JOINT IMPLEMENTATION PROJECT DESIGN DOCUMENT FORM
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SECTION A. General description of the project

A.1. Title of the project:

PJSC "Semiconductor plant" reconstruction with expansion of polycrystalline silicon production

Sector:(3) Energy consumption; (5) Chemical industry

Version 2.0

Date: 02 September, 2011

A.2. Description of the project:

The **aim of the project** is to reconstruct polycrystalline silicon and trichlorosilane production with introduction of energy efficiency measures that will allow reducing greenhouse gas emissions into the atmosphere, reducing specific energy losses in trichlorosilane and polycrystalline silicon production, raising competitiveness of the enterprise on the semiconductors market and meeting the demand of the solar energy market.

Situation prior to the project activity

Polycrystalline silicon fabrication was entirely stopped before the project activity. However, infrastructure and equipment necessary for possible production recovery basing on old technologies remained within the area of the plant. The capacity of the plant before its reconstruction was 257 t. of polycrystalline silicon per year and 18800 t of trichlorosilane per year.

Baseline scenario

In case of absence of the project activity, the plant would resume its operation applying previously tested technology with expansion of pure silicon output rate to 3000 t per year in order to eliminate the production deficit in Ukraine resulting from production cessation. Polycrystalline silicon manufacturing in the baseline scenario will be equal to 3000 tons per year. Estimated general amount of pure polycrystalline silicon produced in 2011 will make up 2 833.2 t, in 2012 - 3 000 t. Trichlorosilane will be produced in amount necessary for polycrystalline silicon manufacturing. More details on the validation of the baseline scenario are presented in the section B.

Project scenario

The plant capacity after the reconstruction will be equal to 44000 t of trichlorosilane and 5000 t of polycrystalline silicon per year. The last will be used to meet the demand for solar energy, in particular for converting into single-crystal silicon and creation of solar elements which will be components of solar panels.

It is planned to put into operation 2 complexes with capacity of 2500 t each per year. In order to provide the manufacture with raw material it is planned to build a trichlorosilane production complex with general capacity of 44000 t per year.

Equipment for steam conversion of the hydrocarbons will be installed to produce hydrogen.

Annual polycrystalline silicon production is expected to be 3000 tons. In case estimated production amount is exceeded, possible emission reductions will not be taken into account.

Historical reference

Open JSC «Semiconductor plant» was founded in January 2002 on the base of a semiconductor silicon production – the former part of the municipal company "Zaporizhzhya titanium magnesium complex».

http://siz.zp.ua/index.php?Lev=history&Lang=ua

Development stages of semiconductor silicon production in Zaporizhzhya:

- 1959 – commissioning of the research site for semiconductor silicon production;
- 1964 – commissioning of full-cycle production of semiconductor silicon from the imported raw tetrachlorosilane (silicon tetrachloride);
- 1967 – commissioning of the research-industrial plant for trichlorosilane production, providing polycrystalline silicon production with own raw material.

Since the mid 90 s, with the decay of the USSR, demand for semiconductor silicon in the CIS countries and, in particular, in Ukraine appeared to be very low. Thus in 1998, silicon production at "Zaporizhzhya titanium magnesium complex" was completely suspended.

In 2007 the plant was privatized. Shareholders of the Open JSC «Semiconductor plant» considered a possibility of implementing the "OJSC "Semiconductor plant" reconstruction with expansion of polycrystalline silicon production" project using the Kyoto protocol mechanism before investments in the project take place because without the project being a joint implementation project investing in it would not be economically viable as there would exist a more profitable alternative to reconstruct and expand the production on the base of old technologies. From April 2011, the plant name was changed to Private JSC «Semiconductor plant» in accordance to the Ukrainian law "About Joint Stock Companies".

Production recovery at Private JSC «Semiconductor plant» will provide jobs for over 1000 people.

Project implementation will allow reducing GHG emissions due to application of more effective energy-efficient technologies of hydrogen production and use of closed production cycle including return of used products into the production cycle.

A.3. Project participants:

Parties Involved	Legal entity project participant	Please indicate if the Party involved wishes to be considered a project participant (Yes/No)
Ukraine (Host party)	Private JSC «Semiconductor plant» Environmental (Green) Investments Fund Ltd	No No
Switzerland	Rutek Trading AG	No

Private JSC «Semiconductor plant» was founded in January, 2002, based on semiconductor silicon production – former part of the public utility company "Zaporizhzhya titanium magnesium complex». http://siz.zp.ua/index.php?Lev=history&Lang=ua .

In 2002 "Zaporizhzhya titanium magnesium complex» was re-engineered and silicon production became a separate manufacture. In 2007, the plant was privatized. Next year the plant became property of «Activ Solar». «Activ Solar» is an Austrian group with two central offices. The head office of the group is located in Kyiv.

From December 2008, monocrystalline silicon of solar quality can be manufactured on the base of tolling raw materials.

Environmental (Green) Investments Fund Ltd – is a non-government consulting organization that carries out expert assessment of policies and strategies referring to the adaptation of the climate change consequences for commercial and public organization.

The stuff includes highly qualified professionals with academic degrees in natural science, climatology, economics and mathematics. Consultants provide clients with efficient advice in time using researches data, political publications which is based on a deep understanding of political processes.

Experts of the Fund have great experience in providing a full range of services regarding technically efficient energy supply and climate issues to a wide range of clients. Everyone has more that a ten-year practice in the sphere of energy efficiency and climate change issues. Experts working in the Fund have profound work experience in following branches:

- *Development of national and sectoral GHG emissions and absorption inventories;*
- *Estimation and development of adaptation projects including mitigation of the impact of GHG emissions, including JI projects;*
- *Development of a JI project database;*
- *Preparation of the national communication on climate change in line with UNFCCC requirements;*
- *Preparation of regional and national action plans regarding climate change issues;*
- *Increase of efficient energy consumption and use in the production;*
- *Preparation of the documents necessary for ratification of the UNFCCC and Kyoto Protocol by the government of Ukraine;*
- *Educational services, conferences, seminars, round tables connected to the problem of climate change.*

A.4. Technical description of the project:

A.4.1. Location of the project:

Private JSC «Semiconductor plant» where the project is to be implemented is located in Zaporizhzhya city (see fig. 1 and 2).

A.4.1.1. Host Party(ies):

Ukraine

A.4.1.2. Region/State/Province etc.:

Zaporizhzhya region

A.4.1.3. City/Town/Community etc.:

Zaporizhzhya

A.4.1.4. Physical location details including information providing for unique identification of the project (maximum one page):

The plant is located in the western part of the Zaporizhzhya city at the following geographical coordinates: Latitude: 47°53′, Longitude 35°12′. The geographical coordinates were measured by GPS-navigator at the plant side.

Fig.1. Location of Zaporizhzhya region and Zaporizhzhya city on the map of Ukraine (Source: http://uk.wikipedia.org)

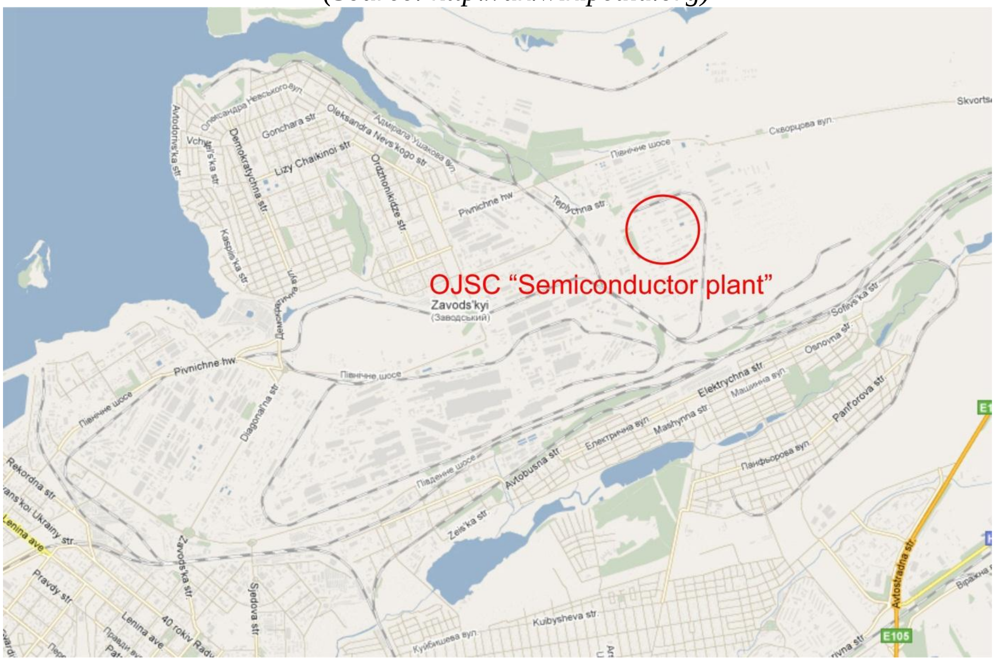

Fig. 2. City of Zaporizhzhya and location of the plant

A.4.2. Technology(ies) to be employed, or measures, operations or actions to be implemented by the project:

Aim of the project:

The technical aim of the project is to reconstruct polycrystalline silicon production in accordance with modern technologies that will not only decrease specific consumption of energy resources (natural gas and electricity), but also decrease emissions of GHGs and harmful substances into the air.

Description of the measures

The project involves reconstruction of the plant including polycrystalline silicon production expansion with the capacity 5000 tons of polycrystalline silicon per year. Two commissioning stages are planned:

- 1-st launching complex - with the capacity of 2500 tons per year;
- 2-nd launching complex - with the capacity of 2500 tons per year.

To provide the production with raw materials it is planned to build a trichlorosilane production complex with general capacity of 44000 tons per year.

In general following complexes are included in the joint implement project:

1. trichlorosilane production complexes (44000 t per year)
2. polycrystalline silicon production complexes (5000 t per year)
3. installation of equipment for steam reforming

Manufacture of polycrystalline silicon is a multistage process consisting of separate cycles, composition and capacity of which depend on quality of final products.
Major elements are:

- Production of trichlorosilane (crushing and grinding of technical silicon, synthesis of hydrogen chloride, partition and purification of silicon chlorides);
- Production of polycrystalline silicon by trichlorosilane hydrogen recovery;
- Condensation of chlorosilanes of polycrystalline silicon production with trichlorosilane, tetrachloride of silicon, hydrogen and hydrogen chloride release;
- Disposal of production wastes;
- Quality control and measurement system for primary, intermediate and final products.

Cycles and measures for trichlorosilane polycrystalline silicon manufacture

The major installation where the main equipment for trichlorosilane synthesis and rectification is placed, power unit with management premises, the department for preparation of raw materials, gas cleaning, power objects for electricity supply, compressed air, cold, nitrogen in gaseous and liquid form, chlorine and hydrogen supply sources.

The management of premises is conducted remotely.

Crystalline silicon of steel quality, chlorine and hydrogen are primary raw materials for trichlorosilane production.

Technical crystalline silicon is crushed and ground to acquire fraction composition necessary for trichlorosilane synthesis with the help of hydrochlorination in the reactors of boiling layer.

Hydrogen is produced by the electrolysis of water. New equipment for hydrogen generation uses natural gas steam reforming.

The synthesis of hydrogen chloride occurs as a result of hydrogen incineration in chlorine.

The synthesis of hydrogen chloride is conducted in a steel apparatus. Its construction allows creating a stream of hot hydrogen chloride which provides for high capacity despite the relatively small sizes of the machine. The apparatus is equipped with a system checking for flare presence and an automatic cut-off sensor stopping supply of the reagents in case of flare fading.

The synthesis of trichlorosilane is conducted by the method of technical silicon hydrochlorination in the reactor of boiling layer in line with the following reaction:

$Si + 3HCl \rightarrow SiHCl_3 + H_2$

Along with the major reaction several side reactions of dichlorosilane and silicon tetrachloride formation take place:

$Si + 2HCl \rightarrow SiH_2Cl_2$

$Si + 4HCl \rightarrow SiCl_4 + 2H_2$

Technical silicon is being continuously supplied to the reactor.

Cleaning of vapour mixture from solid suspensions (silicon dust, solid metal chlorides, polysilane chlorides) is conducted by means of cyclones, wet filters which provide for capture of solids with simultaneous cleaning in soluble high boiling mixed compounds.

Silane chlorides, after cleaning from solids, are condensed by means of the system of heat exchangers which work at low temperatures. Composition of silane chlorides in hydrogen output does not exceed 0.1% (of volume).

Partition of silane chlorides, after condensation and cleaning, is conducted by means of rectification. Before rectification special chemical treatment of silane chlorides is conducted to transform impurities into stable compounds with the high separation factor against trichlorosilane.

Emissions from hydrogen chloride synthesis, chlorine silanes synthesis and rectification are supplied to a scrubber with alkaline solution for neutralization.

Polycrystalline silicon rods are produced in the reactor preliminary equipped with initial substrate-rods. Substrate-rods are preheated with a special starting device. Trichlorosilane mixed with hydrogen is transported to the reactor. Substrate-rods are heated by means of transmitting current through them.

During silicon recovery from trichlorosilane and deposition onto rods, the following major reactions take place:

$SiHCl_3 + H_2 \rightarrow Si + 3HCl$

$4SiHCl_3 \rightarrow Si + 3SiCl_4 + 2H_2$

The vapour mixture from the reactor is supplied to the condensation block where chlorosilanes are transferred into a liquid form.

Installation is based on a method of multistage fractional condensation of chlorosilanes at low temperatures and hydrogen chloride freezing. The installation consists of a network of consistently located heat exchangers in which vapour mixture is pre-cooled from +30°C to -80°C.

The process of silicon tetrachloride hydrogenation takes place in special machines at temperature 1250°C and pressure up to 0.6 MPa in accordance with the basic reaction:

$SiCl_4 + H_2 \rightarrow SiHCl_3 + HCl$

The vapour mixture received after hydrogenation is transported for the redistribution of chlorine silanes condensation.
All equipment for hydrogen renewal, chlorine silanes condensation for hydrogen and chlorous hydrogen excretion, as well as for silicon tetrachloride hydrogenation is compiled in separate independent modules. The minimum equipment module manufactures 2500 t of polycrystalline silicon per year. The module includes 18 hydrogen recovery installations, 10 converters of silicon tetrachloride, 1 regeneration system for hydrogen extraction and its return for hydrogen recovery and hydrogenation, as well as chlorous hydrogen used in trichlorosilane production.
Disposal of gas emissions, waste residue and drains is based on neutralization of chlorides in a limestone solution.

The flow-chart of the proposed complex of polycrystalline silicon production is presented in figure 3.

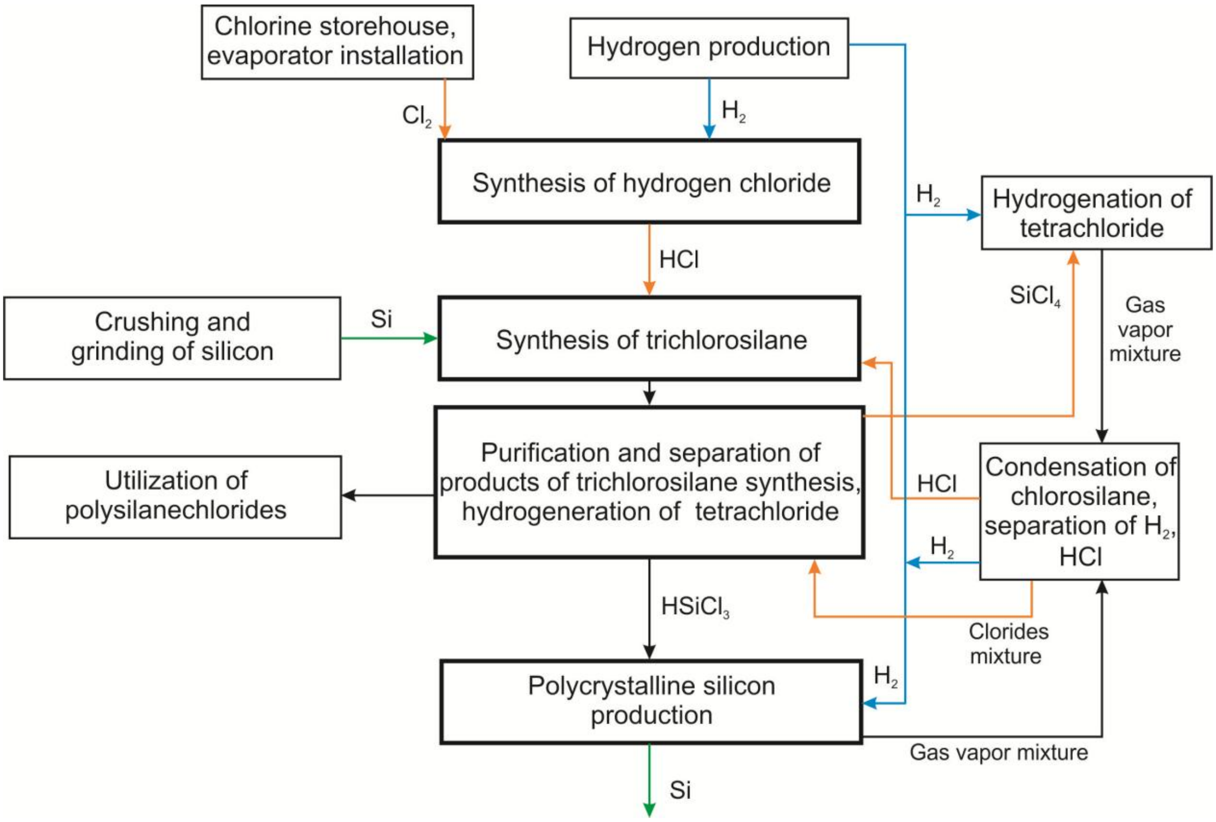

Fig. 3. Flow-chart of polycrystalline silicon production

"Polycrystal 18-03" developed by the State research and project institute of liquid-metal industry "Giridmet" (Moscow) remains the most up-to-date polycrystalline silicon production facility presently used by companies of CIS countries, including Ukraine.

Polycrystalline silicon production involving use of "Centrotherm of photovoltaics AG" installation is based on a "Siemens"-technology - deposition of silicon atoms from gas on substrate-rods. Equipment providing continuous production process consists of three basic systems, namely: "Siemens"-system for deposition of polycrystalline silicon, system for conversion of silicon tetrachloride into trichlorosilane and system for gas mixture division, as well as a number of auxiliary units and equipment which enable operation of the whole complex. Trichlorosilane is the basic raw material for polycrystalline silicon production. The system of conversion of silicon tetrachloride into trichlorosilane allows receiving trichlorosilane from the accompanying product – silicon tetrachloride. Received trichlorosilane goes back for deposition of polycrystalline silicon for further use in the technological cycle. Thus a closed technological cycle and practically non-waste production of polycrystalline silicon are provided.

Planned measures

An investment stage begun in 2009 and must be finished till the middle of 2012. Additional income from ERUs selling is taken into account by project owners before investing begins. An approximate plan of works is presented in table 1

Table 1. Schedule of measures to be carried out within the JI project.

No.	***Measure***	***Beginning of the project design work***	***Beginning of the construction***	***Putting into operation***
1	Trichlorosilane production line	June 2008	August 2010	April 2011
2	Polycrystalline silicon production line	April 2008	August 2010	April 2011
3	Hydrogen production installation (Steam reformer)	October 2009	September 2011	December 2011

No changes to the reconstruction project are foreseen throughout the whole project lifetime.

A.4.3. Brief explanation of how the anthropogenic emissions of greenhouse gases by sources are to be reduced by the proposed JI project, including why the emission reductions would not occur in the absence of the proposed project, taking into account national and/or sectoral policies and circumstances:

Implementation of the project will provide reduction of GHG emissions due to reduction of natural gas consumption and will reduce GHG emissions from electricity generation in electricity grid of Ukraine.

There are no national legislation acts that can make shareholders of the private JSC «Semiconductor plant» invest into the project.

Existing technology is not sufficient yet. Particularly, the production cycle does not provide closed cycles (return of the waste materials, its purification and re-use.) That is why the old technology requires using more raw materials and spending more energy for its production. The proposed technology has equipment for hydrogenation of silicon tetrachloride and separation of the hydrogen and chlorine hydride from vapour-gas mixture that allows returning them into the main technological cycle and wastes spends for its production from the raw materials. The existing equipment for silicon production has low deposition rate that requires additional energy consumption. The new equipment will have much faster silicon separation from trichlorosilane that will allow reducing power consumption per 1 ton of polycrystalline silicon. This technology of the hydrogen production involves water electrolysis. This technology of the hydrogen production requires significant electricity consumption. Steam conversion method of light hydrocarbons is suggested for hydrogen production.

Additional income from usage of the joint implementation mechanism will increase the inner rate of return (IRR) and decrease the pay-back period. This will provide for the project reaching the level equivalent to the level of the old equipment with expansion of the production. That is why this project will not be economically viable and cannot be carried out without implementation of the JI mechanism.

The total volume of emissions reduction is expected to be 24 147 234 tCO_{2e} including 1 679 508 tCO_{2e} during the first commitment period under the Kyoto Protocol.

A.4.3.1. Estimated amount of emission reductions over the crediting period:

Emission reductions during the first agreements under the Kyoto Protocol

	Years
Duration of crediting period	2
Year	Estimation of annual emission reductions in tons of CO_2 equivalent
2011	431 301
2012	1 248 207
Total estimated amount of emission reductions over the crediting period, (tons of CO2-equivalent)	1 679 508
Annual average emission reductions over the crediting period, (tons of CO_2 equivalent)	839 754

Emission reductions after 2012

	Years
Duration of crediting period	18
Year	Estimation of annual emission reductions in tons of CO_2 equivalent
2013	1 248 207
2014	1 248 207
2015	1 248 207
2016	1 248 207
2017	1 248 207
2018	1 248 207
2019	1 248 207
2020	1 248 207
2021	1 248 207
2022	1 248 207
2023	1 248 207
2024	1 248 207
2025	1 248 207
2026	1 248 207
2027	1 248 207
2028	1 248 207
2029	1 248 207
2030	1 248 207
Total estimated amount of emission reductions over the crediting period, (tons of CO2-equivalent)	22 467 726
Annual average emission reductions over the crediting period, (tons of CO_2 equivalent)	1 248 207

A.5. Project approval by the Parties involved:

The project has been officially presented for endorsement to the Ukrainian authorities. The project has received a Letter of Endorsement № 1193/23/7 dated 16.05.2011.

Upon completing of the determination procedure, the PDD and the Determination report will be submitted to the National Environmental Investments Agency of Ukraine for receiving a Letter of Approval. The acceptance of the project by the host and investor party is expected.

SECTION B. Baseline

B.1. Description and justification of the baseline chosen:

Step 1. Definition and description of the baseline approach

Presently there is no approved Clean Development Mechanism methodology that can be used for choosing a baseline scenario and calculating baseline and project emissions. Further there is a specific JI approach that was developed directly for the project "Private JSC "Semiconductor plant" reconstruction with expansion of polycrystalline silicon production" according to the guidelines shown in the Decision of the Conference of the Parties of the Kyoto Protocol.[1].

The proposed JI specific approach includes the use of the following tool:

- *"Combined tool for baseline identification and additionality demonstration"* Version 03.0.1[2].

Step 2. Use of the chosen approach

Determination procedure of the applicable baseline and additionality assessment

The methodological tool is used to choose the most plausible baseline scenario and to prove the additionality. "*Combined tool for baseline identification and additionality demonstration" Version 03.0.1.* Description and application of the mentioned tool for the project is shown in Section B2.

Project boundaries

Project boundaries have to involve the GHG emission sources that are under control of the project participants and deal with proposed project activity.

Boundaries include trichlorosilane and polycrystalline silicon production lines and equipment for hydrogen production and boiler-house that provides for vapour production. All of these objects are located within the area of the plant. The detailed description of the project boundaries is shown in Section B.4.

Baseline

The baseline scenario includes production recovery using existing (old) technology with the expansion of the polycrystalline silicon production to 3000 t of polycrystalline silicon per year and expansion of the capacities of trichlorosilane production to 52560 t per year. The existing water electrolysis equipment will be used for hydrogen production. The capacity of the plant before its reconstruction was 257 t of polycrystalline silicon per year and 18800 t of trichlorosilane per year. The capacity of 52560 t per year of trichlorosilane allows the old technology to produce amount of polycrystalline silicon equal to the 3000 t. In addition to these products at the semiconductor plant the old technological scheme are foreseen oxygen and silicon tetrachloride production. Oxygen was produced as a byproduct of the water electrolysis. Silicon tetrachloride is a byproduct of polycrystalline production.

While calculating baseline emissions CO_2 emissions appearing from trichlorosilane, polycrystalline silicon and hydrogen production - particularly during combustion of the natural gas in the boiler-house to meet the demand for vapour - are taken into account. Other gases emissions, in particular, methane and nitrous oxide are not considered. In accordance with the Order #75[3] of the National Environmental Investment Agency of Ukraine from May 12, 2011 concerning approval of specific factors of carbon

[1] Decision 9/CMP.1, Appendix B

[2] http://cdm.unfccc.int/methodologies/PAmethodologies/tools/am-tool-02-v3.0.1.pdf

[3] http://www.neia.gov.ua/nature/doccatalog/document?id=127498

dioxide emissions for 2011, the national grid emission factor is used to calculate emissions reduction due to decrease of electricity consumption. Carbon Emission Factor used to calculate emissions for baseline and project scenario is equal to 1.090 t CO_2/MWh and was used the same for ex-ante estimation.

Specific JI approach uses data on energy consumption per one production unit in line with regulations presented by Semiconductor plant[4]. Energy consumption is calculated separately for hydrogen, trichlorosilane and polycrystalline silicon production. The end product is polycrystalline silicon. Its manufacture amount is determined by actual data of production operation. The necessary amount of hydrogen is determined in accordance with the regulations to provide for actual production of polycrystalline silicon. The baseline foresees oxygen and silicon tetrachloride production which are auxiliary products when using the old technology. This approach does not take into account consumption of the natural gas for heating. It is assumed that heating needs are equal for the baseline and project scenarios.

Baseline emissions

The baseline emissions consist of emissions from electricity consumption and from thermal energy consumption (steam) that is used for hydrogen, trichlorosilane and polycrystalline silicon production. The emissions from electricity consumption occur as a result of due to use of fossil fuels in the united energy system of Ukraine. Emissions from thermal energy consumption occur due to natural gas combustion in a boiler-house.

Project scenario

If the proposed joint implementation project is implemented, «Semiconductor plant» will generate 3 000 tons of polycrystalline silicon per year. Modern equipment of the «Centrotherm photovoltaics AG» company will be installed and will provide for essential energy saving during production of the above mentioned products, since the new technological cycle includes equipment for hydrogenation of silicon tetrachloride; equipment for chlorosilane condensation, separation of the hydrogen, hydrogen chloride from waste gases with its further return to the technical cycle. Initial production of the hydrogen by water electrolysis will be replaced with steam performing.

The GHG emissions under the project scenario include:

1) CO_2 emissions from natural gas combustion for technological process needs in existing boiler-house;
2) CO_2 emissions from electricity consumption for purified trichlorosilane and polycrystalline silicon production
3) CO_2 emissions from hydrocarbon conversion
4) Emissions from neutralization of waste gases by sodium carbonate (soda ash)

Leakages

Working the previous technology the plant can manufacture additional products like oxygen and silicon tetrachloride. The Semiconductor plant reconstruction is aimed at making these products beyond the project boundary. Production of these products requires fossil fuels and electric power consumption that leads to increased GHG emissions into the atmosphere. So manufacture of oxygen and silicon tetrachloride is considered as leakages.

[4] Actual norms of consumption during the polycrystalline silicon production are set by technical specification 48-4-180-77

GHG emissions related to fugitive methane emission from natural gas production and distribution as well as sodium carbonate production will have positive effect or cannot be estimated so these emissions are excluded from further consideration.

GHG emissions connected with construction works and production reconstruction (emissions from transportation of equipment and materials, and energy resources consumption during construction and mounting works) are not taken into account.

Key parameters that are determined once and are not subject to monitoring.

Data / Parameter:	SEC_{PCS}
Data unit:	MWh/t
Description:	Actual electricity consumption for trichlorosilane production by existing equipment.
Determination/monitoring frequency	Once
Source of data	Private JSC Semiconductor plant
Value of data applied (for ex ante calculations/determinations)	314.4
Justification of the choice of data or description of measurement methods and procedures (to be) applied	Technical specification 48-4-180-77
QA/QC procedures (to be) applied	-
Comments:	

Data / Parameter:	SEC_{TCS}
Data unit:	MWh/t
Description:	Actual electricity consumption for polycrystalline silicon production by existing equipment.
Determination/monitoring frequency	Once
Source of data	Private JSC Semiconductor plant
Value of data applied (for ex ante calculations/determinations)	2.445
Justification of the choice of data or description of measurement methods and procedures (to be) applied	Technical specification 48-4-180-77
QA/QC procedures (to be) applied	-
Comments:	

Data / Parameter:	SMC_{TCS}
Data unit:	t/t
Description:	Actual trichlorosilane consumption per ton of polycrystalline silicon to fulfil existing production.
Determination/monitoring frequency	Once
Source of data	Private JSC Semiconductor plant

Value of data applied (for ex ante calculations/determinations)	17.52
Justification of the choice of data or description of measurement methods and procedures (to be) applied	Technical specification 48-4-180-77
QA/QC procedures (to be) applied	-
Comments:	

Data / Parameter:	SEC_{H2}
Data unit:	kWh/m^3
Description:	Actual electricity consumption for hydrogen production by existing equipment.
Determination/monitoring frequency	Once
Source of data	Private JSC Semiconductor plant
Value of data applied (for ex ante calculations/determinations)	6.441
Justification of the choice of data or description of measurement methods and procedures (to be) applied	Technical specification 48-4-180-77
QA/QC procedures (to be) applied	-
Comments:	

Data / Parameter:	$SMC_{H2,TCS}$
Data unit:	m^3/t
Description:	Actual hydrogen consumption per ton of trichlorosilane to fulfil existing production.
Determination/monitoring frequency	Once
Source of data	Private JSC Semiconductor plant
Value of data applied (for ex ante calculations/determinations)	350
Justification of the choice of data or description of measurement methods and procedures (to be) applied	Technical specification 48-4-180-77
QA/QC procedures (to be) applied	-
Comments:	

Data / Parameter:	$SMC_{H2,PCS}$
Data unit:	m^3/t
Description:	Actual hydrogen consumption per ton of polycrystalline silicon to fulfil existing production.
Determination/monitoring frequency	Once

Source of data	Private JSC Semiconductor plant
Value of data applied (for ex ante calculations/determinations)	23 360
Justification of the choice of data or description of measurement methods and procedures (to be) applied	Technical specification 48-4-180-77
QA/QC procedures (to be) applied	-
Comments:	

Data / Parameter:	SSC_{PCS}
Data unit:	GJ/t
Description:	Actual vapour consumption per ton of polycrystalline silicon to fulfil existing production.
Determination/monitoring frequency	Once
Source of data	Private JSC Semiconductor plant
Value of data applied (for ex ante calculations/determinations)	992.27
Justification of the choice of data or description of measurement methods and procedures (to be) applied	Technical specification 48-4-180-77
QA/QC procedures (to be) applied	-
Comments:	

Data / Parameter:	SSC_{TCS}
Data unit:	GJ/t
Description:	Actual steam consumption per ton of trichlorosilane to fulfil existing production.
Determination/monitoring frequency	Once
Source of data	Private JSC Semiconductor plant
Value of data applied (for ex ante calculations/determinations)	12.037
Justification of the choice of data or description of measurement methods and procedures (to be) applied	Technical specification 48-4-180-77
QA/QC procedures (to be) applied	-
Comments:	

Data / Parameter:	SPC_{O2}
Data unit:	kW/m^3
Description:	Specific power consumption for oxygen production
Determination/monitoring	Once

frequency	
Source of data	Estimation from available sources
Value of data applied (for ex ante calculations/determinations)	0.75
Justification of the choice of data or description of measurement methods and procedures (to be) applied	Oxygen is produced primary on air separation plants. Detailed research on specific power consumption for oxygen generation was not done in Ukraine. Electricity consumption data for oxygen generation of medium pressure are available from plants producers [5] or [6]. Based on conservative assumption the top value of specific power consumption is taken from http://www.nbuv.gov.ua/portal/natural/TG/2010_2/2010_2_31-38.pdf
QA/QC procedures (to be) applied	-
Comments:	

Data / Parameter:	$SEC_{TS,y}$
Data unit:	t/t
Description:	Specific silicon tetrachloride production per ton of polycrystalline silicon
Determination/monitoring frequency	Once
Source of data	Estimation from available sources
Value of data applied (for ex ante calculations/determinations)	15
Justification of the choice of data or description of measurement methods and procedures (to be) applied	Specific silicon tetrachloride production value per ton of polycrystalline silicon for traditional technology is taken from overview [7]
QA/QC procedures (to be) applied	
Comments:	

Data / Parameter:	ρ_{H2}
Data unit:	kg/m^3
Description:	Hydrogen density
Determination/monitoring frequency	Constant value for normal condition
Source of data	Reference information
Value of data applied (for ex ante calculations/determinations)	0.09
Justification of the choice of data or description of	GOST 3022-80 Technical hydrogen

[5] http://www.universalboschi.com/medium-capacity-plants.pdf

[6] http://www.nbuv.gov.ua/portal/natural/TG/2010_2/2010_2_31-38.pdf

[7] http://www.nbuv.gov.ua/portal/natural/newtech/2010_1/articles/1-9.pdf

measurement methods and procedures (to be) applied	
QA/QC procedures (to be) applied	-
Comments:	

Data / Parameter:	ρ_{O2}
Data unit:	kg/m^3
Description:	Oxygen density
Determination/monitoring frequency	Constant value for normal condition
Source of data	Reference information
Value of data applied (for ex ante calculations/determinations)	1.42897
Justification of the choice of data or description of measurement methods and procedures (to be) applied	GOST 30319.1-96 Natural gas. Methods of physical property calculation.
QA/QC procedures (to be) applied	-
Comments:	

Data / Parameter:	M_{H2}
Data unit:	g/mol
Description:	Hydrogen molar weight
Determination/monitoring frequency	Constant value
Source of data	Reference information
Value of data applied (for ex ante calculations/determinations)	2.0159
Justification of the choice of data or description of measurement methods and procedures (to be) applied	GOST 3022-80 Technical hydrogen
QA/QC procedures (to be) applied	-
Comments:	

Data / Parameter:	M_{O2}
Data unit:	g/mol
Description:	Oxygen molar weight
Determination/monitoring frequency	Constant value
Source of data	Reference information
Value of data applied (for ex	31.9988

ante calculations/determinations)	
Justification of the choice of data or description of measurement methods and procedures (to be) applied	GOST 5583-78 Technical and medical gaseous oxygen
QA/QC procedures (to be) applied	-
Comments:	

Parameters that are subject to monitoring are shown in tables D.1.1.1. and D.1.1.3 Section D. A summary of key parameters is shown in Annex 2.

B.2. Description of how the anthropogenic emissions of greenhouse gases by sources are reduced below those that would have occurred in the absence of the JI project:

Step 1. Definition and description of the approach used.

Combined tool for baseline identification and additionality demonstration", Version 03.0.1. is used for baseline definition and additionality analysis[8].

This methodology has the following conditions regarding its possible application:

- *Use of tool is only possible when all potential alternatives of the proposed project are available for project participants*

The proposed project complies with the indicated condition because all the below mentioned alternatives are available to the project owner.

The methodology includes four following steps:

Step 1. Identification of alternatives to the project activity;

Step 2. Barrier analysis;

Step 3. Investment analysis

Step 4. Common practice analysis

Step 2. Application of the chosen approach

Step1. Identification of alternatives to the project activity;

Definition of all possible alternatives that can be approved as a baseline scenario.

Step1a. Definition of alternative scenarios to the proposed JI project activity.

All realistic alternatives similar to the proposed project activity in terms of Joint Implementation can be alternative variants.

These alternatives have to include:

- Proposed project activity without applying the JI mechanism
- All the other possible and true to life scenarios along with common practice in appropriate sector with similar production capacities

[8] http://cdm.unfccc.int/methodologies/PAmethodologies/tools/am-tool-02-v2.2.pdf

- The alternatives have to continue existing practice if possible.

There are three alternative scenarios to the baseline scenario that were considered before implementation of the project; they are:

A.1	Carrying out polycrystalline silicon production reconstruction inclusively expansion at Semiconductor plant without applying the JI mechanism (without selling of the emission reduction units).
A.2	Polycrystalline silicon production reconstruction, including expansion on base of the existing technology scheme.
A.3	Polycrystalline silicon production reconstruction without expansion of capacities.

Prolongation of existing practice is impossible because starting from 2007 the plant has not produced anything. Hence the purchase of the plant in 2007 without carrying out reconstruction and/or renewal of polycrystalline silicon production could mean waste of money.

Step 1b. Compliance with existing laws and regulations.

All the proposed alternatives do not contradict existing laws. Ukrainian legislation does not oblige to use any of proposed alternatives.

Step 2. Barrier analysis

Step 2a. Identifying barriers that could prevent the implementation of alternative scenarios

Technological barrier

Risk of production cessation due to launching of new equipment. «Centrotherm photovoltaics AG» equipment is new to personnel of the plant, that is why the project has certain risks regarding utilization of the new equipment that can lead to unforeseen breaks in the production. “Centrotherm” supplies turn-key equipment with stable operation of the whole cycle and only after this the equipment is receives by the owner.

Market barriers

1) Risk regarding price changes for polycrystalline silicon.
Due to world financial crisis polycrystalline silicon prices decreased by 4-5 times during 2008[9]. Further saturation of the market with polycrystalline silicon can influence further dropping of prices.

2) Dependence of the solar energy on the state support.
Polycrystalline silicon is used for photovoltaic power generation. Therefore the solar energy market demand has direct influence on polycrystalline silicon price.

Today production of the solar energy has state support in many countries including Ukraine. This was achieved through “Green tariff” for producers of the energy from solar radiation. However only several countries have the biggest market shares (USA, Germany). That is why essential changes in energy consumption of these countries will lead to essential changes on the polycrystalline silicon market.

Technological boundary influences only Alternative A1 foreseeing usage of the new equipment. Market boundaries influence all 3 alternatives. That is why we will move to the investment analysis.

Step 3. Investment analysis

The described alternatives are to be considered in order to chose the most financially viable one.

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[9] http://www.greenrhinoenergy.com/solar/industry/ind_01_silicon.php

Alternative A1. Carrying out polycrystalline silicon production reconstruction including expansion at Semiconductor plant without applying the JI mechanism

Alternative A2. Polycrystalline silicon production reconstruction inclusively expansion on base of the existing technology

Alternative A3. Polycrystalline silicon production reconstruction without expansion of industrial capacities.

Calculation results for economic indicators of alternatives A1, A2 and A3 are presented in table 2.

Table 2. Economical indicators of the alternatives

Alternative	A1	A2	A3
NPV	13 781.58	3 143.81	-380.12
IRR	20.48%	24.87%	-10.69%
Payback period	7.3 years	5.6years	

Figures 4, 5 present sensitivity analysis for alternatives A1 and A2 respectively. Price of the energy resources was changed in a range of +-10%, in particular the prices for electricity and natural gas, the polycrystalline silicon price and the price of project investments.

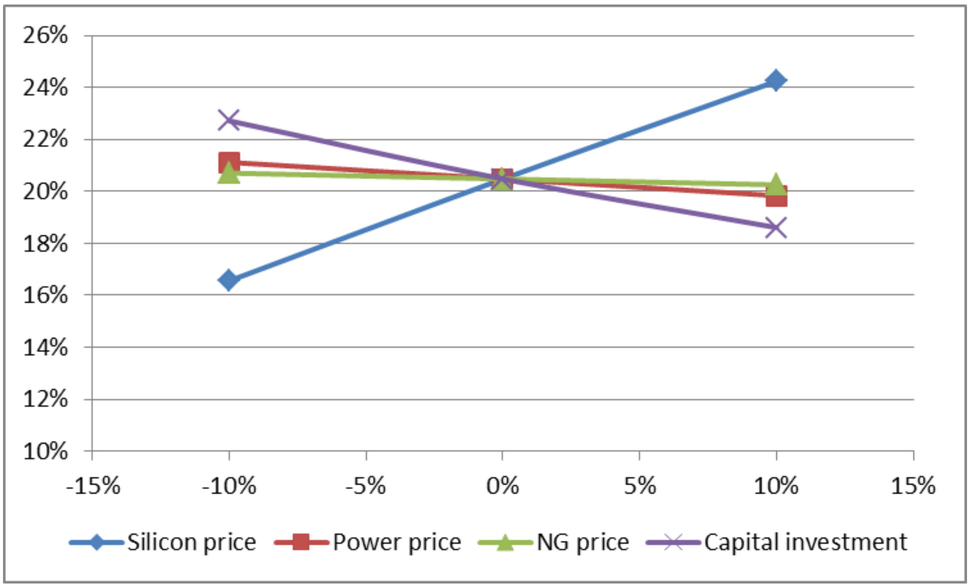

Figure 4. Sensitivity analysis for alternative A1

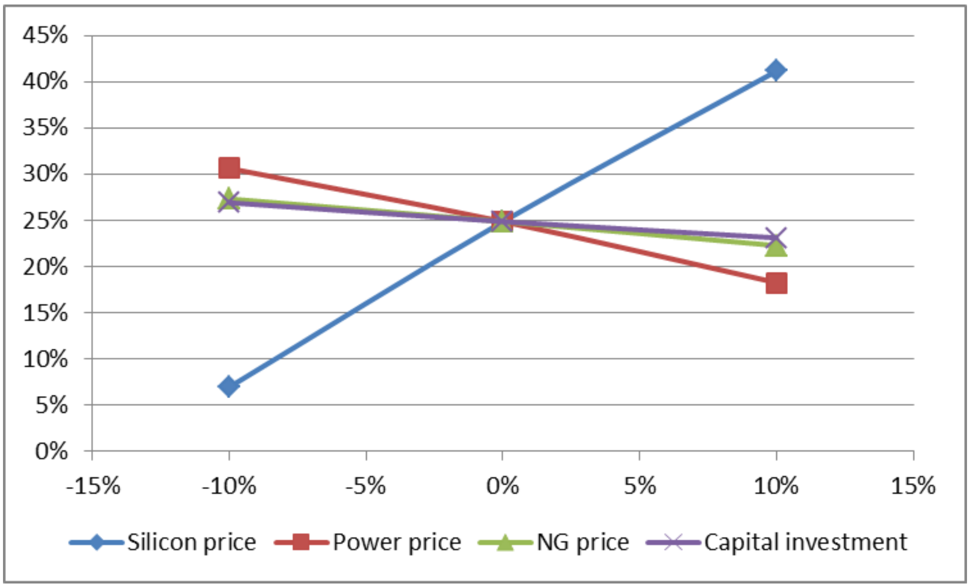

Figure 5. Sensitivity analysis for alternative A2

It is obvious from table 6 that alternative A2 is the most financially profitable. This alternative has the shortest payback period, biggest inner rate of return, but a little smaller net present value. The proposed sensitivity analysis does not contradict with set conclusions. As Alternative A1 also requires more investments and is subject to impact of the technologic barrier, it cannot be considered as a baseline scenario. Alternative 3 as seen from the table 4 also cannot be regarded as a baseline scenario because it is financially unprofitable. As the result, there is only Alternative A2 left.

Profit from ERUs selling will improve economic performance of the project and decrease its dependence on the price fluctuation.

Step 4. Common practice analysis

This project is unique for Ukraine. All the enterprises that existed in Ukraine produced polycrystalline silicon according to the technology similar to the one used at the plant.

B.3. Description of how the definition of the project boundary is applied to the project:

Project boundaries

Boundaries of the proposed JI project include polycrystalline silicon plant (all its main and auxiliary complexes that directly provide for production of polycrystalline silicon, trichlorosilane and hydrogen). Expanded boundaries of the project also include united energy system (UES) of Ukraine (fig. 6). The emissions from natural gas combustion in boiler-house are included in the project boundary only as part for technical steam production. The emissions from natural gas combustion for heating needs are the same for project and baseline scenarios. Monocrystalline silicon production is not included into the project boundary.

To specify project boundaries direct CO_2 emissions from natural gas consumption for steam and hydrogen production in equipment for steam reforming, emissions from combustion of fossil fuel at power stations of Ukraine for electricity generation and emissions from neutralization of steam-vapour mixtures were taken into account.

Other GHGs that appear during the combustion of fossil fuel, in particular nitrous oxide and methane, are not taken into account.

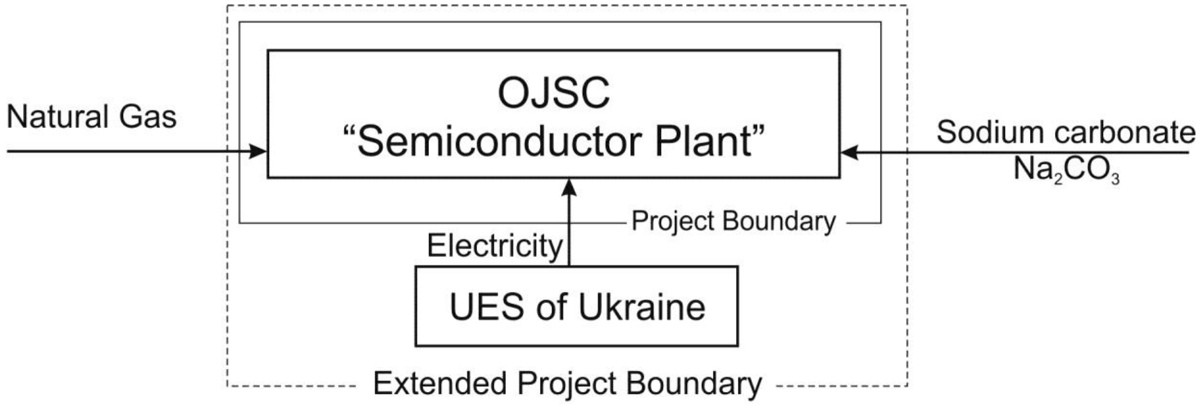

Fig. 6 Project boundary

The GHG emissions that are under the control of the project participants, reasonably attributable to the project, significantly include:

1) CO_2 emissions from natural gas combustion for technological process needs in existing boiler-house;
2) CO_2 emissions from hydrocarbon conversion
3) Emissions from neutralization of waste gases by sodium carbonate (soda ash)

The GHG emissions that are not under the control of the project participants, reasonably attributable to the project, significantly include:

1) CO_2 emissions from electricity consumption for purified trichlorosilane and polycrystalline silicon production

Other GHG emissions such as emissions from use of fossil fuel for electricity and heat generation for oxygen and silicon tetrachloride production, fugitive methane emissions from natural gas production and distribution as well as sodium carbonate production are not under the control of the project participants and not included into the project boundary. List of sources and GHGs that are included into the project boundaries is shown in the table 3.

Table 3. Emissions sources and GHGs that are included or excluded from project boundaries.

	Source	**Gas**	**Included?**	**Justification / Explanation**
Baseline scenario	Emissions from natural gas combustion in boiler-house for production needs.	CO_2	Yes	CO_2 is main source of the NG
		CH_4	No	Non-essential source, this is a conservative simplification
		N_2O	No	Non-essential source, this is a conservative simplification
	Emissions from use of fossil fuels for electricity generation.	CO_2	Yes	CO_2 is main source of the NG

Project activity	Emissions from natural gas combustion in boiler-house for production needs.	CO_2	Yes	CO_2 is main source of the NG
		CH_4	No	Non-essential source
		N_2O	No	Non-essential source
	Emissions from use of fossil fuel for electricity generation.	CO_2	Yes	CO_2 is main source of the NG
	Emissions from the use of soda solution for waste gases purification.	CO_2	Yes	CO_2 is main source of the NG
		CH_4	No	Non-essential source
		N_2O	No	Non-essential source
	Emissions from natural gas using for steam conversion of light carbohydrate.	CO_2	Yes	CO_2 is main source of the NG
		CH_4	No	Non-essential source
		N_2O	No	Non-essential source

B.4. Further baseline information, including the date of baseline setting and the name(s) of the person(s)/entity(ies) setting the baseline:

End date for baseline level research - 11/01/2011.

Baseline level research was made by Environmental (Green) Investments Fund Ltd (project participant)**.**

Contact information:

Address: Sofii Perovskoi 10б, Kyiv 03057, Ukraine
Contact person: Tadlya Kostyantyn
Telephone: +380 44 456 20 31
Telephone/fax: +380 44 456 19 87
E-mail: konstat@ukr.net

SECTION C. Duration of the project / crediting period

C.1. Start date of the project:

07/04/09 (Signing the permission of preparing building works)

C.2. Expected operational lifetime of the project:

Operational resource of the project will be 30 years (360 months)

C.3. Duration of the crediting period:

The overall crediting period will be 19 years and 9 months (237 months).

The beginning of the crediting period is 05/04/2011.

The end date is 31/12/2030.

The beginning of the crediting period according to the agreements under the Kyoto Protocol is 05/04/2011.

The crediting period after the end of the first commitment period of the Kyoto Protocol is 18 years (216 months)

The status of the emission reductions made by project in post Kyoto period will be determined by respective decision of the UNFCCC parties.

SECTION D. Monitoring plan

D.1. Description of monitoring plan chosen:

The monitoring plan is developed on the basis of a specific JI approach in accordance with "Guidance on criteria for baseline setting and monitoring" (version 02).

The main indicator reflecting whether CO_2 emissions reductions were achieved is the decrease of electricity and natural gas specific consumption per ton of polycrystalline silicon. Collected monitoring data shall be archived in electronic and/or paper format during the crediting period plus two years after last ERUs transmission. The measurements are to be done with the help of calibrated measuring equipment in accordance with relevant industrial standards.

The four sources of greenhouse gases is presented at the plant. The measuring equipment is used to determine the emissions from these sources. Just mass of soda ash is determined in accordance with the accounting records. The most values can be cross-check or even have dual measurements, it allows in case of unavailable of data to determine the unknown value based on the balance or alternative measurement equipment.
Natural gas consumption is measured at the entrance to the plant. The technical flow meters can be used to control the consumption in the boiler house and at the shop of hydrogen production. The gas volume registration is held by meters that are calibrated and checked by the natural gas supplier. Certificates of NCV of the natural gas supplier are issued monthly.
The total electricity consumption is being recorded by electric meters belonging to the electricity supplier. Consumption at the shops is registered by technical meters. The power balance is based on indications of technical meters.
Measurement of steam consumption is being performed by flow meters. In the absence of data the steam consumption value can be retrieved through the balance of steam production.
The mass of polycrystalline silicon production is measured by two systems. Weighting system includes a general weighing after growing silicon reactors and second system is used for weighing finished products.

Data and parameters that are not monitored throughout the crediting period, but are determined only once (and thus remain fixed throughout the crediting period), and that are available already at the stage of determination are presented in section B.1. The group of data and parameters that are not monitored throughout the crediting period, but are determined only once (and thus remain fixed throughout the crediting period), but that are not already available at the stage of determination are not applicable in the PDD. Data and parameters that are monitored throughout the crediting period are presented in D.1.1.1. and D.1.1.3.

The key parameters that should be monitored during the crediting period are presented below. Other parameters excluded from the monitoring plan are dependent on the monitored parameters and shall be calculated using the primary parameters presented in the monitoring plan or under the Section **B.1**.

For project emissions the following parameters are to be monitored:

$EC_{P,PCS,y}$ = amount of consumed electricity in project scenario for trichlorosilane and polycrystalline silicon production needs, MWh;
$EC_{B,y}$ = amount of electricity consumption in boiler-house for its own needs, MWh;
$EF_{CO2,Grid,y}$ = CO_2 emission factor for UES of Ukraine for projects, aiming at reduction of electricity consumption t CO_2e/MWh;
$HC_{SC,TCS,y}$ = steam consumption for technical needs of trichlorosilane production, GJ;
$HC_{SC,PCS,y}$ = steam consumption for technical needs of polycrystalline silicon production, GJ;
$HC_{SC, SCNG,y}$ = steam consumption for technical needs of hydrogen production, GJ;
$EC_{SC,y}$ = electricity consumption for technical needs of hydrogen production, MWh;
$FC_{SC,y}$ = natural gas consumption for combustion for hydrogen production, m^3;
$FA_{SC,y}$ = natural gas consumption for steam conversion for hydrogen production, m^3;
$C_{NG,y}$ = natural gas carbon content, t C/TJ;
$NCV_{NG,y}$ = natural gas net calorific value, kJ/m^3;
$EF_{CO2,NG}$ = carbon dioxide emission factor from natural gas, t CO_2/TJ;
EF_{Na2CO3} = carbon dioxide emission factor for sodium carbonate, tCO_2/t;
$FC_{NG,y}$ = Natural gas consumption, TJ
$SG_{,y}$ = steam production, TJ;
$M_{Na2CO3,y}$ = sodium carbonate consumption for technologic needs of waste gases neutralization, t.

For the baseline emissions the following parameters are to be monitored:

$M_{PCS,y}$ = the mass of produced polycrystalline silicon, *t*.

The system of data collection and management is presented in Section D.3.
The project owner is responsible for preparing the respective reports and their submission to an independent entity.

D.1.1. Option 1 – Monitoring of emissions in the project scenario and the baseline scenario:

D.1.1.1. Data to be collected for project emissions monitoring, and method of data archiving:

ID number *(Using numbers eases cross-referencing to D.2.)*	Data variable	Source of data	Data unit	Measured (m), calculated (c), estimated (e)	Recording frequency	Proportion of data to be monitored	Method of data archiving (electronic/ paper format)	Comment

1. $EC_{P,PCS,y}$	*Power consumption for trichlorosilane and polycrystalline silicon production*	*Meter*	*MWh*	*m*	*continuously*	*100 %*	*electronic/ paper*	
2. $EF_{CO2,Grid,y}$	*CO_2 emission factor for UES of Ukraine*		*t CO_2e/MWh*	*c*	*annually*	*100 %*		*Established by National Environmental Investment Agency*
3. $HC_{SC,TCS,y}$	*Steam consumption for trichlorosilane production*	*Flow meter*	*GJ*	*m*	*daily*	*100 %*	*electronic/ paper*	
4. $HC_{SC,PCS,y}$	*Steam consumption for polycrystalline silicon production*	*Flow meter*	*GJ*	*m*	*daily*	*100 %*	*electronic/ paper*	
5. $HC_{SC, SCNG,y}$	*steam consumption for hydrogen production*	*Flow meter*	*GJ*	*m*	*daily*	*100 %*	*electronic/ paper*	
7. $EC_{B,y}$	*Electricity consumption in boiler-house*	*Meter*	*MWh*	*m*	*daily*	*100 %*	*electronic/ paper*	
8. $EC_{SC,y}$	*Electricity consumption for hydrogen production*	*Meter*	*MWh*	*m*	*daily*	*100 %*	*electronic/ paper*	
9. $FC_{SC,y}$	*Natural gas consumption for combustion for hydrogen production*	*Flow meter*	*m^3*	*m*	*daily*	*100 %*	*electronic/ paper*	

10. $FA_{SC,y}$	*Natural gas consumption for needs of steam conversion for hydrogen production*	*Flow meter*	*m^3*	*m*	*daily*	*100 %*	*electronic/ paper*	
11. $C_{NG,y}$	*Carbon content in natural gas*	*IPCC*	*t C/TJ*	*e*	*annually*	*100 %*	*electronic/ paper*	*In accordance with 2006 IPCC Guidelines for National Greenhouse Gas Inventories Table 1.3, V. 2, Chapter 1. In case of appearing national data of carbon content in natural gas the last one will be used*
12. $NCV_{NG,y}$	*Net calorific value of natural gas*	*Certificate from supplier*	*kJ/m^3*	*m*	*monthly*	*100 %*	*electronic/ paper*	
14. EF_{Na2CO3}	*CO_2 emission factor for sodium carbonate*	*IPCC*	*tCO_2/t*	*c*	*annually*	*100 %*	*electronic/ paper*	*In accordance with 2006 IPCC Guidelines for National Greenhouse Gas Inventories*

								Table 2.1 V. 3 Chapter 2.
15. $M_{Na2CO3,y}$	*Sodium carbonate consumption*	*Scales*	*t*	*m*	*daily*	*100 %*	*electronic/ paper*	
16. $FC_{NG,y}$	*Natural gas consumption by boiler house*	*Flow meter*	m^3	*m*	*daily*	*100 %*	*electronic/ paper*	
17. $SG_{,y}$	*Steam production by boiler house*	*Flow meter*	*GJ*	*m*	*daily*	*100 %*	*electronic/ paper*	

D.1.1.2. Description of formulae used to estimate project emissions (for each gas, source etc.; emissions in units of CO_2 equivalent):

The project scenario emissions PE_y are calculated according to the following formulas:

$$PE_y = PE_{ElC,y} + PE_{HG,y} + PE_{SC,y} + PE_{SCD,y}, \quad (1)$$

Where

$PE_{ElC,y}$ = Emissions from electricity consumption for trichlorosilane and polycrystalline silicon production, tCO_2;

$PE_{HG,y}$ = Emissions from heat production for trichlorosilane and polycrystalline silicon production, tCO_2;

$PE_{SC,y}$ = Emissions from steam production by steam conversion of natural gas, tCO_2;

$PE_{SCD,y}$ = Emissions from soda ash consumption for primary neutralization of waste gases, tCO_2;

The emissions from the electricity consumption are calculated according to the formula:

$$PE_{ElC,y} = EC_{P,PCS,y} EF_{CO_2,Grid,y}, \quad (2)$$

Where

$EC_{P,PCS,y}$ = consumed electricity in the project scenario for trichlorosilane and polycrystalline silicon production, MWh;

$EF_{CO2,Grid,y}$ = national emissions factor for the UES of Ukraine for projects aiming at a decrease of electricity consumption, t CO_2e/MWh.

The emissions from heat production for technological process of trichlorosilane and polycrystalline silicon production are equal:

$$PE_{HG,y} = FC_{PTechn,y} \cdot EF_{CO_2,NG} + EC_{B,y} \cdot EF_{CO_2,Grid,y}, \qquad (3)$$

where

$FC_{PTechn,y}$ = natural gas consumption for technical needs of the plant within the project scenario, TJ;

$EC_{B,y}$ = electricity consumption in the boiler-house for auxiliaries, MWh;
$EF_{CO2,NG}$ = emission factor of carbon dioxide from natural gas combustion, t CO_2/TJ;
$EF_{CO2,Grid,y}$ = national emission factor for the UES of Ukraine for projects aiming at a decrease of electricity consumption, t CO_2e/MWh.

Conservative assumption that electricity consumption for auxiliaries of boiler-house does not depend on steam production is taken into account.

Natural gas consumption for technical needs of the plant is calculated according to the following formula:

$$FC_{PTechn,y} = \frac{1}{\eta_{SG,y}}\left(HC_{SC,TCS,y} + HC_{SC,PCS,y} + HC_{SC,SCNG,y}\right), \qquad (4)$$

where

$\eta_{SG,y}$ = boiler-house efficiency;

$HC_{SC,TCS,y}$ = steam consumption for technical needs of trichlorosilane production, GJ;

$HC_{SC,PCS,y}$ = steam consumption for technical needs of polycrystalline silicon production, GJ;

$HC_{SC, SCNG,y}$ = steam consumption for technical needs of hydrogen production, GJ.

The efficiency of the boiler-house is determined by consumption of the natural gas and customers supply with steam

$$\eta_{SG,y} = \frac{SG_y}{FC_{NG,y}}, \qquad (5)$$

where

SG_y = steam production, TJ;

$FC_{NG,y}$ = natural gas consumption at boiler house, TJ.

The waste from hydrogen production includes wastes from electricity consumption by steam conversion equipment, emissions from natural gas combustion and natural gas conversion. Emissions from steam conversion of natural gases are calculated according to equation 3.17 (Vol. 3, Chapter 3 of Guidelines for National Inventory of GHG.[10].

$$PE_{SC,y} = EC_{SC,y} \cdot EF_{CO_2,Grid,y} + FC_{SC,y} \cdot NCV_{NG,y} \cdot C_{NG,y} \cdot \frac{44}{12} + FA_{NG,SC,y} \cdot NCV_{NG,y} \cdot C_{NG,y} \cdot \frac{44}{12}, \quad (6)$$

where

$EC_{SC,y}$ = electricity consumption for technical needs of hydrogen production, MWh;

$FC_{SC,y}$ = natural gas consumption for combustion for hydrogen production needs, m^3;

$FA_{SC,y}$ = natural gas consumption for steam conversion needs for hydrogen production, m^3;

$C_{NG,y}$ = carbon content in natural gas, t C/TJ;

$NCV_{NG,y}$ = net calorific value of the natural gas, TJ/m^3;

$EF_{CO2,Grid,y}$ = national emission factor for the UES of Ukraine for projects aiming at a decrease of electricity consumption, t CO_2e/MWh.

44/12 = proportionality factor for receiving a ton of carbon dioxide from a ton of carbon, t CO_2/t C.

The emissions from neutralization of waste gases $PE_{SCD,y}$ by soda ash are calculated according to equation 2.12 volume 3 chapter 2 of “Guidelines for national inventory of GHG”.[11]

$$PE_{SCD,y} = M_{Na_2CO_3,y} \cdot EF_{Na_2CO_3} \cdot F_{Na_2CO_3}, \quad (7)$$

where

$M_{Na2CO3,y}$ = sodium carbonate consumption for technologic needs of waste gases neutralization, t;

EF_{Na2CO3} = CO_2 emission factor for sodium carbonate, tCO_2/t;

F_{Na2CO3} = level of the engagement in neutralization (set to be equal to 1), fraction.

[10] http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/3_Volume3/V3_3_Ch3_Chemical_Industry.pdf

[11] http://www.ipcc-nggip.iges.or.jp/public/2006gl/russian/pdf/3_Volume3/V3_2_Ch2_Mineral_Industry.pdf

D.1.1.3. Relevant data necessary for estimation of the baseline level of GHGs anthropogenic emissions by sources within the project boundary, and method of data collection and archiving:								
ID number *(Please use numbers to ease cross-referencing to D.2.)*	Data variable	Source of data	Data unit	Measured (m), calculated (c), estimated (e)	Recording frequency	Proportion of data to be monitored	Method of data archiving (electronic/ paper)	Comment
18. $M_{PCS,y}$	*Mass of produced polycrystalline silicon*	*Scales*	*t*	*m*	*daily*	*100 %*	*electronic/ paper*	

D.1.1.4. Description of formulae used to estimate baseline emissions (for each gas, source etc.; emissions in units of CO_2 equivalent):

Baseline emissions consist of emissions from electricity consumption and thermal energy as a steam that is used for hydrogen, trichlorosilane and polycrystalline silicon production. Emissions from electricity consumption occurred as a result of fossil fuels' use by the UES of Ukraine. Emissions from the thermal energy consumption occurred due to natural gas combustion in a boiler-house. As a result, baseline emissions of the BE_y are equal:

$$BE_y = BE_{El,y} + BE_{HG,y}, \qquad (8)$$

where

$BE_{El,y}$ = Baseline emissions from electricity consumption per year, t CO_2e;

$BE_{HG,y}$ = Baseline emissions from thermal consumption, t CO_2e;

y = year for which calculations are made.

The emissions from electricity consumption are calculated according to the following formulas:

$$BE_{El,y} = \left(EC_{BL,PCS,y} + EC_{BL,TCS,y} + EC_{BL,H_2,y}\right) \cdot EF_{CO_2,Grid,y}, \qquad (9)$$

Where:

$EC_{BL,PCS,y}$ = electricity consumption for polycrystalline silicon production in baseline scenario, MWh;

$EC_{BL,TCS,y}$ = electricity consumption for trichlorosilane production in baseline scenario, MWh;
$EC_{BL,H2,y}$ = electricity consumption for hydrogen production in baseline scenario, MWh;
$EF_{CO2,Grid,y}$ = national emission factor for the UES of Ukraine for projects aiming at a decrease of electricity consumption, t CO_2e/MWh.

The baseline electricity consumption is based on actual expenses of hydrogen, trichlorosilane and polycrystalline silicon production.

Electricity amount for polycrystalline silicon production is calculated as shown below:

$$EC_{BL,PCS,y} = SEC_{PCS} \cdot M_{PCS,y}, \qquad (10)$$

Where

SEC_{PCS} = specific electricity consumption for polycrystalline silicon production by traditional technology equipment, MWh/t;
$M_{PCS,y}$ = amount of the produced polycrystalline silicon in year *y*, t;

The electricity for trichlorosilane production is calculated in the same way:

$$EC_{BL,TCS,y} = SEC_{TCS} \cdot M_{BL,TCS,y}, \qquad (11)$$

Where

SEC_{TCS} = specific electricity consumption for trichlorosilane production by traditional technology equipment, MWh/t;
$M_{BL,TCS,y}$ = normative weight of trichlorosilane for polycrystalline silicon production by baseline technologies in year *y*, t.

The normative mass of trichlorosilane is calculated according to specific consumption of trichlorosilane for polycrystalline silicon production

$$M_{BL,TCS,y} = SMC_{TCS} \cdot M_{PCS,y}, \qquad (12)$$

Where

SMC_{TCS} = specific consumption of trichlorosilane per ton of polycrystalline silicon to fulfil baseline production, t/t;
$M_{PCS,y}$ = amount of the produced polycrystalline silicon in year *y*, t.

Electricity consumption for hydrogen production is calculated as follows:

$$EC_{BL,H_2,y} = SEC_{H_2} \cdot V_{BL,H_2,y}, \qquad (13)$$

Where

SEC_{H2} = specific electricity consumption for hydrogen production by water electrolysis equipment, kWh/m^3;
$V_{BL,H2,y}$ = normative hydrogen demand for trichlorosilane and polycrystalline silicon production, m^3.

The hydrogen demand consists of demand in hydrogen chloride synthesis (trichlorosilane production) and silicon hydrogen reduction (polycrystalline silicon production):

$$V_{BL,H_2,y} = SMC_{H_2,TCS} \cdot M_{BL,TCS,y} + SMC_{H_2,PCS} \cdot M_{PCS,y} , \quad (14)$$

Where

$SMC_{H2,TCS}$ = specific hydrogen consumption for trichlorosilane production, m^3/kg;
$SMC_{H2,PCS}$ = specific hydrogen consumption for polycrystalline silicon production, m^3/kg;
$M_{BL,TCS,y}$ = normative weight of trichlorosilane for polycrystalline silicon production by baseline technologies in year *y*, t;
$M_{PCS,y}$ = amount of the produced polycrystalline silicon in year *y*, t.

The emissions from heat consumption in the baseline scenario are calculated according to the following formula:

$$BE_{HG,y} = FC_{BL,SG,y} EF_{CO_2,NG} , \quad (15)$$

Where

$FC_{BL,SG,y}$ = natural gas consumption in baseline scenario for technological needs steam production per year *y*, TJ;

$EF_{CO2,NG}$ = emission factor of carbon dioxide from natural gas, t CO_2/TJ.

Natural gas consumption for steam production in baseline scenario is calculated as shown below:

$$FC_{BL,SG,y} = \frac{1}{\eta_{SG,y}} \cdot \left(SSC_{PCS} \cdot M_{PCS,y} + SC_{TCS} \cdot M_{BL,TCS,y} \right) , \quad (16)$$

Where

$\eta_{SG,y}$ = efficiency of the boiler-house;

SSC_{PCS} = specific steam consumption per ton of polycrystalline silicon for baseline production, GJ/t;

SSC_{TCS} = specific steam consumption per ton of trichlorosilane for baseline production, GJ/t;
$M_{BL,TCS,y}$ = normative weight of trichlorosilane for polycrystalline silicon production by baseline technologies in year *y*, t;
$M_{PCS,y}$ = amount of the produced polycrystalline silicon in year *y*, t.

D. 1.2. Option 2 – Direct monitoring of the project emission reductions (values should be consistent with those in section E.):

D.1.2.1. Data to be collected to monitor emissions reductions from the project, and data archiving method:

ID number *(Please use numbers to ease cross-referencing to D.2.)*	Data variable	Source of data	Data unit	Measured (m), calculated (c), estimated (e)	Recording frequency	Proportion of data to be monitored	Method of data archiving (electronic/ paper)	Comment

D.1.2.2. Description of formulae used to calculate emission reductions from the project (for each gas, source etc.; emissions/emission reductions in units of CO_2 equivalent):

Not applicable

D.1.3. Treatment of leakage in the monitoring plan:

Not applicable

D.1.3.1. If applicable, please describe the data and information collected in order to monitor leakage effects of the project:								
ID number *(Please use numbers to ease cross-referencing to D.2.)*	Data variable	Source of data	Data unit	Measured (m), calculated (c), estimated (e)	Recording frequency	Proportion of data to be monitored	Method of data archiving (electronic/ paper)	Comment

D.1.3.2. Description of formulae used to estimate leakage (for each gas, source etc.; emissions in units of CO_2 equivalent):

Leakages are calculated as sum of emissions related to oxygen and silicon tetrachloride production.

$$LE_y = LE_{O_2,y} + LE_{TS,y}, \qquad (17)$$

де

$LE_{O2,y}$ = leakage from oxygen generation in accordance with the baseline, t CO_2e;

$LE_{TS,y}$ = leakage from silicon tetrachloride generation in accordance with the baseline, t CO_2e.

Leakage from oxygen generation is calculates on the basis of specific electricity consumption per m^3 of oxygen

$$LE_{O_2,y} = SPC_{O_2} \cdot OG_{BL,y} \cdot EF_{CO_2,grid,y}, \qquad (18)$$

where

SPC_{O2} = specific power consumption for oxygen production, kW/m^3;

$OG_{BL,y}$ = oxygen generation in baseline scenario in year y, m^3;

$EF_{CO2,Grid,y}$ = national emission factor for the UES of Ukraine for projects aiming at a decrease of electricity consumption, t CO_2e/MWh.

Baseline oxygen production is calculated according to the following stoichiometric equation:

$$OG_{BL,y} = V_{BL,H_2,y} \cdot \frac{\rho_{H_2}}{\rho_{O_2}} \cdot \frac{M_{O_2}}{2M_{H_2}}, \qquad (19)$$

where

$V_{BL,H2,y}$ = normative hydrogen demand for trichlorosilane and polycrystalline silicon production, m^3;

ρ_{H2} = hydrogen density kg/m^3;

ρ_{O2} = oxygen density kg/m^3;

M_{H2} = hydrogen molar weight, g/mol;

M_{O2} = oxygen molar weight, g/mol.

Leakage from silicon tetrachloride production. Silicon tetrachloride is a co-product of trichlorosilane and polycrystalline silicon production. Manufacturing of silicon tetrachloride is possible during process of hydrochlorination. Based on conservative assumption GHG emissions from silicon tetrachloride production are calculated in accordance with expenditures for silicon trichlorosilane production in the baseline scenario.

$$LE_{TS,y} = LE_{El,y} + LE_{HG,y}, \qquad (20)$$

The emissions from electricity consumption are calculated according to the formula:

$$LE_{El,y} = \left(EC_{TS,y} + EC_{H_2,TS,y}\right) \cdot EF_{CO_2,Grid,y}, \qquad (21)$$

where

$EC_{TS,y}$ = electricity consumption for silicon tetrachloride production, MWh;
$EC_{H2,TS,y}$ = electricity consumption for the hydrogen production to cover demand for silicon tetrachloride production, MWh;
$EF_{CO2,Grid,y}$ = national emission factor for the UES of Ukraine for projects aiming at a decrease of electricity consumption, t CO_2e/MWh.

The electric power consumption for silicon tetrachloride production is based on a specific electricity consumption for hydrogen and silicon tetrachloride manufacture. The emissions from electricity consumption for silicon tetrachloride production are equal:

$$EC_{TS,y} = SEC_{TCS,y} \cdot M_{TS,y}, \qquad (22)$$

where

$SEC_{TCS,y}$ = specific electricity consumption for trichlorosilane production by traditional technology equipment, MWh/t;
$M_{TS,y}$ = mass of silicon tetrachloride that corresponds to the baseline, t.

The mass of silicon tetrachloride corresponding to the baseline is determined in accordance with the baseline polycrystalline silicon production

$$M_{TS,y} = SEC_{TS,y} \cdot M_{PCS,y}, \quad (23)$$

where

$SEC_{TS,y}$ = specific silicon tetrachloride production per ton of polycrystalline silicon, t/t.
$M_{PCS,y}$ = amount of the produced polycrystalline silicon in year *y*, t.

Electricity consumption for the hydrogen production equals:

$$EC_{H_2,TS,y} = SEC_{H_2} \cdot V_{H_2,TS,y}, \quad (24)$$

where

SEC_{H2} = specific electricity consumption for hydrogen production by the water electrolysis equipment, kWh/m^3;
$V_{H2,TS,y}$ = normative need of hydrogen for silicon tetrachloride production, m^3.

The normative hydrogen demand for silicon tetrachloride production is based on a hydrogen demand for trichlorosilane production:

$$V_{H_2,TS,y} = SMC_{H_2,TCS} \cdot M_{TS,y}, \quad (25)$$

where
$SMC_{H2,TCS}$ = specific hydrogen consumption for trichlorosilane production, m^3/kg;.E
$M_{TS,y}$ = mass of silicon tetrachloride that corresponds to the baseline, t.

Emissions from heat consumption are also based on heat demand for trichlorosilane production:

$$LE_{HG,y} = FC_{SG,TS,y} EF_{CO_2,NG}, \quad (26)$$

where

$FC_{SG,TS,y}$ = natural gas consumption of steam production for silicon tetrachloride manufacture in year *y*, TJ;

Natural gas consumption for steam production for silicon tetrachloride manufacture are calculated as shown below:

$$FC_{SG,TS,y} = \frac{1}{\eta_{SG,y}} \cdot \left(SSC_{TCS} \cdot M_{TS,y} \right), \qquad (27)$$

$\eta_{SG,y}$ = efficiency of the boiler-house;

SSC_{TCS} = specific steam consumption per ton of trichlorosilane for baseline production, GJ/t;
$M_{TS,y}$ = mass of silicon tetrachloride that corresponds to the baseline, t.

D.1.4. Description of formulae used to estimate project emission reductions (for each gas, source etc.; emissions/emission reductions in units of CO_2 equivalent):

Emissions reduction is calculated as shown below:

$$ER_y = BE_y - PE_y - LE_y, \qquad (28)$$

where
ER_y = reduction of emissions in year *y*, t CO_2e;
BE_y = baseline GHG emissions in year *y*, t CO_2e;
PE_y = GHG emissions from the project activities in year *y*, t CO_2e;
LE_y = leakages in year *y* , t CO_2e.

D.1.5. Where applicable, information on the collection and archiving of data on the environmental impacts of the project in accordance with procedures required by the host Party:

The information on environmental impacts is presented in Section F of this PDD.

D.2. Quality control (QC) and quality assurance (QA) procedures undertaken for data that are subject to monitoring:		
Data *(Indicate table and ID number)*	Data uncertainty level (high/medium/low)	Explain QA/QC procedures planned for these data, or why such procedures are not necessary.

Table D.1.1.1. 1,7,8	Low	Measurements are carried out by meters. The class of accuracy is 1.0. Calibration is done in accordance with DSTU 2708-2006 "Metrology. Testing of measuring devices. Organization and procedures." The meters have to be calibrated once per 6 years.
Table D.1.1.1. 2,11,12,13,14	Low	No plans for additional QA/QC procedures
Table D.1.1.1. 3	Low	Measurements are carried out by the orifice plate DKS. The class of accuracy is 0.1. Calibration is done in accordance with methodology EUS126.00 MP MPU-005/04-2003 ." The system of calibration has to be provided once per year.
Table D.1.1.1. 4	Low	Measurements are carried out by the flow meters. The class of accuracy is 1.
Table D.1.1.1. 5,9,10	Low	Measurements are carried out by the orifice plate. Calibration is done in accordance with methodologies.
Table D.1.1.1. 15	Low	Measurements are carried out by the scale. Calibration is done in accordance with methodologies.
Table D.1.1.1. 16	Low	Measurements are carried out by the flow meters «FLOUTEC-TM», The class of accuracy is 1 Calibration is done in accordance with methodologies MPU 290/03-2009. The system of calibration has to be provided once per year.
Table D.1.1.1. 17	Low	Measurements are carried out by the orifice plate. The class of accuracy is 1.5%. Calibration is done in accordance with methodologies MPU -005/04-2003. The system of calibration has to be provided once per year.
Table D.1.1.3. 18	Low	Measurements are carried out by the electronic scales VTE-Centroves 109-TZU.

D.3. Please describe the operational and management structure to be applied by the project operator for monitoring plan implementation:

The monitoring plan does not foresee any other additional measures resulting in installation of new measuring equipment or collection of other parameters in addition to those that are already implemented. The data collection scheme is provided in Figure 7.

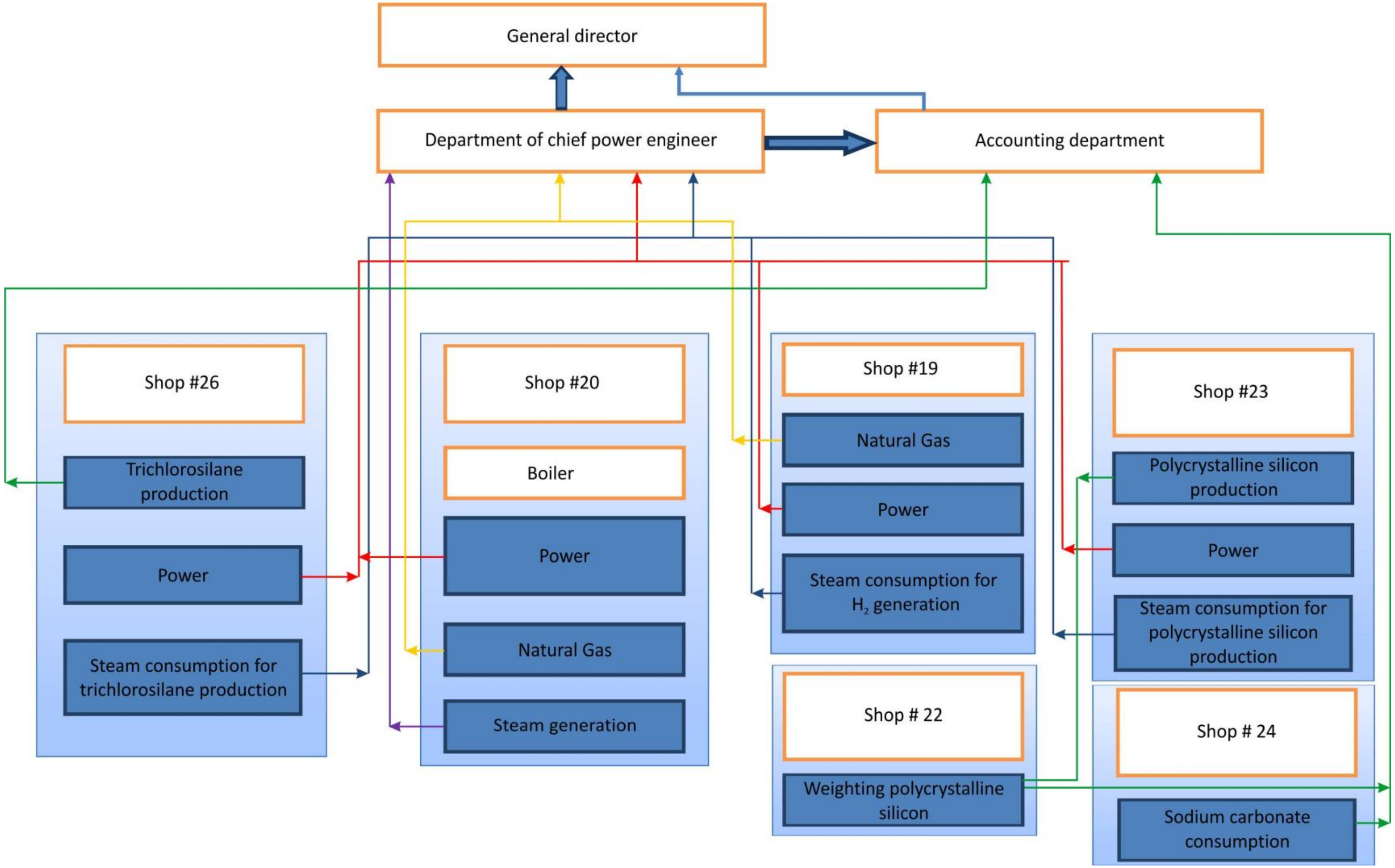

Fig. 7. The scheme of monitoring data collection

In accordance with the scheme of data collection, all information regarding energy consumption goes to the office of chief power engineer. Data on polycrystalline silicon and trichlorosilane production and sodium carbonate consumption go to the accounting department.

D.4. Name of person(s)/entity(ies) establishing the monitoring plan:

Private JSC "Semiconductor plant" (project participant)
Adress: Teplichnaya str. 16, Zaporizhzhya 69600, Ukraine
Director on the job and fire safety and environment protection
Savenkov Yuriy
+38 061 2148514

Environmental (Green) Investments Fund Ltd (project participant)
Contact information:

Address: Sofii Perovskoi 10b, Kyiv 03057, Ukraine
Contact person: Tadlya Kostyantyn
Telephone: +380 44 456 20 31
Telephone/fax: +380 44 456 19 87
E-mail: konstat@ukr.net

SECTION E. Estimation of greenhouse gas emission reductions

E.1. Estimated project emissions:

The volumes of GHG emissions after the implementation of project measures are presented in Table 4 below. Table 5 presents project emissions after 2012.

Table 4. Project emissions

Year			2011	2012
Emissions from trichlorosilane production	$PE_{TCS,y}$	tCO_2	32 790	34 720
Emissions from polycrystalline silicon production	$PE_{PCS,y}$	tCO_2	195 704	509 795
Emissions from hydrogen production	$PE_{H2,y}$	tCO_2	12 049	4 736
Total project emissions	$\boldsymbol{PE_y}$	$\mathbf{tCO_2}$	240 543	549 251

The emissions from trichlorosilane production include emissions from steam generation, emissions from power consumption for trichlorosilane manufacture and emissions from neutralization of waste gases by soda ash. The emissions from polycrystalline silicon production include emissions from steam generation and emissions from electricity consumption for polycrystalline silicon production. The emissions from hydrogen production include emissions from electricity and natural gas consumption for hydrogen production.

Table 5. Project emissions after 2012

Year	Emissions from trichlorosilane production, tCO_2	Emissions from polycrystalline silicon production, tCO_2	Emissions from hydrogen production, tCO_2	Total Project Emissions, tCO_2
	$PE_{TCS,y}$	$PE_{PCS,y}$	$PE_{H2,y}$	$\boldsymbol{PE_y}$
2013	34 720	509 795	4 736	549 251
2014	34 720	509 795	4 736	549 251
2015	34 720	509 795	4 736	549 251
2016	34 720	509 795	4 736	549 251
2017	34 720	509 795	4 736	549 251
2018	34 720	509 795	4 736	549 251
2019	34 720	509 795	4 736	549 251
2020	34 720	509 795	4 736	549 251
2021	34 720	509 795	4 736	549 251
2022	34 720	509 795	4 736	549 251
2023	34 720	509 795	4 736	549 251
2024	34 720	509 795	4 736	549 251
2025	34 720	509 795	4 736	549 251
2026	34 720	509 795	4 736	549 251
2027	34 720	509 795	4 736	549 251
2028	34 720	509 795	4 736	549 251
2029	34 720	509 795	4 736	549 251
2030	34 720	509 795	4 736	549 251

E.2. Estimated leakage:

The project activity leads to leakages resulting from oxygen generation and silicon tetrachloride production. The volumes of GHG emissions from leakages are presented in tables 6 and 7

Table 6. Volumes of emissions generated by leakages

			2011	2012
Emissions from oxygen generation	$LE_{O2,y}$	tCO_2	13 864	36 115
Emissions from silicon tetrachloride manufacture	$LE_{TS,y}$	tCO_2	89 997	187 077
Total leakage emissions	$\boldsymbol{LE_y}$	$\mathbf{tCO_2}$	103 861	223 192

Table 7. Volumes of emissions generated by leakages after 2012

Year	Emissions from oxygen generation, tCO_2	Emissions from silicon tetrachloride manufacture, tCO_2	**Total leakage emissions, tCO_2**
	$LE_{O2,y}$	$LE_{TS,y}$	LE_y
2013	36 115	187 077	223 192
2014	36 115	187 077	223 192
2015	36 115	187 077	223 192
2016	36 115	187 077	223 192
2017	36 115	187 077	223 192
2018	36 115	187 077	223 192
2019	36 115	187 077	223 192
2020	36 115	187 077	223 192
2021	36 115	187 077	223 192
2022	36 115	187 077	223 192
2023	36 115	187 077	223 192
2024	36 115	187 077	223 192
2025	36 115	187 077	223 192
2026	36 115	187 077	223 192
2027	36 115	187 077	223 192
2028	36 115	187 077	223 192
2029	36 115	187 077	223 192
2030	36 115	187 077	223 192

E.3. The sum of E.1. and E.2.:

The sum of leakage emissions and project emissions is presented below in Table 8 and Table 9.

Table 8. The sum of leakages and project emissions

Year			2011	2012
The sum of E.1. and E.2.	PE_y	tCO_2	344 404	772 443

Table 9. The sum of leakages and project scenario emissions after 2012

Year			2013	2014	2015	2016	2017	2018	2019	2020	2021
The sum of E.1. and E.2.	PE_y	tCO_2	772 443	772 443	772 443	772 443	772 443	772 443	772 443	772 443	772 443
Year			2022	2023	2024	2025	2026	2027	2028	2029	2030
The sum of E.1. and E.2.	PE_y	tCO_2	772 443	772 443	772 443	772 443	772 443	772 443	772 443	772 443	772 443

E.4. Estimated baseline emissions:

The baseline scenario emissions are presented in Table 10 and Table 11 below.

Table 10. Baseline scenario emissions

Year			2011	2012
Emissions from trichlorosilane production	$BE_{TCS,y}$	tCO_2	69 339	180 621
Emissions from polycrystalline silicon production	$BE_{PCS,y}$	tCO_2	467 909	1 218 866
Emissions from hydrogen production	$BE_{H2,y}$	tCO_2	238 457	621 163
Total Baseline Emissions	$\boldsymbol{BE_y}$	$\mathbf{tCO_2}$	775 705	2 020 650

Table 11. Baseline scenario emissions after 2012

Year	Emissions from trichlorosilane production, tCO_2	Emissions from polycrystalline silicon production, tCO_2	Emissions from hydrogen production, tCO_2	Total Baseline Emissions, tCO_2
	$BE_{TCS,y}$	$BE_{PCS,y}$	$BE_{H2,y}$	$\boldsymbol{BE_y}$
2013	180 621	1218866	621 163	2 020 650
2014	180 621	1218866	621 163	2 020 650
2015	180 621	1218866	621 163	2 020 650
2016	180 621	1218866	621 163	2 020 650
2017	180 621	1218866	621 163	2 020 650
2018	180 621	1218866	621 163	2 020 650
2019	180 621	1218866	621 163	2 020 650
2020	180 621	1218866	621 163	2 020 650
2021	180 621	1218866	621 163	2 020 650
2022	180 621	1218866	621 163	2 020 650
2023	180 621	1218866	621 163	2 020 650
2024	180 621	1218866	621 163	2 020 650
2025	180 621	1218866	621 163	2 020 650
2026	180 621	1218866	621 163	2 020 650
2027	180 621	1218866	621 163	2 020 650
2028	180 621	1218866	621 163	2 020 650
2029	180 621	1218866	621 163	2 020 650
2030	180 621	1218866	621 163	2 020 650

E.5. Difference between E.4. and E.3. representing the emission reductions within the project:

The emission reductions are presented below in the Table 12 and Table 13.

Table 12. Emission reductions

Year			2011	2012
Emission reductions	***ER***	$\mathbf{tCO_2}$	431 301	1 248 207

Table 13. Emission reductions after 2012

Year			2013	2014	2015	2016	2017	2018	2019	2020	2021
Emission	***ER***	$\mathbf{tCO_2}$	1248207	1248207	1248207	1248207	1248207	1248207	1248207	1248207	1248207

reductions											
Year			2022	2023	2024	2025	2026	2027	2028	2029	2030
Emission reductions	***ER***	**tCO_2**	1248207	1248207	1248207	1248207	1248207	1248207	1248207	1248207	1248207

E.6. Table providing values obtained when applying formulae above:

Table 14. Summarized emissions and emission reductions

Year	Estimated project emissions (tonnes of CO_2 equivalent)	Estimated leakage (tonnes of CO_2 equivalent)	Estimated baseline emissions (tonnes of CO_2 equivalent)	Estimated emission reductions (tonnes of CO_2 equivalent)
2011	240 543	103 861	775 705	431 301
2012	549 251	223 192	2 020 650	1 248 207
Total (tonnes of CO_2 equivalent)	789 794	327 053	2 796 355	1 679 508

Table 15. Summarized emissions and emission reductions after 2012

Year	Estimated project emissions (tonnes of CO_2 equivalent)	Estimated leakage (tonnes of CO_2 equivalent)	Estimated baseline emissions (tonnes of CO_2 equivalent)	Estimated emission reductions (tonnes of CO_2 equivalent)
2013	549 251	223 192	2 020 650	1 248 207
2014	549 251	223 192	2 020 650	1 248 207
2015	549 251	223 192	2 020 650	1 248 207
2016	549 251	223 192	2 020 650	1 248 207
2017	549 251	223 192	2 020 650	1 248 207
2018	549 251	223 192	2 020 650	1 248 207
2019	549 251	223 192	2 020 650	1 248 207
2020	549 251	223 192	2 020 650	1 248 207
2021	549 251	223 192	2 020 650	1 248 207
2022	549 251	223 192	2 020 650	1 248 207
2023	549 251	223 192	2 020 650	1 248 207
2024	549 251	223 192	2 020 650	1 248 207
2025	549 251	223 192	2 020 650	1 248 207
2026	549 251	223 192	2 020 650	1 248 207
2027	549 251	223 192	2 020 650	1 248 207
2028	549 251	223 192	2 020 650	1 248 207
2029	549 251	223 192	2 020 650	1 248 207
2030	549 251	223 192	2 020 650	1 248 207

Total (tonnes of CO_2 equivalent)	9 886 518	4 017 456	36 371 700	22 467 726

SECTION F. Environmental impacts

F.1. Documentation on the assessment of the environmental impacts of the project, including transboundary impacts, in accordance with procedures determined by the host Party:

The environmental impact assessment (EIA)[12] of enterprise's reconstruction was carried out in compliance with the following documents:

- UNCR A.2.2.1-2003 «Structure and contents of materials on environmental impact assessment (EIA) during design and construction of enterprises, houses and other buildings»;
- UNCR A.2.2-3-2004 «List of project documentation, design, endorsement, and approval procedures for construction»
- Law of Ukraine «On Ecological Assessment»

The EIA was performed for the first stage of the reconstruction project. Impact of the project activity on the following spheres was considered:

- air
- water
- soil
- flora and fauna
- social and external man-caused environment

Air

Calculations analysis of pollutants dispersion into the atmospheric air on the border of the sanitary protection zone showed that maximal value of ground concentrations did not exceed the sanitary-hygiene regulations of the atmospheric air quality.

Water

Flows from purification of process gases and digesters are expected to be transferred to sewage treatment facilities of the "Zaporizhzhya titanium magnesium complex" where they will be neutralized and purified before being discharged into existing drainage outflow.
Melt and rain water from the territory of the plant is discharged into the existent sewerage drain network of the "Zaporizhzhya titanium magnesium complex".

Soil

Estimated total volume of solid equals to 11302 t per year. The greater part of graphite and silica dust is suggested to be sold to steel industry enterprises for further use as deoxidizers. The other part will be discharged at landfills.

Flora and fauna

The reconstruction of the plant does not have impact on flora and fauna as well as on objects of sanitary protection because:

- the plant is located at a considerable distance from natural reserve objects;
- the reconstruction does not require felling of trees or other plantings on the territory of the plant;
- Regional location of the plant does not cross migration routes of animals and birds;
- There are no museums, architecture, culture and history landmarks or natural reserve objects in the location area of the plant and adjacent territory

[12] Reconstruction with expansion of polycrystalline silicon production 1528/2-1-0.P1-OVOS.1

Conservation measures

To provide for environmental safety of the social environment the following conservation measures are planned:

- The reconstruction of production and new constructions are conducted with application of the newest first-class technologies and equipment in line with European standards;
- Installation of dust-arresting equipment on technological vehicles;
- Use of modern equipment for purification of waste gases from trichlorosilane, hydrogen chloride and silicon polycrystalline production, which meets European requirements to the technological standards of pollutants emissions from sources acting on the territory of Ukraine;
- Solid surface of the site prevents contamination of soils;
- Organization of collection, storage and disposal of solid and domestic wastes;
- Neutralization and purification of industrial wastes at sewage treatment plants.

Transboundary impacts

Ukraine has adopted three protocols of UN Conventions on transboundary air pollution. Two of these protocols regard commitments on reduction and control of pollutants. These protocols are:

- The 1985 Helsinki Protocol on the Reduction of Sulphur Emissions or their Transboundary Fluxes by at least 30 per cent that came into force on 2nd September 1987.
- The 1988 Sofia Protocol concerning the Control of Emissions of Nitrogen Oxides or their Transboundary Fluxes that came into force on 14th February 1991.

Sulphur emission do not occur at the plant. Taking into account that a closed production cycle will be provided after reconstruction and renewal of manufacture, nitrogen oxide emissions will decrease comparing to the baseline scenario and will be under total control of the utilities. Therefore project activity complies with Ukraine's commitments within the terms of UN Conference on Transboundary air pollution.

F.2. If environmental impact is considered significant by the project participants or the host Party, please provide conclusions and all references to supporting documentation of an environmental impact assessment undertaken in accordance with the procedures required by the host Party:

Proposed project will have overall positive impact on the environment comparing to the baseline situation because reconstruction will provide for a closed cycle and new equipment for gas and sewage purification will be installed. Therefore overall environment impact of the renewed production is nonessential.

SECTION G. Stakeholders' comments

G.1. Information on stakeholders' comments on the project, if necessary:

Interested parties are citizens of Zaporizhzhya city informed by mass media about the project implementation. There were be held public hearings. Information on the project and related public hearings was published in a local newspaper "Zaporizhska Sich"

As this project has positive intention to make social situation better there were no remarks from the citizens.

Annex 1

CONTACT INFORMATION ON PROJECT PARTICIPANTS

Project owners:

Organisation:	Private JSC "Semiconductor plant"
Street/P.O.Box:	16, Teplichnaya str.
Building:	
City:	Zaporizhzhya
State/Region:	
Postal code:	69600
Country:	Ukraine
Phone:	+38 061 2148514
Fax:	+38 061 2148514
E-mail:	
URL:	http://siz.zp.ua/
Represented by:	Zub Gennadiy Yuriyovych
Title:	Head of the law department
Salutation:	Mr
Last name:	Zub
Middle name:	Yuriyovych
First name:	Gennadiy
Department:	Law department
Phone (direct):	+38 061 2148514
Fax (direct):	+38 061 2148514
Mobile:	
Personal e-mail:	zyb@ukr.net

Project designer:

Organisation:	Environmental (Green) Investments Fund Ltd
Street/P.O.Box:	Sofii Perovskoi
Building:	10 b
City:	Kyiv
State/Region:	
Postal code:	03057
Country:	Ukraine
Phone:	+ 38 044 4562031
Fax:	+ 38 044 4561987
E-mail:	
URL:	http://www.ecoinvest.com.ua
Represented by:	
Title:	
Salutation:	Mr
Last name:	Tadlya
Middle name:	Anatoliyovich
First name:	Kostyantyn
Department:	
Phone (direct):	+380444562031
Fax (direct):	
Mobile:	
Personal e-mail:	konstat@ukr.net

Annex 2

BASELINE INFORMATION

The aggregated tables of key parameters of baseline and project scenario are presented below:

Table 1 of Annex 2. Data and parameters that are not monitored throughout the crediting period, but are determined only once (and thus remain fixed throughout the crediting period), and that are available already at the stage of determination

Parameter	Data source	Units	Values
SEC_{PCS} Specific electricity consumption for polycrystalline silicon production by existing equipment	PJSC "Semiconductor plant"	MWh/t	314.4
SEC_{TCS} Specific electricity consumption for trichlorosilane production by existing equipment	PJSC "Semiconductor plant"	MWh/t	2.445
SMC_{TCS} Specific consumption of trichlorosilane per ton of polycrystalline silicon to fulfill baseline production	PJSC "Semiconductor plant"	t/t	17.52
SEC_{H2} Specific electricity consumption for hydrogen production by the water electrolysis equipment	PJSC "Semiconductor plant"	kWh /m^3	6.441
$SMC_{H2,TCS}$ Specific hydrogen consumption for trichlorosilane production	PJSC "Semiconductor plant"	m^3/kg	0.35
$SMC_{H2,PCS}$ Specific hydrogen consumption for polycrystalline silicon production	PJSC "Semiconductor plant"	m^3/kg	23.36
SSC_{PCS} Specific steam consumption per ton of polycrystalline silicon for baseline production	PJSC "Semiconductor plant"	Gcal/t	237
SSC_{TCS} Specific steam consumption per ton of trichlorosilane for baseline production	PJSC "Semiconductor plant"	Gcal/t	2.875
SPC_{O2} Specific power consumption for oxygen production	http://www.nbuv.gov.ua/portal/natural/TG/2010_2/2010_2_31-38.pdf	kW/m^3	0.75
$SEC_{TS,y}$ Specific silicon tetrachloride production per ton of polycrystalline silicon	http://www.nbuv.gov.ua/portal/natural/newtech/2010_1/articles/1-9.pdf	t/t	15
ρ_{H2} Hydrogen density	GOST 3022-80 Technical hydrogen	kg/m^3	0.09
ρ_{O2} Oxygen density	GOST 30319.1-96 Natural gas. Methods of physical property calculation.	kg/m^3	1.42897
M_{H2} Hydrogen molar weight	GOST 3022-80 Technical hydrogen	g/mol	2.0159

M_{O2} Oxygen molar weight	GOST 5583-78 Technical and medical gaseous oxygen	g/mol	31.9988

Table 2 of Annex 2. Data and parameters that are monitored throughout the crediting period

Parameter	Data source	Units	Ex-ante value
$EC_{P,PCS,y}$, consumed electricity in the project scenario for trichlorosilane and polycrystalline silicon production	Register	MWh	477060
$EF_{CO2,Grid,y}$ national emission factor for the UES of Ukraine for projects aiming at a decrease of electricity consumption for 1st class consumers	In accordance to the order #75 from 12/05/2011 of National environmental investment agency	t CO_2e/ MWh	1.090
$HC_{SC,TCS,y}$ steam consumption for technical needs of trichlorosilane production	Flow meter	Gcal	14916
$HC_{SC,PCS,y}$ steam consumption for technical needs of polycrystalline silicon production	Flow meter	Gcal	65700
$HC_{SC, SCNG,y}$ steam consumption for technical needs of hydrogen production	Flow meter	Gcal	4472
$EC_{B,y}$ electricity consumption in the boiler-house for auxiliaries	Register	MWh	1875.12
$EC_{SC,y}$ electricity consumption for technical needs of hydrogen production	Register	MWh	580.03
$FC_{SC,y}$ natural gas consumption for combustion for hydrogen production needs	Flow meter	m^3*10^3	609
$FA_{SC,y}$ natural gas consumption for steam conversion needs for hydrogen production	Flow meter	m^3*10^3	1428
$C_{NG,y}$ carbon content in natural gas	IPCC	t/TJ	15.3
$NCV_{NG,y}$ net calorific value of the natural gas	Certificate from natural gas supplier	kJ/m^3	8160
EF_{Na2CO3} CO_2 emission factor for sodium carbonate	IPCC	tCO_2/t	0.41492
$M_{Na2CO3,y}$ sodium carbonate consumption for technologic needs of waste gases neutralization	Scales	t	2034.25
$FC_{NG,y}$ natural gas consumption by boiler house	Flow meter	m^3	1658000
SG_y steam production, TJ	Flow meter	Gcal	11843
$M_{PCS,y}$ weight of the produced polycrystalline silicon	Scales	t	3000

Annex 3

MONITORING PLAN

Please see section D.

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Key legends and abbreviations

NG – natural gas

TCS – trichlorosilane

PCS – polycrystalline silicon

TS – silicon tetrachloride

El – electricity

BL – baseline

UES of Ukraine – United Energy System of Ukraine

JI – Joint Implementation

ERUs – Emission Reduction Units

JSC – Joint Stock Company

OJSC – Open Joint Stock Company

PJSC – Private Joint Stock Company

GHG – Greenhouse Gas

IPCC – Intergovernmental Panel on Climate Change

UNFCCC – United Nations Framework Convention on Climate Change

EIA – Environmental Impact Assessment

USSR – The Union of Soviet Socialist Republics

CIS - Commonwealth of Independent States