kazakhstan (18). The country’s largest field, Sarykol, is located in the Karatal area of the country. Proven reserves there are estimated to be 1.7 million tons, with level of ore impurities at 0.5%. In 2012, the country produced metallurgical silicon at its Kazsilikon plant at a daily capacity of between 12 to 13 tons. The plant is expected to reach an annual production level of 5,000 tons this year (18).

3.2.5 Kyrgyzstan

Solar insolation varies from 1,000 to 1,700kWh/m^2 per year in Kyrgyzstan. The potential for solar energy in the country is 490GWh/year for thermal and 22.5GWh/year for electric (PV and CSP) yet less than 1% is practically used (19). Reasons for this are weak mechanisms for financial support, lack of qualified specialists in the renewable energy sector, imperfect legislation and low awareness of the population about the benefits of using this kind of technology. The law “On Renewable Energy”, adopted in 2008, plans to further develop the use of renewable energies in the country.

3.2.6 Tajikistan

Hydro power is the most used source of energy in Tajikistan, followed by oil and gas (20). Rural population has difficulties in accessing electric power due to deficient infrastructure. As a result, interest in solar energy has grown in the last years. Estimated solar potential in Tajikistan is 410 million MWh/year in Tajikistan (16). In order to decrease energy dependence, rural areas of the country are installing solar systems and some micro-finance institutions have already begun to develop credit lines in order to enable the purchase of solar systems (21). Solar thermal and PV is not used in a large scale in the country (22).

3.2.7 Turkmenistan

86% of the country is covered by desert and annual solar insolation varies between 1,700 and 1,900kWh/m^2 (23). Average of annual sunshine hours is 2,925 (23). Even though Turkmenistan is self-sufficient in electrical power generation, producing 14GWh annually, renewable energy is in demand in a number of localities, such as the Caspian islands, which are not connected to the country's centralized electric power lines (24). Turkmenistan's Giun Scientific and Production Association, founded in 2007, has become a key player in the country's alternative energy development plans. Giun's research projects include the development of solar PV technologies and integrated wind and solar power complexes, both for generating electricity and pumping water.

3.3 SOLAR ENERGY IN UZBEKISTAN

Currently, no large solar power plant is in operation in Uzbekistan. The country is highly dependent on fossil fuels despite a small percentage of hydro generation. Power plants are classified according to the fossil fuel used.

In Uzbekistan, the joint stock company Uzbekenergo, is responsible for power generation, transmission and distribution. Uzbekenergo is 100% state-owned and controls thirteen “unitary” generation enterprises, three heat production enterprises, an electricity transmission enterprise and fifteen regional distribution enterprises. The share of power plants that are not part of Uzbekenergo is less than 3% (320 MW).The other power generation company, Uzsuvenergo under the Ministry of Agriculture and Water Resources (MAWR), focuses on development and operation of the small hydropower plants on water reservoirs and irrigation canals managed by the MAWR.

Total production of electricity amounted to 52.7 TWh in year 2011. Total installed generating capacity is equal to 12.3 GW in 38 power plants, including 10 thermal power plants (TPP) with a total capacity of 10.9 GW and 28 hydropower plants (HPP) with a total capacity of1.4GW.

The energy mix in Uzbekistan is dominated by fossil fuel-fired thermal power stations, 85% of them use natural gas, 11% fuel oil and 4% coal.

Uzbekistan has an ambitious plan to upgrade and increase capacity; currently, it holds around 50% of the total Central Asia interconnected system capacity (25).

Global solar irradiation potential in Uzbekistan is presented in Figure 10 Direct Normal Irradiation (DNI) and in Figure 11 Global Horizontal Irradiation (GHI).The first one is correlated with CSP potential and the second with PV potential. To check the potential of solar energy in Uzbekistan a selection process has been carried to identify feasible sites for the installation of meteorological ground stations. These sites are close to areas where, a priori, feasible solar power plants could be built (26)[4]. Meteorological stations locations are showed in the above mentioned figures.

Solar experimentation has been going on in the country since 1925 with actinometrical measurements at the Uzbek Hydro meteorological institute. Since then, research and development has been carried out and a landmark was established in 1987, when a large solar furnace 1MW was set in operation and "Physics-Sun" was organized within Uzbekistan Academy of Science. Uzbekistan has a good technical capacity and knowledge in Concentrated Solar, materials and photovoltaic technology and an incipient solar component industry.

[4] A summary can be found in ANNEX III: SITE SELECTION.

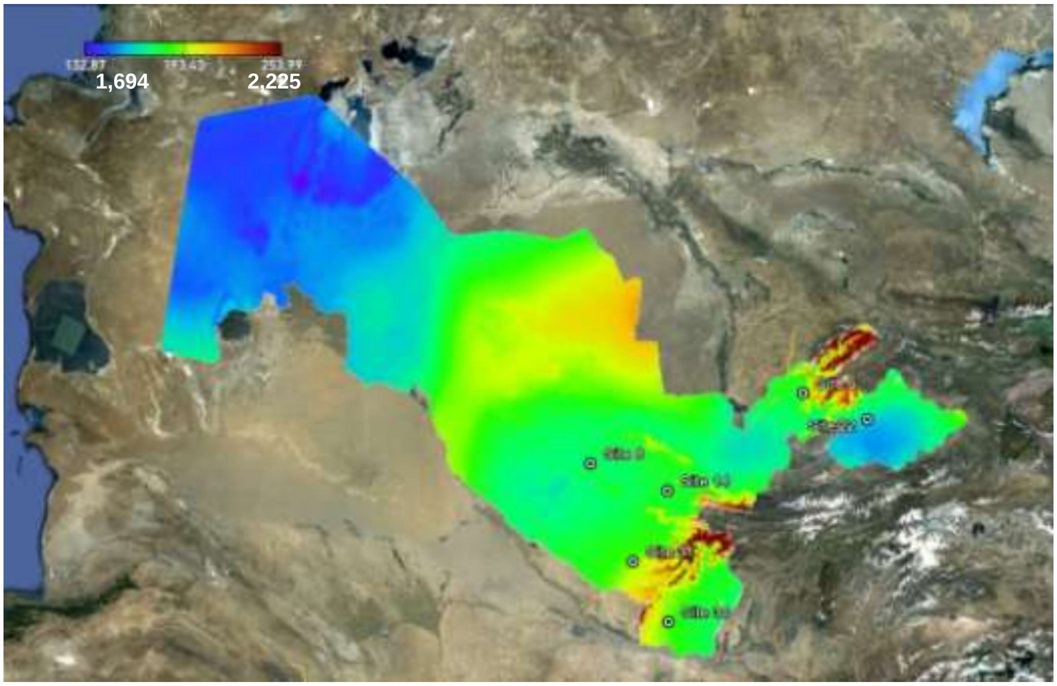

Figure 10. Ground meteo-station locations and (DNI (W/m^2 /year kWh/m^2 year) source: 3Tier)

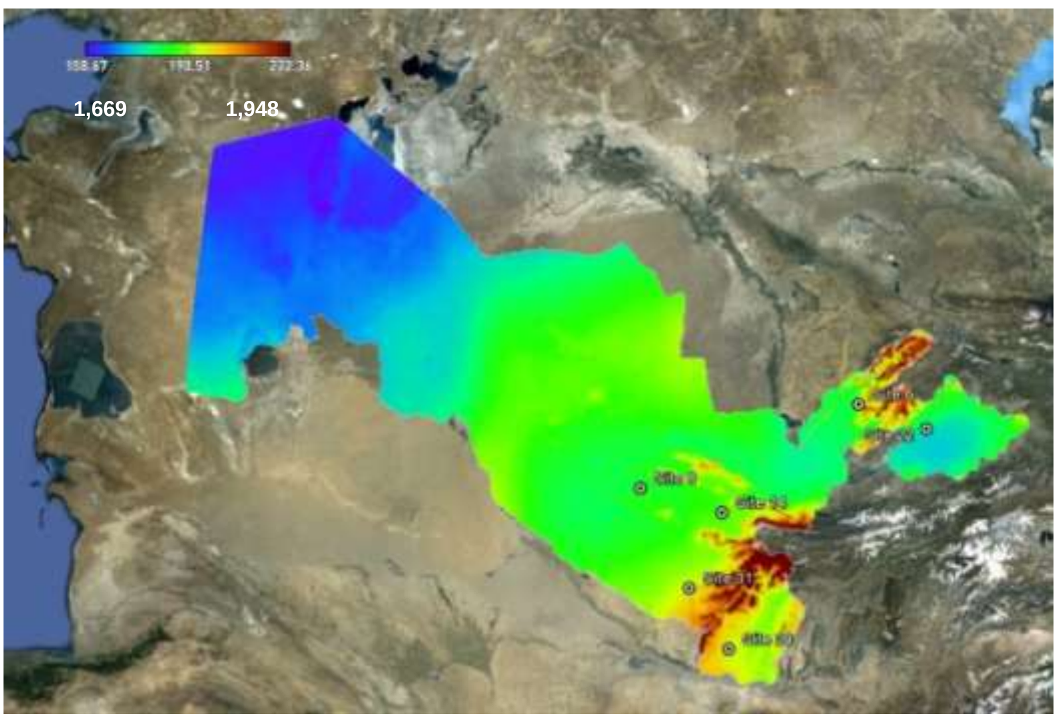

Figure 11. Ground meteo-station locations and (GHI (W/m2 /year kWh/m2 year) source: 3Tier)

The coordinates of the meteo-station locations are the following:

Nº	Province	Name	Coordinates N	Coordinates E
6	Tashkent	Parkent District, 'Solar' Village	N 41º 18' 57''	E 69° 44' 28''
8	Navoi	Karmana Village, Meteostation	N 40º 08' 43''	E 65º 18' 32''
14	Samarkand	Dagbit Village, Meteostation	N 39º 45' 28''	E 66º 54' 54''
22	Namangan	Pap District, Pap city, Meteostation.	N 40º 52' 41''	E 71º 06' 43''
30	Surkhandarya	Sherabad city, Meteostation.	N 37º 39' 57''	E 67º 00' 31''
31	Kashkadarya	Guzar city, Meteostation.	N 38º 37' 05''	E 66º 15' 17"

Table 3. Meteo-station selected sites.

The data gathered during six months in ground meteorological stations has been correlated with 13 year satellite data to estimate the long term solar resource in the selected sites Figure 12.

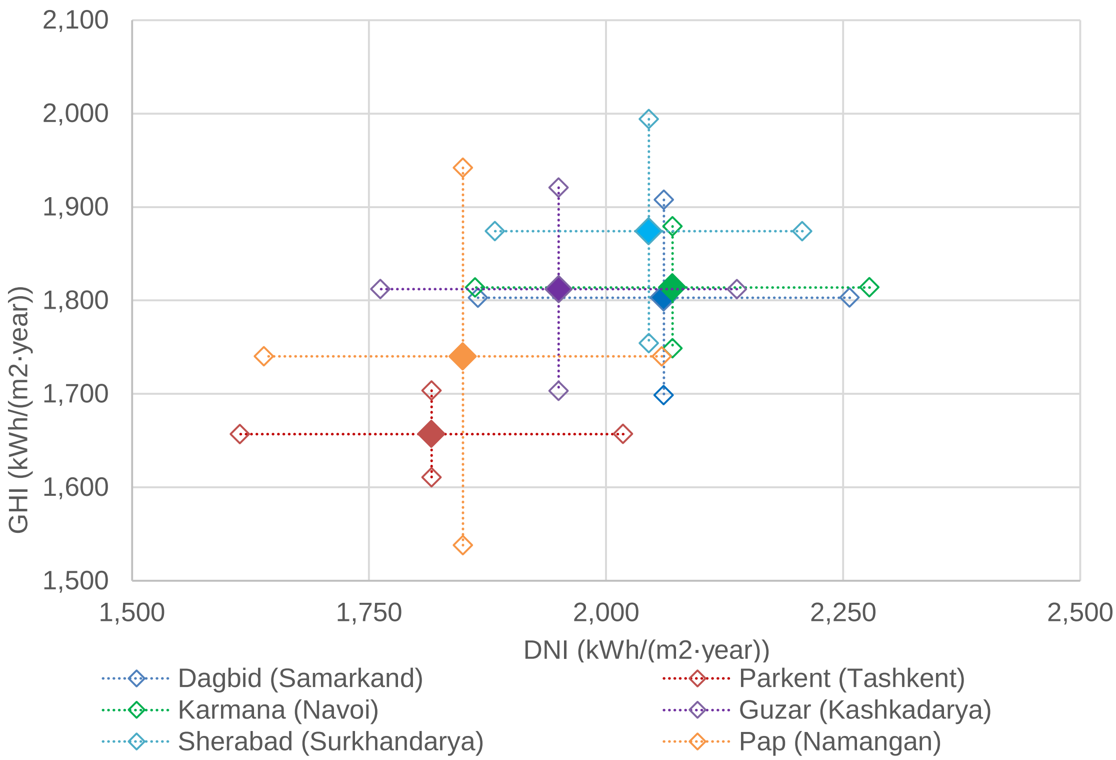

Figure 12. Long term yearly irradiation and error (95%) on the six meterological stations site (13 years satellite data calibrated with 6 months on-site measurement)

Thus, there are locations with GHI higher than 1.800 kWh/m^{2}year and DNI higher than 2.000 kWh/m^{2}year which are suitable to set up solar energy power plants, both CSP and PV. Considering only the criteria of higher resource available to prioritize, and based on the values shown in Figure 12, the best locations to develop CSP and PV are shown in Table 4:

	Best (+) ←					(-) Worst
CSP (Solar Resouce: DNI)	Karmana	Dagbid	Sherabad	Guzar	Pap	Parkent
PV (Solar Resource: GHI)	Sherabad	Karmana	Guzar	Dagbid	Pap	Parkent

Table 4. Best locations available according to Solar Resource and Technology used..

Nevertheless, to evaluate an specific project, other variables must be considered.

Developing solar energy production plants is an option in Uzbekistan which would assure sustainability, liberate national natural gas for other higher value added uses and contribute to future country energy security.

3.4 FORECASTED COST EVOLUTION OF SOLAR ENERGY

Both CSP and PV technologies are forecasted to decrease their generation costs in the next years, the tendency is shown in Figure 13 and Figure 14 as per International Energy Agency (IEA) forecasts.

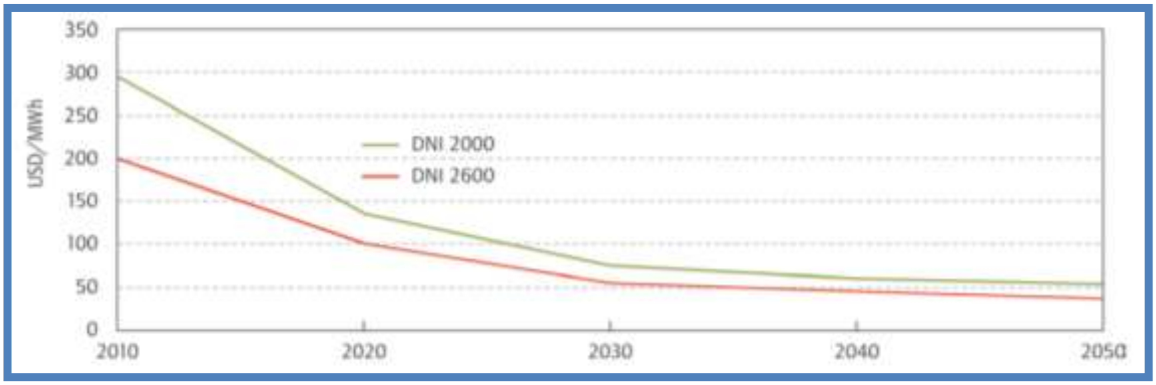

Figure 13. Projected evolution of levelised electricity cost from CSP plants, in USD/MWh, under different DNI levels in kWh/m2/year (9).

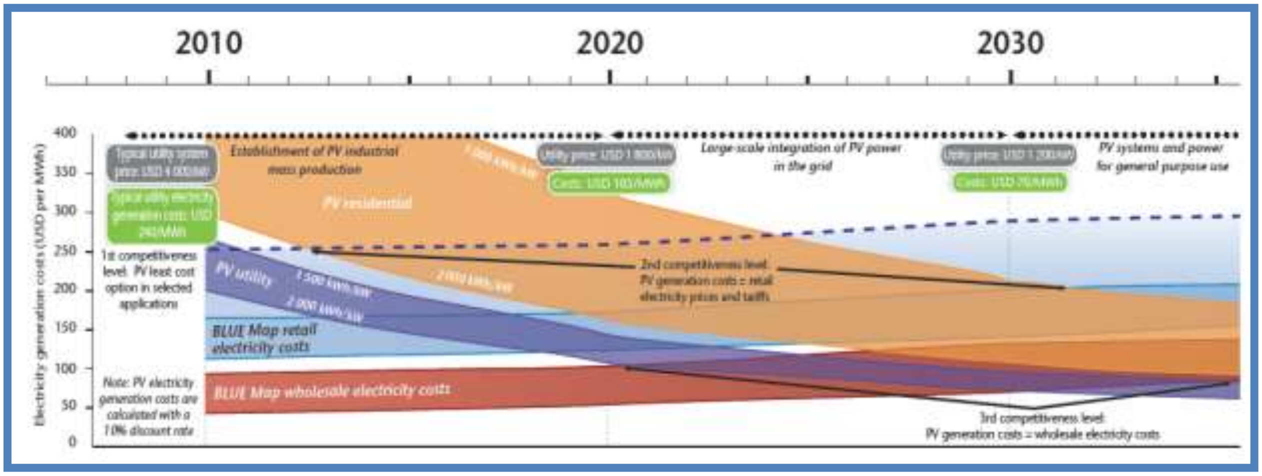

Figure 14. Projected evolution of levelised electricity cost from PV plants, in USD/MWh (3).

These figures show a forecasted trend developed by IEA (further details: (9) and (3)) which are based on underlying hypotheses and business models. They can only be considered as a reference. In the present roadmap, only the trend has been used and customized to Uzbek case.

4 DESCRIPTION OF SOLAR ENERGY DEVELOPMENT SCENARIOS

4.1 CONSUMPTION SCENARIOS

Table 5 forecasts the demand of energy from 2015 to 2030. In Republic of Uzbekistan, demand is to be satisfied using national power plants.

Three consumption scenarios have been analyzed:

- Conservative Scenario
- Intermediate Scenario
- Proactive Scenario

The 'Conservative' scenario is based on lower growth rates and lower energy intensity of demand, whereas the 'Proactive' scenario assumes higher economic growth rates and higher energy intensity.

Energy Consumption Scenarios (TWh)	2015	2020	2025	2030
Conservative Scenario	58	63	68	75
Intermediate Scenario	58	70	85	105
Proactive Scenario	58	75	98	130

Table 5. Energy consumption [TWh] according to 3 scenarios. Source: Consultant´s elaboration in communication with Uzbekenergo.

4.2 GENERATION SCENARIOS

4.2.1 Introduction

Three scenarios have been defined by the team of experts taking into account several factors such as energy demand, land availability, investment, water, human resources and materials requirements. Energy generation was divided in the following scenarios:

- Neutral Scenario
- Optimistic Scenario

- Pessimistic Scenario

After an evaluation of the existing power plants and the on-going modernization plans following hypotheses have been considered to define these scenarios:

- Value of energy production by means of fossil fuels is set to 59TWh in all scenarios in 2030.[5] (1).
- Biomass energy generation is envisaged and accounts for 1TWh in 2030.
- Hydro Power Plants upgrade will allow to produce 8,5 TWh in 2030.

From these scenarios, a forecast on: land, investment, water and human resources requirements, is presented in Chapter 0.

4.2.2 Neutral Scenario

In this scenario, Uzbekistan's renewable energy[6] share will be sufficient to cope with the 100% of Conservative Scenario of consumption[7] in 2030.

This scenario will also allow to produce 22% of the total generation of the country (2) in 2030 using renewable sources.

4.2.3 Optimistic Scenario

The Optimistic Generation Scenario considers that the installed PV capacity reaches the 15% of installed capacity with the current energetic mix (Uzbekenergo plan to upgrade HPP and new generation to TTP and combined cycle gas has been taken into account.).

4.2.4 Pessimistic Scenario

This scenario would be able to cover 95% of Uzbekistan's conservative scenario demand for 2030 combining renewable energy plants with the current mix.

---

[5]Hypothesis based on actual capacity and developing modifications for 3 hydro power generation plants (due 2016) and 9 fossil fuel plants (due on 2025). For further information see Progress Report (Component A).

[6] Hydro power plants are considered as renewable energy in the 21% objective.

[7] Conservative Scenario Consumption in 2031 is 75 TWh.

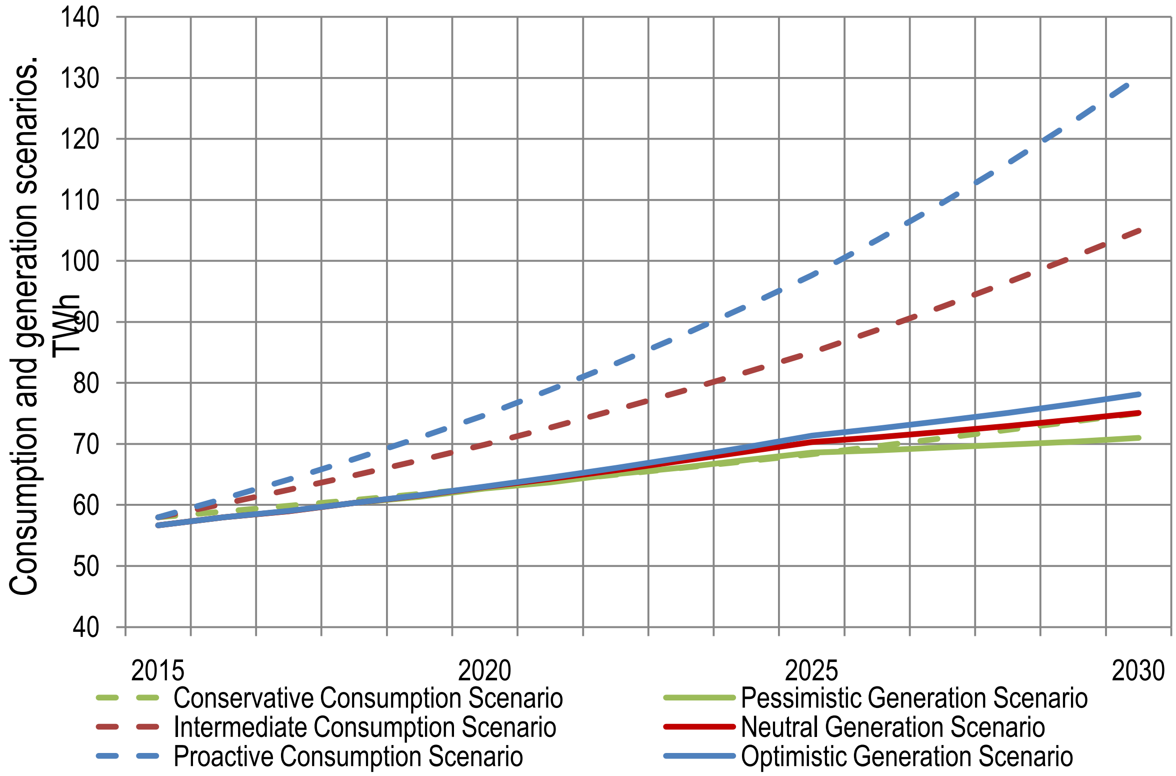

Figure 15. Consumption and generation scenarios. TWh.

4.2.5 Energy to be supplied using solar technologies

Three scenarios have been defined for solar energy deployment: neutral, optimistic and pessimistic. These target scenarios are summarized by means of:

$$E = E_0 + A\,(year - year_0)^{\alpha} \tag{1}$$

where E_0 = 103 MW and α = 2 for all scenarios in 2016, A = 6, 14.65 and 92.68 for pessimistic, neutral and optimistic respectively.

For these three scenarios, the yearly increase in installed capacity has been shared between Photovoltaic (PV) and Concentrated Solar Power (CSP) 5:1 ratio in 2030) following (27) but setting up a limit of 15 % on PV installed capacity over total capacity (system stability).

For PV technology, as the capacity factor is only linked to the meteorological conditions, it is kept constant during time and equal to 18% as an average value for Uzbekistan, which has been calculated by modelling fix tilt PV power plants in 25 adequate Uzbekistan locations using Solar Advisor Model (SAM).

The capacity factor for CSP will increase linearly 1% yearly from 22% in 2016 (28) (average for 50 MW CSP parabolic trough without storage modelled in 25 good Uzbekistan locations using SAM).

To estimate efficiency evolution both of CSP and PV technologies, the figures proposed by (29) (30) have been used.

Thus, splitting the yearly increase of solar energy to be supplied between PV and CSP and later taking into account the capacity factor, the yearly increase in capacity is estimated. The value has been compared with a pipeline of feasible projects in Uzbekistan and, after priorities where defined, an implementation scenario has been built for the next ten years. From 2024 till 2030, no adjustment has been made on the capacity increase to fulfill the target (Eq. 1).

For 2016-2024 period, feasibility of identified projects of solar power plants have been included in the scenarios as to be developed. The remaining are those which match the predicted energy needs as described in Table 5.

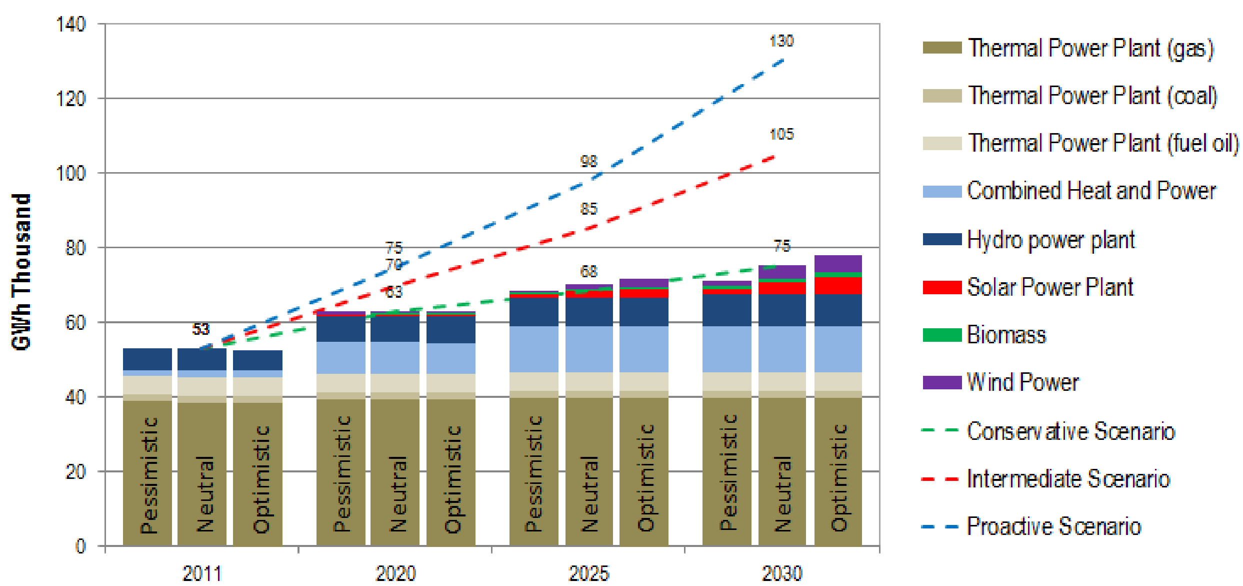

Figure 16. Energy mix and consumption scenarios.

Figure 17 shows the PV installed capacity forecast:

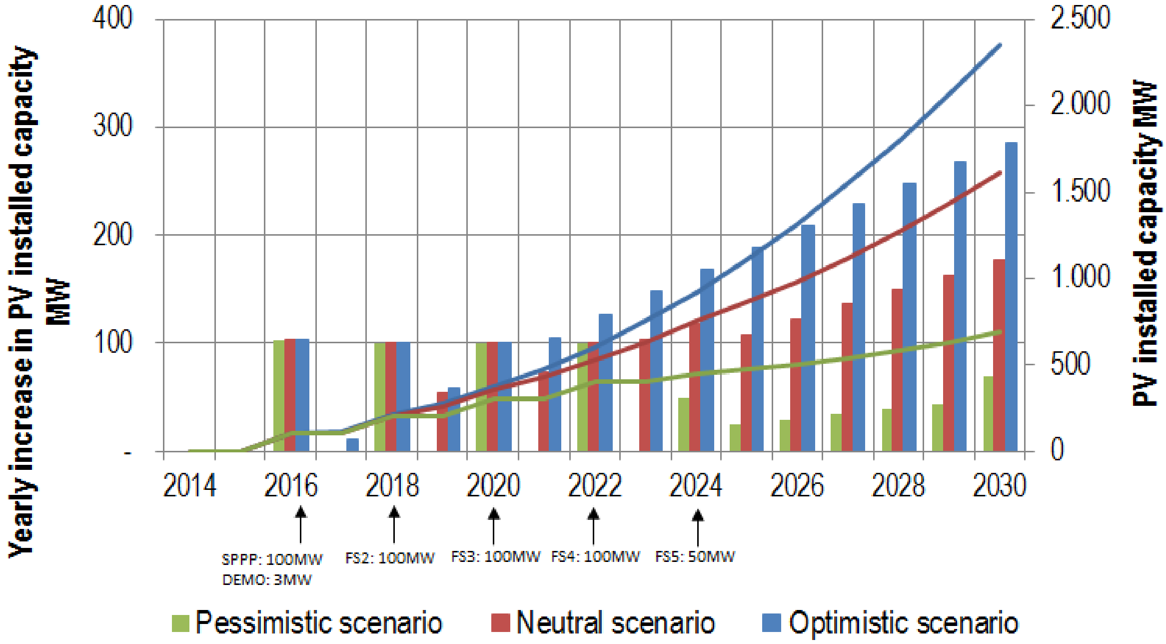

Figure 17. PV installed capacity forecast scenarios. MW.

Figure 18 shows the CSP installed capacity forecast and shows the CSP annual power installed according to different scenarios.

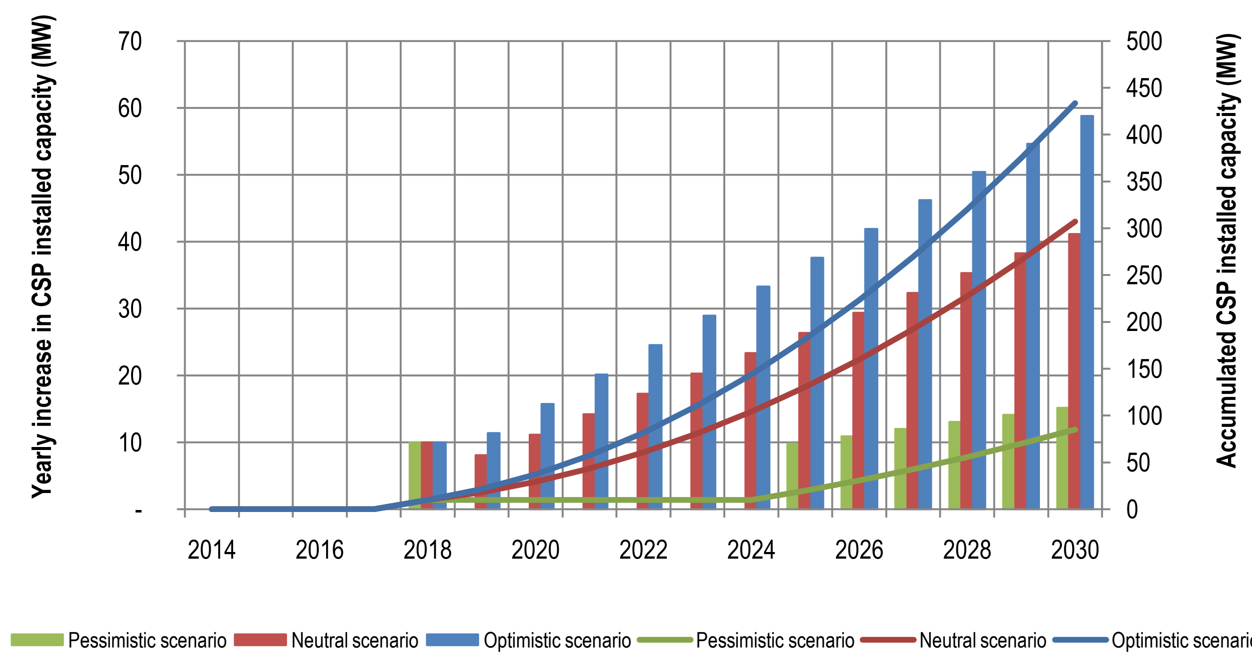

Figure 18. CSP installed capacity forecast scenarios. MW.

Figure 19 and

Figure 20 show the energy produced using PV and CSP technologies.

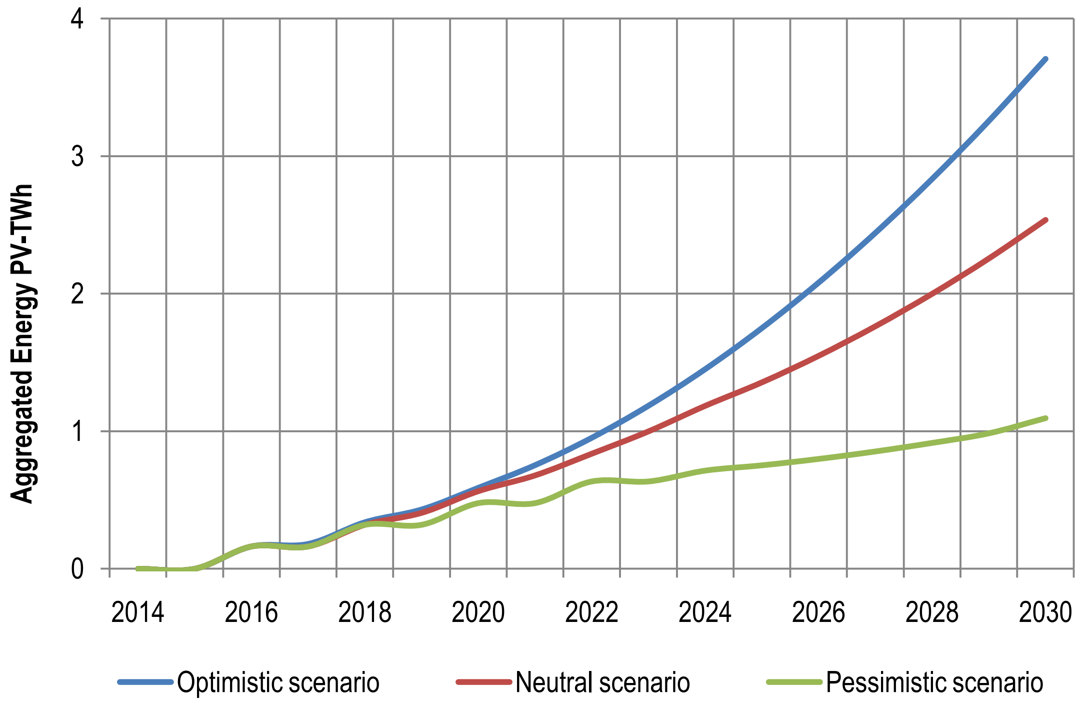

Figure 19. Yearly PV generated energy scenarios. TWh/year.

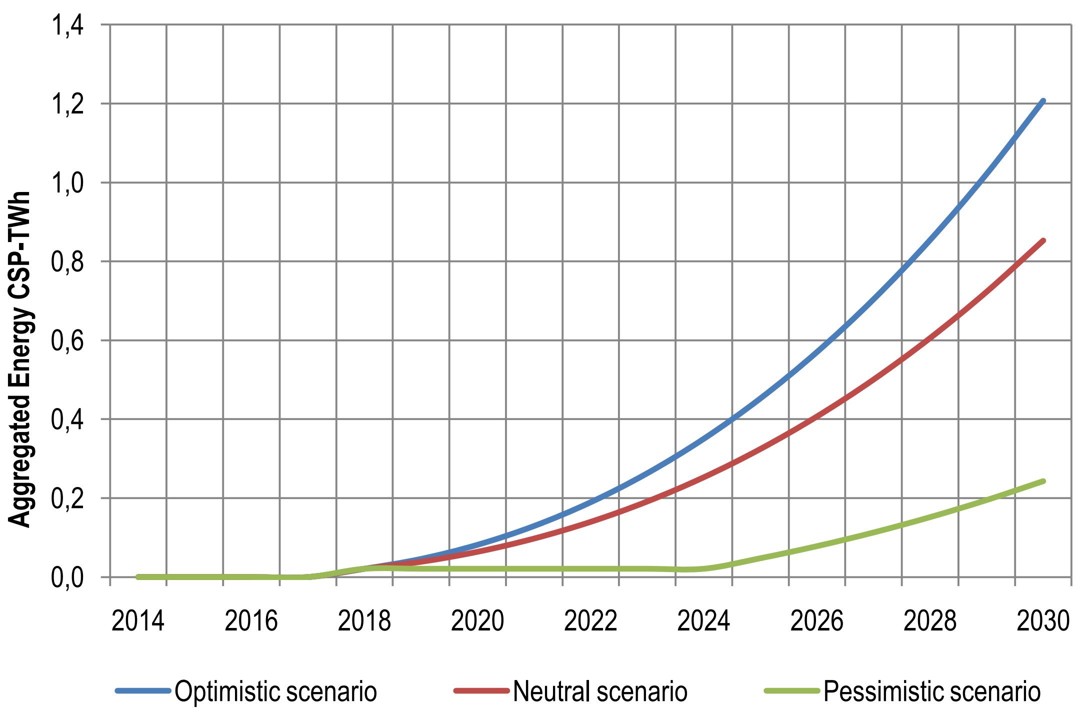

Figure 20. Yearly CSP generated energy scenarios. TWh/year.

4.3 COSTS-BENEFIT ANALYSIS OF THE GENERATION SCENARIOS

The execution of the solar development plan would: liberate natural gas for higher value added uses, decrease the CO_2 emission (possible source of income), avoid the increase of fossil fuels costs and increase energy supply security leading to profits for society in the long run[8].

This Roadmap takes into account the forecast evolution path towards solar energy development which will narrow the existing gaps between solar and conventional energy generation costs. To estimate the real cost of leveraged cost of energy for PV and CSP technologies the following methodology was used (31). Solar real leveraged cost of energy (LCOE) evolution is evaluated for PV by means of eq. 2.and for CSP using eq 3. A, n, and b coefficients are those that better adjust to IEA (3) (9) forecast adapted to Uzbek reality. To adjust these coefficients, LCOE value for PV is equal to 137 USD/MWh in 2012 and CSP LCOE is equal to 223 USD/MW in 2012. Initial LCOE values have been calculated taking into account: meteorological conditions in Uzbekistan (SAM model was run for 25 possible projects), current fiscal system in Uzbekistan, 20 year loan with 5% real interest rate and three years grace period, 70% leverage ratio, 10% real discount rate and investment and operation and maintenance costs (O&M).

$$\mathrm{LCOE_{PV}} = \mathrm{A} \cdot \mathrm{e}^{-\mathrm{n}\cdot(\mathrm{year}-2012)} + \mathrm{b};\ \mathrm{A} = 107.04\,\frac{\mathrm{USD}}{\mathrm{MWh}};\ \mathrm{n} = \frac{0.24}{\mathrm{year}};\ \mathrm{b} = \frac{29.77\mathrm{USD}}{\mathrm{MWh}} \tag{2}$$

$$\mathrm{LCOE_{CSP}} = \mathrm{A} \cdot (\mathrm{year} - 2012)^{-\mathrm{n}} + \mathrm{b};\ \mathrm{A} = 71.20\,\frac{\mathrm{USD}}{\mathrm{MWh\ year}};\ \mathrm{n} = -1;\ \mathrm{b} = 44.83\,\frac{\mathrm{USD}}{\mathrm{MWh}} \tag{3}$$

The forecasted incomes due to natural gas sales and CO_2 emissions and other greenhouse gases (GHG) have been subtracted from the above mentioned LCOE for PV and CSP. This has led to a costs which can be compared with Combined Cycle Gas Turbine (CCGT) LCOE (31) to check the competitively of the solar option. Results are shown in Figure 21.

Cost for society evaluates the impact that solar energy development will have on Uzbek population if compared to a fully conventional energy generation scenario. Reaching parity between the benefit from natural gas savings plus reduction of CO_2 emissions and the higher LCOE (compared to CCGT) is when society start to profit.

[8] The model is a long-term model and cost estimations on alternative sources of energy and international gas prices are based on studies carried by international organizations, namely IAE.

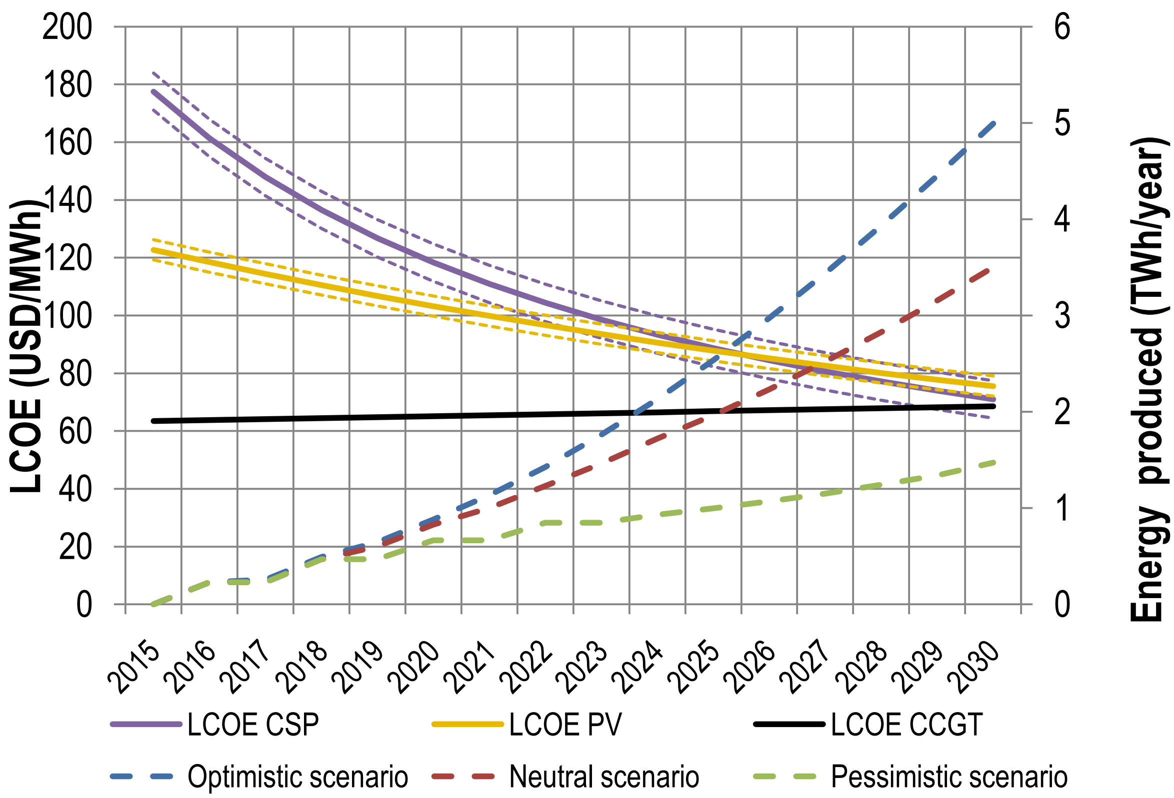

Figure 21. Energy production scenarios and cost of energy comparison between CCGT, CSP and PV technologies.

The cost of energy of solar energy production will reach **parity** with conventional energy production between 2028 and 2030.

Benchmarked technologies have to be evaluated under the same fiscal and economic conditions to obtain reliable results. Therefore, CCGT energy generation has to be striped of any subsidy or privileged policy that represents a difference towards PV and CSP energy generation.

Here again, free disposal of fuel is one of the main advantages of RES electricity generation technologies against CCGT. Consequently, the price paid by conventional power plants for natural gas is fixed to actual market levels. (32)

Levelized cost of energy estimations are particularly sensible to variations on equipment costs, labor costs and fuel costs. For instance, the estimated impact of increasing fuel costs 50% is a consequent 35% rise of LCOE. (33)

The evolution of the social standards, the political structure and the economy of the Republic of Uzbekistan determine the progress of solar energy development. At the same time, the real growth of the electric industry approaches the proposed generation scenarios.

The cost for society, calculated comparing conventional and solar option for the three scenarios, for the whole life of the power plants and CER as reference price for CO2 emissions selling price, is shown in Figure 22 The Figure 23 shows the cost for society considering EUA as a reference price for CO2 emissions selling price.

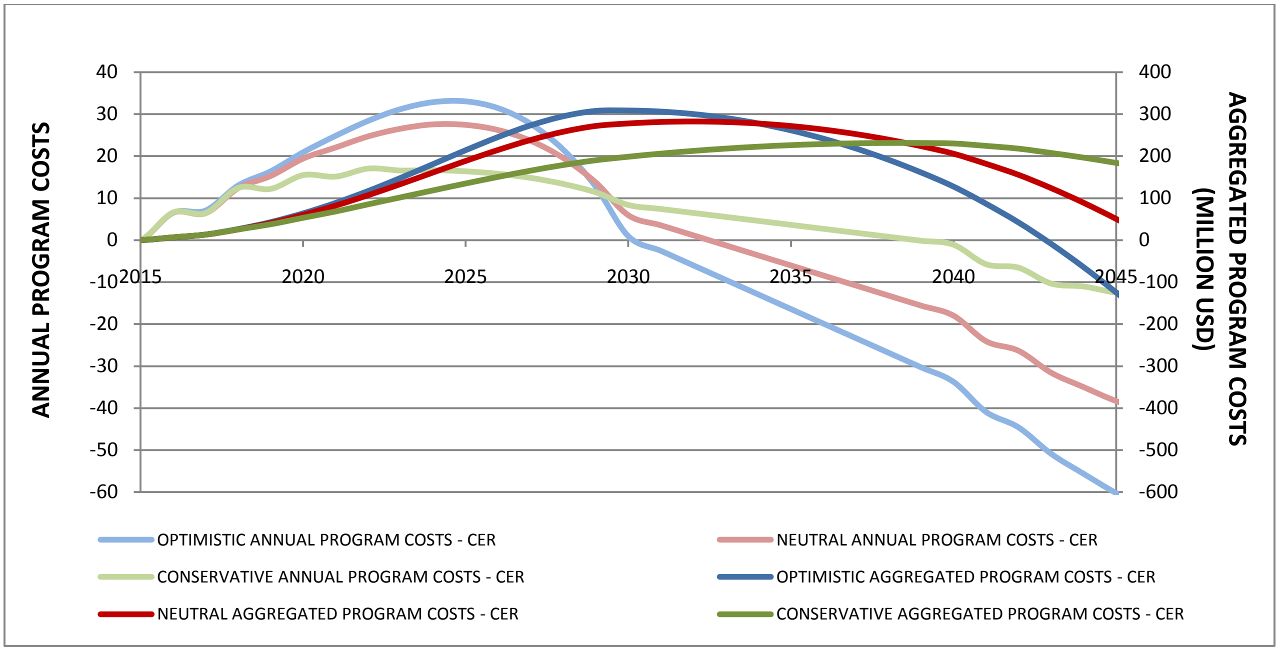

Figure 22. Cost for society evolution over the years (Mill USD), considering CER market for the reference CO2 emissions selling price (mean annual value). Source: Sendeco2

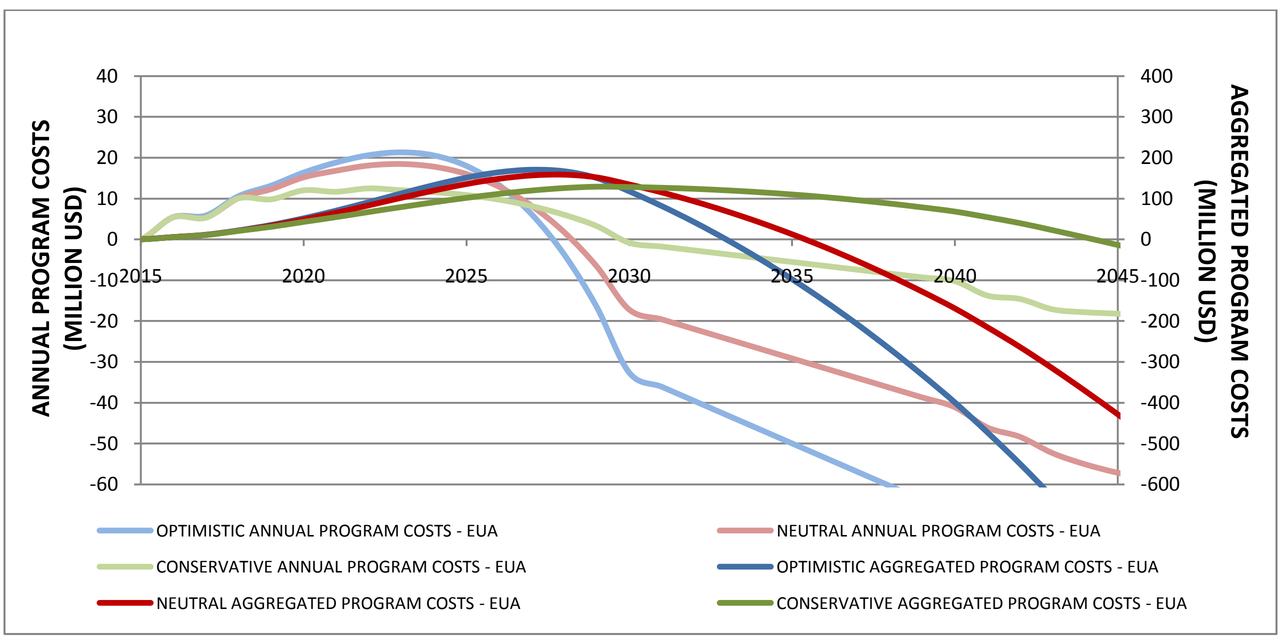

Figure 23. Cost for society evolution over the years (Mill USD), considering EUA market for the reference CO2 emissions selling price (mean annual value). Source: Sendeco2

The cost for society is highly dependent on the social, political and economic evolution of the Republic of Uzbekistan. In the Optimistic scenario Uzbek society bears a higher cost within the first 10 years but on the other hand **the economic benefit (savings and profit from gas sales) will grow faster** if compared to Neutral and Pessimistic scenarios. (**Ошибка! Источник ссылки не найден.**).

The cost for society is highly dependent on the reference market used for CO_2 emissions selling prices.

5 CONSTRAINTS

5.1 INTRODUCTION

The Government of Uzbekistan has shown commitment to develop solar energy. Currently, some constraints may slow down solar energy deployment in the Republic of Uzbekistan.

5.2 LAND REQUIREMENT[9]

PV and CSP technologies require land with specific characteristics. Table 6 contains the cumulative necessary surface to build CSP and PV power plants according to the forecasted capacity scenarios.

Aggregated Land for solar (10^2 ha)		2016	2020	2025	2030
PV	Optimistic scenario	3.2	11.8	30	58.4
	Neutral scenario	2.9	10.7	22.6	40.5
	Pessimistic scenario	2.9	7.8	12.2	17.4
CSP	Optimistic scenario	0.4	3.8	13.7	29.3
	Neutral scenario	0.4	2.8	9.8	20.7
	Pessimistic scenario	0.4	0.4	2.2	6.2

Table 6. Aggregated land requirements for CSP and PV expressed in 10^2 hectares.

Up to around 3.8 million ha of free land fulfill the minimum technical requirements could be adequate to host solar energy. Nevertheless, final rejection or acceptance of different terrains requires technical and economic feasibility analysis.

If a comparison of the needed land with the total surface of Uzbekistan[10]is done for the different generation scenarios, the percentage of land that could be covered by solar energy plants in 2030 is, consecutively: 0.02%, 0.01% and irrelevant (Optimistic, Neutral and Pessimistic) and, if compared with land that fulfils the minimum technical requirements: 0.23%, 0.16% and 0.06%(Optimistic, Neutral and Pessimistic).

[9] Detailed requirements for land selection criteria can be found in (70)

[10] 44,700,000 ha surface, 42,540,000 land surface (excluding water) 88% of it dedicated to uses different than agriculture. (38)

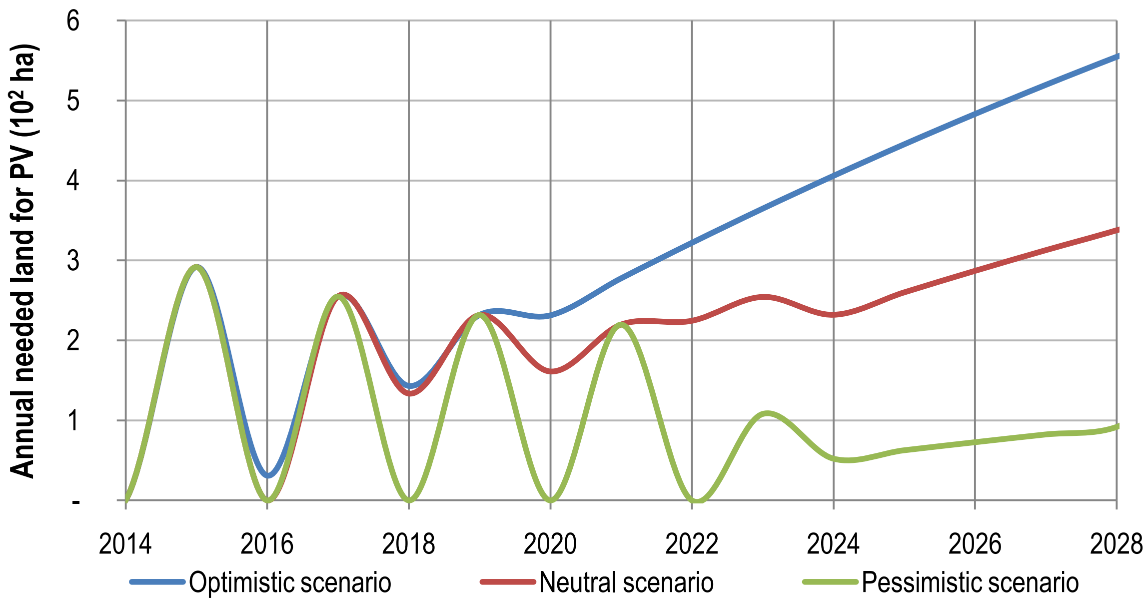

Figure 24. Annual required. Aggregated land requirement for PV (Upper figure) and aggregated land needed (Lower Figure). Annual Land needed considers that the required land is needed one year prior to the installation of the PV power plants.

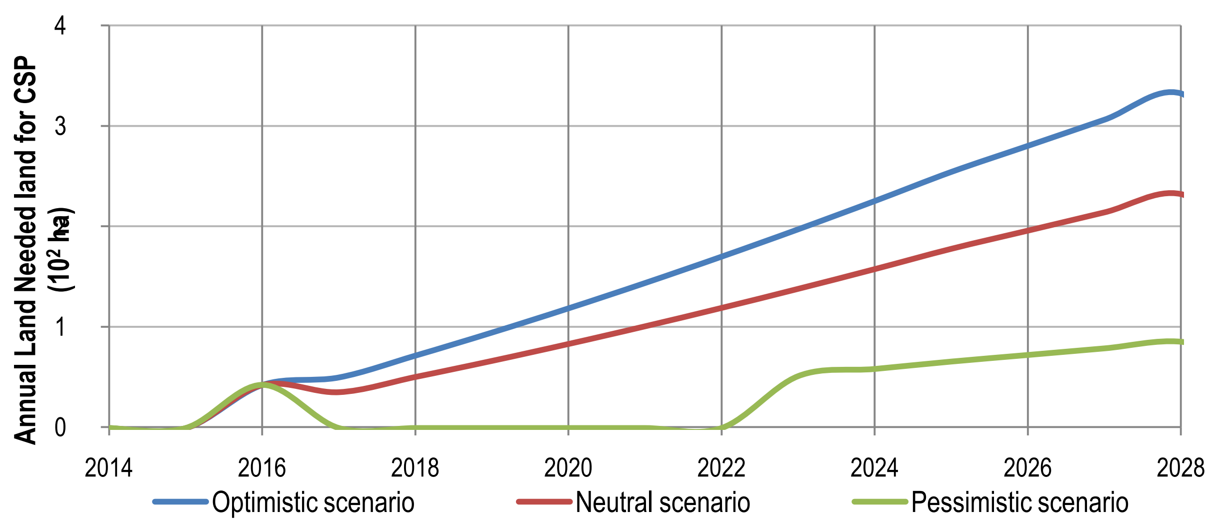

Figure 25. Annual required Aggregated land requirement for CSP (Upper figure) and aggregated land needed (Lower Figure). Annual Land needed considers that the required land is needed two years prior to the installation of the CSP power plants

Inadequate slope, protected spaces or land dedicated to agriculture represent barriers towards technical feasibility. Inadequate slope requires land removal and leveling which is an expensive procedure; protected spaces and their proximities have difficult or forbidden access and agriculture is one of the main pillars of Uzbek economy. Mean wind speed must also be taken into account as wind defocuses the mirrors in CSP plants decreasing energy generation.

Locations that are technically suitable also must also be economically feasible: Detailed analysis of costs must be evaluated during the feasibility study of each project, both land cost variations due to alternative uses and complementary infrastructures needed. LCOE of a new plant should be compared with the benchmark in the country to identify the economic suitability of each location[11].

Suitable areas, not taken into account low irradiation restriction, are shown in Figure 26 and following. Low irradiation areas 1.500 kWh/year m^2 for GHI and 1.800 kWh/year m^2 for DNI with current state of the art technology will, almost for sure, not be economically feasible.

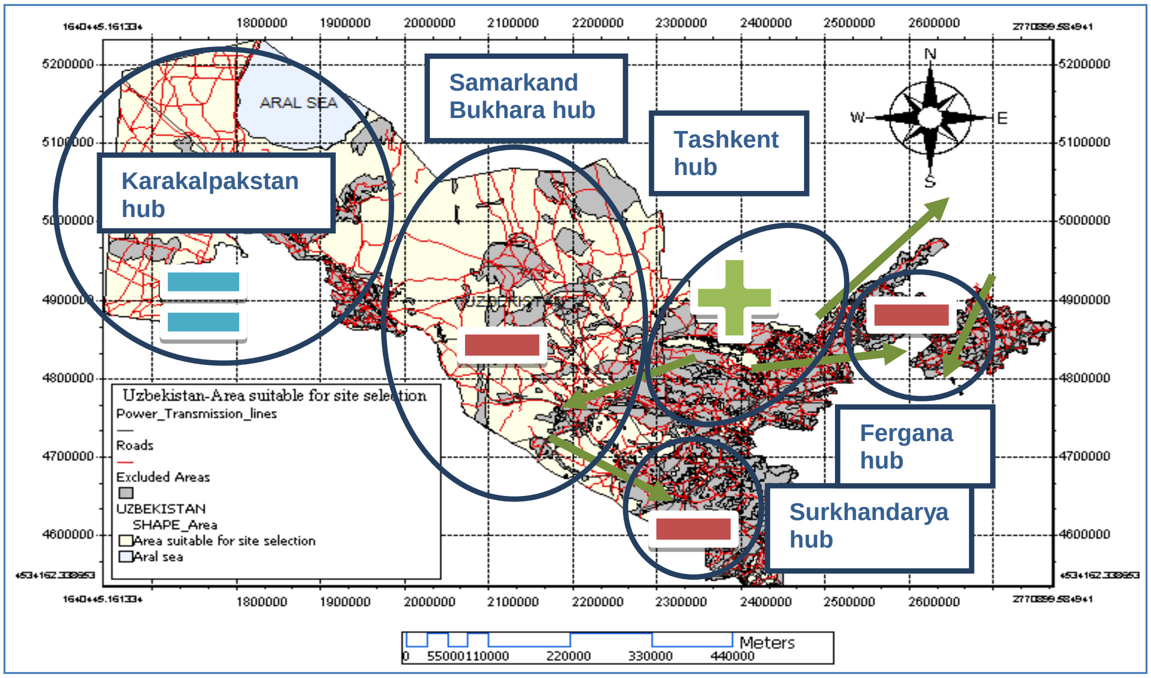

Figure 26. Map of the Republic of Uzbekistan technically suitable areas for solar energy production installation with actual generation / consumption hubs and energy generation-consumption balance in each[12].

[11] The forecasted LCOE gap with conventional power plants has been analyzed in 4.3

[12] Samarkand and Bukhara region entering to South-West Magistral energy Networks (MEN) also belong to energy deficit regions. A new generating capacity on Navoi PS in 2012, with the construction of 2 Block with 450 MW Capacity in this Power Plant, has improved the energy supply in this region. Also, Government's and Uzbekenergo are working in programmes and measures to improve the situation of zones with deficit of generating capacities.

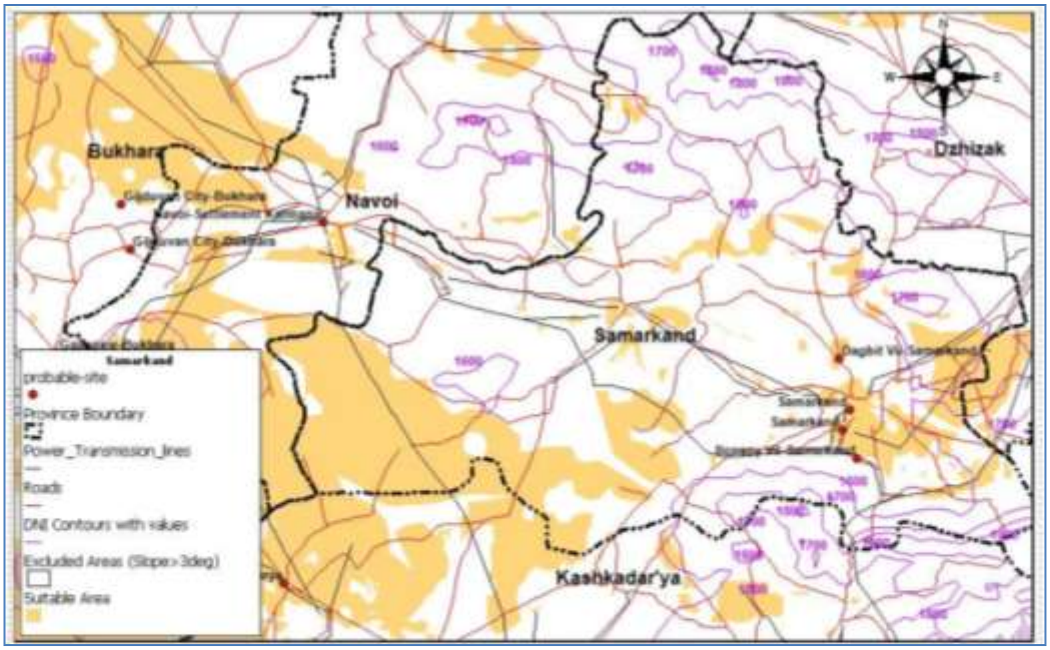

Figure 27. Samarkand province with probable sites for CSP and DNI contour lines.

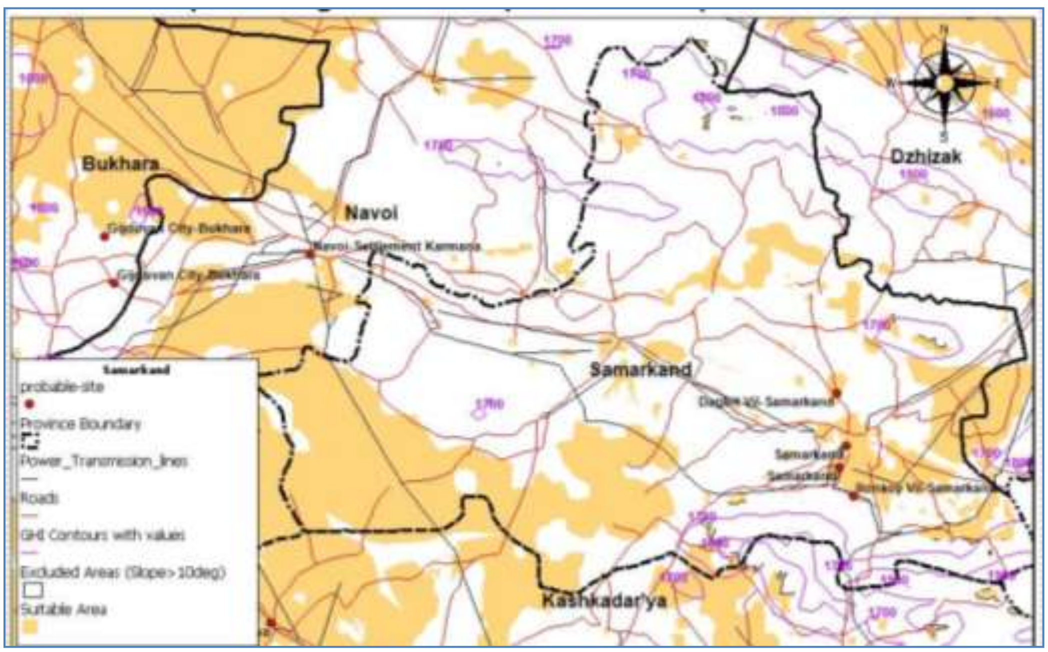

Figure 28. Samarkand province with probable sites for PV and GHI contour lines.

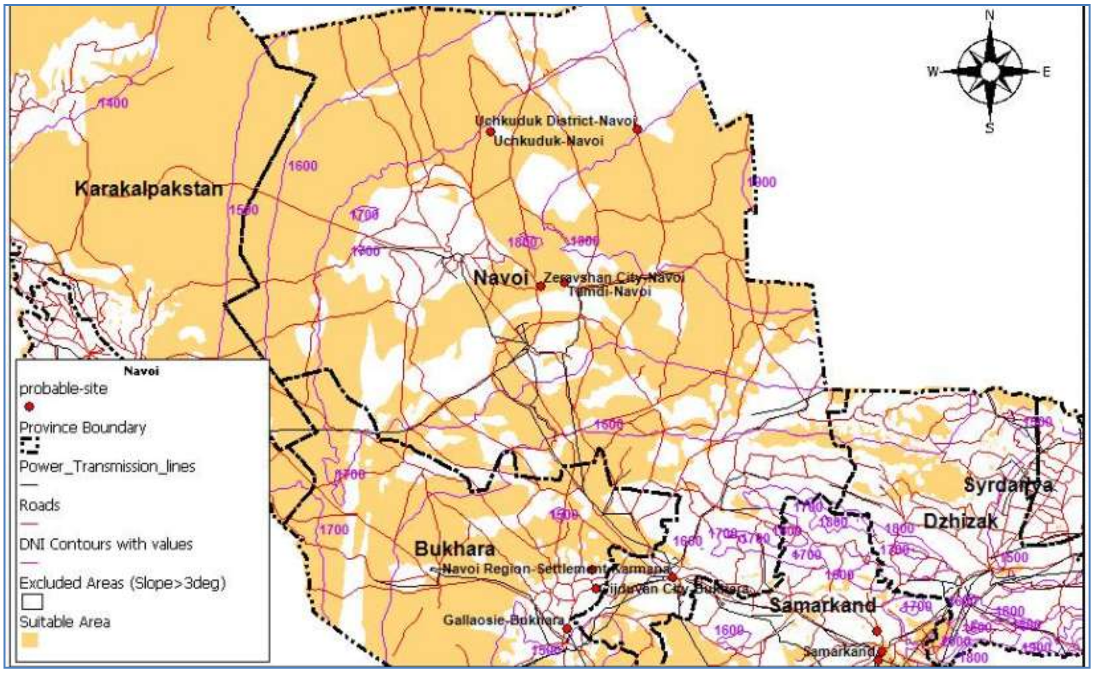

Figure 29. Navoi province with probable sites for CSP and DNI contour lines.

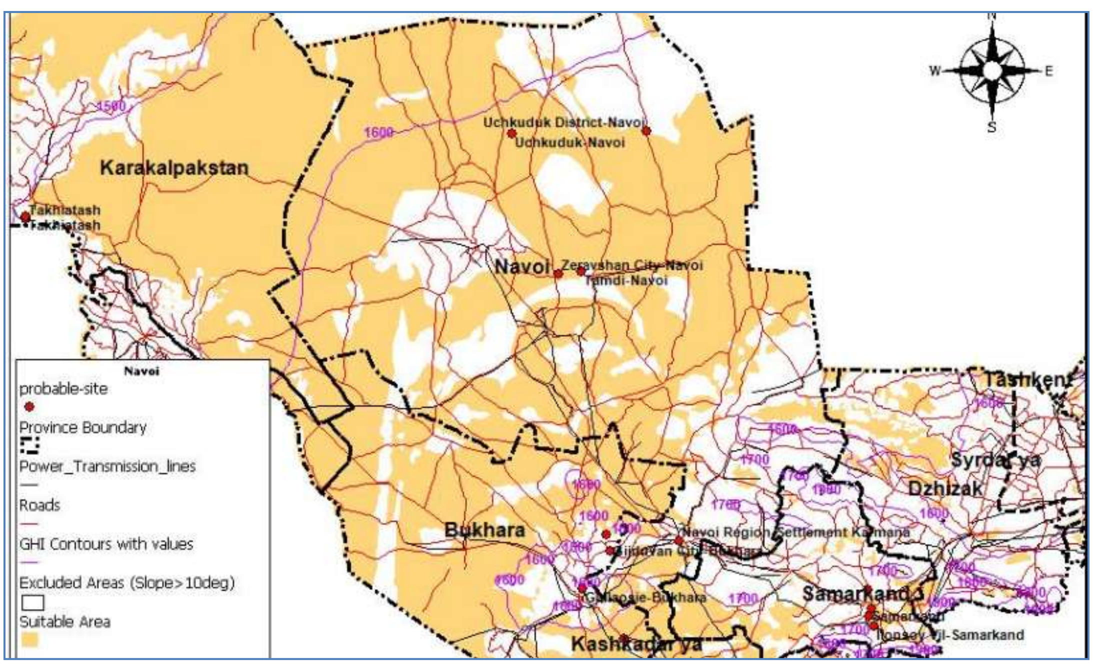

Figure 30. Navoi province with probable sites for PV and GHI contour lines.

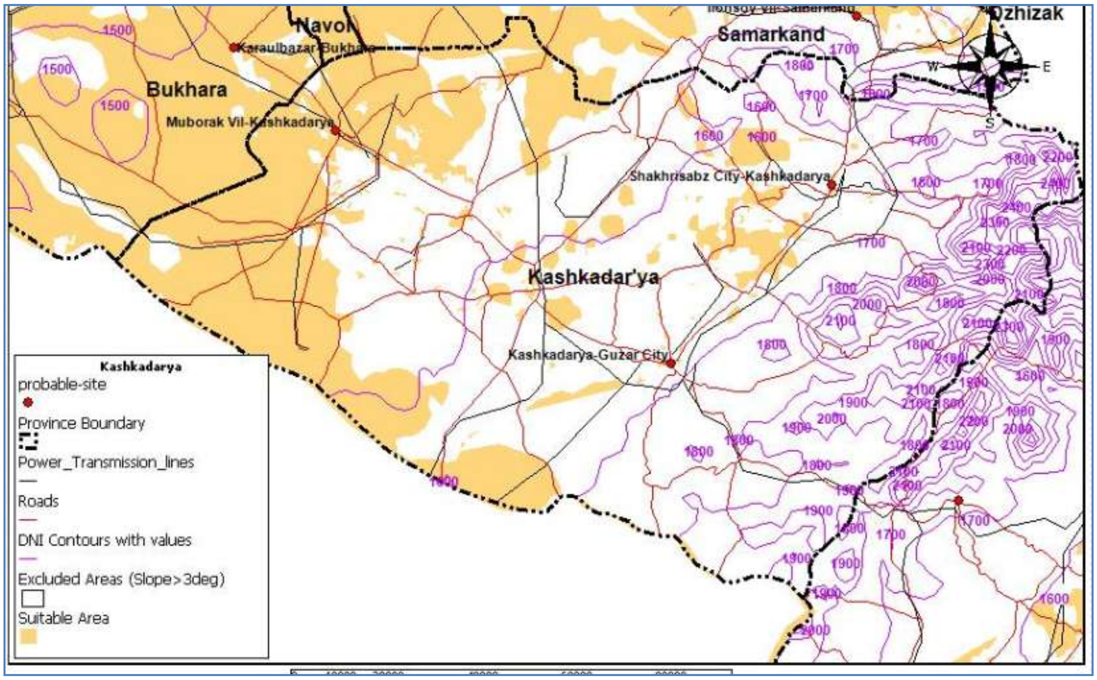

Figure 31. Kashkadarya province with probable sites for CSP and DNI contour lines.

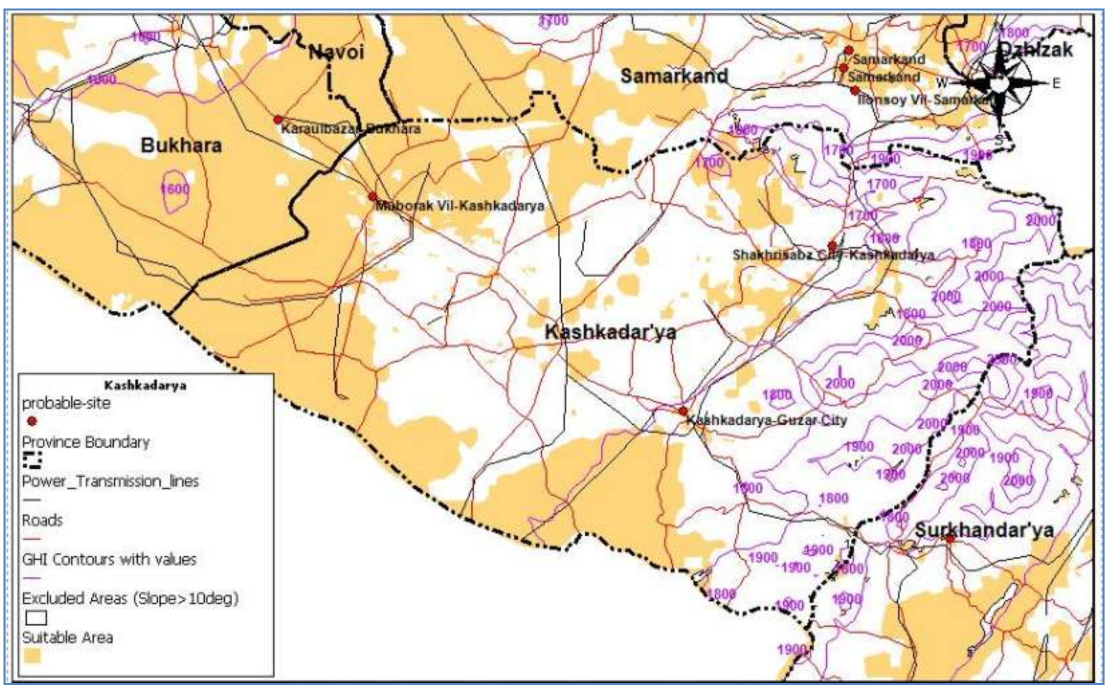

Figure 32. Kashkadarya province with probable sites for PV and GHI contour lines.

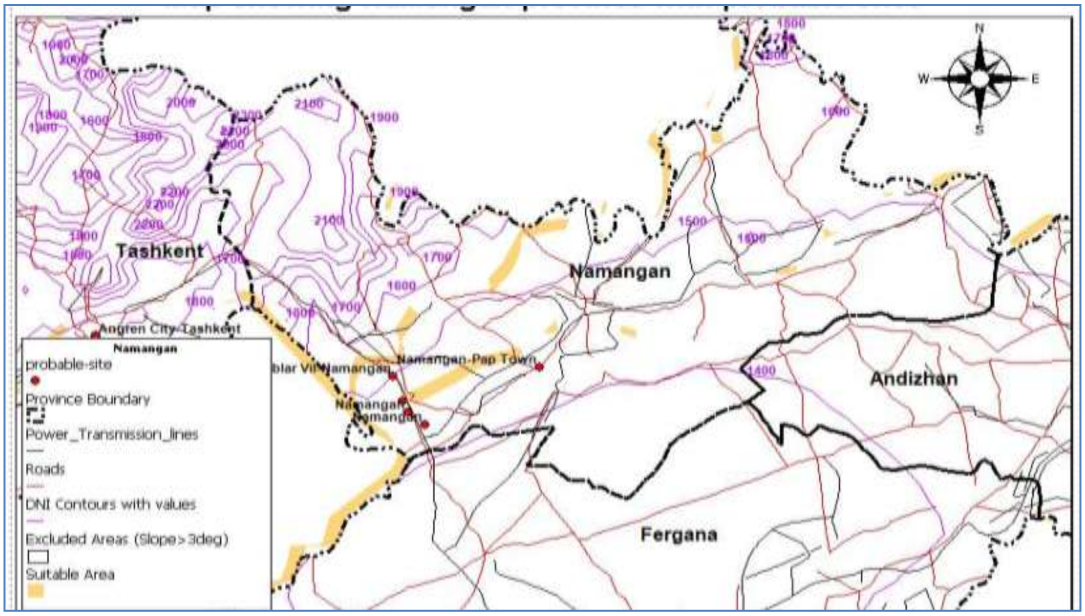

Figure 33. Namangan province with probable sites for CSP and DNI contour lines.

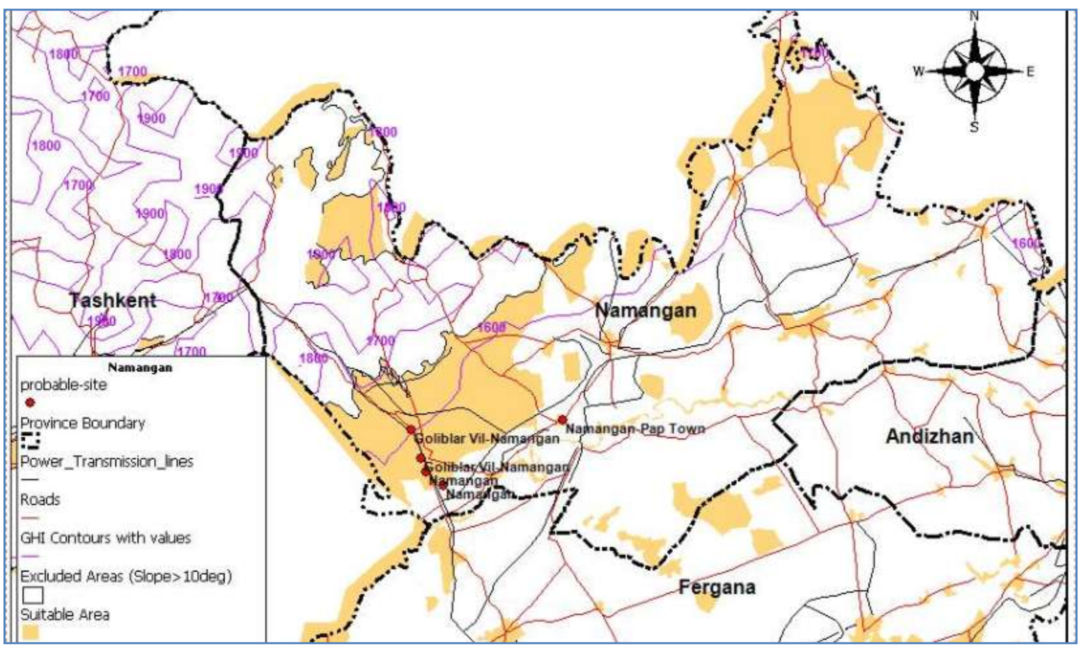

Figure 34. Namangan province with probable sites for PV and GHI contour lines.

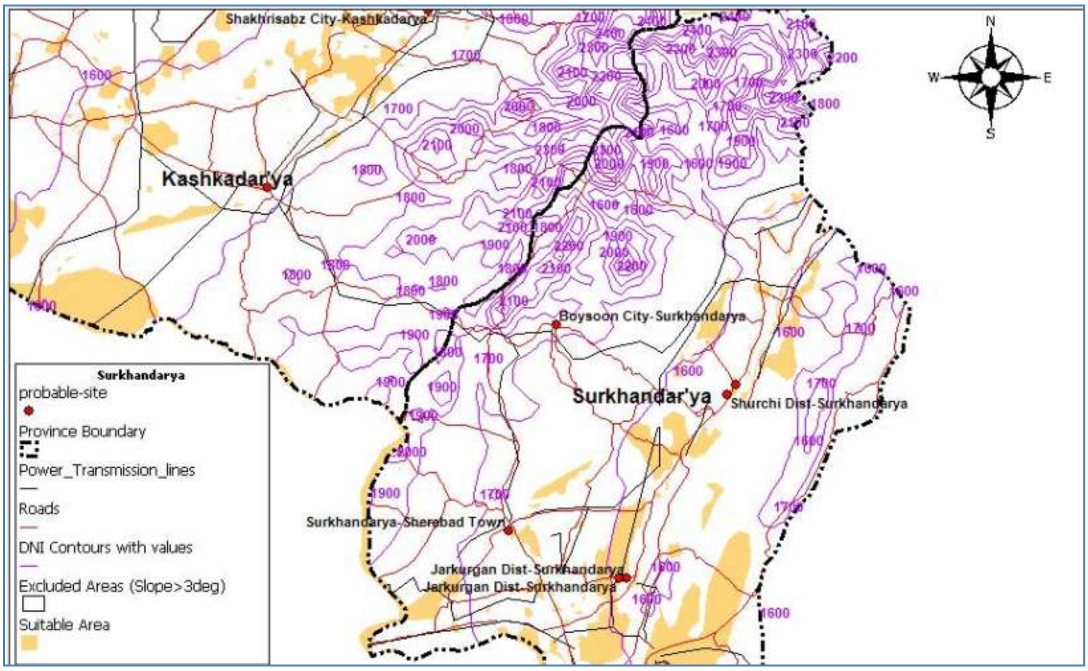

Figure 35. Surkhandarya province with probable sites for CSP and DNI contour lines.

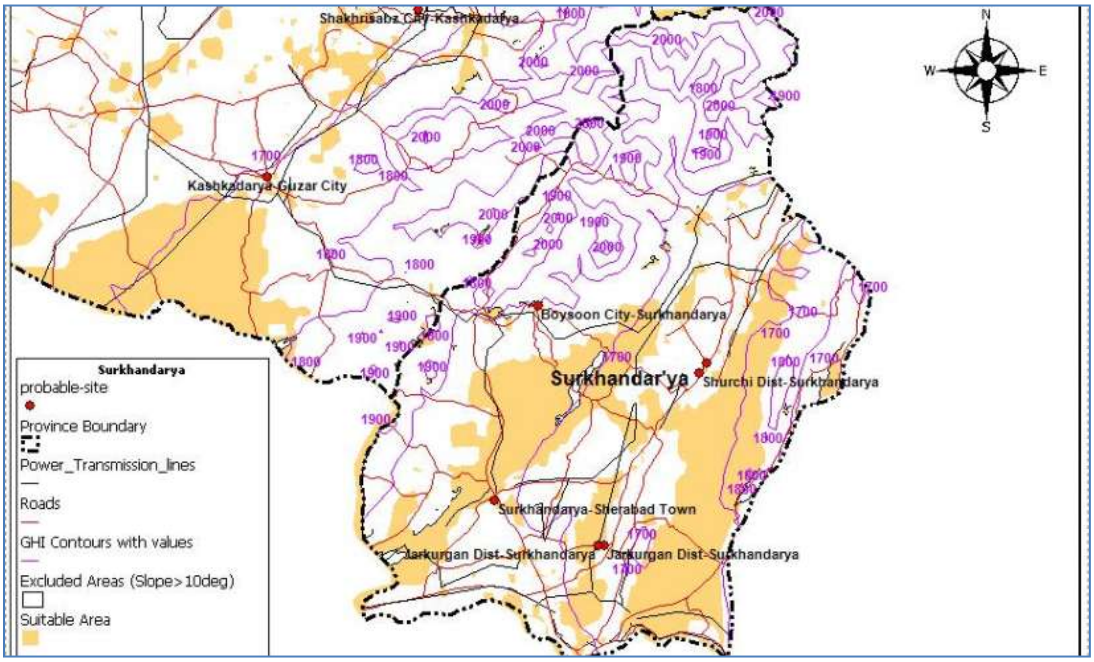

Figure 36. Surkhandarya province with probable sites for PV and GHI contour lines.

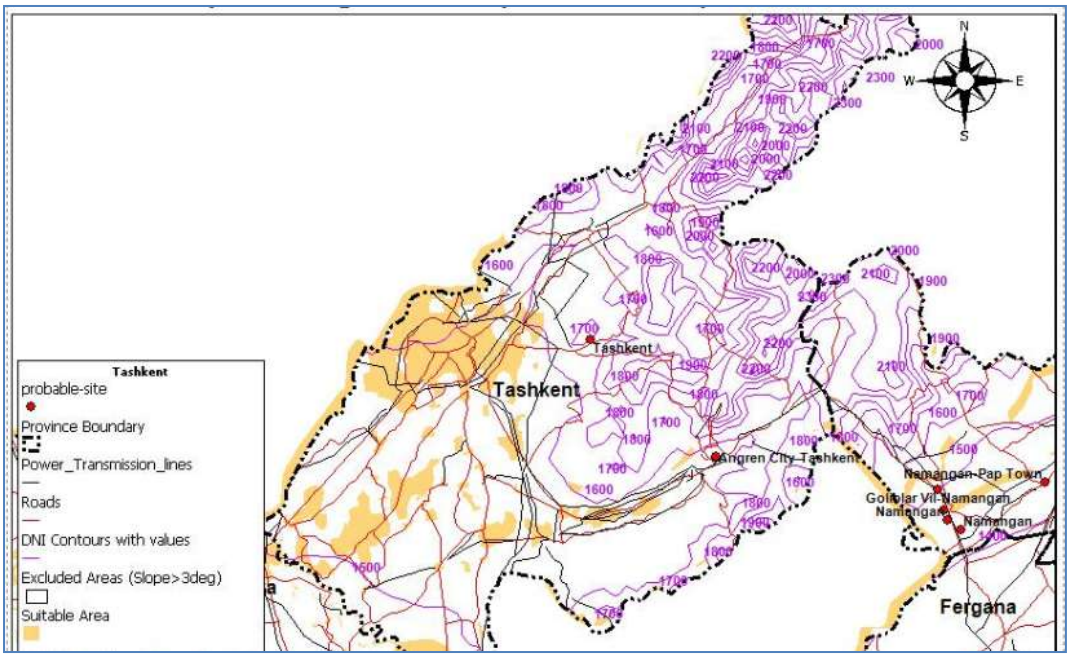

Figure 37. Tashkent province with probable sites for CSP and DNI contour lines.

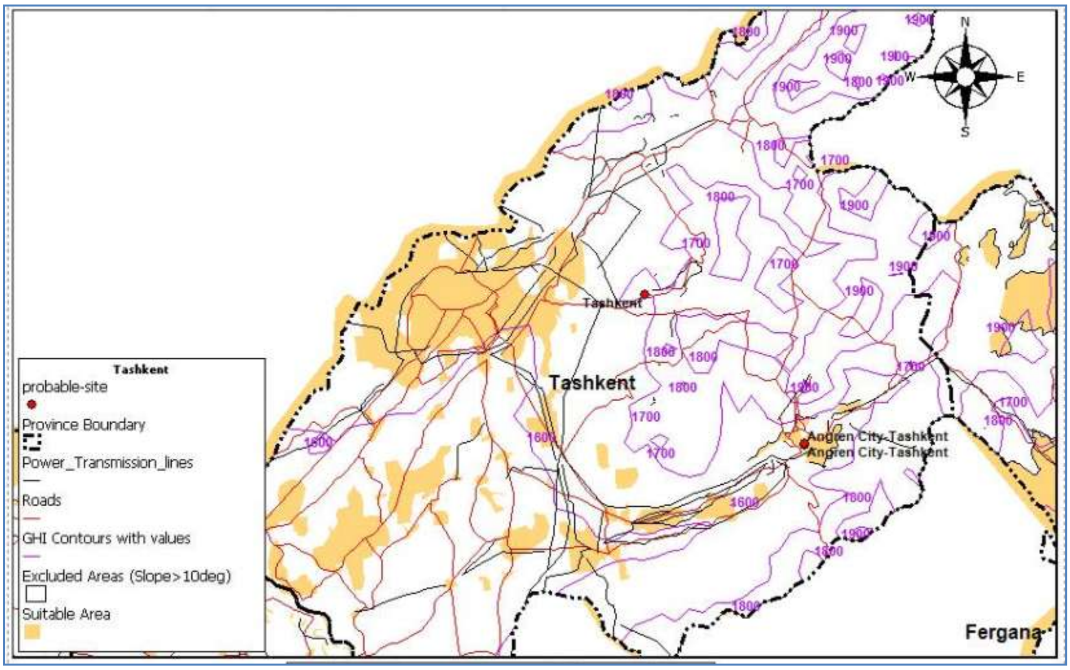

Figure 38. Tashkent province with probable sites for PV and GHI contour lines.

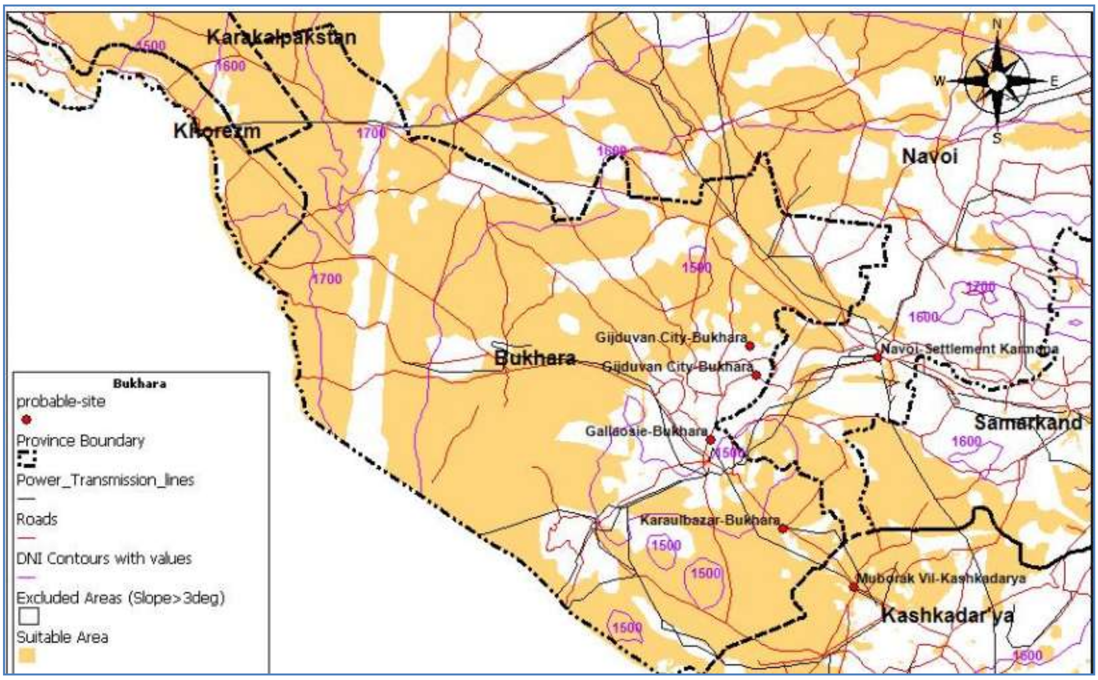

Figure 39. Bukhara province with probable sites for CSP and DNI contour lines.

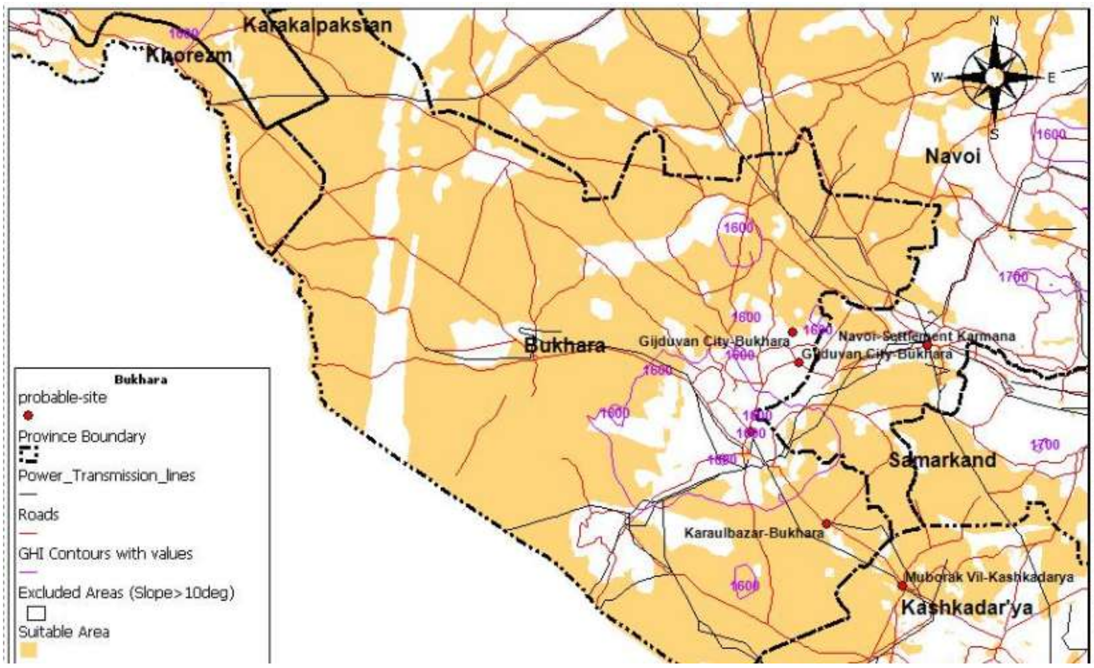

Figure 40. Bukhara province with probable sites for PV and GHI contour lines.

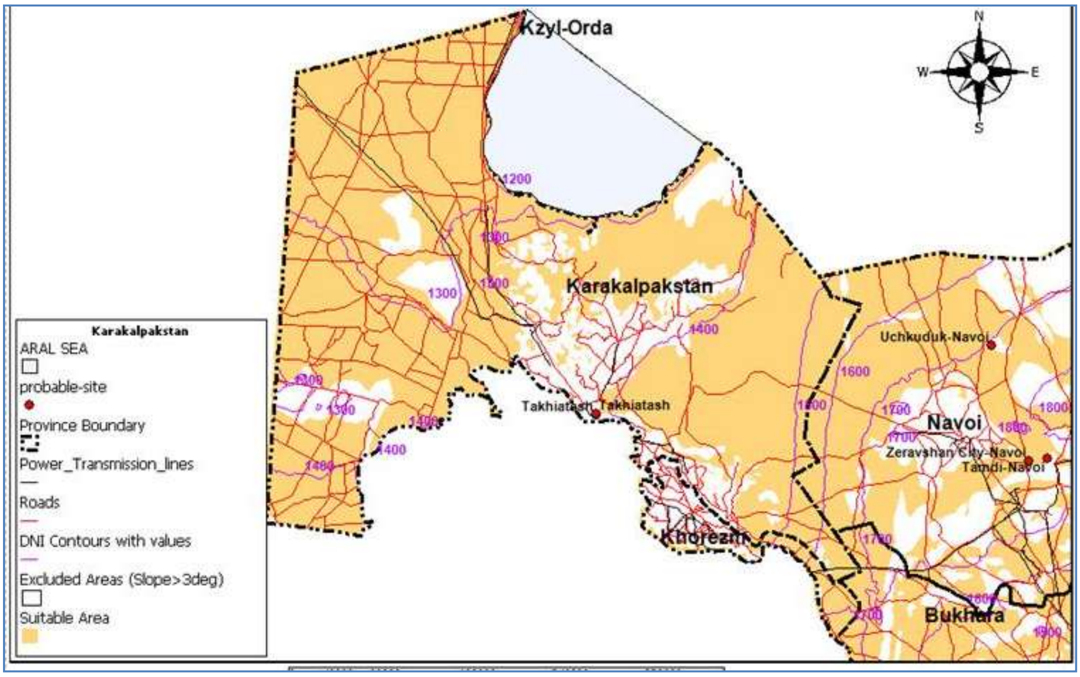

Figure 41. Karakalpakstan province with probable sites for CSP and DNI contour lines.

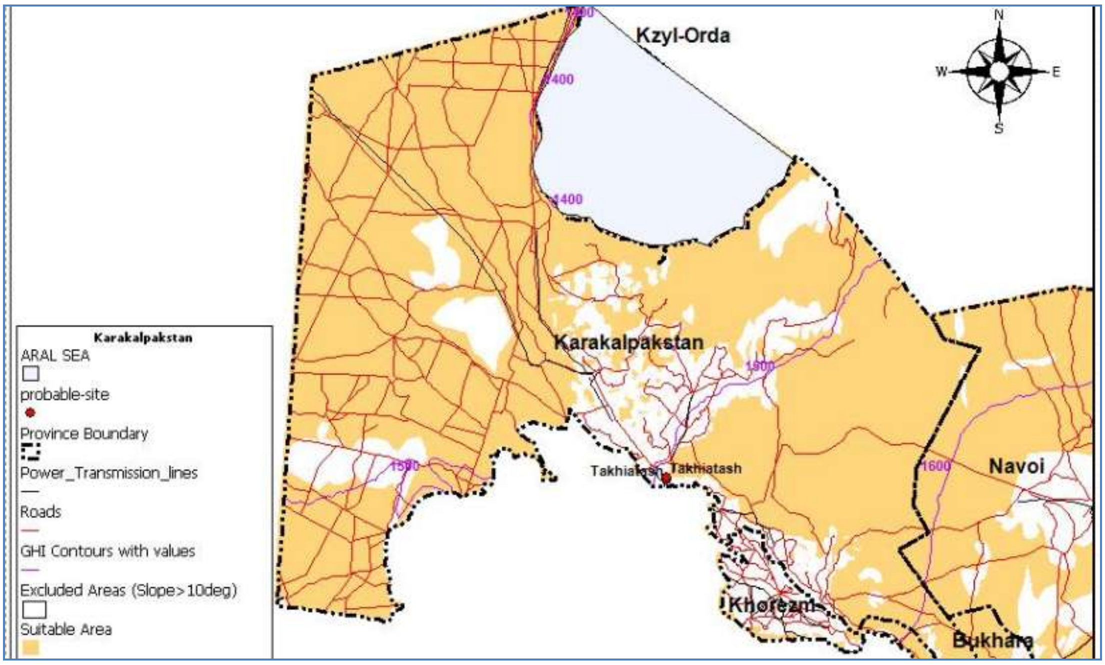

Figure 42. Karakalpakstan province with probable sites for PV and GHI contour lines.

Land requirements determine the deployment of solar energy. If the available land is not sufficient then capacity and energy production are limited.

Land location affects workforce availability, cost of transport infrastructure, cost of connection to the grid, and cost of water supply.

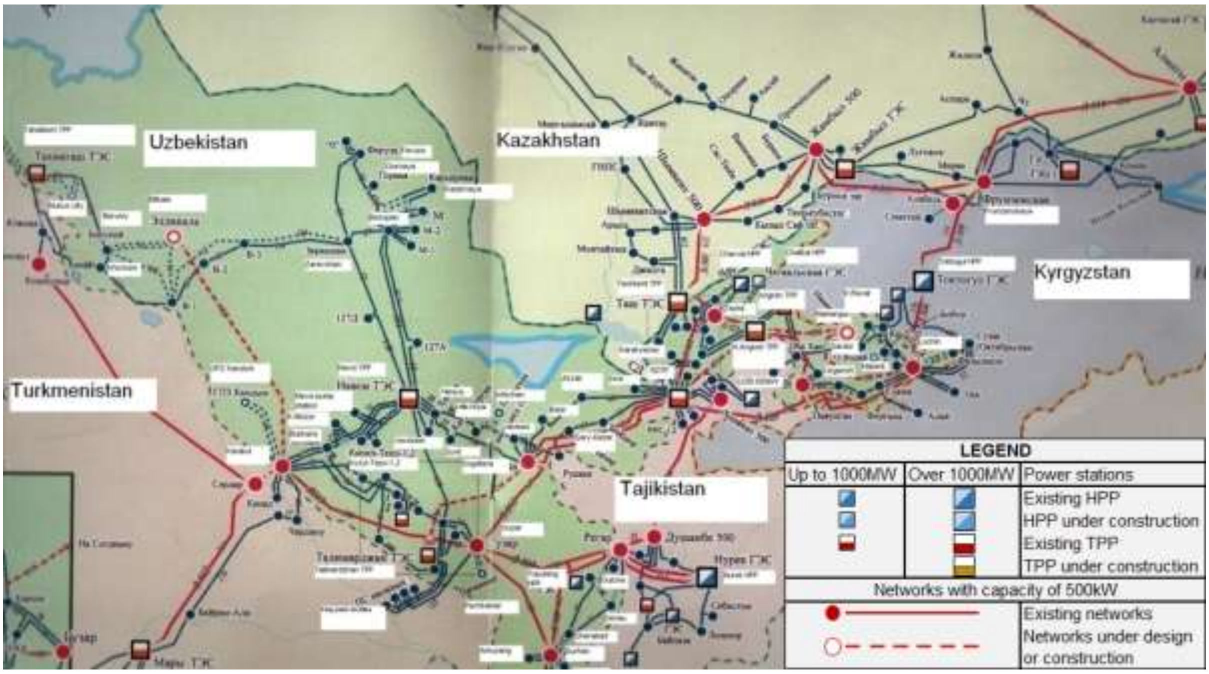

Figure 43. Existing and under construction networks and power stations in Uzbekistan.

Location of the power plant should benefit from already built substations and from the power generation and consumption hubs. Figure 26 shows a map of the Republic of Uzbekistan, identifying the existing hubs and the existing deficit (-) or surplus (+) on the energy generation-consumption balance and fluxes among them.

In Figure 26 the blue equal sign represents self-sustainable regions, the red minus represents regions with power deficit and the green plus represents regions with power surplus. Green arrows provide information about power flows compensating deficits and surpluses. When energy is transported through transmission lines losses occur; by locating plants close to demand hubs they will be diminished .

Figure 44. Pictures of the site for 100MW PV plant in Samarkand.

The solar power plant should be located where enough suitable land exists and near the areas of power drain. The first project 100MW PV solar plant has been identified in Samarkand, complemented by a pipeline of five others.

5.3 LABOR FORCE

An essential factor to turn the solar energy project into a reality is the workforce needed to design, build, operate and maintain solar energy power plants. Forecasted jobs created for photovoltaic professionals in 2015 are close to 1,200 and there is not a sufficiently trained labor force in the Republic of Uzbekistan to cover this demand. To face this constraint, developing a training program of specialization for engineers is recommended.

Table 7 shows total annual jobs needed to install the new solar power plants and to maintain and operate the existing ones. Figure 45 and Figure 46 highlight the differences between the created jobs by PV and CSP and within each technology the relevance of the building jobs and O&M jobs.

The values of forecasted created jobs is calculated following The World Bank data (34) and complemented with experts' experience[13].

Total jobs CSP + PV (thousands)	2015	2016	2017	2018	2019	2020	2025	2030	2031
Optimistic scenario	1.26	1.10	1.88	2.50	3.45	4.25	8.11	12.60	13.54
Neutral scenario	1.26	0.34	0.65	0.98	1.11	1.46	2.61	4.03	4.33
Pessimistic scenario	1.26	0.02	0.04	0.16	0.35	0.23	0.29	0.43	0.47

Table 7. Total employees working on installation, operation and maintenance of CSP and PV plants by year. Units: Thousand works. (34)

The building process of PV power plants creates 4 direct jobs per MW of capacity installed and another 2 jobs to maintain each 5 MW of installed power. CSP plants need 6 jobs per MW to be built: 2 for the first year of the construction process and 4 for the second year. On the other hand, operation and maintenance procedures of a 50MW CSP power plant require 30 on-site professionals. Tasks required in a PV plant include the cleaning of modules, electric and electronic maintenance and operation of the plant. For CSP plants, the tasks required are the cleaning of mirrors, electric, electronic and mechanical maintenance, fluid analysis and operation of the plant, which is more complex than that of PV plants.

[13]For CSP World Bank data is used, for PV installation expert advice from international experience is used.

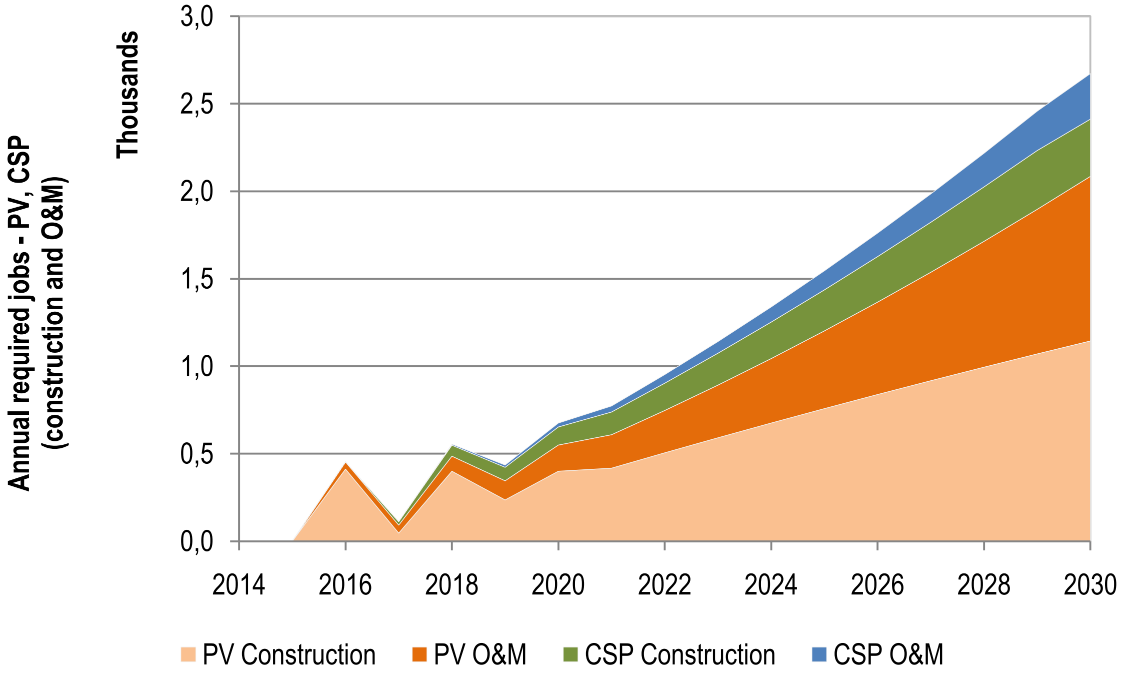

Figure 45. Annual required jobs according to technology and working field. In thousands.

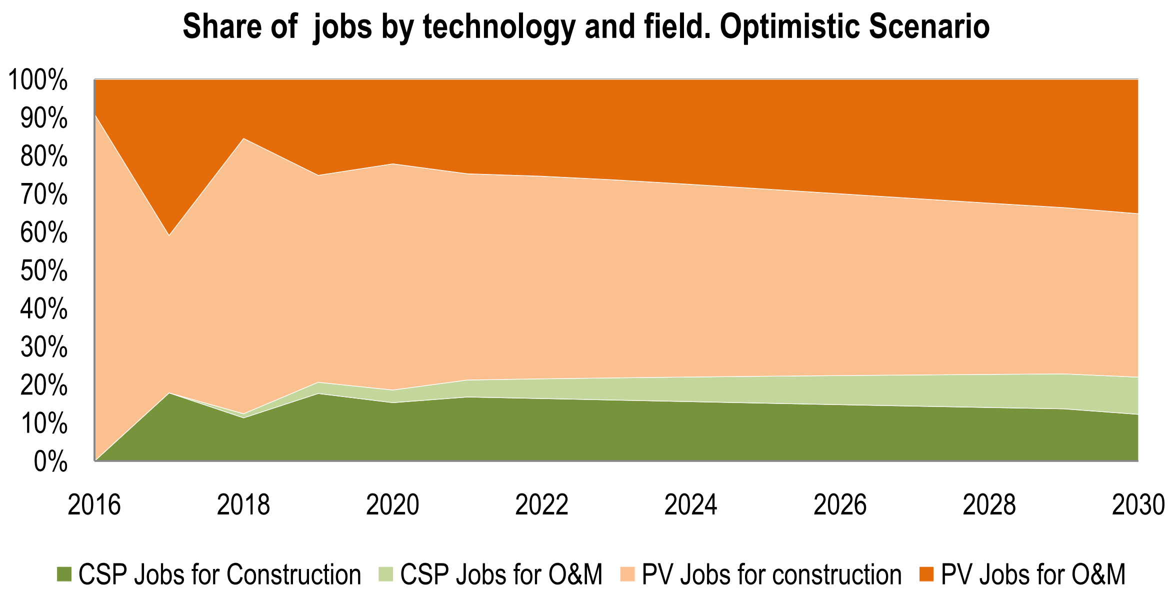

Figure 46. Percentage of jobs dedicated to PV and CSP and differentiation by field (Construction, O&M)[14].

Figure 45 describes the cumulative O&M jobs and the annual building jobs for CSP and PV. Figure 46 presents the percentage of each working field referred to the annual created jobs.

[14]Percentages shown are calculated with the Optimistic Scenario of solar energy production.

PV technology is expected to develop faster than CSP, setting the higher demand of trained professionals at PV building, operation and maintenance. Demand for PV professionals is higher as it is estimated that the ratio between PV and CSP yearly increase in installed capacity is going to be 5:1 in 2030 (26).

It is advisable to train future professionals in both installation and O&M to fulfill the vacancies of both fields as O&M jobs are cumulative, and installation provides jobs for as long as new projects are developed

5.4 INVESTMENT

The 100MW PV in Samarkand will be one of the 10 biggest[15] photovoltaic power plants of the World.

The progress of solar energy deployment on the Republic of Uzbekistan directly depends on the investment. A forecast of the annual investment required to develop solar energy according to the generation scenarios is shown in Figure 47.

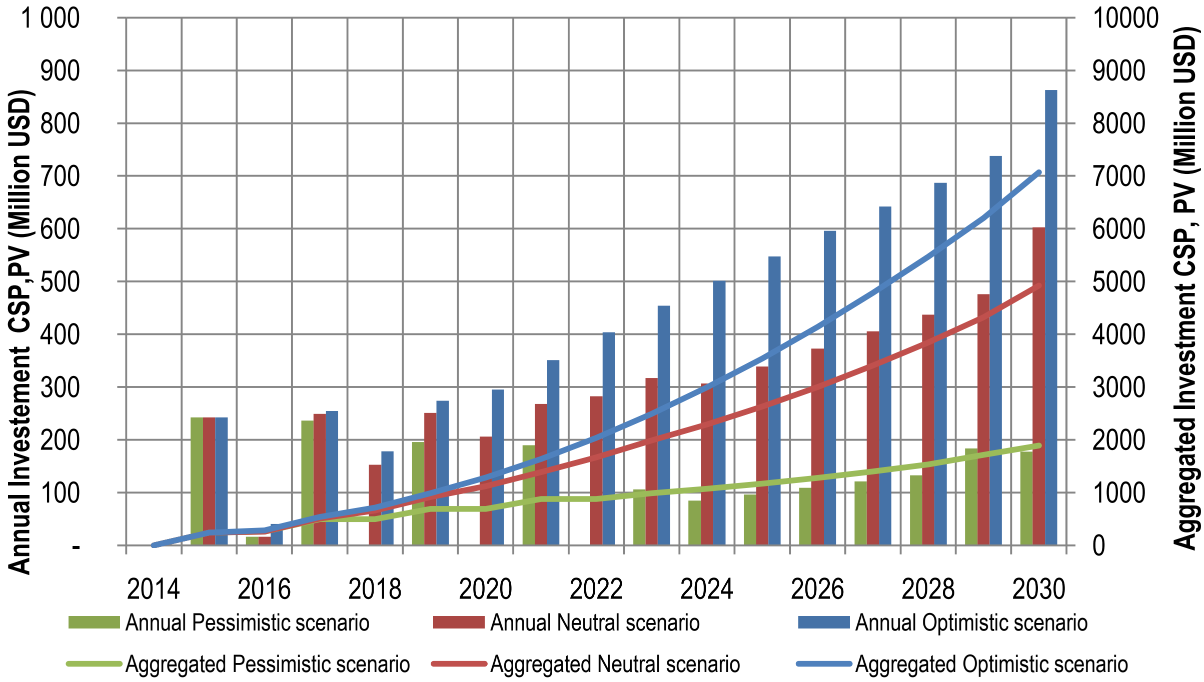

Figure 47. Annual and Aggregated Investment evolution considering CSP and PV deployment. Millions of US dollars.

The first project (100MW Solar Power PV Plant) financing has been defined so that financial institutions will provide 77.4% of the budget as debt. The remaining projects have been defined considering that the financial institutions provide 70% of the budget as debt. In both cases, the remaining equity has to be provided by SJSC Uzbekenergo or other investors.

[15] Relative to nominal capacity [MWp]

Figure 48 represents the investment required to build the forecasted CSP and PV power plants if financial institutions provide a share of 70% of the investment as debt in the forthcoming years.

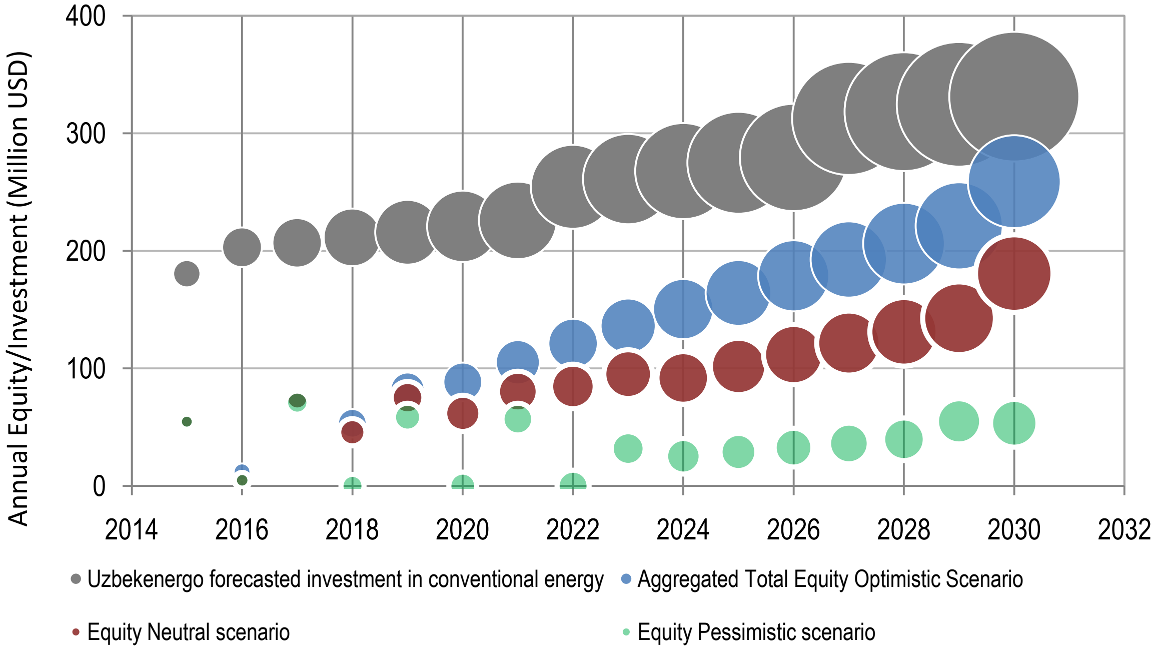

Figure 48. Annual equity needs to fulfill the forecasted increase in installed capacity and comparison with Uzbekenergo forecasted investment in conventional energy (Million USD). The size of the bubble represents aggregated investment..

To calculate the investment, a classical learning curve model has been used (35) and (31) where the installed capacity for the different technologies has been evaluated from (36) and (37), Learning Ratio (LR), PR=1-LR, has been set up for the different solar components and BOP for PV and CSP technologies.

$$C_{\text{year}} = C_0 \cdot \left\{\frac{P_{year}}{P_0}\right\}^{\log(PR)/\log(2)}$$

Values for PR and C_0 used are shown in Table 8 and Table 88.

	CSP		
	PR	C_0 (year 2012)	
Solar Field	90,0 %	355	USD/m2
Power Block	98,0 %	1,479	USD/kW
Storage	92,0 %	63	USD/kWh

Table 8. PR and C_0 values for CSP. _Source: (38), (39)

	PV		
	PR	C_0 (year 2013)	
Modules	82%	0.78	USD/Wp
BOS	98%	1.60	USD/Wp
Others	90%	1.00	USD/Wp

Table 9. PR and C_0 values for PV. Source: (38), (40)

Regarding the electricity generation of SJSC Uzbekenergo and the investment dedicated to ongoing projects of modernization and expansion of the Hydro Power Plants (HPP) and Thermal Power Plants (TPP) Figure 49 depicts the evolution of the solar investment and the conventional energy investment.

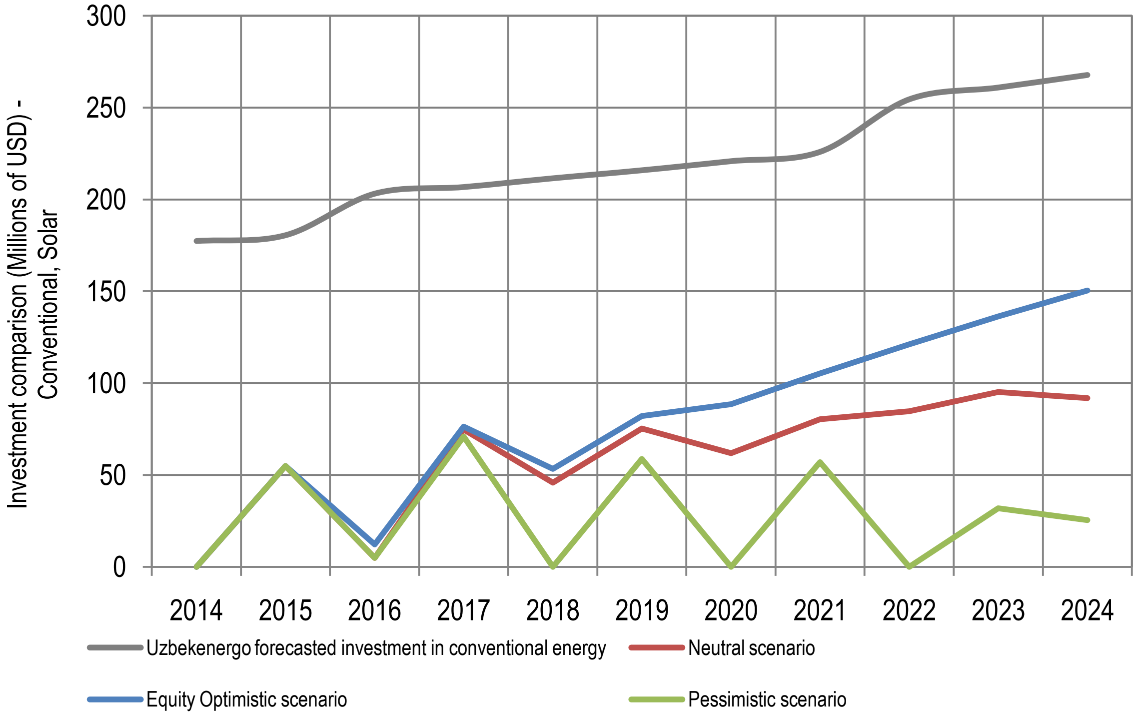

Figure 49. Comparison of forecasted equity needs on solar (for the different scenarios considered) and conventional energy. Millions of USD.

	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Uzbekenergo forecasted investment in conventional energy	180	203	207	212	216	221	226	255	261	268
Required equity for optimist scenario	55	12	76	53	82	89	105	121	136	150
Ratio (%) of Solar over Conventional forecasted investment	30%	6%	37%	25%	38%	40%	47%	48%	52%	56%

Table 10. Forecasted solar energy investment compared to forecasted conventional generation investment. Millions of USD.

	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Uzbekenergo forecasted investment in conventional energy	180	203	207	212	216	221	226	255	261	268
Required equity for optimist scenario	55	12	76	53	82	89	105	121	136	150
Ratio (%) of Solar over Conventional forecasted investment	30%	6%	37%	25%	38%	40%	47%	48%	52%	56%

Table 10 shows the relation between the forecasted equity required to build the solar power plants of Uzbekistan and the forecasted amount that Uzbekenergo invests on conventional facilities.

Investment may become a constraint for SJSC Uzbekenergo in the period of 2023-2024.

5.5 ENVIRONMENTAL PHENOMENA

Environmental phenomena such as sand storms, wind, pollution, birds and critically low temperatures set boundaries to the implantation of solar energy generation and increase the cost of O&M. These phenomena increase the amount of water needed for cleaning procedures and also the frequency of parts' replacement.

The frequency and severity of dust storms in desert and semi-desert areas results in extinction of solar radiation as well as a higher need for cleaning of mirrors and solar cells surfaces. Regions such as Surkhandarya, Kashkadarya, Bukhara, Navoi and most regions of Karakalpakstan have higher dustiness in the atmosphere, increased in the last decades due to the Aral Sea drying up. Locations like Takhiatash may average up to 32 dust storms per year. Those dust storms have a duration of approximately 6-8 hours per day in more than 85% of the cases.

It's been proved that dust deposition decreases efficiency drastically when concentrations of 1 g/m^3 are reached. For further values a slower linear progression of efficiency drop occurs. The reduction of maximum output power reduction reaches 34% (41). A constraint of this magnitude over the plant's output will turn solar energy development into an economically unfeasible project.

Flooded or with any record or prediction of flooding areas are withdrawn from feasible solar power placements or should be analyzed in detail.

It is necessary to make sure that the development of solar plants in Uzbekistan is economically feasible. All possible risks that may have an influence on the projects should be taken into account.

More information about the influence of environmental phenomena on the implantation of solar energy can be found in (26).

5.6 WATER SUPPLY

5.6.1 Introduction and context

Water usage is needed by PV and CSP technologies **and its scarcity or intermittent supply represents a hazard** to the integrity and efficiency of the plant.

Water use in the Republic of Uzbekistan is dominated by agriculture which also contributed to GDP by 21 % (2008, (42)). Besides agriculture, industry and domestic users account for a 3 and 5 per cent of the total water consumption. Industrial use accounted 3% of the total amount of water consumption in the Republic of Uzbekistan while contributing to 30% (2008, (42)) of GDP.

In Samarkand Region water is available (there are surface and ground water sources). The main water source is Zarafshan river. Total length of the Zarafshan river is 781 km with tributaries, and is the third-longest river in Central Asia, by water content it comes after Amu Darya and Syr Darya. The catchment area of the river is 11 722 km^2. There are a number of water reservoirs - Kattakurganskoe (900 mln m^3), Akdaryinskoe (113 mln m^3), Karasuyskoe (27,6 mln m^3) and others.

The main water source of Navoi province is Zarafshan river. Also, there is some ground water deposits on the territory of Navoi province. But water in Zarafshan river has a high level of minerals and ground water has high level of hardness. There are 2 water reservoirs – Quyi-mozor and Tudaqul. The water of the Zarafshan river in the middle and lower reaches are intensively diverted for irrigation and heavily modified. There originate more than 60 main canals. In the middle of the river the runoffs of drainage systems are added to the remaining water stock. All of this transformed flow of the middle part is withdrawn for the second time for irrigation of downstream areas. As a result, the lower reaches practically ceased to receive natural flow, which made the lower reaches of the Zarafshan river in effect act as the receiver of collector-drainage and waste water.

The main water source is Kashkadarya river with its inflows – Jinnidrayo, Oqsuv, Yakkabog'daryo, Tanxozdaryo, G'uzordaryo. There are three main water reservoirs - Chimqo'rg'on (500 mln m3), Qamashi (25 mln m3) and Pachkamar (260 mln m3).

Fergana Valley has formed under conjunction of rivers Naryn and Karadarya, which flow into valley in its beginning on the east and create Syrdarya River. Syrdarya River forms about 70% of total flow of Fergana Valley water resources, the rest of the rivers and says form flow within 30%. Surface water inflow to Fergana Valley from flow formation zone constitutes basic amount of Syrdarya river basin water resources.

Majority of small rivers is transboundary and provides water delivery to irrigated lands and several oblasts (rayons) of several states. Region has a significant ground water deposits hence availability of water for meeting the requirements of CSP or Solar PV power plant may not be a constraint.

North part of Surkhandarya province has enough water resources. But, south part of the province has a water scarcity problem. There are surface and ground water sources. The main rivers - Sukhandarya and Sherabad rivers have a number of inflows – Qoratog, Tupolondaryo, Sangardaryo. Three main water reservoirs were built in 1950-1977 – Uchqizil (160 mln.m^3), South Surkhon (800 mln.m3) and Dergez (12.8 mln.m^3). There also big ground water deposit – Nort Surhadaryou, which has been using for drinking water supply.

Tashkent region has significant surface and ground water resources. Surface water resources belong to Syrdarya river basin. Tashkent province locates in middle stream of Syrdaryo river and its Chirchiq, Pskom, Ahangaran inflows. There are several irrigation canals – Bozsuv, Dalvarzin, Qorasuv, and also number of reservoirs: Tuyabuguz (250 mln.m^3, Charvaq (2006 mln.m^3), Ahangaran (198 mln.m^3).

The main water source of Buhara region is Amu-Buhara machinery (pumping) canal (takes water from Amudarya river and supply with irrigation water Buhara region) 194 kilometers long and with a discharge of 124 cubic meters per second with two huge pumping stations - the Khamza-I and Kuyumazar, lifting water to a total height of 68 meters. This made it possible to switch 72,000 hectares of already irrigated lands from supply by the Zeravshan to supply by the Amu Darya, to guarantee their water supply, as well as to reclaim 25,000 hectares of virgin lands and water 320,000 hectares of pastures. The main water reservoirs are Quyimozor (total volume 310 mli.m^3), Tudakul (1200 min.m^3), Shurkul (170 mln.m^3). There are a number of discharge lakes, where drainage water from irrigated area are discharging – Dengizkul, Qorariq, Katta Tuzkon va Devonhona. 94,4 % of province land area is saline (within different level of salinization). Quality of surface water is not good, ground water has a high level of hardness (up to 24 mg- equivalent/L) and salinization (up to 2,2 g/l). There a scarcity of drinking water – water comes from other province – Samarqand. For setting up of CSP power plant in this region we need to evaluate the option of desalinization plant along with the power plant. With respect to solar PV as well a smaller water treatment facility need to be explored by assessing the water quality in the site.

5.6.2 Water supply for PV

PV technology requires water for cleaning processes. Average values of water supply required are on the range of 0.09 m^3 per MWh produced (43). Although values for Uzbekistan may be higher, new cleaning technologies, reducing water consumption, are under development.

Both the cost of water supply and the cost of the infrastructure needed to connect the plant to a water source affect the total budget and the O&M costs.

Inadequate or insufficient cleaning procedures **diminish the efficiency** of the Photovoltaic modules (up to 10%).

5.6.3 Water supply in CSP

Concentrating Solar Power plants Rankine cycle, which is used to transform thermal energy into electricity and which is similar to the one used in conventional coal fired thermal power plants, has to be cooled either using water (wet cooling) which is evaporated in the cooling tower or atmospheric air which is heated up (dry cooling). Dry cooling is chosen in areas where water is not an abundant resource even if LCOE is affected. Implementation of dry cooling increases the investment, the operation costs and also reduces the efficiency of the plant; the Levelised Cost of Energy increment ranges from 3% to 8% (33).

5.7 GRID CAPACITY

Most of the equipment is inherited from the Soviet era and outdated, becoming ballast for solar energy development. However, Uzbek Government and Uzbekenergo are currently developing plans on modernization and reconstruction of existing transmission lines and construction of new ones, in terms of correlation with the potential zones of placement of big SPPs.

Transmission lines and power substations upgrading process is advisable.

There are several projects that have the modernization, maintenance and refurbishing of the electric grid as their goal.

6 KEY FINDINGS

SUPPLY

- Solar Energy can play a major role in the Republic of Uzbekistan energy supply in 21st Century. Arid areas can become an important source of energy and wealth for Uzbekistan.

BACKGROUND

- Uzbekistan, due to its background, already acquired experience in solar technology and its strategic situation in Central Asia could become a regional knowledge, technology, and energy and production hub.

CONSTRAINTS

- There are some constrains and capacity gaps in Uzbekistan: lack of knowledge of the technology, even though a long R&D traditions exists, its utility scale application is new for the country, lack of water needed for cooling and cleaning, extreme winters and dust storms, grid capacity, specific regulation and lack of indigenous developed industry.
- **Land requirements** it is not a constraint for solar development in Uzbekistan.
- **Land location** affects workforce availability, cost of transport infrastructure, cost of connection to the grid, and cost of water supply.
- Water usage is needed by PV and CSP technologies **and its scarcity or intermittent supply represents a hazard** to the integrity (CSP) and efficiency of the plant.
- **CSP and PV** energy generation processes could consume 101% of the water used in all power plants – TPP, HPP, PV, and CSP – to meet the optimistic scenario's energy demand.

INITIAL SUPPORT

- Initial support is needed to achieve momentum, creating a virtuous circle: pipeline of projects →industry development→cost reduction. ADB capacity building and financial support is a useful tool to reach this goal.

ECONOMIC

- **BOT** agreements could allow SJSC Uzbekenergo to obtain external financing to keep increasing solar installed capacity. After an established period, the utility becomes the owner of the facility.
- **DBO** agreements could allow SJSC Uzbekenergo to invest directly on solar power plants avoiding expenses on design, responsibilities on civil operations and on initial performance.

- Existing RES electricity generation plants may unlock foreign investors' trust and wiliness to participate in solar energy development.
- **Equity** to be assumed by SJSC Uzbekenergo may stifle other electric capacity development projects by 2023.
- **Debt** to be assumed by the UFRD should be taken into consideration.

ENERGY MIX

- If appropriate actions are taken, in 2030, it would be feasible to supply 6% of total electricity produced in Uzbekistan using solar technologies, less than 0.1% of its territory (88 km^2) would be needed.
- Solar energy can be a major driving force on local economy and energy production. In the optimistic scenario, the installed capacity could reach 3 GW in 2030: generating 5 TWh and around USD 50 million yearly incomes, creating 2,700 direct jobs and needing USD 900 million of annual investment. The cumulative investment would be USD 7,000 million USD.

TECHNOLOGY

- Cost of the energy produced will reach parity with international cost for natural gas combined cycle around 2028 and the solar program economical break-even for Uzbekistan would be reached around 2030.
- Concentrated Solar power (CSP) is a manageable source of energy that can stabilize photovoltaic (PV) allowing to increase the share of solar in the energy mix. Thus, and adequate combination of both sources is needed.
- It will be necessary to further develop the grid to deliver the electricity from arid areas to the demand centers.
- Solar electricity has some unique features: Availability and security of supply of primary resource, dispatchability and potential for cost reduction. Also, its use liberates natural gas for other uses than domestic energy production.
- CSP and PV are nowadays commercially proven technologies; nevertheless the technology can be improved: there is room for research, development and innovation for companies and research institutions.

SOCIETY

- **The cost for society** is highly dependent on the social, political and economic evolution of the Republic of Uzbekistan. In the Optimistic scenario Uzbek society bears a higher cost within the first 10 years but, on the other hand, **the ulterior benefits for society have a steeper growth** if compared to Neutral and Pessimistic scenarios.
- Development of PV technology will have a bigger support in the short term, setting the higher demand of trained professionals at PV building, operation and maintenance.
- Development of solar energy in the Republic of Uzbekistan might have a **positive impact on local industry** by maximizing the local components share.

Nevertheless, energy competitiveness should not be jeopardized due to higher components costs.

- Developing solar energy in the Republic of Uzbekistan creates a new area of practice, research, support and training.

POLICY

- The commitment to reduce the gaps between the Republic of Uzbekistan and benchmark countries could reduce the investment load of the UFRD, enhance timing of solar energy deployment and avoid economic constraints.
- In a competitive energy market, Feed in Tariffs, Feed in Premium and tenders should efficiently promote RES electricity generation.
- In a non-competitive energy market, price regulations and governmental subsides might be suitable mechanisms to promote RES electricity generation.
- Elaboration and integration in existing regulation of specific references to solar energy production could pave the way for investment.

7 KEY ACTIONS

MODERNIZATION

Modernization, maintenance and refurbishing of the electric grid to adapt the electric grid to the forthcoming energy generation and demand..

CAPACITY DEVELOPMENT

- National banks' capacity development through participation in project financing taking a ticket in solar projects.
- Local industry improvement and preparation to be able to manufacture the middle technology-investment relation pieces and materials.
- Engineering and construction companies could develop their capacity to suit the demand requested by the construction of the 100MW Samarkand power plant and subsequent projects.
- Reduce the gaps in the *ease of doing business* between the Republic of Uzbekistan and benchmark countries.
- Support Centers of Excellence nationally and locally.
- International Solar Energy Institute as and information hub
- Defining a training program for potential solar energy experts could be a target for Centers of Excellence (ISEI).
- Define and homologate a solar expert's training program.
- Increase the local workforce capable of installation, maintenance and operation of solar power plants.

FINANCIAL

- Finance the first power plants in Uzbekistan – Uzbekenergo, the Government, the Fund for Reconstruction and Development of Uzbekistan (UFRD) together with Multilateral Banks and other donors could provide the necessary funds.
- Develop Build Operate and Transfer (BOT) and Design Build and Operate (DBO) agreements to alleviate Uzbekenergo investment.
- Invest in a solar energy research and development program.

POLICY

- Elaboration and include in the regulation **specific references to solar energy** production.
- When appropriate, support Renewable Energy electricity generation through direct Government intervention (i.e. Feed in Tariffs, Feed in Premium, tenders).

8 ACTIONS

8.1 INTRODUCTION

Constraints and gaps which may make difficult to develop solar energy in Uzbekistan have been identified. To overcome them, objectives and tools have been prioritized and selected in order to evolve towards a suitable environment to host solar energy electricity generation.

The key actors to unlock Uzbekistan's solar potential are:

- Government of Uzbekistan
- SJSC Uzbekenergo
- Financial Institutions
- R&D institutions and University
- Industry

8.2 GOVERNMENT OF THE REPUBLIC OF UZBEKISTAN

8.2.1 Financial Actions

Financing new solar power plants in the short term promotes further investment – consolidated projects with reliable results increase potential investors' trust and will to finance solar energy.

A financial venture including the Government of Uzbekistan, SJSC Uzbekenergo, the Fund for Reconstruction and Development of Uzbekistan (UFRD) and Multilateral Banks such as the Asian Development Bank is advisable to overcome the initial investment barrier and attract different investors to the purpose of developing solar energy in the Republic of Uzbekistan. For future projects, main financial mechanisms can be found in ANNEX II: FINANCIAL MECHANISMS.

CASE STUDY – CAREC Talimarjan Power Project (50)

The ADB has previously financed various projects in the Republic of Uzbekistan related to transport and energy. One of these projects is the Talimarjan Power Project. As an example of the abovementioned initial financing of renewable energy sources power plants the shares of the investment in the Talimarjan project were:

Total funding amount: 1,280 million USD

· $350 million ADB	27.4%
· $300 million JICA	23.4%
· $250 million UFRD	19.5%
· $150 million Uzbekenergo	11.7%

In the Republic of Uzbekistan there are several financing entities (around 30 commercial banks). Within them, there are 5 banks with capacity to finance development programs (44), namely the National Bank of Uzbekistan for foreign Economic Activity, Asaka Bank, Uzbek Industrial – Construction Bank, Paxta Bank and Ipoteka Bank. Since 2006 the Uzbekistan Reconstruction and Development Fund has been financing development programs of high importance and impact on Uzbek economy. The Fund started with 1 billion USD charted capital in 2006 provided by the Ministry of Finance of the Republic of Uzbekistan and the previously mentioned 5 bigger banks[16].

In the following figure, per year financial resources to develop the solar roadmap (optimistic scenario) are shown:

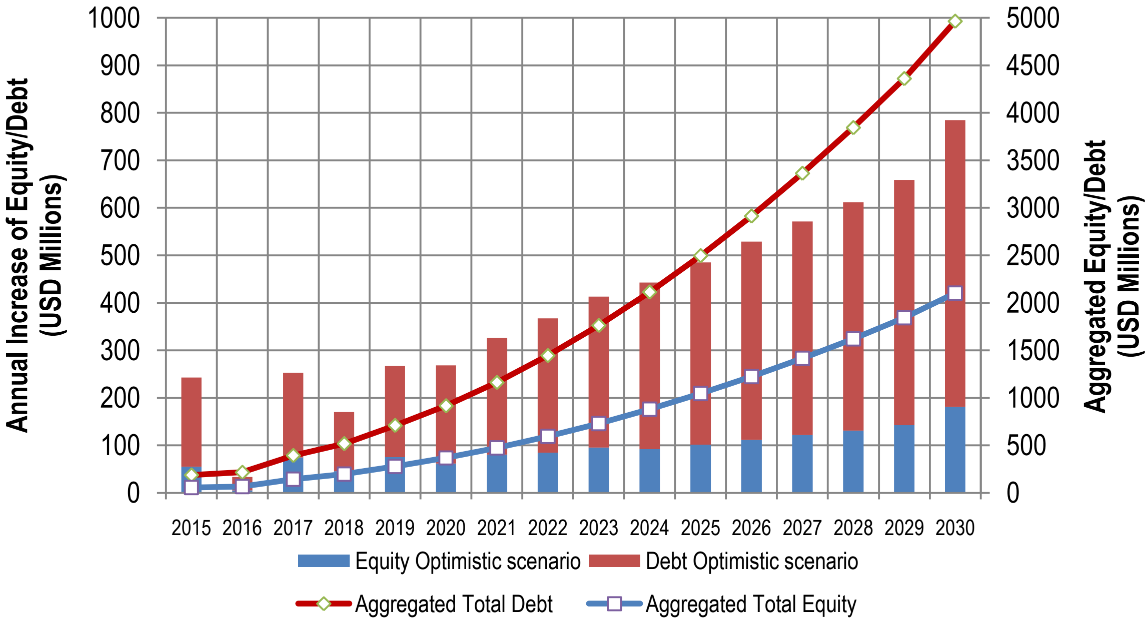

Figure 50. Financial resources to be allocated for the development of the optimistic scenario. Millions of USD.

[16]National Bank of Uzbekistan for foreign Economic activity, Asaka Bank, Uzbek Industrial-Construction Bank, Paxta Bank and Ipoteka Bank.

8.2.2 Regulatory Actions

Elaboration and integration in existing regulation of **specific references to solar energy** production.

Discussion of policies and specifications of technical parameters should involve government's law experts, solar energy experts and energy systems experts.

Lack of specific regulation on new projects of solar energy (regarding PV, CSP and ISCC technologies) might result in a threat and a general slowdown of the development of solar energy production.

Lately, the government has evaluated several projects for the development of solar energy but not yet completed. Solar Energy is mentioned under "On priorities of industrial development of Republic of Uzbekistan in 2011-2015" decree stating that 44 investment projects will be carried out within this period and that one of them is a solar power plant of 50MW installed capacity.

To overcome the investment constraint, private investors (both foreign and national) should be attracted towards solar energy development in Republic of Uzbekistan before 2023. To enhance the timing and relevance of the investments the Government may strengthen the policy frame that has a direct impact on solar energy.

Further, the law requires that the Ministry of Finances must take into account the necessity of accelerated return on investments into facilities of renewable energy. It also describes subsidies to both legal and natural persons who realize and undertake activities and measures leading to decrease of energy demand, utilization of secondary energy resources and renewable energy sources. It also states that the legal and natural persons have the right to produce electric power for their own use, and they may supply it to other legal and natural persons through their own electric networks.

On implementation of Uzbekistan Presidential Decree "On further development of alternative of energy sources", Ministry of Economy jointly with interested ministries and agencies developed the Uzbek Law "on alternative of Energy Sources". The project by itself represents a great achievement in comparison with existing normative acts – it attempts to deal with problems of utilization of solar energy from a self-consistent approach.

The law "On the rational use of energy" applies to legal and physical persons associated with the extraction, production, refining, storage, transport, distribution and demand of fuel and energy. It guarantees the right to independent producers of energy to deliver the electricity to the grid. Utility companies are obligated to accept and to buy this energy with the prices which must be defined by the Ministry of Finances in accordance with "the established order" (or in "the prescribed manner").

However, the statements contained in the existing laws could be extended and detailed to strengthen the policy frame of solar energy power production. The benchmarks against which the country's policy strategy may be compared are: (45)

- Clear, coherent and targeted policy, supported by primary legislation that sets out the rights and obligations of different sector participants and supplemented by consistent secondary legislation (all publicly accessible)
- A solid institutional framework of regulation in the form of an energy regulator, ideally independent but at least sufficiently separated from industry and from policy-making
- A liberalized electricity market, or a framework that supports steady movement towards such a market
- The effective separation of the network business from (commercial) generation and supply activities
- The elimination of cross-subsidies and promotion of cost-reflective tariffs
- A dispute resolution and appeal process that is efficient and accessible
- A transparent framework that holds the regulatory authority accountable
- Public service obligations that are carefully targeted to support vulnerable customers, rural or outlying customers, environmental protection and security of supply, while not impeding liberalization.

Hence, to achieve these benchmarks it is advised that the Government of Uzbekistan defines a complete set of actions: (45)

- Adopt laws “On alternative energy sources,” , and “On solar energy.”
- Empower Uzenergonadzor role as independent regulator.
- Adopt the necessary regulations to set up a clear frame for future independent power producers: electrical market, access to the grid, land use, taxation, environmental and social requirements, water use, financial needs and foreign investment needs.
- Continue the process of liberalization of the electrical sector.
- Promote Private-Public Partnership as a first stage to an open market in renewable energy, decreasing the private sector perceived risks.
- Define a body responsible and how the rules and regulations are publicly available and accessible and subject to public consultation and comment.
- Policies to promote human resources capacity building.

Implementing these actions before 2017 may avoid confronting the investment bottleneck by the Government and SJSC Uzbekenergo. These measures should build a solid policy foundation for the development of solar energy in Uzbekistan, providing legal certainty for those investors interested on enrolling in RES power production.

Besides, fiscal measures could be implemented to benefit solar energy power producers. For example, Figure 51, Figure 52 and Figure 53 compares the relevance of taxes compared to other expenses aggregated during the life of the power plant[17].

[17] Monetary flows (USD) have been discounted using a discount rate equal to 10%.

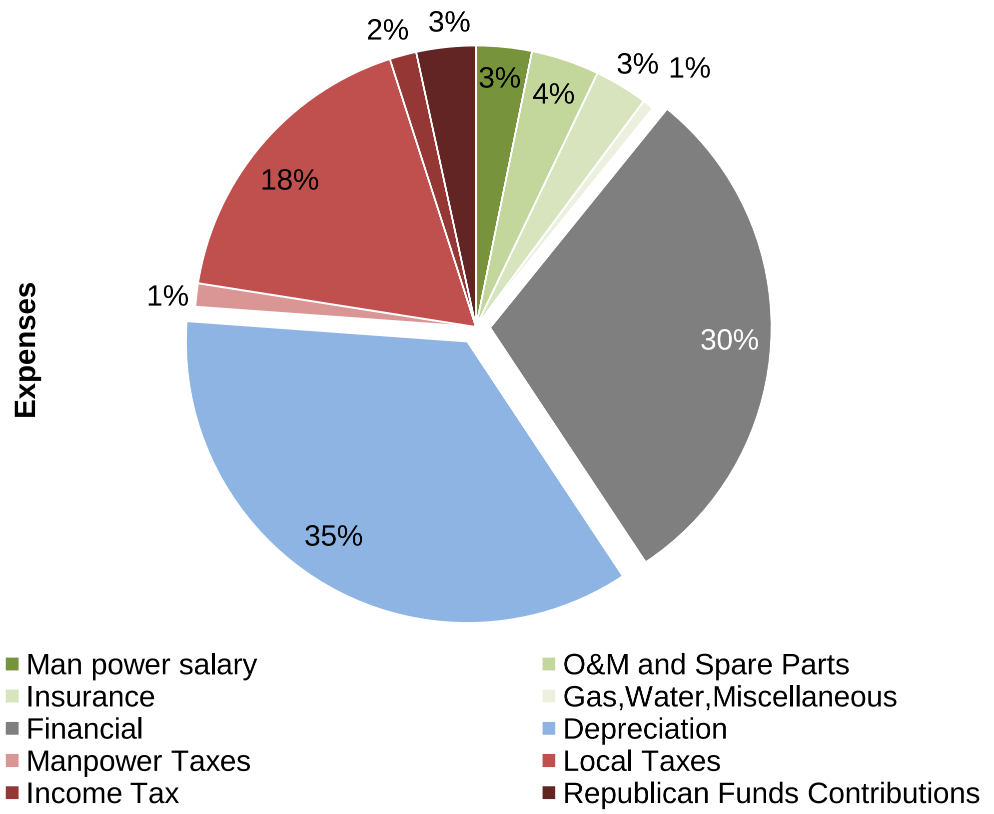

Figure 51. Comparison of Expenses: Financial, Depreciation, Operational expenses and Taxes.[18]

Local taxes represent about 16% of the income of the project.

Decreasing the property tax ‘ceteris paribus’ by 50% may reduce the OPEX by 25%

Property tax exemption ‘ceteris paribus’ may reduce the OPEX by 51%

Property tax reduction could be an effective fiscal benefit, as it represents over 50% of the operational expenses and practically makes negligible the taxes on the workforce salaries and on the income.

Additional information on international practices can be found in ANNEX I: SUPPORT INSTRUMENTS FOR RES-ELECTRICITY.

[18] Loan is considered to be ADB concessional debt (LIBOR+0.6%) rates in Figure 51, Figure 52 and Figure 53.

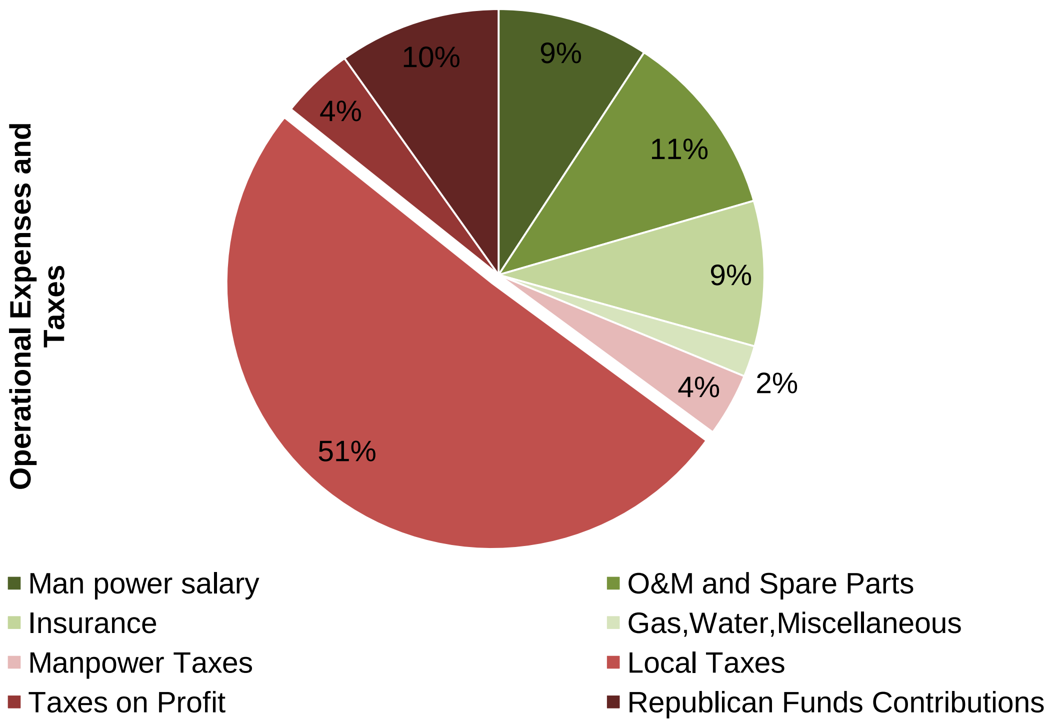

Figure 52. Local taxes compared to Operational Expenses.

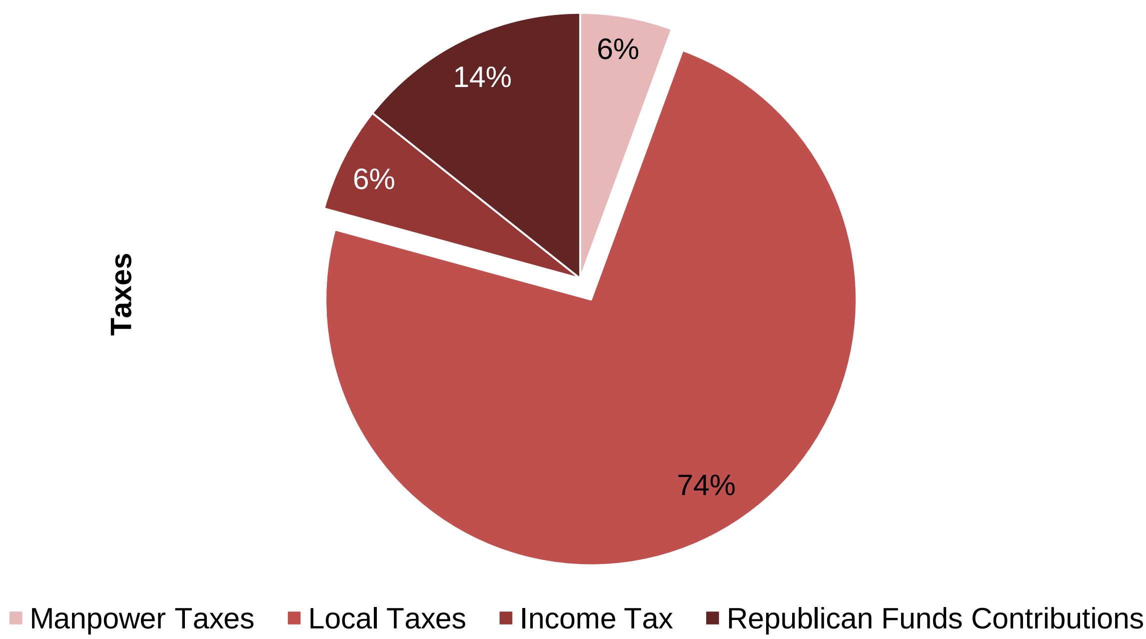

Figure 53. Local taxes compared to Manpower taxes, Republican taxes and taxes on profit.

8.2.3 Capacity Development

8.2.3.1 Local Industry Capacity Development

Substitute imports by local products without jeopardizing energy competitiveness.

Adapt the local industry to be able to manufacture the middle technology-investment relation pieces and materials.

The development of solar industry requires materials and parts that can be either imported from countries that already have the needed technology or manufactured locally. Not all the pieces or materials used in both PV and CSP equipment are able to be produced in any country, as the level of complexity increases the cost of manufacturing.

Substituting imports by local products might represent an advantage for local industry and therefore for society.

A differentiation between the components of CSP and PV regarding the degree of complexity on the manufacturing process is shown in Figure 54 and Figure 55.

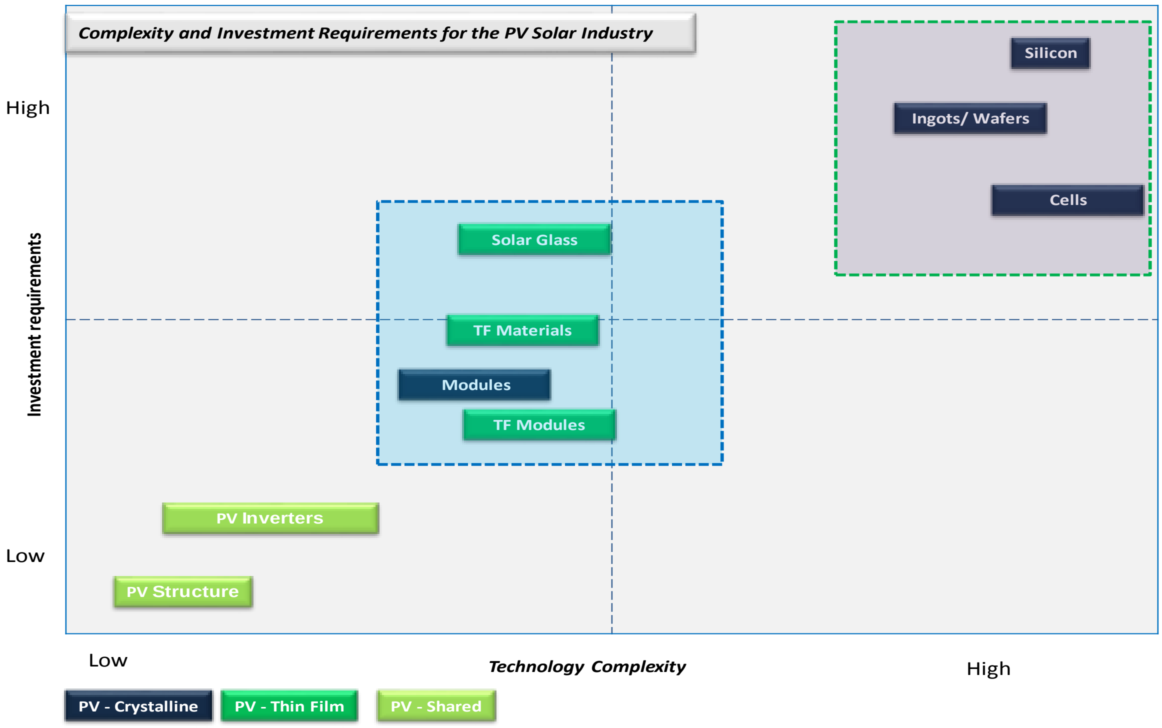

Figure 54. PV complexity and investment requirements.

Silicon, ingots and cells have a higher technology complexity and a higher investment is required. Government of Uzbekistan is currently considering projects for the production of solar grade silicon in the country and production of photovoltaic panels in Navoi FIEZ.

In addition, adapting domestic industry to be able to manufacture the middle/low technology-investment relation pieces and materials has to be evaluated. Inverters and structure for PV modules can be manufactured by local industry and they are common for both PV technologies, namely crystalline and thin Film. Thin film materials and modules have manufacturing processes complex enough to be at the border of feasibility, together with crystalline modules.

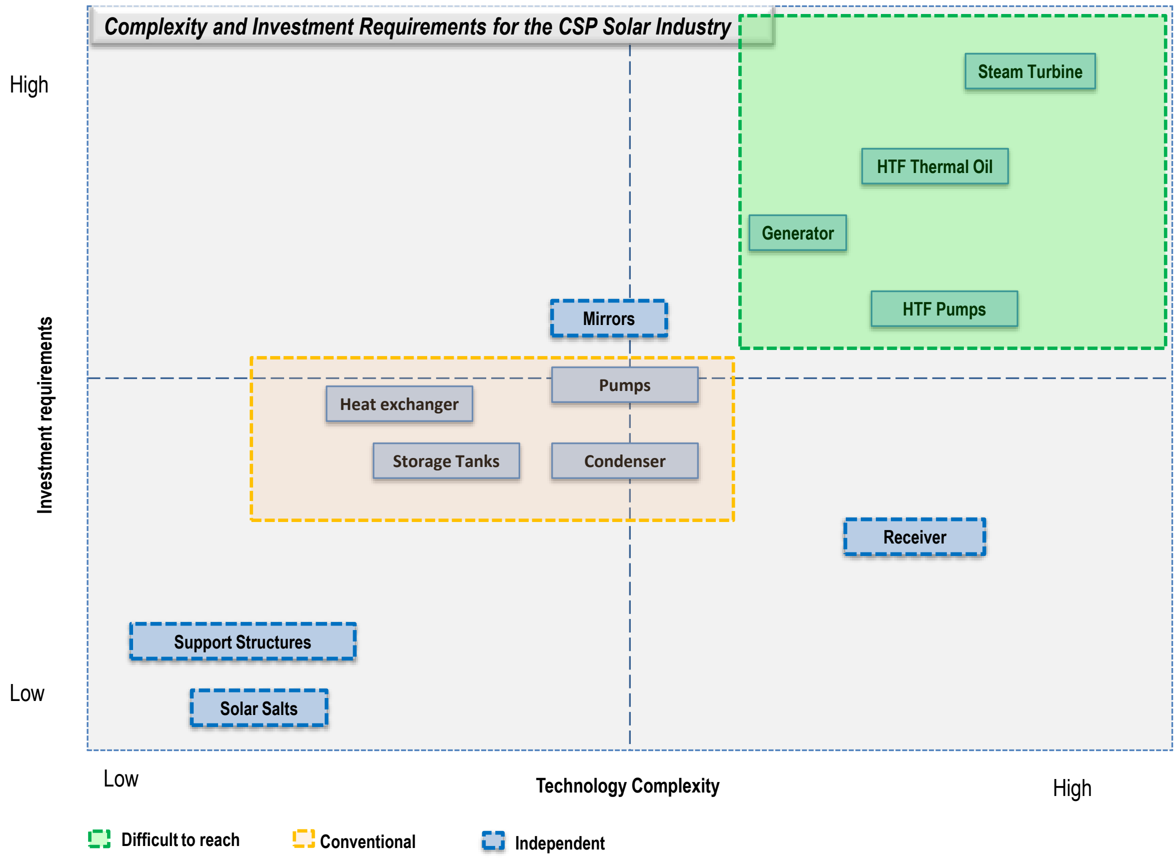

Figure 55. CSP complexity and investment requirements.

Support structures and Solar Salts have the lower combination of technology complexity and investment requirements making them a suitable choice for local industry.

Development of solar energy in the Republic of Uzbekistan might have a **positive impact on local industry** by maximizing the local components share. Nevertheless, energy competitiveness should not be jeopardized due to higher components costs.

On top, the construction of a RES power plant has other needs such as civil construction. This is an opportunity for local industry to provide basic materials that need no complex technology to be manufactured. Construction of a CSP plant with 7 hours storage system (34) requires steel, concrete, copper, glass, insulation and storage medium. According to the forecasted CSP annual capacity the evolution of the amount of raw materials is shown in Figure 56.

Civil engineering companies could develop their capacity to suit the demand of civil works requested by the construction of the 100MW Samarkand power plant and subsequent projects.

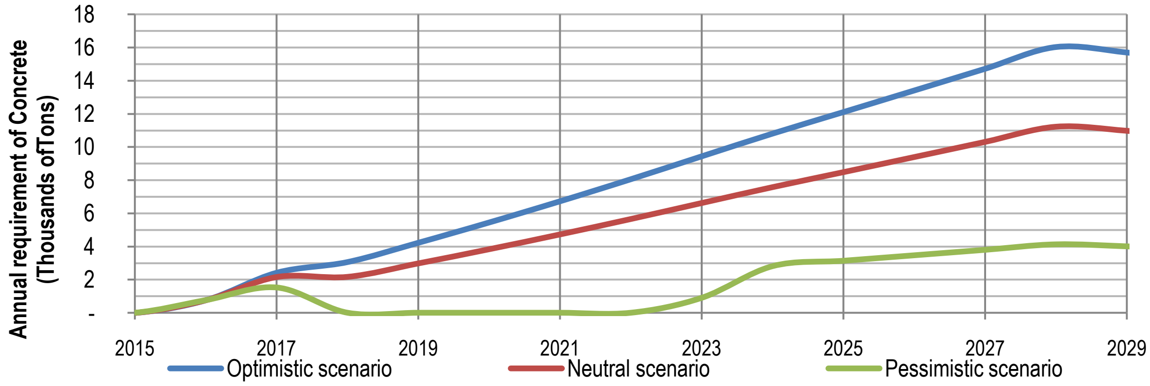

Figure 56. Evolution of material requirement for CSP according to forecasted capacity. Tons of material.

The highest share of material falls under storage medium, followed by glass and steel. Here again, to increase the positive impact that developing solar energy may have on local suppliers it is advisable to develop local industry capacity far enough to cope with the basic materials demand.

8.2.3.2 Labor Force Capacity Development

The deployment of solar energy electricity generation in the Republic of Uzbekistan could start in 2016 (100MW PV power plant in Samarkand). The building stage of this plant relies on the hands of four hundred workers for a forecasted period of one year . During operation and maintenance (O&M) procedures employ up to 25 workers.

To ensure optimal evolution of the project there has to be available workforce, trained and experienced in solar energy technologies. The existing fellowship of PV and CSP experts in Uzbekistan is not enough to cover the annual demand for the first projects. Foreign experts could assist on the building processes of the first power plants and could contribute to the training process of local professionals.

The first 100 MW PV power plant will roughly require 400 direct jobs during the first construction year. Following years, smaller plants are forecasted comprising around 300 jobs and 800 jobs on year two and three. These figures do not take into account the indirect jobs creation such as construction related services or the equipment supply chain. (34)

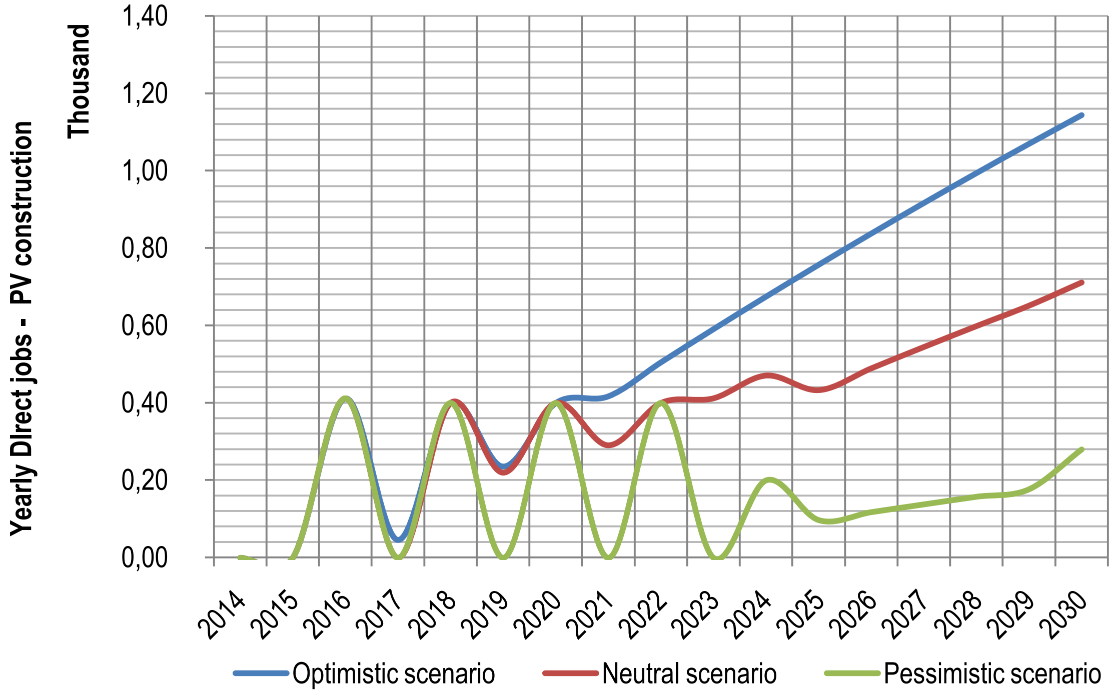

Figure 57. Yearly direct jobs required to install the forecasted PV capacity. Logarithmic Scale.

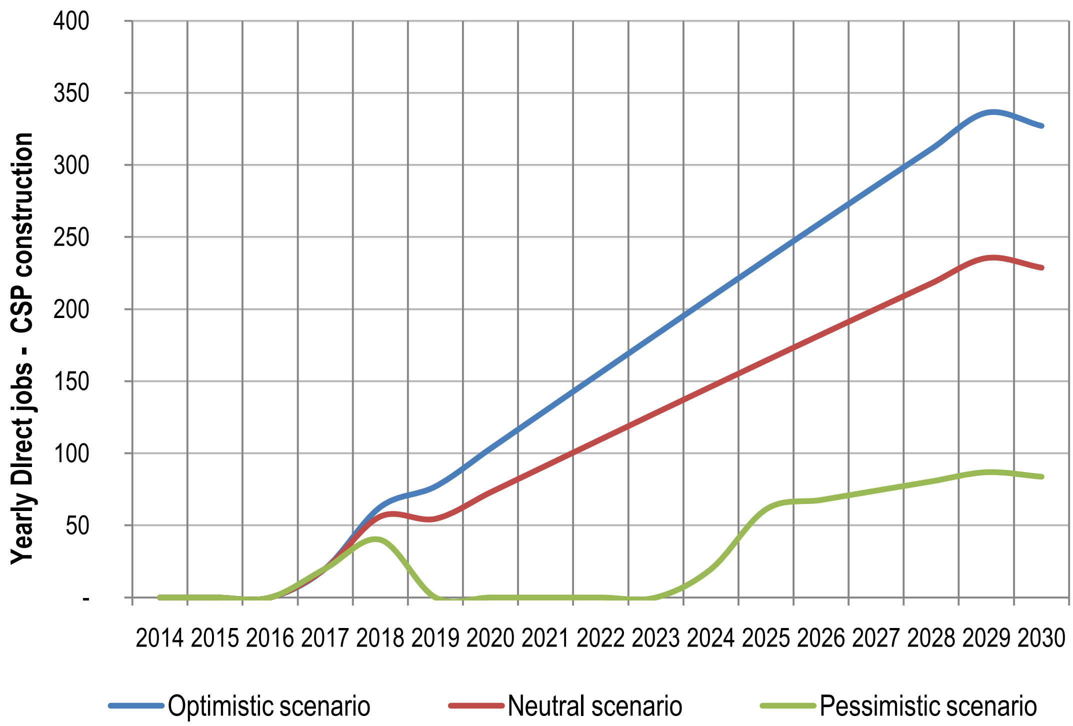

Figure 58. Yearly direct jobs required to install the forecasted CSP capacity. Logarithmic Scale.

Increasing the local workforce capable of installation, maintenance and operation of PV power plants should evolve parallel to its deployment – it's advisable to promote the creation of a training program.

It is advisable that regions planning to host new solar power plants support excellence centers to train the work force demand **around 2015**

8.2.4 Market Regulations

8.2.4.1 Utility-Scale Projects

Capital needs will follow, the solar energy installed capacity growth rate, see Figure 47. On parallel, both in Uzbekistan and abroad solar energy will become more mature and competitive. To attract investment to cover capital needs a clear stable market frame is a key element.

The 'status quo' of the energy market in the Republic of Uzbekistan could evolve in parallel to the country's pace. Regulations are a key element to define the market frame.

Gradually introducing competitors in electricity generation may alleviate the investment bottleneck. Besides, support instruments such as Feed in Tariffs (FiT), Feed in Premium (FiP) or tenders could be implemented to promote RES electricity generation.[19] Project

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1 [19] FOR FURTHER MECHANISMS OTHER APPLICATIONS OF SOLAR ENERGY

1.1 INTRODUCTION

Stable electricity supply is a basic need for medical centers, schools and other social care institutions. Solar energy could be a solution for remote rural areas under situations of intermittence and absence of electricity supply. Large power production systems connected to the grid can be complemented with smaller autarkic systems installed on the spot.

Further, water heating and air cooling systems could be implemented in parallel to power supply. Solar cooling is an advanced technology; however, it is nowadays commercially available for air conditioning systems and in pilot stage for ice production.

1.2 REMOTE HOUSEHOLDS

This Roadmap is focused on large scale power plants. Nevertheless, remote regions require different assistance: fresh water supply, house heating and stable electricity supply are basic needs to improve and guarantee the quality of life.

1.2.1 Photovoltaics

Photovoltaic systems could provide different improvements for remote households. Small scale installations may:

- Allow fresh water pumping
- Increase time of light
- Give access to electricity and associated services.
- Increase the stability of the electricity supply

Possible configurations of small scale systems depend on the available budget – Government subsidy and promotion play a role on the development of PV technology in remote areas.

1.3 HYBRID SOLAR-BIOMASS POWER PLANTS

Cotton is one of the main pillars of Uzbek economy and at the same time the organic residues it produces (namely bowls, roots, stalk and branches) are suitable for biomass power plants. Higher calorific values range from 17 to 18 mega joules per kilogram. Besides, the process of harvesting is energy efficient: the energy requested for the construction and O&M of the machinery and materials is lower than the energy content of the biomass – the result of the energy balance is around 35,000 MJ per hectare of harvested land.

Hybrid Solar-Biomass power plants could be designed to work with cotton's organic residues and concentrated solar power (CSP) becoming a sustainable energy generation process.

Republic of Uzbekistan dedicates 1.4 million hectares to cotton harvesting and it represents one of the main engines of the economy.

1.4 REMOTE INSTITUTIONS

Schools, medical centers, daycare centers and elderly care centers are examples of remote institutions that find a constraint in intermittent or unobtainable energy supply. Solar energy technologies unveil the possibility of widening their duties and strengthening their services.

Here again, already grid-connected institutions could see their electricity supply stabilized and isolated centers could become autonomous energy suppliers by installing PV systems.

Hot water supply may also be assisted by CSP technologies, reducing the dependence on conventional boilers and increasing sustainability.

1.5 DESALINATION

bidding could be a useful mechanism if the forecasted cost of solar energy represents a burden for the electric sector.

Here, SJSC Uzbekenergo and the Ministry of Agriculture and Water Resources (MAWR) control 100% of the production capacity of Uzbekistan binding the electricity generation sector.

This 'modus operandi' leaves little room for regulations under the Government's management. Even so, the final consumer price and the decision to subside the price of natural gas directly affect the development of electricity generation through solar energy.

In a competitive energy market, direct Government intervention through different mechanisms could effectively promote RES electricity generation. Feed in Tariffs, Feed in Premium and tenders are examples of these mechanisms.

In a non-competitive energy market, price regulations and governmental subsides might be suitable mechanisms to promote RES electricity generation.

Under the Soviet Union the electricity grid was developed regardless of actual borders, increasing the difficulty of national distribution in the independent Central Asia Countries (CAC). Reconsidering the existing regulations on international energy transactions may result on a less stiff energy market.

8.2.4.2 Other projects

This Roadmap is focused on large scale power plants. Nevertheless, remote regions require different assistance: fresh water supply, house heating and stable electricity supply are basic needs to improve and guarantee the quality of life.

Stable electricity supply is a basic need for medical centers, schools and other social care institutions. Solar energy could be a solution for remote rural areas under situations of

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Desalination processes are energy intensive, enhancing the research and development programs to find a Renewable Energy Source (RES) that is able to reduce the commercial electricity consumed.

Solar energy assistance has been already tested as a support for desalinization processes:

- Solar-thermal energy is applicable to the following desalination technologies: (i) solar distillation, (ii) multiple effect humidification, (iii) membrane distillation, (iv) thermal vapour compression, (v) multi stage flash and (vi) multiple effect desalination.
- Solar-electricity is applicable to the following desalination technologies: (i) electro dialysis, (ii) mechanical vapour compression and (iii) reverse osmosis.

Coupling desalination facilities with solar power plants could improve the fresh water resource of Republic of Uzbekistan and contribute to higher sustainability.

ANNEX I: SUPPORT INSTRUMENTS FOR RES-ELECTRICITY intermittence and absence of electricity supply. Large power production systems connected to the grid can be complemented with smaller autarkic systems installed on the spot.

Further information can be found in section 11. Other Applications of Solar Energy

8.2.5 Doing business

Investors decide where, when and how much to invest based on different factors. Diminishing the gap with leading countries would attract and lower the capital cost (minimum yield) for future investment in RES electricity generation projects.

The commitment to reduce the gaps between the Republic of Uzbekistan and benchmark countries could reduce the investment cost and lower the pressure upon UFRD, enhance timing of solar energy deployment and avoid economic constraints.

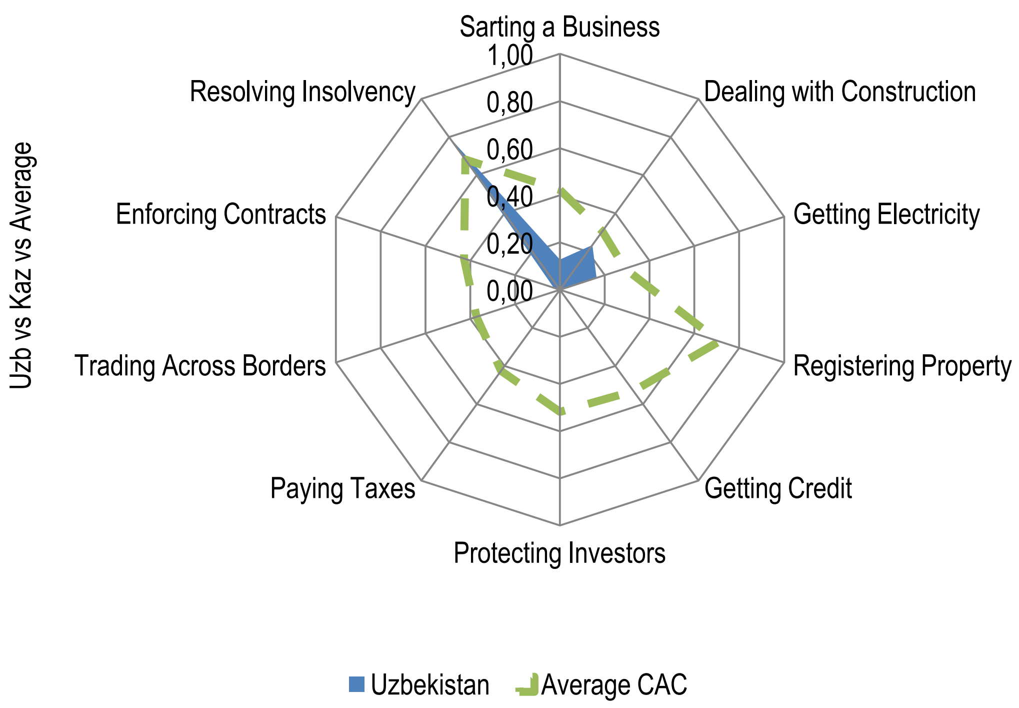


Figure 59. Ease of doing business indicators. Uzbekistan and CAC Average. Source: (46).

Figure 59 represents the indicators of the ease of doing business, as prepared by the World Bank for Uzbekistan and the average of the economies in the same region (namely Kazakhstan, Kyrgyz Republic, Moldova, Russian Federation and Tajikistan).

8.3 SJSC UZBEKENERGO

8.3.1 Financial Actions

8.3.1.1 Introduction

Fist stages of the solar power plant's development project is bonded to Uzbekenergo's investment program. Financial actions are recommended for new project's deployment and further research and development of new technologies.

8.3.1.2 Finance Construction Projects

Financial institutions might finance part of the investment; however, a share of it remains to be beard by the utility that will later operate and benefit from the power plant. Here again, the financing mechanism of the first bunch of power plants (Table 11) differs from the subsequent.

Once the first steps of the path towards RES generation have been covered, the dependence on Multilateral Institution's funds will decrease and finally cease. Hence, Uzbekenergo should embrace mechanisms to finance successive solar power plants and supply Uzbek society's electricity demand using RES.

Otherwise, the investment bore by Uzbekenergo (Figure 60) would overcome the acceptable levels for a standard electric company.

Based on previous joint projects between Multilateral Banks and the Republic of Uzbekistan to develop the electricity sector:

Equity (30%)[20]		Debt (70%)	
Government	SJSC Uzbekenergo	Multilateral Banks & donors	UFRD
15%	15%	49%	21%

Table 11. Investment shares by stakeholder. Based on previous projects.

[20] Contribution shares to the project by the Government and Uzbekenergo are flexible (i.e. 18% Government, 12% Uzbekenergo)

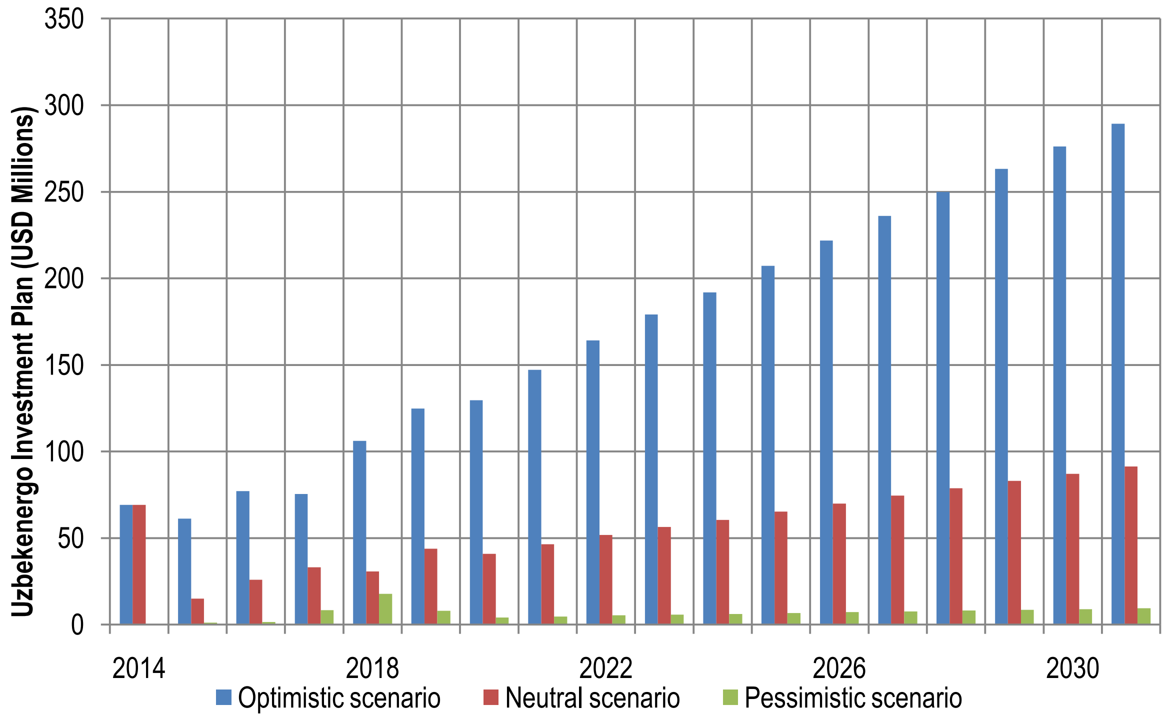


Figure 60. Uzbekenergo's Investment plan according to generation scenarios. Millions of USD If the Uzbekenergo-UFRD-multilateral banks scheme is kept.

Once the first steps of the path towards RES electricity generation have been covered, the dependence on Multilateral Institution's funds should be diminished and finally ceased.

SJSC Uzbekenergo could develop **BOT and DBO agreements** according to the company's investment plan.

8.3.1.2.1 Build Operate Transfer (BOT) Agreements

Build-Operate-Transfer agreements lay the responsibility of financing on a private party, generally a Special Purpose Vehicle (SPV) that then builds, operates and then transfers the plant. The ownership of the plant belongs to the private entity until the operating period expires: SJSC Uzbekenergo will be the final owner.

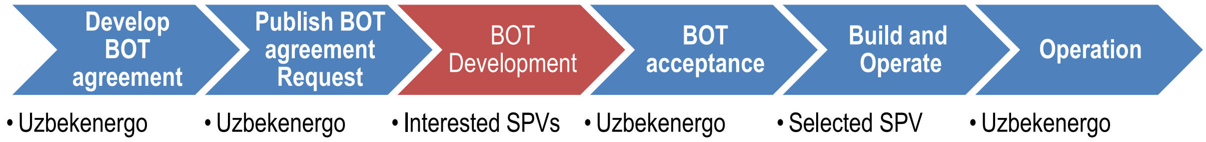


Figure 61. Time structure of BOT agreement.

	Building	Operation	Maintenance	Financing	Ownership	Purchaser
Period 1	SPV	SPV	SPV	SPV	SPV	Uzbekenergo [21]
Period 2	-	Uzbekenergo	Uzbekenergo	Uzbekenergo	Uzbekenergo	Citizens

Table 12. BOT responsibilities. Period 1 before transfer, Period 2 after transfer. (47)

BOT agreements allow SJSC Uzbekenergo to obtain external financing and keep increasing solar installed capacity. After an established period, the company becomes the owner of the facility.

8.3.1.2.2 Design-Build-Operate (DBO) agreements

Design-Build-Operate agreements resemble BOTs in the design and build processes but differ in the ownership and financing: SJSC Uzbekenergo will be the owner of the power plant from the beginning and it is also responsible of financing it.

Figure 62. Time structure of DBO agreements.

[21] Through Power Purchase Agreements (PPA).

	Building	Operation	Maintenance	Financing	Ownership	Purchaser
Period 1	SPV	SPV	SPV	Uzbekenergo	Uzbekenergo	Uzbekenergo[22]
Period 2	-	Uzbekenergo	Uzbekenergo	Uzbekenergo	Uzbekenergo	Citizens

Table 13. DBO responsibilities. (47)

DBO agreements allow SJSC Uzbekenergo to invest directly on solar power plants avoiding expenses on design, responsibilities on civil operations and on initial performance.

Uzbekenergo should evaluate the capacity to invest directly on building solar power plants through DBO agreements and suit the excess of demand by BOT agreements.

8.3.1.3 Finance R&D on new technologies

Due to its location, the availability of solar resource and the will to develop RES technologies, the Republic of Uzbekistan gathers all the requirements to become a solar technology hub. For this, an investment in research and development of solar technologies is a must.

CASE STUDY – Investment on CSP technologies Research, Plataforma Solar de Almería (PSA)

The Government of Spain has the commitment to invest 11 Million USD annually to promote research and development of concentrating solar power technologies.

Jointly, private sector does business with the PSA for approximately 3 Million USD annually. (54)

8.3.2 Capacity Development

8.3.2.1 Grid Infrastructure

Actions to decrease losses in the Uzbek grid to benchmarks (around 5%) such as:

- Increase the voltage of the medium and large transmission lines.
- Reduce the grid's layout linearity by increasing its meshing.
- Determine the suitable locations for power plants near hubs with excess of electricity demand.

There are ongoing projects of grid refurbishing and construction led by the ADB and financed by both public funds and ADB loans.

Grid improvement will have an effect both on energy supply needs (reduction) and on possibility to integrate renewable energy into the system.

[22] Through Power Purchase Agreements (PPA)

8.3.3 Market Regulations

A gap between electricity tariffs and cost recovery levels exists.

Further, electricity market should undergo a progressive makeover that gradually narrows the gap between the real energy generation price and the price paid by final consumers. In spite of the fact that consumer tariff is considered high for society in Central Asia Countries– and even higher in the Republic of Uzbekistan – they are far from covering the energy production cost.

SJSC Uzbekenergo has to undertake a procedure of **gradual increase of consumers' tariff** in order to cover generation costs without the Government's subsides.

Arranging DBO and BOT agreements includes tying one loose end: Once the power plant is operative, under which conditions the electricity is purchased?

- The buyer will be SJSC Uzbekenergo
- The contracted capacity and energy must be bought by the electric utility.
- The price has to be arranged by both parties and should cover the project's company fixed and variable costs.

Power Purchase Agreements (PPA) secure the payment stream to the Special Purpose Vehicle (SPV) before the ownership is transferred to Uzbekenergo.

8.4 FINANCIAL INSTITUTIONS

8.4.1 Introduction

Project finance for solar power plants is an extended financial mechanism in countries with experience in RES electricity generation, providing a frame for financial institutions involved in solar energy development in the Republic of Uzbekistan.

Commercial banks evaluate the risk of financing a project without specific feedback or previous implementation; however, multilateral banks such as the Asian Development Bank (ADB) assume the risk, promoting Uzbekistan's evolution towards sustainable energy generation and responsible consumption of fossil fuel reservoirs.

To start developing solar energy in the Republic of Uzbekistan, a kickoff financial plan is proposed in Figure 63. This plan is built according to the Optimistic Scenario forecast.

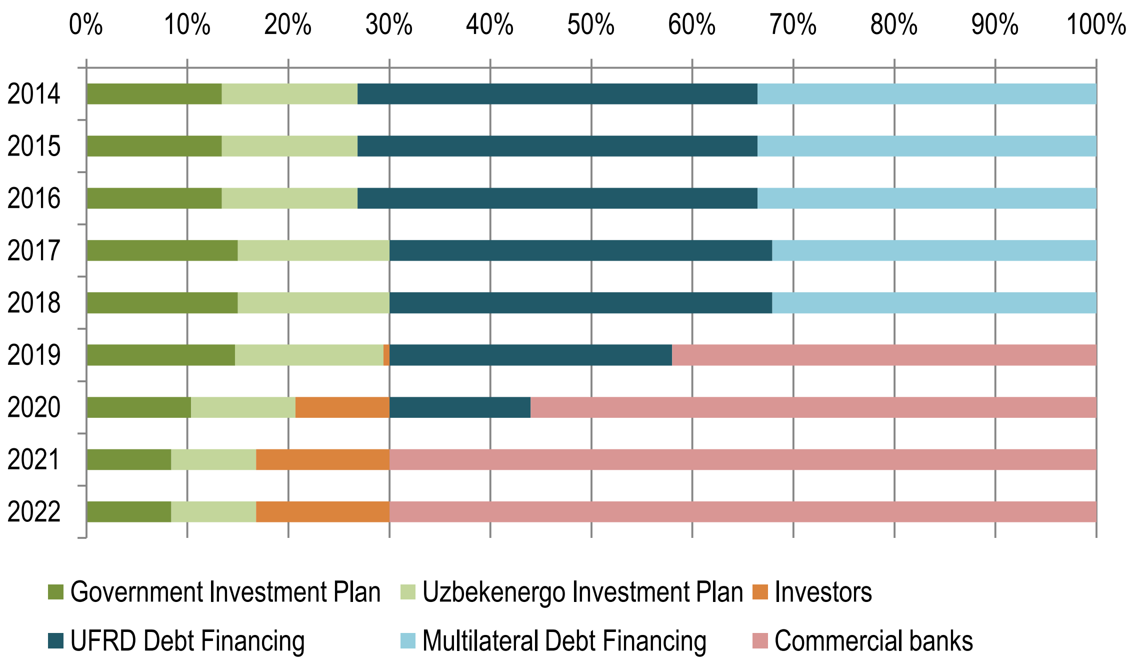


Figure 63. Investment evolution from 2014 to 2022, by stakeholder. Shares.

8.4.2 Multilateral Banks and other donors

8.4.2.1 Introduction

Multilateral banks such as the Asian Development Bank are pillars of the development process of the Republic of Uzbekistan. "*By targeting our investments wisely, in partnership with our developing member countries and other stakeholders, we can alleviate poverty and help create a world in which everyone can share in the benefits of sustained and inclusive growth."* Asian Development Bank Overview, November 2012. (48)

Existing records of these partnerships include multilateral organizations such as the Asian Bank of Development, the United Nations Development Program and the World Bank. Besides, bilateral cooperation and development banks can play a role.

8.4.2.2 Financial Actions

Multilateral banks' financing by granting soft loans to the Government has a direct effect on solar energy development in the Republic of Uzbekistan. In the best scenario Multilateral banks and donors will cover 100% of the debt in a 70-30 debt-equity share of the needed investment to deploy and install solar power plants until the energy market is stable and feedback from previous projects is solid enough to attract commercial banks' financing.

Alternative scenario considers contribution from the Fund for Reconstruction and Development of the Republic of Uzbekistan lowering the share of the Multilateral Banks and other donors to 70% of the debt (50% of the total investment).

8.4.2.3 Regulatory Actions

Multilateral Banks take into account the main and collateral effects of financing solar energy deployment in Uzbekistan, assuring that the farther beneficiary is Uzbek society.

8.4.3 National Financial Institutions

8.4.3.1 Capacity Development

Solar energy power plants are nowadays financed in many countries, offering the chance of participation to Uzbekistan's national banks. Acquiring experience through **ticket purchase** may develop national banks' capacity to deal with subsequent projects.

Foreign financial institutions that work with *project finance* seek further financing to decrease the extent that is directly financed by the main entity. Offering tickets for fractions of the total investment volume with lower risks and responsibility in the project is a common procedure when financing solar energy plants.

Further, domestic banks could support national and regional excellence centers as the ISEI to build infrastructure for higher education, science and technology.

At the same time, the Fund for Reconstruction and Development of the Republic of Uzbekistan (UFRD) provides Uzbek financial entities the chance to invest in development projects, such as solar energy deployment.

8.5 CENTERS OF EXCELLENCE

8.5.1 Capacity Development

Developing solar energy in the Republic of Uzbekistan creates a new area of practice, research, support and training. The Government of Uzbekistan and the ADB are supporting the setting up of International Solar Energy Institute (ISEI)

Promoting the use of solar energy, controlling and registering the evolution of solar power generation and training new specialists are features of the centers of excellence.

Centers of excellence and solar energy development shall evolve equally. Further, it's advisable that subsides to start developing capacity are provided by the Government of Uzbekistan. Mainstreaming training programs and research projects should become the source of income of the centers of excellence, allowing autonomous financing and steady capacity growth.

Defining a training program for potential solar energy experts should be one of the main targets of the Centres of Excellence.

Further, they should become the knowledge hub of solar energy in Central Asia, attracting potential customers from the neighbour countries.

8.5.1.1 Development of a training program

Centers of excellence have to meet the expectations of the potential trainees and prepare them to meet the employing companies' requirements. Hence, developing the capacity to train new solar experts is advisable.

CASE STUDY – Photovoltaic Energy Post grade (58).

Theoretical

Fundamentals of solar cells

Energy and society

Electrical engineering of PV systems

Physics of photovoltaic materials

Optical engineering

PV applied mathematics

PV engineering

Grid-connected PV power plants

Engineering of support structure

Cutting edge solar cells' technologies

Practical

Laboratory - Solar cells characterization

Laboratory - Solar cells technology

Laboratory – Modules and installations

Laboratory – concentrating PV systems

Laboratory – PV system simulation

Laboratory – Electrical PV engineering

Laboratory – PV materials

Consolidating the programs of the Centers of excellence can profit from guidance and acceptance of foreign experts and Universities. Ambitions of these institutions should overcome Uzbek borders and attract potential experts from foreign countries, particularly from CAC group. To this purpose, homologation of the courses by an institution with international recognition is advisable.

8.5.1.2 Gathering and making accessible information

Once solar energy deployment starts its advisable to build upon experience to provide a better understanding of the actual technologies and, therefore, to be able to improve them. It is, as a matter of fact, necessary to have information about irradiation improving satellite data, average deposition of dust over the modules and mirrors and other parameters facilitating a better understanding and forecasting of the behavior and of the efficiency of solar energy generation plants.

Centres of Excellence should **gather and make accessible information:** pre-installation; installation and operational data could be available to entities interested in solar energy development in Republic of Uzbekistan.

Relevant information may comprise:

- Meteorological data
- Location of power plants
- Size of power plants
- Cost of the power plants
- Date of construction
- Production of each power plant
- Efficiency of each power plant
- Cost per watt of each power plant
- Plant characteristics.

9 DEPLOYMENT

9.1 FROM 2014 TO 2016

In 2016 solar energy development project can start through planning and constructing a 100 MW PV solar power plant in Samarkand and a Demostration PV installation in Parkent. From 2014 to 2016, actions to support the development of solar technologies and to reduce the costs and increase the efficiency are recommended.

Starting in 2014, security and sustainability of the process should be shown to the stakeholders to make credible the support and to promote the creation of a projects pipe-line for the next five years and to bust the components industry and capabilities.

At the end of this period 103MW of solar energy could be installed.

9.2 FROM 2016 TO 2024

Based on the momentum created, the whole industry value chain should already be on place to supply the Republic of Uzbekistan and the neighboring countries.

Further demonstration projects will be developed to increase solar energy capacities in Uzbekistan while reducing the financial support from multilateral banks and UFRD. This support should be provided by commercial banks and other investors.

At this stage the situation of the energy market will play a major role on further solar energy development. The regulations chosen by the Government will decide the outcome of coming years. If BOT and DBO projects are the only mechanisms implemented in this period, the growth of solar energy could be slow compared to the growth that might occur if the energy market was de-regulated and FiT, public-private partnerships and IPPs implemented.

9.3 FROM 2024 TO 2030

At this stage grid parity will be reached and solar energy technologies might be able to commercially compete with conventional energy production.

(GW)	2018	2024	2030
Optimistic	0.2	1.0	2.8
Neutral	0.2	0.8	1.9
Pessimistic	0.2	0.5	0.8

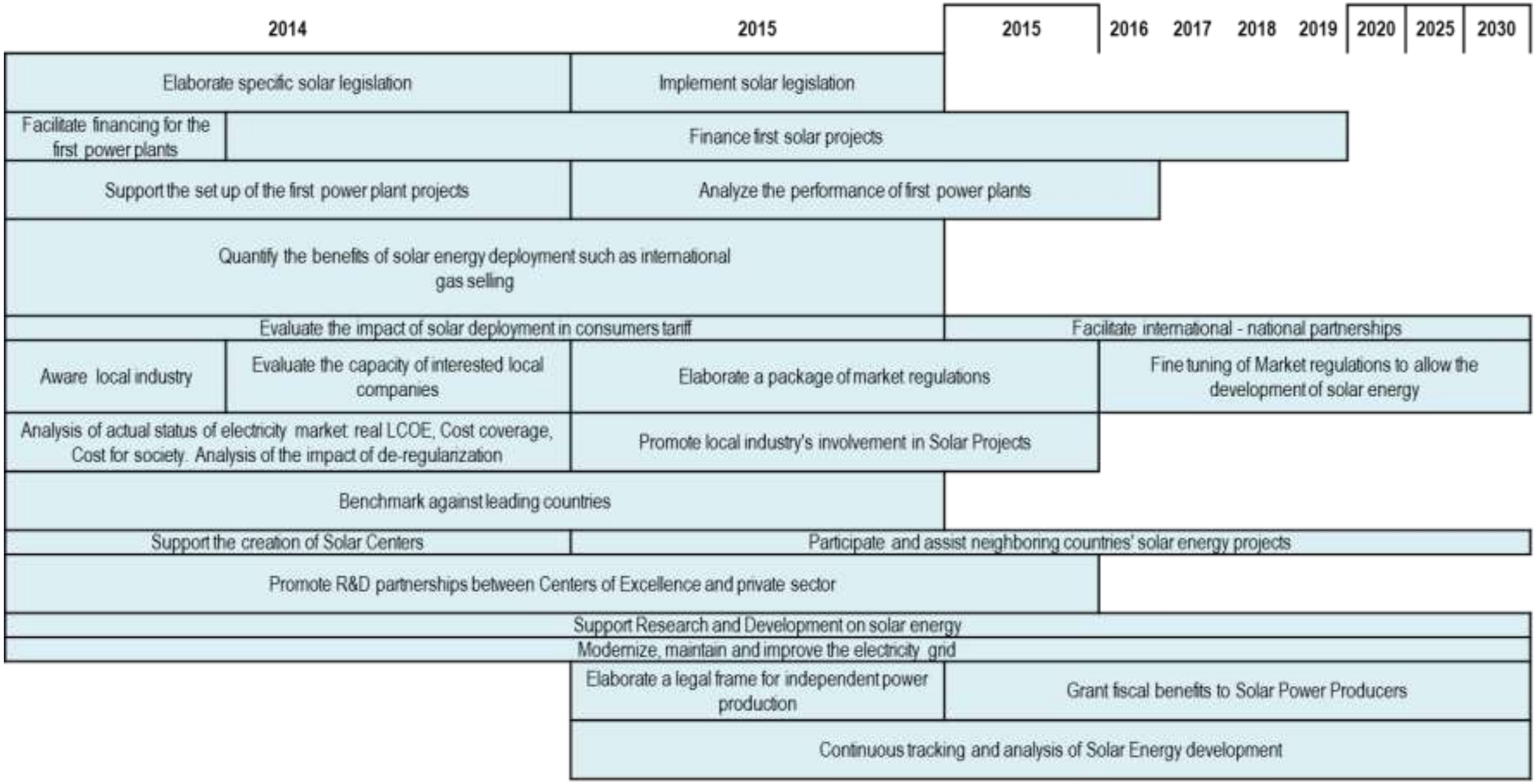
Table 14. Estimated capacity (GW) of installed solar energy production by the end of each deployment period. PV+CSP.

10 ACTION PLAN

A series of actions have been defined to address the existing gaps and enable the conditions under which solar development can become a reality in the Republic of Uzbekistan. Nevertheless, an action plan is defined to assist the stakeholders with specific timings and intensity tuning. The following organisms play a major role in this project's feasibility and therefore a particular action plan is developed for each of them:

- The Government of Republic of Uzbekistan
- State Join Stock Company Uzbekenergo
- Financial Institutions:
- Universities and Research Centers
- Industry

THE GOVERNMENT OF REPUBLIC OF UZBEKISTAN



GOVERNMENT OF THE REPUBLIC OF UZBEKISTAN										
2014		2015	2016	2017	2018	2019	2020	2021	2025	2030
Elaborate specific solar legislation		Integrate solar legislation								
Facilitate financing for the first power plants	Finance first solar projects									
Evaluate the Financial Analysis of the first solar projects		Analysis of performance of first powe plants								
Evaluate the impact of solar deployment in gas sellings			Allow competitiveness in the electricity generation market							
Evaluate the impact of solar deployment in consumers tariff			Facilitate international - national partnerships							
Publish EOI for local industry	Evaluate the capacity of interested local companies	Elaborate a package of market regulations	Implement FiT ,FiP or project bidding	Fine tuning of Market regulations to allow the development of solar energy and protect Uzbekistan's energy market						
Analysis of actual status of electricity market: real LCOE, Cost coverage, Cost for society. Analysis of the impact of de-regularization		Promote local industry's involvement in Solar Projects								
Analysis of the existing gaps in "doing bussines"	Reduce the gaps between benchmark countries - package of measures to improove attractiveness indexes.									
Support the creation of Solar Centers		Participate and assist neighboring countries' solar energy projects								
Promote R&D partnerships between Centers of Excellence and private sector										
Support Research and Development of solar energy										
Modernize, maintain and improve the electricity grid										
		Elaborate a legal frame for ISPP	Grant fiscal benefits to Solar Power Producers							
		Continuous tracking and analysis of Solar Energy development								

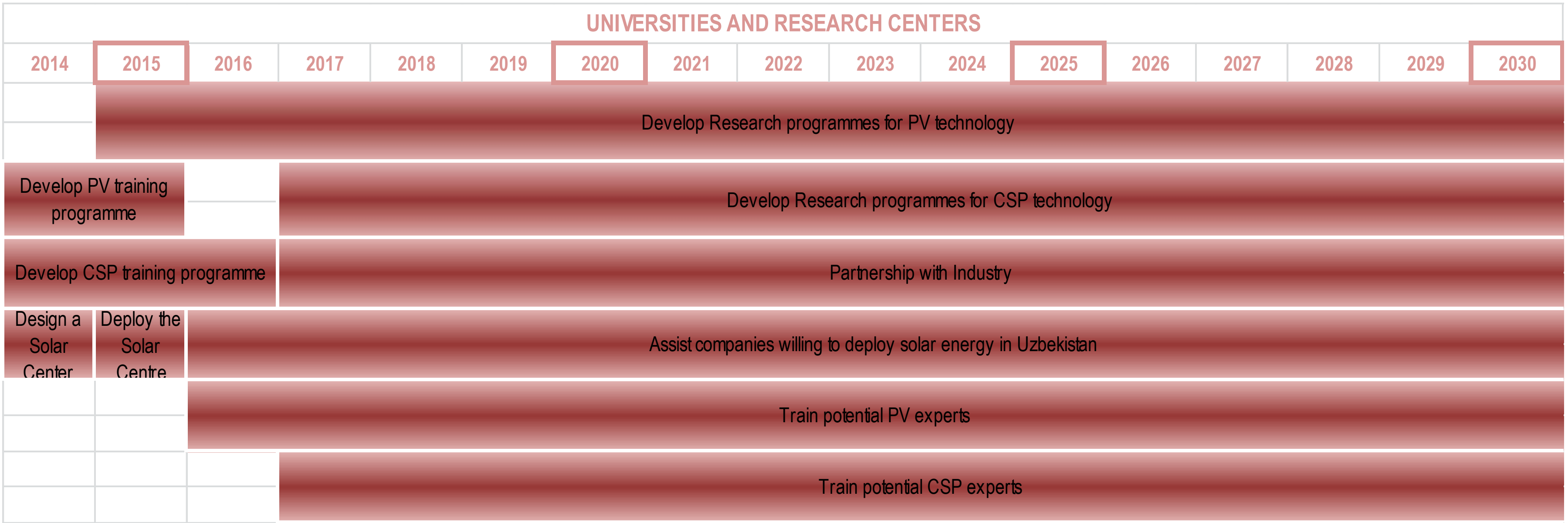
UZBEKENERGO

<table>
<tr><th colspan="11">UZBEKENERGO</th></tr>
<tr><th colspan="2">2014</th><th>2015</th><th>2016</th><th>2017</th><th>2018</th><th>2019</th><th>2020</th><th>2021</th><th>2025</th><th>2030</th></tr>
<tr><td colspan="2">Create a Solar Energy department</td><td colspan="2">Train engineers on PV and CSP technologies</td><td colspan="7"></td></tr>
<tr><td colspan="4">Acquire experience from international ongoing solar projects</td><td colspan="7"></td></tr>
<tr><td colspan="11">Develop the transmission grid to host Solar Power Plants</td></tr>
<tr><td>Elaborate a programme of R&D of Solar Energy</td><td colspan="10">R&D solar energy technologies</td></tr>
<tr><td>Elaborate an investment plan for Solar Energy</td><td colspan="10">Invest in Solar Power Projects</td></tr>
<tr><td colspan="2">Define a strategy to develop solar energy according to the company's capacity</td><td>Define a protocol for ISPP grid connection</td><td colspan="8">Facilitate grid acces to ISPP</td></tr>
<tr><td>Elaborate a draft analysis of the impact of demonopolization of the energy market</td><td>Estiamte the costs of transition to competitiveness</td><td>Monitorize the effects of PV power plants on the electric system</td><td colspan="8">Participate in third party solar projects</td></tr>
<tr><td colspan="2"></td><td colspan="9">Promote the restructuration of the company towards competitiveness</td></tr>
<tr><td colspan="11">Monitorize the effect of solar energy deployment on internal accounting</td></tr>
<tr><td colspan="3">Coordinate the investment for the first solar power plants with the Government</td><td colspan="8"></td></tr>
<tr><td colspan="11">Promote national and international experience sharing</td></tr>
</table>

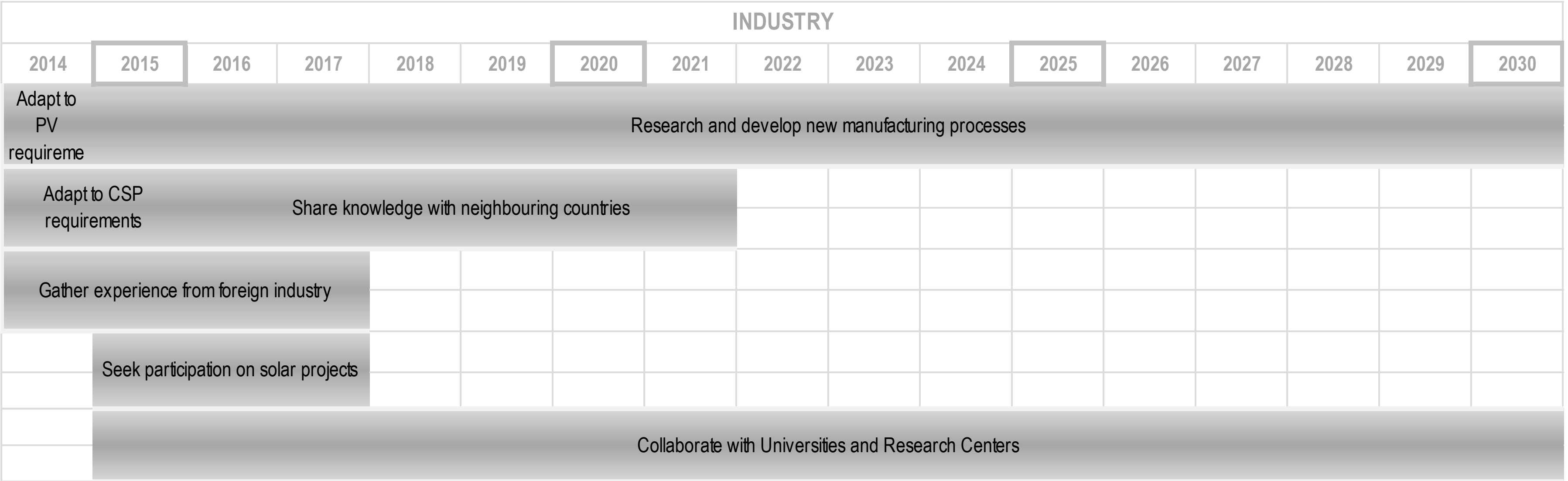
FINANCIAL INSTITUTIONS

<table>
<tr><th colspan="17">FINANCIAL INSTITUTIONS</th></tr>
<tr><th>2014</th><th>2015</th><th>2016</th><th>2017</th><th>2018</th><th>2019</th><th>2020</th><th>2021</th><th>2022</th><th>2023</th><th>2024</th><th>2025</th><th>2026</th><th>2027</th><th>2028</th><th>2029</th><th>2030</th></tr>
<tr><td colspan="3">Multilateral institutions and other donors: Support and finance energy sector improvements</td><td colspan="14">Commercial International banks: Fiance solar projects</td></tr>
<tr><td colspan="3">National Banks: Capacity Development</td><td colspan="14">National Banks: Joint international solar project financing</td></tr>
<tr><td colspan="4">Multilateral Institutions and other donors: Promote experience sharing</td><td colspan="13">National Banks: Solar project financing</td></tr>
<tr><td colspan="16">Multilateral Institutions and other donors: Surveilance of milestones</td><td></td></tr>
</table>

UNIVERSITIES AND RESEARCH CENTERS



INDUSTRY


INDUSTRY
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023
2024
2025
2026
2027
2028
2029
2030
Adapt to PV requireme
Research and develop new manufacturing processes
Adapt to CSP requirements
Share knowledge with neighbouring countries
Gather experience from foreign industry
Seek participation on solar projects
Collaborate with Universities and Research Centers

11 OTHER APPLICATIONS OF SOLAR ENERGY

11.1 INTRODUCTION

Stable electricity supply is a basic need for medical centers, schools and other social care institutions. Solar energy could be a solution for remote rural areas under situations of intermittence and absence of electricity supply. Large power production systems connected to the grid can be complemented with smaller autarkic systems installed on the spot[23].

Further, water heating and air cooling systems could be implemented in parallel to power supply. Solar cooling is an advanced technology; however, it is nowadays commercially available for air conditioning systems and in pilot stage for ice production.

11.2 REMOTE HOUSEHOLDS

This Roadmap is focused on large scale power plants. Nevertheless, remote regions require different assistance: fresh water supply, house heating and stable electricity supply are basic needs to improve and guarantee the quality of life.

11.2.1 Photovoltaics

Photovoltaic systems could provide different improvements for remote households. Small scale installations may:

- Allow fresh water pumping
- Increase time of light
- Give access to electricity and associated services.
- Increase the stability of the electricity supply

Possible configurations of small scale systems depend on the available budget – Government subsidy and promotion play a role on the development of PV technology in remote areas.

11.3 HYBRID SOLAR-BIOMASS POWER PLANTS

Cotton is one of the main pillars of Uzbek economy and at the same time the organic residues it produces (namely bowls, roots, stalk and branches) are suitable for biomass power plants. Higher calorific values range from 17 to 18 mega joules per kilogram. Besides, the process of harvesting is energy efficient: the energy requested for the construction and O&M of the machinery and materials is lower than the energy content of the biomass – the result of the energy balance is around 35,000 MJ per hectare of harvested land. (49)

[23] Both Government and the Academy of Science have acknowledged and shown commitment to support the development of energy supply for remote regions, promoting their autonomy and sustainability.

Hybrid Solar-Biomass power plants could be designed to work with cotton's organic residues and concentrated solar power (CSP) becoming a sustainable energy generation process.

Republic of Uzbekistan dedicates 1.4 million hectares to cotton harvesting (50) and it represents one of the main engines of the economy. [24]

Cotton's biomass has a potential electricity generation of around 5 TWh per harvesting season.

CSP power production may add up to 2 TWh to biomass annual production. Hence, hybridization of biomass power plants with solar technology has a potential energy generation of around 7TWh. (59)

11.4 REMOTE INSTITUTIONS

Schools, medical centers, daycare centers and elderly care centers are examples of remote institutions that find a constraint in intermittent or unobtainable energy supply. Solar energy technologies unveil the possibility of widening their duties and strengthening their services.

Here again, already grid-connected institutions could see their electricity supply stabilized and isolated centers could become autonomous energy suppliers by installing PV systems.

Hot water supply may also be assisted by CSP technologies, reducing the dependence on conventional boilers and increasing sustainability.

11.5 DESALINATION

Desalination processes are energy intensive, enhancing the research and development programs to find a Renewable Energy Source (RES) that is able to reduce the commercial electricity consumed.

Solar energy assistance has been already tested as a support for desalinization processes: (51)

- Solar-thermal energy is applicable to the following desalination technologies: (i) solar distillation, (ii) multiple effect humidification, (iii) membrane distillation, (iv) thermal vapour compression, (v) multi stage flash and (vi) multiple effect desalination.
- Solar-electricity is applicable to the following desalination technologies: (i) electro dialysis, (ii) mechanical vapour compression and (iii) reverse osmosis.

Coupling desalination facilities with solar power plants could improve the fresh water resource of Republic of Uzbekistan and contribute to higher sustainability.

[24] The potential energy production is calculated assuming that the entire surface sown by cotton is harvested and the residues burned in biomass-fired power plants. Solar potential energy is calculated assuming that all the biomass was burnt in hybrid CSP-biomass power plants.

12 ANNEX I: SUPPORT INSTRUMENTS FOR RES-ELECTRICITY

Main support instruments for RES-electricity are: feed-in tariff, premium feed-in tariff, quota obligation, investment grants, tax exemptions and fiscal incentives, tenders and net metering. All those instruments try to compensate the difference, to bridge the gap, between generation costs and the tariff applied to customers. Most remarkable characteristics of them are as follows:

Support Instrument	***Feed-in Tariff (FiT)***
Description	A fixed and guaranteed price is paid to the eligible producers for all the power they feed to the grid.
Implementation	Very high implementation, most of the EU countries (21 from 27)
Economic impact	Usually reduce the price because cost of capital is lower as market risk and its associated costs are avoided
Investors perception	This system gives certainty to investors guaranteeing the price and providing a secure demand for a limited period of time (15 to 25 years) with certain on return of their investment.
Regulator perception	The regulator has to review regularly tariffs in order to adjust the system to the latest available generation cost projections and to stimulate technology learning and updates.
Sustainability	The system is sustainable in terms of stability and while policy keeps the same trend of incrementing the participation of RES in the total electricity production
Society perception	Lower average cost support
Risks	Producers could not be generally stimulated to adjust their production and efficiency to the price signals on the market. Cost-efficiency decreases when policy makers overestimate the cost of producing renewable electricity
Advantages	Lower investment risks, Allowing faster growth

Table 15. Characteristics of Feed in tariff. Source: Own elaboration.

Support Instrument	***Feed-in Premium***
Description	A guaranteed premium is paid to the producers in addition to the income received for the electricity from renewable sources that is being sold in the electricity market.
Implementation	Lower implementation in EU countries (6 from 27)
Economic impact	Price could be higher because cost of capital is higher as far market risk and its associated costs should be considered.
Investors perception	This system provides less certainty to investors exposing them to electricity price risk and increment costs of capital.
Regulator perception	The regulator has to determine regularly premiums and, usually, cap and floor prices, based on electricity market trends and technology learning rates.
Sustainability	The system is sustainable in terms of stability and while policy keeps the same trend of incrementing the participation of RES in the total electricity production
Society perception	Lower average cost support
Risks	To induct additional costs for society and windfall profits for producers when production costs are over-estimated, or electricity prices and learning rates are underestimated by policy makers, to minimize the risk usually cap and floor is introduced in the remuneration
Advantages	Producers of RES are stimulated to adjust their production according to the price signals on electricity market

Table 16. Characteristics of Feed in Premium. Source: Own elaboration.

Support Instrument	***Quota obligations***
Description	Government imposes minimum shares of RES on suppliers (or producers and consumers) creating a market for the renewable property of electricity. This usually is a percentage which has been incremented over the time. If obligations are not met, financial penalties are to be paid. Obligations are combined with renewable obligation certificates (ROC) that can be traded.
Implementation	Little implementation in EU countries (6 from 27)
Economic impact	Price could be higher because the uncertainty of the electricity market prices in addition to the risk of certificates market.
Investors perception	This system provides some uncertainty to investors as they in the electricity market and in the certificates market.
Regulator perception	As far as the system tends to stimulate lower-cost technologies, the regulator has to regulate quota obligations per technology specification and penalties (if there is an interest on developing a particular one).
Sustainability	The system is sustainable as far as market rules are in force and penalties for non-compliance remain effective.
Society perception	Lower average cost
Risks	This system tends to stimulate lower-cost technologies and generally discard innovations in more costly options.
Advantages	Quota obligations with certificates expose producers to market signals, which can be beneficial from a power system operation perspective.

Table 17. Characteristics of Quota obligations. Source: Own elaboration.

Support Instrument	***Tax exemptions and fiscal incentives***
Description	Government establish privileges to investors such as benefits exemption, investment subsidies, accelerated depreciation, credits per unit of produced renewable energy
Implementation	High implementation in EU countries (15 of 27)
Economic impact	Tax income is reduced and electricity cost is reduced
Investors perception	Stop-and-go mechanism
Regulator perception	Fiscal incentives should be declared and guaranteed for a couple of years in advance.
Sustainability	The system depends on government budget, so that it is subject to political negotiations and annual budget constraints.
Society perception	Higher average cost support
Risks	It limits the incentive for increasing efficiency. If incentive is not reduced as costs decline could lead to over-subsidization
Advantages	Directly indicates the degree of importance of one particular technology over others.

Table 18. Characteristics of Tax exemptions and fiscal incentives. Source: Own elaboration.

Support Instrument	***Tenders***
Description	Government draft a tender for a project determining the capacity and/or production to be achieved and can be technology- or even project/site-specific
Implementation	Little implementation in EU countries (4 of 27)
Economic impact	The market determine what the required level of support should be
Investors perception	This system may be indexed to inflation The financial risk can be transferred from the project developer to the institution which draft the tender
Regulator perception	The regulator should establish a standard long-term purchase
Sustainability	The system is sustainable as long as the government develops larger-scale projects.
Society perception	It is an efficient system, furthermore, tendering allows for incorporation of additional conditions, e.g. regarding local manufacturing of technology
Risks	The cost of the project can be higher than the one estimated when drafting the tender. The project development phase has higher risks as not all bids will be successful
Advantages	A tender which approve several projects facilitate grid design and reinforcement.

Table 19. Characteristics of Tenders. Source: Own elaboration.

Support Instrument	***Net Metering***
Description	It is a retail market policy. A consumer generates from renewable sources on-site electricity. When he or she generates power without consumption is exporting electricity to the grid. This exported-electricity is equivalent, on a 1:1 kWh basis, for future consumption of utility's power. Compensation could be made in energy or in money and can be cleared along the time (2 years maximum)
Implementation	High implementation in US (43 states and District of Columbia and Puerto Rico). It's starting to be implemented in some EU countries.
Economic impact	Reduce cost of aggregation electricity. The consumer has certainty of net excess generation and can estimate payments easily.
Investors perception	Generation and use of PV sources with minimal effort. The end-user receives the benefit easily as a reduction in the utility bill.
Regulator perception	The regulator should determine whether the net excess generation supposes a credit for next bill or a payment
Sustainability	The system is sustainable as long as retail tariff is clearly defined
Society perception	Lower average cost
Risks	A tariff based on high demand charge estimations may cause a reduction in installed capacity. A high reduction on retail tariff would imply disincentive on future installation.
Advantages	The system trends to meet on-site generation and consumption. It decreases long run costs of utilities and customers' payment.

Table 20. Characteristics of Net Metering. Source: Own elaboration.

12.1 EVALUATION OF MECHANISMS

Different countries have implemented different mechanism through years. The success of a mechanism depends on the maturity of the technology and conditions of the country. Thus, a mechanism of which success in a country may not cause the desirable achievements in other country.

Factors to be considered for evaluating the mechanism are the following:

- **Efficiency**: this feature evaluates the capacity of increase RES using the lower amount of resources possible and avoiding unexpected consequences. The ideal scenario is developing the renewable energy sector without numerous changes in policies and with lower costs for the Government as possible.

- **Effectiveness**: this criterion analyses the ability of the mechanism for reaching the objective. Technology development should meet the estimations.
- **Certainty for investors**: it analyses the facility of the mechanism to predict the results for investors. Thus, reduce risks for investors.
- **Competitiveness**: this factor indicates the capacity of the mechanism to create a sustainable sector in the long term. Governments should avoid a measure which increase the number of RE projects but reduce the ability of companies for reducing costs.
- **Governance**: it evaluates the feasibility of the mechanism. Hence, it indicates the facility of the mechanism to be implemented and controlled by the Government.
- **Market compatibility**: it indicates the possibility of implement the mechanism without affecting the open-market.

The next table shows a qualitative assessment. This is an approximation of what is expected from a mechanism considering the different factors analyzed. Last column is a performance average of all the factors.

	Efficiency	Effectivenes s	Investment Certainty	Competitivenes s	Governance	Market Compatibility
Mechanism	**Score**	**Score**	**Score**	**Score**	**Score**	**Score**
Feed in tariff	■■■■■	■■■■■	■■■■□	■■■■□	■■■■□	■□□□□
Feed in Premium	■■■■□	■■■■■	■■■□□	■■■□□	■■■■□	■■■■■
Quota obligations	■■■□□	■■■□□	■■□□□	■■■□□	■■■□□	■■■■■
Fiscal incentives	■■■□□	■■■□□	■■■□□	■■■□□	■■■□□	■■■■■
Tenders	■■■■■	■■□□□	■■□□□	■■■■□	■■■□□	■■■□□
Net metering	■■■■■	■■■■■	■■■■□	■■■□□	■■■■□	■■■■□

Table 21. Evaluation of mechanisms, source: ECOFYS, Financing Renewable Energy in the European Energy Market.

As mentioned before the success of a mechanism depends on the degree of technology's maturity. Next table indicates the appropriate phase for each mechanism. Right use of measures during the maturity phase of technology increases the effectiveness of a mechanism.

Further to this, regulators should consider the benefits of implement more than one mechanism as the majority of the countries do. Combination reinforces the objective of RES development. For instance, a quota obligation will increase RES development but if it is accompanied with a Feed in Tariff it increases the incentive to develop a renewable technology pool.

The selection and implementation of above related instruments are generally conditioned by several factors:

Electricity sector relevance. As stronger is the electricity sector in the country, higher certainty will be given to its investments.

Economic situation of the country. Healthier economies afford easily more expensive instruments.

Financial culture, ranging from fully market oriented to subsidies prices and tariffs.

Commitment with environmental policies. To higher level of commitment, instruments guaranteeing faster results will be selected

	Degree of maturity					
Mechanism	**R&D**	**Pre-commercialization**	**Commercialization**	**Start-up**	**Construction**	**O&M**
Feed in Tariff			X			X
Feed in Premium			X			X
Quota obligations			X			X
Fiscal incentives	X	X	X	X	X	
Tenders				X		
Net Metering			X			

Table 22. Adequacy of mechanisms for Technology Degree of maturity or implementation phase. Source: ECOFYS, Financing Renewable Energy in the European Energy Market.

13 ANNEX II: FINANCIAL MECHANISMS

The most relevant financing mechanisms that have been used for solar energy deployment are as follows:

Finance Mechanism	Description	
R&D Grants	R&D grants are provided by states to research organizations in order to fund research programs related to RES technologies when private sector is reluctant to invest because uncertainty. Very useful for technologies early stages, but usually return of investment is not linked to expenses incurred.	E
Capital/Project Grants	Usually provide significant funds from public sector to prove industrial potential of R&D innovations and to operate them in real-market conditions.	E
Contingent Grants	Subsidies from states that are converted into loans when project turns out to be successful and profitable. Sometimes reimbursement can be re-invested in other projects in a revolving approach.	E
Venture Capital	It's a private option for financing technology innovation. Investors obtain equity shares in start-up companies playing a significant role in the management of the company. Venture Capital requires very high return and are usually present in pre-commercialization stages. In some countries, venture capital mechanisms have been developed by government agencies.	E
Private Equity	Funds come from private institutions with medium risk profile for later stage of projects and more mature technologies. Require high return of investment on a short period of time. Usually play a significant role in bridging the gap between research and commercialization.	E
Infrastructure Funds	These funds invest in proven technology with low risk and lower return of investment and medium term.	E
Senior Debt	Provided by banks for financing renewable projects usually during construction phases, adjusting debt interest rates and terms with increasing risks. Cost of lending is calculated based on technology maturity, regulations, experience in the sector, political risks and returns offered.	D

Finance Mechanism	Description	
Asset finance	It's a lending secured on a physical asset. Transactions are lower but margins may be similar. A variant of this is the Vendor Finance, where the vendor or a technology provider financing to the project, typically their own financing arm.	D
Export Credit Agencies	Usually credits and loans or credit insurance and guarantees given to investors not willing to finance project risks but not willing to assume political risks of the country where the project is located. Export Credits Agencies are frequently government-sponsored or with private participation.	D
Bond financing	Green bonds are a "plain vanilla" fixed income product. They are dedicated to climate change and requested by a broad range of investors; provide standard financial features.	D
Debt Finance from Public Sector	Public organizations provide soft loans to projects in partnership with banks. The bank provides the loan and the public entity bear the credit risk. Are usually addressed to SME and small to medium projects.	D
Mezzanine finance	It's a useful product when the bank debt reached is insufficient, is between senior bank debt and equity. It takes more risk than senior debt and usually shorter and with higher return.	D
Guarantees	It's a contractual obligation by which an institution assures compensating payment to a lender or an investor in case of default on an obligation that another party is committed to.	D

E =Equity D = Debt

Table 23. Finance Mechanisms. Source: Own elaboration.

14 ANNEX III: SITE SELECTION

14.1 METEO-STATION SELECTED SITES SUMMARY

Six sites to install the stations are proposed. These places are suggested to install ground measurement stations because they are existing sites of the Uzbek meteorological service, which gives the warranty that the equipment is properly guarded, maintained and operated.

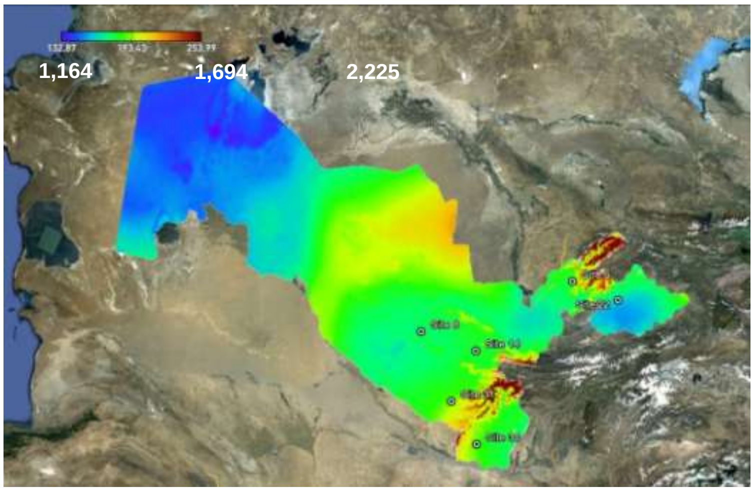


Figure 64. Ground meteo-station locations and (DNI (W/m^2 /year kWh/m^2 year) source: 3Tier).

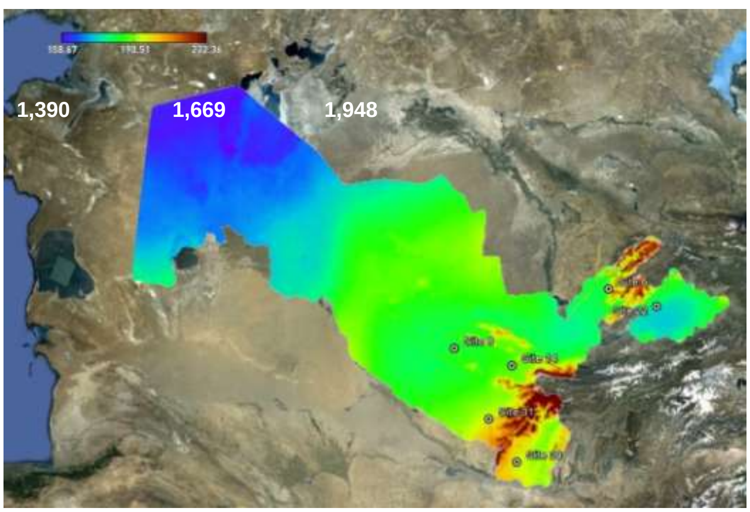


Figure 65. Ground meteo-station locations and (GHI (W/m^2 /year kWh/m^2 year) source: 3Tier).

14.2 SITES FOR METEO-STATION INSTALLATION FINAL SELECTION

14.2.1 Selected sites

The consulting team has visited a total of 36 pre-selected sites and studied their features:

- 18 of them are located near transformer stations
- 5 of them are located on free flat-land areas
- 13 of them are located near existing weather stations. The installation of the measurement equipment near currently operating weather stations has several advantages: the availability of qualified personnel, a good organization of the data collection and transfer system and physical security of the equipment.

Additionally, all sites are located in a range of 5-10 km far from the power grid.

Composite landform and the absence of free area within the locations near transformer substations and power grids have substantially limited the number of acceptable sites of this type. It has been taken into account also that meteorological equipment is not recommended for installation nearby the power grid.

The same limitation was found in mountainous areas, though they are usually characterized by a high solar resource.

On the other hand, some limitations of social concern were brought in by the Government of Uzbekistan. They kindly requested the Working Group not to consider locations on lands used for agricultural purposes or lands which would require resettlement of local residents. Besides, in agreement with Uzbekenergo, the Government also proposed to study the possibility of construction of solar power plant in Fergana Valley as it is the most densely populated region of Uzbekistan with the aim to contribute to solve the power supply deficit.

Particular consideration has been given by the working team to the site ‘Tamdy’, located in the Navoi region as most of parameters are evaluated positively, including a good solar resource, the water scarcity being the only drawback. This could make it suitable for PV or for CSP with dry-cooling technology.

14.2.2 Discarded sites

Some regions such as Surkhandarya, Kashkadarya, Bukhara, Navoi and most regions of Karakalpakstan have higher dustiness in the atmosphere resulting in extinction of solar radiation as well as a higher need for cleaning of mirrors and solar cells surfaces (higher water consumption and maintenance burden). For instance, yearly average number of days with dusty windstorms is 32 in Takhiatash. The duration of such dusty windstorms is of 6-8 hours per day in more than 85% of the cases. From this, it can be concluded that dusty windstorms happen in the above areas every 3-5 days as an average, significantly decreasing the profitability of a solar power plant.

Northern and north-eastern parts of Navoi region which are characterized by high solar irradiation has the following constrains: desert area with frequent dusty windstorms, non-availability of water, no road access, remoteness from populated area and lack of skilled staff.

14.2.3 Six sites suitable for ground meteo-stations

The 36 visited sites were narrowed down to 15 pre-selected sites. A more detailed study of these sites and discussion with stakeholders leaded to 6 sites for ground measurement station located in the following regions of the country:

- Samarkand,
- Navoi,
- Kashkadarya,
- Surkhandarya,
- Namangan and
- Tashkent.

Finally, proposed sites are:

Nº	Province	Name	Coordinates N	Coordinates E
6	Tashkent	Parkent District, 'Solar' Village	N 41º 18’ 57’’	E 69° 44’ 28’’
8	Navoi	Karmana Village, Meteostation	N 40º 08’ 43’’	E 65º 18’ 32’’
14	Samarkand	Samarkand city, Meteostation 1	N 39º 45’ 28’’	E 66º 54’ 54’’
22	Namangan	Pap city, Meteostation.	N 40º 52’ 41’’	E 71º 06’ 43’’

Nº	Province	Name	Coordinates N	Coordinates E
30	Surkhandarya	Sherabad city, Meteostation.	N 37º 39’ 57’’	E 67º 00’ 31’’
31	Kashkadarya	Guzar city, Meteostation.	N 38º 37’ 05’’	E 66º 15’ 17''

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