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International Energy Agency
Photovoltaic Power Systems Programme

Task 12 PV Sustainability

PVPS

Life Cycle Inventories and Life Cycle Assessments of Photovoltaic Systems 2020

Report IEA-PVPS T12-19:2020

What is IEA PVPS TCP?

The International Energy Agency (IEA), founded in 1974, is an autonomous body within the framework of the Organization for Economic Cooperation and Development (OECD). The Technology Collaboration Programme (TCP) was created with a belief that the future of energy security and sustainability starts with global collaboration. The programme is made up of 6.000 experts across government, academia, and industry dedicated to advancing common research and the application of specific energy technologies.

The IEA Photovoltaic Power Systems Programme (IEA PVPS) is one of the TCP's within the IEA and was established in 1993. The mission of the programme is to "enhance the international collaborative efforts which facilitate the role of photovoltaic solar energy as a cornerstone in the transition to sustainable energy systems." In order to achieve this, the Programme's participants have undertaken a variety of joint research projects in PV power systems applications. The overall programme is headed by an Executive Committee, comprised of one delegate from each country or organisation member, which designates distinct 'Tasks,' that may be research projects or activity areas.

The IEA PVPS participating countries are Australia, Austria, Belgium, Canada, Chile, China, Denmark, Finland, France, Germany, Israel, Italy, Japan, Korea, Malaysia, Mexico, Morocco, the Netherlands, Norway, Portugal, South Africa, Spain, Sweden, Switzerland, Thailand, Turkey, and the United States of America. The European Commission, Solar Power Europe, the Smart Electric Power Alliance (SEPA), the Solar Energy Industries Association and the Cop- per Alliance are also members.

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What is IEA PVPS Task 12?

Task 12 aims at fostering international collaboration in safety and sustainability that are crucial for assuring that PV grows to levels enabling it to make a major contribution to the needs of the member countries and the world. The overall objectives of Task 12 are to 1. Quantify the environmental profile of PV in comparison to other energy technologies; 2. Investigate end of life management options for PV systems as deployment increases and older systems are decommissioned; 3. Define and address environmental health & safety and other sustainability issues that are important for market growth. The first objective of this task is well served by life cycle assessments (LCAs) that describe the energy-, material-, and emission-flows in all the stages of the life of PV. The second objective is addressed through analysis of including recycling and other circular economy pathways. For the third objective, Task 12 develops methods to quantify risks and opportunities on topics of stakeholder interest. Task 12 is operated jointly by the National Renewable Energy Laboratory (NREL) and University of New South Wales (UNSW). Support from the United States Department of Energy (DOE) and UNSW are gratefully acknowledged.

This report addresses the first objective above by providing life cycle inventories (LCIs) which are often the greatest barrier for conducting LCA. Further information on the activities and results of the Task can be found at: https://iea-pvps.org/research-tasks/pv-sustainability/

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Task 12: PV Sustainability

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APAC	Asia and Pacific
BOS	Balance of system
CdTe	Cadmium telluride
CI(G)S	Copper indium (gallium) selenide
CH	Switzerland
CH_3NH_3I	Methylammonium iodide
CN	China
c-Si	Crystalline silicon
CO_2	Carbon dioxide
CPV	Concentrating photovoltaics
DE	Germany
ENTSO	European Network of Transmission Systems Operators for Electricity
GLO	Global
Hg	Mercury
IEA	International Energy Agency
KR	Korea
kW	Kilowatt
kWp	Kilowatt peak
LCA	Life cycle assessment
LCI	Life cycle inventory
Li-ion	Lithium ion
m-c-Si	Multi-crystalline silicon
MG	Metallurgical grade
MW	Megawatt
MY	Malaysia
NO	Norway
NO_x	Nitrogen oxides
NORDEL	Nordic Countries Power Association
O_3	Ozone
OCE	Oceanic
Pb	Lead

PbI_2	Lead iodide
PM	Particulate matter
PV	Photovoltaics
RAS	Asia
RER	Europe (continental)
s-c-Si	Single-crystalline silicon
Si	Silicon
SiH4	Silane
$SiHCl_3$	Trichlorosilane
SO_2	Sulfur dioxide
US	United States of America
VTD	Vapor transport deposition
W	Watt

EXECUTIVE SUMMARY

Life Cycle Assessment (LCA) is a structured, comprehensive method of quantifying material- and energy-flows and their associated impacts in the life cycles of products (i.e., goods and services). One of the major goals of IEA PVPS Task 12 is to provide guidance on assuring consistency, balance, transparency and quality of LCA to enhance the credibility and reliability of the results. The current report presents the latest consensus life cycle inventories among the authors, PV LCA experts in North America, Europe, Asia and Australia. At this time consensus is limited to four technologies for which there are well-established and up-to-date life cycle inventory (LCI) data (mono- and multi-crystalline Si, CdTe, CIGS, as well as one emerging technology (perovskite silicon tandem).

LCIs are necessary for LCA and the availability of such data is often the greatest barrier for conducting LCA. The Task 12 LCA experts have put great efforts in gathering and compiling the LCI data presented in this report. These include detailed inputs and outputs during manufacturing of cell, wafer, module, and balance-of-system (i.e., structural and electrical components) that were estimated from actual production and operation facilities. In addition, data are presented to enable analyses of various types of PV installations; these include operational data of rooftop and ground-mount PV systems and country-specific PV-mixes. The LCI datasets presented in this report are the latest that are available to the public describing the status in 2018 for crystalline Si (some manufacturing data from 2011 were not updated), 2015 and 2017-2018 for CdTe, 2010 for CIGS, 2010 for HCPV, and 2017 for perovskite silicon tandem technology.

This report provides an update of the life cycle inventory data in the previous report:
R. Frischknecht, R. Itten, P. Sinha, M. de Wild-Scholten, J. Zhang, V. Fthenakis, H. C. Kim, M. Raugei, M. Stucki, 2015, Life Cycle Inventories and Life Cycle Assessment of Photovoltaic Systems, International Energy Agency (IEA) PVPS Task 12, Report T12-04:2015.

Updated life cycle inventory data tables are provided in section 3, with electronic versions available at IEA PVPS (http://www.iea-pvps.org; select Task 12 under Archive) and treeze Ltd (http://treeze.ch; under Publications). Note that not all sections of this report have been updated from the previous edition. Updates are provided for crystalline Si supply chain (Section 3.2), thin film CdTe PV module manufacturing (Section 3.3), perovskite silicon tandem PV manufacturing (Section 3.5), PV recycling (Section 3.6), low power (2.5-20 kW) inverters and Li-ion battery storage (Section 3.8), country-specific PV mixes (Section 3.10), and water usage (Section 3.12).

The goal of this report is to curate complete life cycle inventories for the most recent year of each technology available in the public domain. The data collected may not always be directly comparable when they do not represent the same year of technology. This discrepancy may be addressed in part through life cycle assessment harmonization procedures: https://www.nrel.gov/analysis/life-cycle-assessment.html.

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1 INTRODUCTION

Life Cycle Assessment (LCA) enables us to take into account life cycle stages, from cradle to grave, in measuring environmental and resource sustainability. There has been continuous and remarkable progress in photovoltaic (PV) technologies during the last two decades as governments and the industry stepped up investments in solar energy. Economies of scale and improvements in material utilization and process and module efficiencies have contributed to drastic reductions in production costs and to lower environmental footprints. In this report, we present life cycle inventory data of commercial PV technologies that are the basis for life cycle assessment. The data pertain to mono-and multi-crystalline silicon (Si), cadmium-telluride (CdTe), copper-indium-gallium-selenide (CIGS / CIS), and perovskite silicon tandem PV. We also include in the report additional inventory data describing balance of systems and recycling.

The life-cycle of photovoltaics starts from the extraction of raw materials (cradle) and ends with the disposal (grave) or recycling and recovery (cradle) of the PV components (Figure 1).

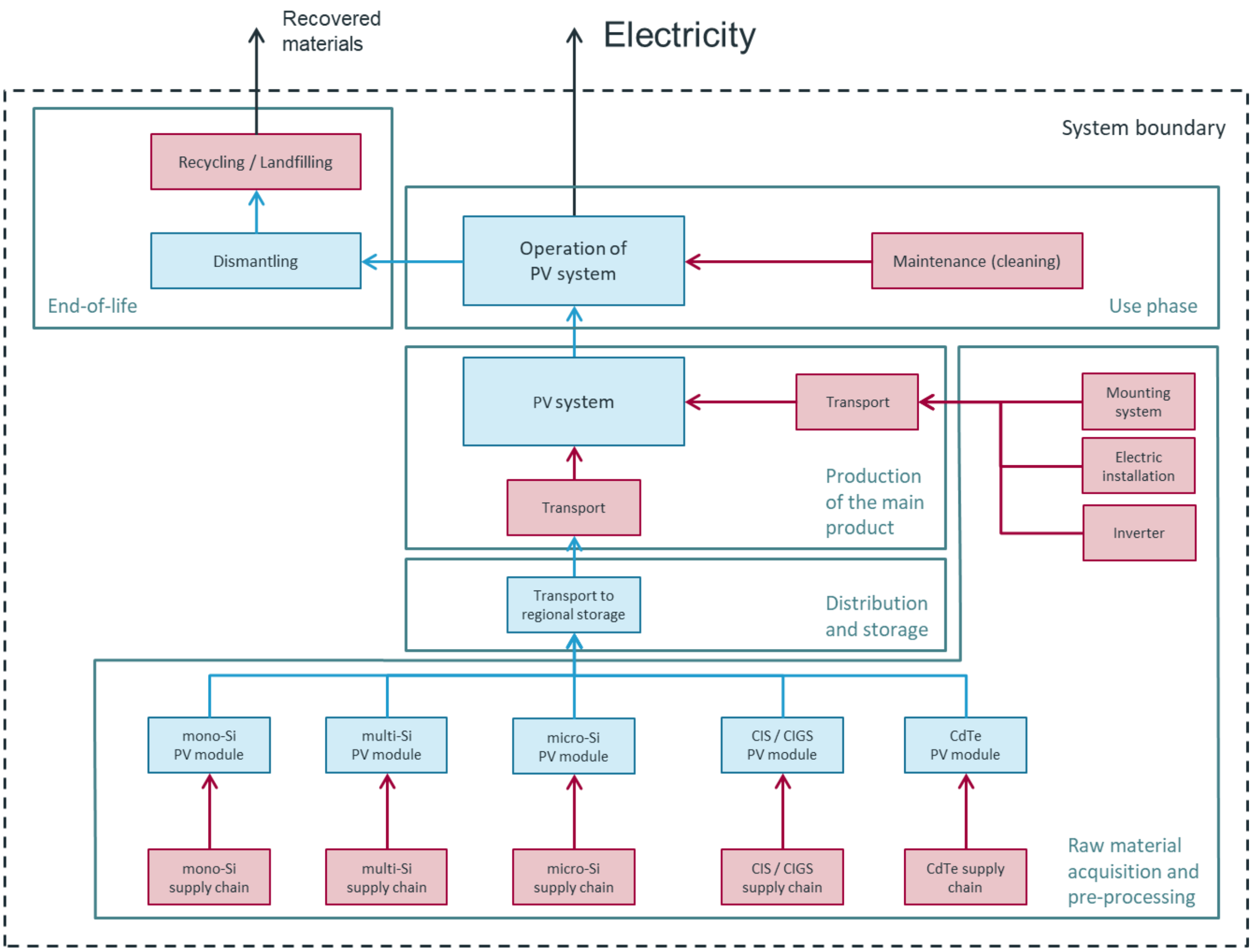

Figure 1: Product system of PV electricity production, adapted from [1]

The mining of raw materials, for example, quartz sand for silicon PVs, is followed by further processing and purification stages, to achieve the required high purities, which typically entails a large amount of energy consumption. The silica in the quartz sand is reduced in an arc furnace to metallurgical-grade silicon, which must be purified further into solar grade silicon (99.9999999%, [2]), typically through a modified-Siemens process. Metal-grade cadmium and tellurium for CdTe PV is primarily obtained as a byproduct of zinc and copper production respectively, and further purification is required for solar-grade purity (>99.999%). Similarly, metals used in CIGS PV are recovered as byproducts; indium and gallium are byproducts of zinc production while selenium is mostly recovered from copper production.

The raw materials include those for encapsulations and balance-of-system components, for example, silica for glass, copper ore for cables, and iron and zinc ores for mounting structures. The manufacture of a bulk silicon PV device is divided into several steps, that is, wafer, cell, and module. In the wafer stage, solar-grade polycrystalline or single-crystal silicon ingots are sliced into ~0.2 mm thick wafers. During the cell stage, a p-n junction is formed by dopant diffusion and electric circuit is created by applying and sintering metallization pastes. In the module stage, cells are connected physically and electronically, and encapsulated by glasses and plastics. The manufacturing stage is relatively simple for thin-film PVs which typically rely on semiconductor layer deposition followed by cell definition, as well as module fabrication steps (e.g., encapsulation) similar to those for silicon PVs. During the PV system installation stage, support structures are erected, PV systems are mounted, and PV modules, cables, and power conditioning and potentially storage equipment are integrated. At the end of their lifetime, PV systems are decommissioned and disposed with valuable parts and materials recycled.

Methodology guidelines for conducting life cycle assessment and net energy analysis of PV systems have been developed by IEA PVPS Task 12 [3][4]. Life cycle impact categories cover a range of indicators including climate change, primary energy demand, water scarcity, land use impacts on biodiversity, abiotic resource depletion, energy payback time, and energy return on investment. Specific rules for quantifying a variety of these life cycle impacts for PV systems have been developed under a EU product environmental footprint study [1]. A rapid screening tool (ENVI-PV) for estimating life cycle impacts of PV systems by location has been developed by Mines Paris Tech and IEA PVPS Task 12 (http://viewer.webservice-energy.org/project_iea/). Examples of publications estimating a variety of life cycle impacts for different PV technologies are shown in Table 1.

Table 1: Examples of PV life cycle assessments

Publication	PV technologies	Life cycle impact categories
Fthenakis, V. M., H. C. Kim, and E. Alsema. 2008. Emissions from Photovoltaic Life Cycles. Environmental Science and Technology, 42, 2168-2174, DOI: 0.1021/es071763q.	Mono-c-Si, multi-c-Si, ribbon-Si, CdTe	Carbon footprint, SO_2, NO_x, heavy metals
Fthenakis, V., and H. C. Kim. 2009. Land use and electricity generation: A life-cycle analysis. Renewable and Sustainable Energy Reviews, 13: 1465–1474.	PV, CPV, wind, hydro, biomass, coal, nuclear, natural gas	Land occupation, land transformation
Fthenakis, V. and H. C. Kim. Life-cycle uses of water in U.S. electricity generation. Renewable and Sustainable Energy Reviews vol. 14, pp. 2039–2048, 2010	Multi-c-Si, CdTe, wind, hydro, biomass, coal, nuclear, oil/gas	Water withdrawal and consumption
Hertwich, E. G., T. Gibon, E. A. Bouman, A. Arvesen, S. Suh, G. A. Heath, J. D. Bergesen, A. Ramirez, M. I. Vega, and L. Shi. 2014. Integrated life cycle assessment of electricity supply scenarios confirms global environmental benefit of low-carbon	Multi-c-Si, CdTe, CIGS	Carbon footprint, particulate matter, ecotoxicity, eutrophication, land occupation, human toxicity,

Publication	**PV technologies**	**Life cycle impact categories**
technologies. Proceedings of the National Academy of Sciences. doi:10.1073/pnas.1312753111		metal depletion, photochemical oxidation, terrestrial acidification
Lecissi, E., M. Raugei, and V. Fthenakis. 2016. The Energy and Environmental Performance of Ground-Mounted Photovoltaic Systems—A Timely Update, Energies, 9, 622; doi:10.3390/en9080622	Mono-c-Si, multi-c-Si, CdTe, CIGS	Cumulative energy demand, energy payback time, energy return on investment, carbon footprint, acidification potential, ozone depletion potential
Liu, F., and J. C.J.M. van den Bergh. 2020. Differences in CO2 emissions of solar PV production among technologies and regions: Application to China, EU and USA, Energy Policy, https://doi.org/10.1016/j.enpol.2019.111234	Mono-c-Si, multi-c-Si, a-Si, CdTe, CIS	Energy return on investment, net energy return on carbon invested, carbon footprint
Louwen, A., R.E.I. Schropp, W.G.J.H.M. van Sark, and A.P.C. Faaij. 2017. Geospatial analysis of the energy yield and environmental footprint of different photovoltaic module technologies. Solar Energy, 155, 1339-1353. http://dx.doi.org/10.1016/j.solener.2017.07.056	Mono-c-Si, multi-c-Si, a-Si, Si-heterojunction CdTe, CIGS	Energy payback time, carbon footprint
Peng, J., L. Lu, and H. Yang. 2013. Review on life cycle assessment of energy payback and greenhouse gas emission of solar photovoltaic systems. Renewable and Sustainable Energy Reviews, 19, 255–274. http://dx.doi.org/10.1016/j.rser.2012.11.035	Mono-c-Si, multi-c-Si, a-Si, CdTe, CIS	Energy payback time, carbon footprint
Pérez-López, P., Gschwind, B., Blanc, P., Frischknecht, R., Stolz, P., Durand, Y., Heath, G., Ménard, L., and Blanc, I. 2017. ENVI-PV: an interactive Web Client for multi-criteria life cycle assessment of photovoltaic systems worldwide. Prog. Photovolt: Res. Appl., 25: 484–498. doi: 10.1002/pip.2841.	Mono-c-Si, multi-c-Si, µm-Si, CdTe, CIGS	Cumulative energy demand, human toxicity, freshwater ecotoxicity, land use, particulate matter, carbon footprint
A. Rashedi and T. Khanam. 2020. Life cycle assessment of most widely adopted solar photovoltaic energy technologies by mid-point and end-point indicators of ReCiPe method. Environmental Science and Pollution Research. https://doi.org/10.1007/s11356-020-09194-1	Mono-c-Si, multi-c-Si, a-Si, CdTe	CO_2, PM, O_3, water, acidification, eutrophication, human toxicity, ecotoxicity, ionising radiation, land use, resource depletion
Seitz, M., M. Kroban, T. Pitschke, and S. Kriebe. 2013. Eco-Efficiency Analysis of Photovoltaic Modules, Bifa Environmental Institute on behalf of Bavarian State Ministry of the Environment and Consumer Protection. http://www.bifa.de/en/news/detail-view/news/bifa-text-no-62-ecoefficiency-analysis-of-photovoltaic-modules	Mono-c-Si, multi-c-Si, CdTe, CIS	Ecology index based on carbon footprint, acidification, resource use, human toxicity, photochemical ozone creation, terrestrial eutrophication, ecotoxicity

Publication	**PV technologies**	**Life cycle impact categories**
Sinha, P., M. de Wild-Scholten, A. Wade, C. Breyer. 2013. Total Cost Electricity Pricing of Photovoltaics. 28th EU PVSEC, Paris, France, pp. 4583 - 4588. DOI: 10.4229/28thEUPVSEC2013-6DO.10.4.	Multi-c-Si, CdTe	SO_2, NOx, CO_2, Hg, Cd, Pb, NMVOC, $PM_{2.5}$, water, total social cost
Stolz, P., R. Frischknecht, F. Wyss, and M. de Wild-Scholten, “PEF screening report of electricity from photovoltaic panels in the context of the EU Product Environmental Footprint Category Rules (PEFCR) Pilots, v. 2.0,” treeze Ltd. and SmartGreenScans, Uster, Switzerland, 2016. http://ec.europa.eu/environment/eussd/smgp/ef_pilots.htm#pef	Mono-c-Si, multi-c-Si, µm-Si, CdTe, CIGS	CO_2, PM, O_3, water, land use, ecosystem health, human health, acidification, eutrophication, resource depletion, cumulative energy demand, nuclear waste
P. Stolz, R. Frischknecht, G. Heath, K. Komoto, J. Macknick, P. Sinha, A. Wade, 2017, Water Footprint of European Rooftop Photovoltaic Electricity based on Regionalised Life Cycle Inventories, IEA PVPS Task 12, International Energy Agency Power Systems Programme, Report IEA-PVPS T12-11:2017	Mono-c-Si, CdTe, reservoir hydro, hard coal, nuclear	Water withdrawal, water consumption, water stress
UNEP. 2015. Summary for Policymakers, Green Energy Choices: The Benefits, Risks and Trade-Offs of Low-Carbon Technologies for Electricity Production. http://web.unep.org/ourplanet/march-2016/unep-publications/green-energy-choices-benefits-risks-and-trade-offs-low-carbon	Multi-c-Si, CdTe, CIGS	Carbon footprint, human health (ionizing radiation, photochemical oxidant formation, particulate matter, human toxicity, ozone depletion), ecosystems (freshwater ecotoxicity, freshwater eutrophication, marine ecotoxicity, terrestrial acidification, terrestrial ecotoxicity), land occupation, resource use
Wade A., Stolz P, Frischknecht R, Heath G, and Sinha P. The Product Environmental Footprint (PEF) of photovoltaic modules—Lessons learned from the environmental footprint pilot phase on the way to a single market for green products in the European Union. Prog Photovolt Res Appl. 2017;1–12. https://doi.org/10.1002/pip.2956	Mono-c-Si, multi-c-Si, µm-Si, CdTe, CIGS	CO_2, PM, O_3, water, land use, ecosystem health, human health, acidification, eutrophication, resource depletion, cumulative energy demand, nuclear waste
de Wild-Scholten, M. 2013. Energy payback time and carbon footprint of commercial photovoltaic systems. Solar Energy Materials & Solar Cells 119: 296–305. http://dx.doi.org/10.1016/j.solmat.2013.08.037	Mono-c-Si, multi-c-Si, a-Si, µm-Si, CdTe, CIGS	Energy payback time, carbon footprint

2 LIFE CYCLE INVENTORIES

The life cycle inventory phase of LCA involves data compilation of materials and energy inputs, and emissions and product outputs for the complete life cycle of the system under analysis. For PV LCA, these data are separately collected or modeled for the PV modules and the balance of system (BOS).

2.1 PV modules

The material and energy inputs and outputs during the manufacturing of PV modules (multi-c-Si, mono-c-Si, thin-film CdTe, thin-film CIGS PV, and thin-film perovskite silicon tandem) were obtained from PV production plants. Module efficiency values were taken from the Fraunhofer ISE Photovoltaics Report [5].

The typical thickness of multi- and mono-Si PV wafer is 180 and 170 µm, respectively; 60 individual cells of 243 cm^2 (156 mm x156 mm) are assumed to comprise a module of 1.6 m^2 for all c-Si PV types. Whereas a variety of cell architectures and module sizes exist in the current PV market, life cycle inventory data for cell, laminate and panel production are normalized per unit area (m^2). The conversion efficiency of multi- and mono-Si module is taken as 18.0%, and 19.5%, respectively [5]. For thin film PV, as of 2015, First Solar manufactured frameless, double-glass, CdTe PV modules of 1.2 m by 0.6 m, which are rated at 15.5% conversion efficiency with ~3 µm thick active layer. In 2017-2018, conversion efficiency increased to 17.5% for framed, double-glass CdTe modules of 2.005 m by 1.230 m with ~3 µm thick active layer. They are now at 18% conversion efficiency [5], which is used in this LCI report. The CIGS panel efficiency is at 15-17% [5] and taken as 16% in this LCI report. Although beyond the scope of this report, mono-Si modules based on passivated emitter and rear contact (PERC), heterojunction (HJT), and interdigitated back contact (IBC) technology can have conversion efficiency of ≥ 20% [5].

2.1.1 Crystalline–Si PV

Key parameters of the LCI of crystalline silicon module supply chain covering polycrystalline silicon feedstock purification, crystallization, wafering, cell processing, and module assembly have been updated using relevant public information [2][6][7], as presented in Section 3.2 of this report.

The metallurgical-grade silicon that is extracted from quartz is purified into solar-grade polysilicon by either a silane (SiH_4) or trichlorosilane ($SiHCl_3$)-based process. The energy requirement for this purification step is significant for crystalline Si PV modules. The Siemens reactor method accounts for the majority of solar-grade silicon production, in which silane- or trichlorosilane-gas is introduced into a thermal decomposition furnace (reactor) with high temperature (~1100-1200 °C) polysilicon rods. The silicon rods grow as silicon atoms in the gas deposit onto them, up to 150 mm in diameter and up to 150 cm in length.

Most silicon modules need an aluminium frame of 2.1 kg per m^2 for structural robustness and easy installation, while a glass backing performs the same functions for frameless PV modules.

2.1.2 CdTe PV

The LCI data were obtained at First Solar's CdTe PV manufacturing plants in Perrysburg, OH and Kulim, Malaysia for the periods of 2015 (Series 4) and 2017-2018 (Series 6) [8]. The CdTe PV module electricity conversion efficiency was 15.5% in 2015, 17.5% in 2017-2018, and 18% in 2019. The cadmium telluride (CdTe) absorber layer in First Solar's production scheme is laid down by vapor transport deposition (VTD), based on subliming the powders and condensing the vapors on glass substrates. A stream of inert carrier gas guides the sublimed dense vapor cloud to deposit the films on glass substrates at 500–600 °C. Depositing layers of common metals followed by series of scribing and heat treatment forms interconnections and back contacts.

2.1.3 CIGS PV

Data on material, energy consumption and emissions for CIGS PV manufacturing in Europe (Germany) for the status of 2010 was obtained in the previous version of this report from life cycle inventory data published by Jungbluth et al [9] updated by de Wild-Scholten [10]. Further updates to CIGS PV LCI have not been made in this report.

2.1.4 Perovskite silicon tandem PV

The LCI data were obtained from the European research project "Production technology to achieve low Cost and Highly Efficient photovoltaic Perovskite Solar cells" (CHEOPS). De Wild-Scholten [11] performed screening level life cycle assessment of production a perovskite silicon tandem PV panel based on primary data provided by Oxford Photovoltaics Ltd. for a factory located in Germany. The analysed perovskite silicon tandem modules are still in development and not yet produced at a commercial scale. The screening level assessment is based on PV panel area of 1.6 m^2 comprising 6 x 10 mono-crystalline silicon cells each with a size of 156 mm x 156 mm. The perovskite composition is made of lead-iodide (PbI_2) and methylammonium iodide (CH_3NH_3I). The panel is completed by a double glazing. The module frame is made of aluminium. As the panel under study is under development there are so far no estimations of panel efficiency and lifetime which would be needed to assess the environmental impacts per kWh PV electricity.

2.2 Balance of System (BOS)

Depending on the application, solar cells are either rooftop- or ground-mounted, both operating with a respective balance of system (BOS). For a rooftop PV application, the BOS typically includes inverters, mounting structures, cable, and connectors. Large-scale ground-mounted PV installations require additional equipment and facilities, such as grid connections, office facilities, and concrete. Note that depending on size and location, some ground-mounted PV installations may not have on-site office facilities.

2.2.1 Mounting structures

Life cycle inventory datasets of the following types of photovoltaic mounting systems are established in compliance with the ecoinvent data quality guidelines (v2) [12] as part of the Swiss contribution to the IEA PVPS Task 12:

- Mounting on façade
- Integrating in façade
- Mounting on flat roof
- Mounting on slanted roof
- Integrating in slanted roof
- Mounting on open ground

The inventory data are based on manufacturer information and literature. The amount of materials of each type of mounting system is weighted based on the average mass per type published by Jungbluth et al. [9]. The inventory data in this report are slightly simplified and do not reflect one-to-one the original ecoinvent datasets. In case of any uncertainties, it is recommended to apply the original ecoinvent datasets.

2.2.2 Complete roof-top BOS

The LCI data of BOS components for year 2006 was collected by the project "Technologie- en Milieuverkenningen" with ECN project number 7.4750 financed by the Ministry of Economic Affairs, the Netherlands. De Wild-Scholten et al. [13] studied two classes of rooftop mounting systems based on a mc-Si PV system called SolarWorld SW220 with dimensions of 1001 mm x 1675 mm, 220 Wp: they are used for on-roof mounting where the system builds on existing roofing material, and in-roof mounting where the modules replace the roof tiles. The latter case is credited in terms of energy and materials use because roof tile materials then are not required. Section 3.7 details the LCI of several rooftop mounting systems, cabling, and inverters. Four types (2.5 kW, 5 kW, 10 kW, and 20 kW) of small inverters adequate for rooftop PV design were recently inventoried by Tschümperlin et al [14].

2.2.3 Complete ground mount BOS

An analysis of a large PV installation at the Springerville Generating Station in Arizona, USA [15] affords a detailed materials- and energy-balance for a ground-mounted BOS. The Springerville PV plant at the time of data collection had 4.6 MWp of installed PV modules, of which 3.5 MW were mc-Si PV modules. For this study, Tucson Electric Power (TEP) prepared the BOS bill of materials- and energy-consumption data for their multi-Si PV installations. The life expectancy of the PV metal support structures is assumed to be 60 years. Inverters and transformers are considered to last for 30 years, but parts must be replaced every 10 years, amounting to 10% of their total mass, according to well-established data from the power industry on transformers and electronic components. The inverters are utility-scale, Xantrex PV-150 models with a wide-open frame, allowing failed parts to be easily replaced. The life-cycle inventory includes the office facility's materials and energy use for administrative, maintenance, and security staff, as well as the operation of maintenance vehicles. Aluminum frames are shown separately, since they are part of the module, not of the BOS inventory; note there are both framed and frameless modules on the market.

2.3 Medium-Large PV Installations in Europe

Within the framework of the UVEK LCA database DQRv2:2018 [16] and the Swiss contribution to the IEA PVPS Task 12, life cycle inventory datasets of the following real photovoltaic installations are established:

- 93 kWp slanted-roof installation, single-Si laminates, Switzerland
- 280 kWp flat-roof installation, single-Si panels, Switzerland
- 156 kWp flat-roof installation, multi-Si panels, Switzerland
- 1.3 MWp slanted-roof installation, multi-Si panels, Switzerland
- 324 kWp flat-roof installation, single-Si panels, Germany
- 450 kWp flat- roof installation, single-Si panels, Germany
- 569 kWp open ground installation, multi-Si panels, Spain
- 570 kWp open ground installation, multi-Si panels, Spain

The inventory data are based on information from installers, operators, and literature [17]. The inventories can be combined with information about mounting systems and Si PV modules presented in this report. The inventory data in this report are slightly simplified and do not reflect one-to-one the original ecoinvent datasets. In case of any uncertainties it is recommended to apply the original ecoinvent datasets.

2.4 Country-specific photovoltaic mixes

Life cycle inventory datasets of 33 country-specific photovoltaic electricity mixes are established within the Swiss contribution to the IEA PVPS Task 12. These are based on national and international statistics and estimations about the shares of different module technologies; the shares of different mounting systems, the share of centralized/decentralized installations, and country specific electricity yields that are dependent on solar irradiation [17], with updates provided in section 3.10.

3 LIFE CYCLE INVENTORY DATA

These data update those in section 3 of the report:
R. Frischknecht, R. Itten, P. Sinha, M. de Wild-Scholten, J. Zhang, V. Fthenakis, H. C. Kim, M. Raugei, M. Stucki, 2015, Life Cycle Inventories and Life Cycle Assessment of Photovoltaic Systems, International Energy Agency (IEA) PVPS Task 12, Report T12-04:2015.

Updated life cycle inventory data tables are provided in section 3, with electronic versions available at IEA PVPS (http://www.iea-pvps.org; select Task 12 under Archive) and treeze Ltd (http://treeze.ch; under Publications). Updates are provided for crystalline Si supply chain (Section 3.2), thin film CdTe PV module manufacturing (Section 3.3), perovskite silicon tandem PV manufacturing (Section 3.5), PV recycling (Section 3.6), low power (2.5-20 kW) inverters and Li-ion battery storage (Section 3.8), country-specific PV mixes (Section 3.10), and water usage (Section 3.12).

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Updated life cycle inventory data tables are provided here with electronic versions available at IEA PVPS (http://www.iea-pvps.org; select Task 12 under Archive) and treeze Ltd (http://treeze.ch; under Publications).

3.1 Bill of materials and country specific annual yield

Table 2 shows the bill of materials and the panel efficiency of single crystalline and multi-crystalline silicon, CdTe and CIGS PV panels as modelled in this LCI report. Table 3 shows country specific annual average yields from the life cycle assessment of national PV electricity mixes described in section 3.10.

Table 2: Bill of materials and panel efficiency of single crystalline and multi-crystalline silicon, CdTe and CIGS PV panels; adapted and updated from [1]

Material			Photovoltaic module (laminate/unframed and panel/framed)			
			Mono-Si	Multi-Si	CI(G)S	CdTe
Source			PVPS Task 12 2020	PVPS Task 12 2020	Jungbluth et al. 2012	PVPS Task 12 2020
Laminate/unframed	**Subtotal wafer / semiconductor**		**5.20%**	**5.58%**	**0.06%**	**0.15%**
	Wafer / semiconductor	silicon for photovoltaics	5.20%	5.58%	0.00%	0.00%
		silane, at plant	0.00%	0.00%	0.00%	0.00%
		indium	0.00%	0.00%	0.02%	0.00%
		cadmium telluride	0.00%	0.00%	0.00%	0.14%
		cadmium sulphide	0.00%	0.00%	0.00%	0.00%
		gallium	0.00%	0.00%	0.01%	0.00%
		selenium	0.00%	0.00%	0.04%	0.00%
	Subtotal metals		**1.47%**	**1.46%**	**0.55%**	**0.09%**
	Metals	aluminium	0.38%	0.38%	0.00%	0.00%
		aluminium, production mix	0.00%	0.00%	0.30%	0.00%
		aluminium alloy	0.00%	0.00%	0.00%	0.00%
		copper	0.93%	0.93%	0.07%	0.08%
		lead	0.01%	0.01%	0.00%	0.00%
		molybdenum	0.00%	0.00%	0.04%	0.00%
		silver	0.03%	0.03%	0.00%	0.00%
		steel	0.00%	0.00%	0.00%	0.00%
		chromium steel	0.00%	0.00%	0.00%	0.01%
		tin	0.12%	0.12%	0.08%	0.00%
		zinc oxide	0.00%	0.00%	0.06%	0.00%
		brazing solder	0.00%	0.00%	0.00%	0.00%
		soft solder	0.00%	0.00%	0.00%	0.00%
	Subtotal plastics		**13.41%**	**13.35%**	**12.20%**	**3.28%**
	Plastics	ethylvinylacetate	7.94%	7.90%	5.05%	2.38%
		polyvinylfluoride film	1.01%	1.01%	0.00%	0.00%
		polyvinylbutyral foil	0.00%	0.00%	1.27%	0.00%
		polyphenylene sulfide	0.00%	0.00%	0.58%	0.00%
		polyethylene terephthalate, PET	3.13%	3.12%	2.26%	0.00%
		polyethylene, HDPE	0.22%	0.21%	0.33%	0.00%
		packaging film, LDPE	0.00%	0.00%	0.00%	0.00%
		glass fibre reinforced plastic, polyamide	0.00%	0.00%	0.00%	0.67%
		silicone product	1.11%	1.10%	2.72%	0.23%
		synthetic rubber	0.00%	0.00%	0.00%	0.00%
	Subtotal solar glass		**79.93%**	**79.61%**	**87.19%**	**96.48%**
	Solar glass	flat glass	0.00%	0.00%	35.43%	46.75%
		solar glass	79.93%	79.61%	51.76%	49.73%
Panel/ frame	**Subtotal metals panel**		**19.27%**	**19.20%**	**14.79%**	**2.03%**
	Metals	aluminium alloy	19.27%	19.20%	14.79%	2.03%
Total laminate/unframed			**100.00%**	**100.00%**	**100.00%**	**100.00%**
Total panel/framed			**119.27%**	**119.20%**	**114.79%**	**102.03%**
Total weight in kg per square meter of unframed module			**11.0**	**11.1**	**14.9**	**16.0**
Rated power in Wp per square meter of module			**195**	**180**	**160**	**180**
Module efficiency in percent			**19.5%**	**18.0%**	**16.0%**	**18.0%**
Module area for 3kWp PV systems in square meter			**15.4**	**16.7**	**18.8**	**16.7**
Module area for 570kWp PV systems in square meter			**2923**	**3167**	**3563**	**3167**

Table 3: Country specific annual average yields

Country	Avg. Irradiation fixed optimally tilted (pop-weighted)	Average Yield	Yield rooftop	Yield façade	Yield centralized
	kWh/(m²a)	kWh/(kWp·a)	kWh/(kWp·a)	kWh/(kWp·a)	kWh/(kWp·a)
Australia	1'914	1'254	1'240	868	1'314
Austria	1'389	1'042	1'044	731	1'111
Belgium	1'203	913	908	635	962
Canada	1'554	1'216	1'173	821	1'243
Chile	2'124	1'698	1'603	1'122	1'699
China	1'631	1'010	971	679	1'029
Czech Republic	1'251	962	944	661	1'001
Denmark	1'287	982	971	680	1'030
Finland	1'181	886	891	624	945
France	1'441	988	968	678	1'026
Germany	1'222	932	922	645	978
Greece	1'753	1'348	1'323	926	1'402
Hungary	1'445	1'111	1'090	763	1'156
Ireland	1'055	811	796	557	844
Israel	2'247	1'754	1'695	1'187	1'798
Italy	1'720	1'340	1'298	908	1'376
Japan	1'578	1'041	1'024	717	1'086
Korea	1'770	1'187	1'129	790	1'197
Luxembourg	n.a.	913	908	635	962
Malaysia	1'766	1'380	1'332	933	1'413
Mexico	2'136	1'694	1'612	1'128	1'709
Netherlands	1'242	961	937	656	994
New Zealand	1'644	1'255	1'240	868	1'315
Norway	1'103	827	832	583	882
Portugal	1'891	1'480	1'427	999	1'513
South Africa	2'166	1'717	1'634	1'144	1'733
Spain	1'886	1'503	1'423	996	1'509
Sweden	1'218	916	919	643	974
Switzerland	1'467	975	976	683	1'040
Thailand	1'903	1'506	1'436	1'005	1'522
Turkey	1'839	1'471	1'388	971	1'471
United Kingdom	1'128	864	848	593	899
USA	1'796	1'448	1'401	981	1'485

3.2 Crystalline Si PV

3.2.1 Description of the supply chain

Figure 2 shows the supply chain of photovoltaic electricity production according to Jungbluth et al. [9]. The already existing supply chains for Europe and China are extended with two more world regions, namely North America (US) and Asia & Pacific (APAC). Furthermore, world markets are introduced on the level of the production of polysilicon, the wafer production and the panel production. Additional descriptions of specific manufacturers in the crystalline Si PV supply chain and their manufacturing processes are available in de Wild-Scholten [10].

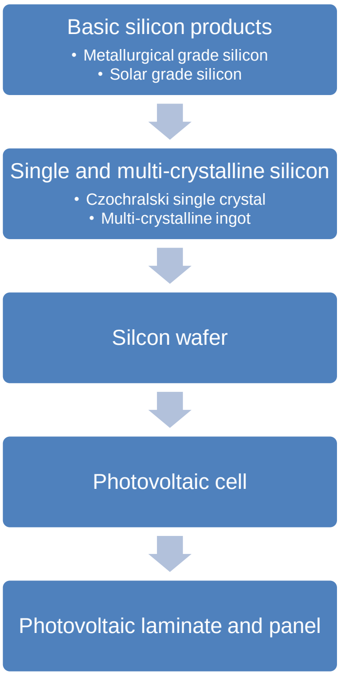
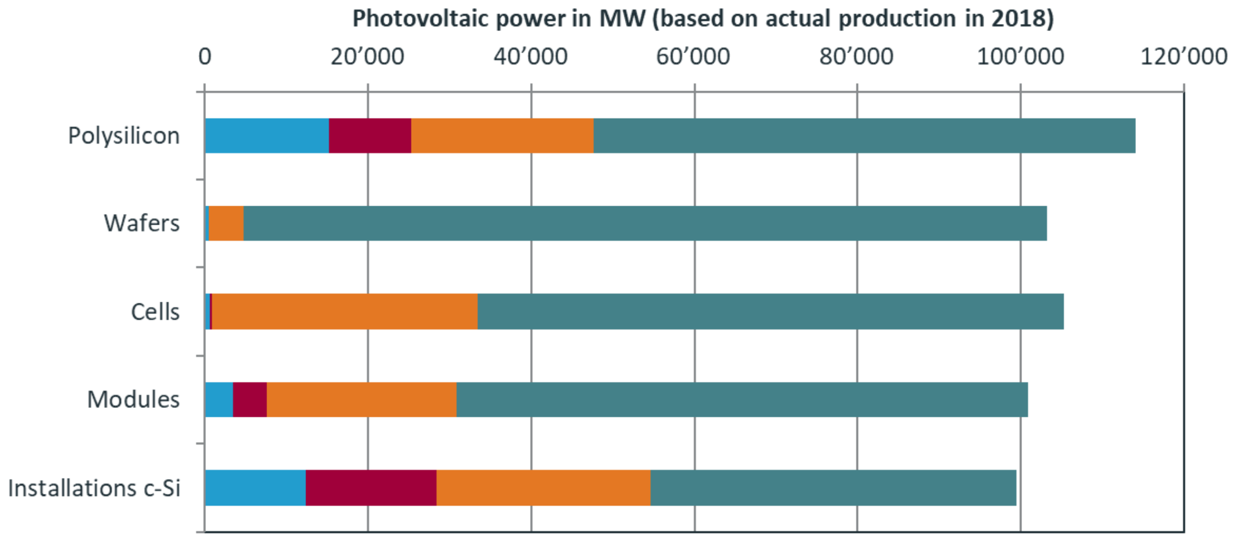


Figure 2: Supply chain of silicon-based photovoltaic electricity production

3.2.2 Market Mixes

Figure 3 shows the market shares of the four world regions on the different levels of the supply chain in 2018. The production is given in MW of PV power and based on the 2019 market report of IHS Markit. The amount of silicon in metric tons is converted to MW based on an average consumption of about 3'910 kg of polysilicon per MW of photovoltaic power capacity.

The polysilicon production is spread rather evenly across the four world regions with China having the highest share. China and Asia & Pacific (APAC) contribute about 78 % to the world market of polysilicon. Wafers, cells and modules are mainly produced in China (with shares of 95.5 %, 68.3 % and 69.5 %, respectively of the world production) and in APAC (with shares of 4.1 %, 30.8 % and 23.0 %, respectively of the world production). Europe and the Americas produce about 3.4 % and 4.1 % of the PV modules, respectively. In contrast to production, which mainly takes place in Asia, nearly 29 % of the crystalline silicon photovoltaic modules are installed in Europe (12.5 %) and the Americas (16.1 %).The largest share is mounted in China (45.1 %), and in APAC (26.4 %).



	Installations c-Si	Modules	Cells	Wafers	Polysilicon
Europe	12'383	3'468	582	455	15'244
Americas	16'004	4'103	308	0	10'105
Asia & Pacific	26'204	23'245	32'483	4'225	22'304
China	44'847	70'120	71'996	98'546	66'434

Figure 3: Market shares in 2018 of the four world regions on polysilicon, wafer production, crystalline silicon cells and modules manufacture, and installed crystalline silicon modules, in MW power capacity

Tables 2-4 show the supply volumes and market shares derived from the information shown in Figure 3. Note the column headers indicate the location of use, and the rows show the region of production. The market shares are determined with the simplifying assumption that production volumes in Europe, the Americas, and APAC are fully absorbed by the subsequent production step in the same region. Furthermore, it is assumed that the missing supply volumes are imported from China first and then from APAC. Excess production is shipped to China in case of polysilicon and to the European Market in case of the (installed) modules.

Table 4a shows the supply volumes and market mixes of polysilicon used in wafer production in China, the Americas, APAC and Europe. All regions except China rely on their own production. The Chinese polysilicon supply mix corresponds to the surplus production volumes from the other regions available for export after covering their domestic demand. China covers 61 % of its demand by domestic production.

Table 4a: Supply volumes (domestic production and imports) and market mixes in 2018 of polysilicon used in wafer production in China, the Americas, Asia and Pacific and Europe, and wafer production volumes as reported by IHS Markit

Polysilicon Production	China		Asia & Pacific		Americas		Europe	
2018	MW	%	MW	%	MW	%	MW	%
China	66'434	61.0%	0	0.0%	0	0.0%	0	0.0%
Asia & Pacific	17'634	16.2%	4'670	100.0%	0	0.0%	0	0.0%
Americas	10'105	9.3%	0	0.0%	0	100.0%	0	0.0%
Europe	14'741	13.5%	0	0.0%	0	0.0%	503	100.0%
Total	**108'915**	**100.0%**	**4'670**	**100.0%**	**0**	**100.0%**	**503**	**100.0%**

Table 4b shows the supply volumes and market mixes of wafers used in cell production in China, the Americas, APAC, and Europe. All wafers required in Chinese cell production are produced domestically. One third of the American wafer demand (as a feedstock to cell production in the Americas) is covered by American production. The remaining two thirds are imported from China. Three quarter of the wafer demand in APAC are covered by domestic production. The remaining quarter is imported from China. In Europe, wafer production covers 79.8 % of the demand. 20.2 % of the European wafer demand is imported from China to complement the domestic supply.

Table 4b: Supply volumes (domestic production and imports) and market mixes in 2018 of wafers used in cell production in China, the Americas, Asia and Pacific and in Europe and production volume of cells

Wafer Production	China		Asia & Pacific		Americas		Europe	
2018	MW	%	MW	%	MW	%	MW	%
China	70'532	100.0%	27'597	86.7%	302	100.0%	115	20.2%
Asia & Pacific	0	0.0%	4'225	13.3%	0	0.0%	0	0.0%
Americas	0	0.0%	0	0.0%	0	0.0%	0	0.0%
Europe	0	0.0%	0	0.0%	0	0.0%	455	79.8%
Total	**70'532**	**100.0%**	**31'822**	**100.0%**	**302**	**100.0%**	**570**	**100.0%**

Table 5a shows the supply volumes and market mixes of Si cells produced in China, the Americas, APAC and Europe. Cells are produced in China (68.3 %), Asia & Pacific (30.8 %), and Europe and the Americas (less than 1 %). Asia & Pacific covers a large share of the cell demand in the Americas (92.8 %) and Europe (83.9 %). More than 98 % of the Chinese demand is covered domestically.

Table 5a: Supply volumes (domestic production and imports) and market mixes in 2018 of cells produced in China, the Americas, Asia and Pacific and Europe

c-Si Cell Production	China		Asia & Pacific		Americas		Europe	
2018	MW	%	MW	%	MW	%	MW	%
China	71'996	98.4%	0	0.0%	0	0.0%	0	0.0%
Asia & Pacific	1'204	1.6%	24'266	100.0%	3'975	92.8%	3'038	83.9%
Americas	0	0.0%	0	0.0%	308	7.2%	0	0.0%
Europe	0	0.0%	0	0.0%	0	0.0%	582	16.1%
Total	**73'200**	**100.0%**	**24'266**	**100.0%**	**4'283**	**100.0%**	**3'620**	**100.0%**

Table 5b shows the supply volumes and market mixes of panels installed in China, the Americas, APAC and Europe. Panels installed in Europe are produced in China (72.4 %) and Europe (27.6 %). All panels installed in China are produced domestically. 7 out of 8 panels installed in APAC region is imported from China. In the Americas and in Europe about one quarter of the installed modules are produced domestically, the rest is imported from China.

Table 5b: Supply volumes (domestic production and imports) and market mixes in 2018 of panels installed in China, the Americas, Asia and Pacific and Europe

c-Si Module Production	China		Asia & Pacific		Americas		Europe	
2018	MW	%	MW	%	MW	%	MW	%
China	45'523	100.0%	3'354	12.6%	12'142	74.7%	9'102	72.4%
Asia & Pacific	0	0.0%	23'245	87.4%	0	0.0%	0	0.0%
Americas	0	0.0%	0	0.0%	4'103	25.3%	0	0.0%
Europe	0	0.0%	0	0.0%	0	0.0%	3'468	27.6%
Total	**45'523**	**100.0%**	**26'599**	**100.0%**	**16'245**	**100.0%**	**12'570**	**100.0%**

3.2.3 General Approach

Key parameters of the existing datasets describing the PV supply chain in Europe, China, the Americas and APAC [19] have been updated. The electricity consumption on all process levels is modelled with specific electricity mixes corresponding to these world regions. The supply chains of the regions are modelled based on the market shares described in Section 3.2.2. Water use and consumption is modelled using country specific elementary flows. This allows for a regionalised assessment of water scarcity. All other inputs and outputs are not changed because of lacking information about the material, energy, and environmental efficiencies of the production in the different world regions.

3.2.4 Basic Silicon Products

Basic Silicon Products

The first stage in the photovoltaic supply chain is the production of metallurgical grade silicon (MG-silicon). Table 6 shows the unit process data of the MG-Silicon production in Europe (NO), China (CN), North America (US) and Asia & Pacific (APAC). European MG-silicon factories are located in Norway, which implies use of the Norwegian electricity mix. The South Korean electricity mix is selected for the APAC region, because South Korea produces the highest share of MG-Silicon in the APAC region. The US electricity mix is used to model electricity consumption in the North American production.

Data about material and energy consumption as well as about emissions correspond to the life cycle inventory data of MG-silicon published by Frischknecht et al. [19].

Table 6: Unit process LCI data of MG-Silicon production in Europe (NO), China (CN), North America (US) and Asia & Pacific (APAC)

	Name	Location	InfrastructureProcess	Unit	MG-silicon, at plant	MG-silicon, at plant	MG-silicon, at plant	MG-silicon, at plant	UncertaintyType	StandardDeviation95%	GeneralComment
	Location				NO	CN	US	APAC			
	InfrastructureProcess				0	0	0	0			
	Unit				kg	kg	kg	kg			
product	MG-silicon, at plant	NO	0	kg	1	0	0	0			
	MG-silicon, at plant	CN	0	kg	0	1	0	0			
	MG-silicon, at plant	US	0	kg	0	0	1	0			
	MG-silicon, at plant	APAC	0	kg	0	0	0	1			
technosphere	electricity, medium voltage, at grid	NO	0	kWh	1.10E+1	0	0	0	1	1.22	(2,2,4,1,1,3); Literature, lower range to account for heat recovery
	electricity, medium voltage, at grid	CN	0	kWh	0	1.10E+1	0	0	1	1.22	(2,2,4,1,1,3); Literature, lower range to account for heat recovery
	electricity, medium voltage, at grid	US	0	kWh	0	0	1.10E+1	0	1	1.22	(2,2,4,1,1,3); Literature, lower range to account for heat recovery
	electricity, medium voltage, at grid	KR	0	kWh	0	0	0	1.10E+1	1	1.22	(2,2,4,1,1,3); Literature, lower range to account for heat recovery
	wood chips, production mix, wet, measured as dry mass, at forest road & at sawmill	RER	0	kg	3.25E-3	3.25E-3	3.25E-3	3.25E-3	1	1.22	(2,2,4,1,1,3); Literature, 1.35 kg
	hard coal coke, at plant	RER	0	MJ	2.31E+1	2.31E+1	2.31E+1	2.31E+1	1	1.22	(2,2,4,1,1,3); Literature, coal
	graphite, at plant	RER	0	kg	1.00E-1	1.00E-1	1.00E-1	1.00E-1	1	1.22	(2,2,4,1,1,3); Literature, graphite electrodes
	charcoal, at plant	GLO	0	kg	1.70E-1	1.70E-1	1.70E-1	1.70E-1	1	1.22	(2,2,4,1,1,3); Literature
	petroleum coke, at refinery	RER	0	kg	5.00E-1	5.00E-1	5.00E-1	5.00E-1	1	1.22	(2,2,4,1,1,3); Literature
	silica sand, at plant	DE	0	kg	2.70E+0	2.70E+0	2.70E+0	2.70E+0	1	1.22	(2,2,4,1,1,3); Literature
	oxygen, liquid, at plant	RER	0	kg	2.00E-2	2.00E-2	2.00E-2	2.00E-2	1	1.60	(3,4,5,3,1,5); Literature
	disposal, slag from MG silicon production, 0% water, to inert material landfill	CH	0	kg	2.50E-2	2.50E-2	2.50E-2	2.50E-2	1	1.22	(2,2,4,1,1,3); Literature
	silicone plant	RER	1	unit	1.00E-11	1.00E-11	1.00E-11	1.00E-11	1	3.09	(1,2,4,1,3,3); Estimation
	transport, transoceanic freight ship	OCE	0	tkm	2.55E+0	2.55E+0	2.55E+0	2.55E+0	1	2.09	(4,5,na,na,na,na); Charcoal from Asia 15000km
	transport, freight, lorry, fleet average	RER	0	tkm	1.56E-1	1.56E-1	1.56E-1	1.56E-1	1	2.09	(4,5,na,na,na,na); Standard distance 50km, 20km for sand
	transport, freight, rail	RER	0	tkm	6.90E-2	6.90E-2	6.90E-2	6.90E-2	1	2.09	(4,5,na,na,na,na); Standard distance 100km
emission air, low population density	Heat, waste	-	-	MJ	7.13E+1	7.13E+1	7.13E+1	7.13E+1	1	1.22	(2,2,4,1,1,3); Calculation based on fuel and electricity use minus 25 MJ/kg
	Arsenic	-	-	kg	9.42E-9	9.42E-9	9.42E-9	9.42E-9	1	5.34	(3,4,5,3,1,5); Literature, in dust
	Aluminium	-	-	kg	1.55E-6	1.55E-6	1.55E-6	1.55E-6	1	5.34	(3,4,5,3,1,5); Literature, in dust
	Antimony	-	-	kg	7.85E-9	7.85E-9	7.85E-9	7.85E-9	1	5.34	(3,4,5,3,1,5); Literature, in dust
	Boron	-	-	kg	2.79E-7	2.79E-7	2.79E-7	2.79E-7	1	5.34	(3,4,5,3,1,5); Literature, in dust
	Cadmium	-	-	kg	3.14E-10	3.14E-10	3.14E-10	3.14E-10	1	5.34	(3,4,5,3,1,5); Literature, in dust
	Calcium	-	-	kg	7.75E-7	7.75E-7	7.75E-7	7.75E-7	1	5.34	(3,4,5,3,1,5); Literature, in dust
	Carbon monoxide, biogenic	-	-	kg	6.20E-4	6.20E-4	6.20E-4	6.20E-4	1	5.34	(3,4,5,3,1,5); Literature
	Carbon monoxide, fossil	-	-	kg	1.38E-3	1.38E-3	1.38E-3	1.38E-3	1	5.34	(3,4,5,3,1,5); Literature
	Carbon dioxide, biogenic	-	-	kg	1.61E+0	1.61E+0	1.61E+0	1.61E+0	1	1.22	(2,2,4,1,1,3); Calculation, biogenic fuels
	Carbon dioxide, fossil	-	-	kg	3.58E+0	3.58E+0	3.58E+0	3.58E+0	1	1.22	(2,2,4,1,1,3); Calculation, fossil fuels
	Chromium	-	-	kg	7.85E-9	7.85E-9	7.85E-9	7.85E-9	1	5.34	(3,4,5,3,1,5); Literature, in dust
	Chlorine	-	-	kg	7.85E-8	7.85E-8	7.85E-8	7.85E-8	1	1.85	(3,4,5,3,1,5); Literature
	Cyanide	-	-	kg	6.87E-6	6.87E-6	6.87E-6	6.87E-6	1	1.85	(3,4,5,3,1,5); Estimation
	Fluorine	-	-	kg	3.88E-8	3.88E-8	3.88E-8	3.88E-8	1	1.85	(3,4,5,3,1,5); Literature, in dust
	Hydrogen sulfide	-	-	kg	5.00E-4	5.00E-4	5.00E-4	5.00E-4	1	1.85	(3,4,5,3,1,5); Estimation
	Hydrogen fluoride	-	-	kg	5.00E-4	5.00E-4	5.00E-4	5.00E-4	1	1.85	(3,4,5,3,1,5); Estimation
	Iron	-	-	kg	3.88E-6	3.88E-6	3.88E-6	3.88E-6	1	5.34	(3,4,5,3,1,5); Literature, in dust
	Lead	-	-	kg	3.44E-7	3.44E-7	3.44E-7	3.44E-7	1	5.34	(3,4,5,3,1,5); Literature, in dust
	Mercury	-	-	kg	7.85E-9	7.85E-9	7.85E-9	7.85E-9	1	5.34	(3,4,5,3,1,5); Literature, in dust
	NMVOC, non-methane volatile organic compounds, unspecified origin	-	-	kg	9.60E-5	9.60E-5	9.60E-5	9.60E-5	1	1.85	(3,4,5,3,1,5); Literature
	Nitrogen oxides	-	-	kg	9.74E-3	9.74E-3	9.74E-3	9.74E-3	1	1.58	(3,2,4,1,1,3); Calculation based on environmental report
	Particulates, > 10 um	-	-	kg	7.75E-3	7.75E-3	7.75E-3	7.75E-3	1	1.58	(3,2,4,1,1,3); Calculation based on environmental report
	Potassium	-	-	kg	6.20E-5	6.20E-5	6.20E-5	6.20E-5	1	5.34	(3,4,5,3,1,5); Literature, in dust
	Silicon	-	-	kg	7.51E-3	7.51E-3	7.51E-3	7.51E-3	1	5.34	(3,4,5,3,1,5); Literature, SiO2 in dust
	Sodium	-	-	kg	7.75E-7	7.75E-7	7.75E-7	7.75E-7	1	5.34	(3,4,5,3,1,5); Literature, in dust
	Sulfur dioxide	-	-	kg	1.22E-2	1.22E-2	1.22E-2	1.22E-2	1	1.24	(3,2,4,1,1,3); Calculation based on environmental report
	Tin	-	-	kg	7.85E-9	7.85E-9	7.85E-9	7.85E-9	1	5.34	(3,4,5,3,1,5); Literature, in dust

Solar grade silicon

Table 7 shows the unit process data of solar grade silicon production in Europe (RER), China (CN), North America (US) and Asia & Pacific (APAC). The South Korean electricity mix is selected for the APAC region, because South Korea produces the highest share of solar grade silicon in the APAC region. Electricity from hydro power and from the US grid is chosen to model electricity consumption in the North American production, since one of the most important North American producers mainly relies on hydroelectric power. The thermal energy demand is 8 kWh and the electricity demand is 49 kWh per kg [2].

All other data about material and energy consumption as well as about emissions correspond to the life cycle inventory data of solar grade silicon published in Frischknecht et al. [19].

Table 7: Unit process LCI data of solar grade silicon production in Europe (RER), China (CN), North America (US) and Asia & Pacific (APAC)

	Name	Location	InfrastructureProcess	Unit	silicon, solar grade, modified Siemens process, at plant	silicon, solar grade, modified Siemens process, at plant	silicon, solar grade, modified Siemens process, at plant	silicon, solar grade, modified Siemens process, at plant	UncertaintyType	StandardDeviation95%	GeneralComment
	Location				RER	CN	US	APAC			
	InfrastructureProcess				0	0	0	0			
	Unit				kg	kg	kg	kg			
product	silicon, solar grade, modified Siemens process, at plant	RER	0	kg	1	0	0	0			
	silicon, solar grade, modified Siemens process, at plant	CN	0	kg	0	1	0	0			
	silicon, solar grade, modified Siemens process, at plant	US	0	kg	0	0	1	0			
	silicon, solar grade, modified Siemens process, at plant	APAC	0	kg	0	0	0	1			
technosphere	MG-silicon, at plant	NO	0	kg	1.13E+0	0	0	0	1	1.23	(2,3,4,2,1,3); Literature
	MG-silicon, at plant	CN	0	kg	0	1.13E+0	0	0	1	1.23	(2,3,4,2,1,3); Literature
	MG-silicon, at plant	US	0	kg	0	0	1.13E+0	0	1	1.23	(2,3,4,2,1,3); Literature
	MG-silicon, at plant	APAC	0	kg	0	0	0	1.13E+0	1	1.23	(2,3,4,2,1,3); Literature
	hydrochloric acid, 30% in H2O, at plant	RER	0	kg	1.60E+0	1.60E+0	1.60E+0	1.60E+0	1	1.25	(3,3,4,2,1,3); de Wild 2007, share of NaOH, HCl and H2 estimated with EG-Si data
	hydrogen, liquid, at plant	RER	0	kg	5.01E-2	5.01E-2	5.01E-2	5.01E-2	1	1.25	(3,3,4,2,1,3); de Wild 2007, share of NaOH, HCl and H2 estimated with EG-Si data
	sodium hydroxide, 50% in H2O, production mix, at plant	RER	0	kg	3.48E-1	3.48E-1	3.48E-1	3.48E-1	1	1.25	(3,3,4,2,1,3); de Wild 2007, share of NaOH, HCl and H2 estimated with EG-Si data
	transport, freight, lorry, fleet average	RER	0	tkm	2.87E+0	2.87E+0	2.87E+0	2.87E+0	1	2.09	(4,5,na,na,na,na); Transport distance MG-Si: 2000 km; Chemicals: 100 km
	transport, freight, rail	RER	0	tkm	3.65E+0	3.65E+0	3.65E+0	3.65E+0	1	2.09	(4,5,na,na,na,na); Transport distance chemicals: 600 km
	electricity, at cogen 1MWe lean burn, allocation exergy	RER	0	kWh	1.75E+1	0	0	0	1	1.10	(2,3,1,2,1,3); Total electricity demand: 49 kWh/kg (IEA-PVPS Trends Report 2019)
	electricity, hydropower, at run-of-river power plant	RER	0	kWh	3.93E+0	0	1.18E+1	0	1	1.10	(2,3,1,2,1,3); Total electricity demand: 49 kWh/kg (IEA-PVPS Trends Report 2019)
	electricity, medium voltage, at grid	DE	0	kWh	2.23E+1	0	0	0	1	1.10	(2,3,1,2,1,3); Total electricity demand: 49 kWh/kg (IEA-PVPS Trends Report 2019)
	electricity, medium voltage, at grid	NO	0	kWh	5.37E+0	0	0	0	1	1.10	(2,3,1,2,1,3); Total electricity demand: 49 kWh/kg (IEA-PVPS Trends Report 2019)
	electricity, medium voltage, at grid	CN	0	kWh	0	4.90E+1	0	0	1	1.10	(2,3,1,2,1,3); Total electricity demand: 49 kWh/kg (IEA-PVPS Trends Report 2019)
	electricity, medium voltage, at grid	US	0	kWh	0	0	3.72E+1	0	1	1.10	(2,3,1,2,1,3); Total electricity demand: 49 kWh/kg (IEA-PVPS Trends Report 2019)
	electricity, medium voltage, at grid	KR	0	kWh	0	0	0	4.90E+1	1	1.10	(2,3,1,2,1,3); Total electricity demand: 49 kWh/kg (IEA-PVPS Trends Report 2019)
	heat, at cogen 1MWe lean burn, allocation exergy	RER	0	MJ	2.88E+1	2.88E+1	2.88E+1	2.88E+1	1	1.10	(2,3,1,2,1,3); Woodhouse et al. (2019): c-Si PV Manufacturing Costs 2018; IEA-PVPS Trends Report 2019
	silicone plant	RER	1	unit	1.00E-11	1.00E-11	1.00E-11	1.00E-11	1	3.05	(1,3,4,2,3,3); Estimation
emission air, high population density	Heat, waste	-	-	MJ	1.76E+2	1.76E+2	1.76E+2	1.76E+2	1	1.23	(2,3,4,2,1,3); Calculation
emission water, river	AOX, Adsorbable Organic Halogen as Cl	-	-	kg	1.26E-5	1.26E-5	1.26E-5	1.26E-5	1	1.68	(4,2,4,1,3,3); Environmental report 2002, average Si product
	BOD5, Biological Oxygen Demand	-	-	kg	2.05E-4	2.05E-4	2.05E-4	2.05E-4	1	1.68	(4,2,4,1,3,3); Environmental report 2002, average Si product
	COD, Chemical Oxygen Demand	-	-	kg	2.02E-3	2.02E-3	2.02E-3	2.02E-3	1	1.68	(4,2,4,1,3,3); Environmental report 2002, average Si product
	Chloride	-	-	kg	3.60E-2	3.60E-2	3.60E-2	3.60E-2	1	3.14	(4,2,4,1,3,3); Environmental report 2002, average Si product
	Copper	-	-	kg	1.02E-7	1.02E-7	1.02E-7	1.02E-7	1	3.14	(4,2,4,1,3,3); Environmental report 2002, average Si product
	Nitrogen	-	-	kg	2.08E-4	2.08E-4	2.08E-4	2.08E-4	1	1.68	(4,2,4,1,3,3); Environmental report 2002, average Si product
	Phosphate	-	-	kg	2.80E-6	2.80E-6	2.80E-6	2.80E-6	1	1.68	(4,2,4,1,3,3); Environmental report 2002, average Si product
	Sodium, ion	-	-	kg	3.38E-2	3.38E-2	3.38E-2	3.38E-2	1	5.16	(4,2,4,1,3,3); Environmental report 2002, average Si product
	Zinc	-	-	kg	1.96E-6	1.96E-6	1.96E-6	1.96E-6	1	5.16	(4,2,4,1,3,3); Environmental report 2002, average Si product
	Iron	-	-	kg	5.61E-6	5.61E-6	5.61E-6	5.61E-6	1	5.16	(4,2,4,1,3,3); Environmental report 2002, average Si product
	DOC, Dissolved Organic Carbon	-	-	kg	9.10E-4	9.10E-4	9.10E-4	9.10E-4	1	1.68	(4,2,4,1,3,3); Environmental report 2002, average Si product
	TOC, Total Organic Carbon	-	-	kg	9.10E-4	9.10E-4	9.10E-4	9.10E-4	1	1.68	(4,2,4,1,3,3); Environmental report 2002, average Si product

Silicon production mix

Nowadays 93.5% of polysilicon produced worldwide is used in the solar industry. That is why electronic grade and electronic off-grade silicon are no longer used in the crystalline silicon PV supply chain. Fluidised bed reactor technology has a share of less than 5 % and LCI data describing this technology are not available. That is why it is assumed that 100 % of solar grade silicon is produced with the Siemens process. Table 8 shows the market shares of solar grade silicon in the four different world regions.

Table 8: Unit process LCI data of the silicon production mixes 2018 of global and European production (GLO), China (CN), North America (US) and Asia & Pacific (APAC)

	Name	Location	InfrastructureProcess	Unit	silicon, production mix, photovoltaics, at plant	silicon, production mix, photovoltaics, at plant	silicon, production mix, photovoltaics, at plant	silicon, production mix, photovoltaics, at plant	UncertaintyType	StandardDeviation95%	GeneralComment
	Location				CN	APAC	US	GLO			
	InfrastructureProcess				0	0	0	0			
	Unit				kg	kg	kg	kg			
product	silicon, production mix, photovoltaics, at plant	CN	0	kg	1	0	0	0			
	silicon, production mix, photovoltaics, at plant	APAC	0	kg	0	1	0	0			
	silicon, production mix, photovoltaics, at plant	US	0	kg	0	0	1	0			
	silicon, production mix, photovoltaics, at plant	GLO	0	kg	0	0	0	1			
	silicon, solar grade, modified Siemens process, at plant	CN	0	kg	6.10E-01	0.00E+00	0.00E+00	0.00E+00	1.00	1.11	(3,1,1,1,1,1); Market share Chinese Polysilicon
	silicon, solar grade, modified Siemens process, at plant	APAC	0	kg	1.62E-01	1.00E+00	0.00E+00	0.00E+00	1.00	1.11	(3,1,1,1,1,1); Market share APAC Polysilicon
	silicon, solar grade, modified Siemens process, at plant	US	0	kg	9.28E-02	0.00E+00	1.00E+00	0.00E+00	1.00	1.11	(3,1,1,1,1,1); Market share US Polysilicon
	silicon, solar grade, modified Siemens process, at plant	RER	0	kg	1.35E-01	0.00E+00	0.00E+00	1.00E+00	1.00	1.11	(3,1,1,1,1,1); Market share European Polysilicon
	transport, transoceanic freight ship	OCE	0	tkm	5.37E+00	0.00E+00	0.00E+00	0.00E+00	1.00	2.09	(4,5,na,na,na,na); Transport distance CN-EU: 19994 km, CN-US: 20755 km, CN-APAC: 4584 km
	transport, freight, rail	RER	0	tkm	2.00E-01	2.00E-01	2.00E-01	2.00E-01	1.00	2.09	(4,5,na,na,na,na); Standard distance 200km
	transport, freight, lorry, fleet average	RER	0	tkm	5.00E-02	5.00E-02	5.00E-02	5.00E-02	1.00	2.09	(4,5,na,na,na,na); Standard distance 50km

3.2.5 Single and multi-crystalline silicon

Table 9 and Table 10 show the unit process data of the single- and multi-crystalline silicon production in Europe (RER), China (CN), North America (US) and Asia & Pacific (APAC). The South Korean electricity mix is selected for the APAC region, because South Korea produces the highest share of single-and multi-crystalline silicon in the APAC region. The US electricity mix is chosen to model electricity consumption in the North American production. The electricity consumption of the Czochralski-process (mono-Si ingot) is estimated at 32 kWh/kg, and of the casting of multi-Si ingots 7 kWh/kg [7]. The emission of waste heat is calculated based on the fuel and electricity demand. The production of 1 kg ingot is assumed to require 1.015 to 1.02 kg of solar grade silicon (1.5 to 2 % material losses according to [2]). These losses are included in the losses accounted for in the wafer manufacturing (see Section 3.2.6). The amount of deionised water and cooling water consumption is based on the water footprint of photovoltaic electricity described in section 3.12.

The remaining LCI data on material and energy consumption as well as about emissions are identical with the ones published in [19].

Table 9: Unit process LCI data of the single-crystalline silicon production in Europe (RER), China (CN), North America (US) and Asia & Pacific (APAC)

	Name	Location	InfrastructureProcess	Unit	CZ single crystalline silicon, photovoltaics, at plant	CZ single crystalline silicon, photovoltaics, at plant	CZ single crystalline silicon, photovoltaics, at plant	CZ single crystalline silicon, photovoltaics, at plant	UncertaintyType	StandardDeviation 95%	GeneralComment
	Location				CN	US	APAC	RER			
	InfrastructureProcess				0	0	0	0			
	Unit				kg	kg	kg	kg			
product	CZ single crystalline silicon, photovoltaics, at plant	CN	0	kg	1	0	0	0			
	CZ single crystalline silicon, photovoltaics, at plant	US	0	kg	0	1	0	0			
	CZ single crystalline silicon, photovoltaics, at plant	APAC	0	kg	0	0	1	0			
	CZ single crystalline silicon, photovoltaics, at plant	RER	0	kg	0	0	0	1			
technosphere	silicon, production mix, photovoltaics, at plant	CN	0	kg	1.00E+0	0	0	0	1	1.33	(2,4,4,2,1,5); Pot scrap losses (1.5 to 2%, according to Woodhouse (2019)) are accounted for in wafer manufacturing
	silicon, production mix, photovoltaics, at plant	US	0	kg	0	1.00E+0	0	0	1	1.33	(2,4,4,2,1,5); Pot scrap losses (1.5 to 2%, according to Woodhouse (2019)) are accounted for in wafer manufacturing
	silicon, production mix, photovoltaics, at plant	APAC	0	kg	0	0	1.00E+0	0	1	1.33	(2,4,4,2,1,5); Pot scrap losses (1.5 to 2%, according to Woodhouse (2019)) are accounted for in wafer manufacturing
	silicon, production mix, photovoltaics, at plant	GLO	0	kg	0	0	0	1.00E+0	1	1.33	(2,4,4,2,1,5); Pot scrap losses (1.5 to 2%, according to Woodhouse (2019)) are accounted for in wafer manufacturing
materials	argon, liquid, at plant	RER	0	kg	1.00E+0	1.00E+0	1.00E+0	1.00E+0	1	1.32	(1,4,4,2,1,5); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (table 9)
	hydrogen fluoride, at plant	GLO	0	kg	1.00E-2	1.00E-2	1.00E-2	1.00E-2	1	1.65	(3,4,5,3,3,5); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (table 9)
	nitric acid, 50% in H2O, at plant	RER	0	kg	6.68E-2	6.68E-2	6.68E-2	6.68E-2	1	1.65	(3,4,5,3,3,5); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (table 9)
	sodium hydroxide, 50% in H2O, production mix, at plant	RER	0	kg	4.15E-2	4.15E-2	4.15E-2	4.15E-2	1	1.65	(3,4,5,3,3,5); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (table 9)
	ceramic tiles, at regional storage	CH	0	kg	1.67E-1	1.67E-1	1.67E-1	1.67E-1	1	1.32	(1,4,4,2,1,5); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (table 9)
	lime, hydrated, packed, at plant	CH	0	kg	2.22E-2	2.22E-2	2.22E-2	2.22E-2	1	1.65	(3,4,5,3,3,5); waste water treatment, Hagedorn 1992
	electricity, medium voltage, at grid	CN	0	kWh	3.20E+1	0	0	0	1	1.22	(2,2,1,2,1,5); ITRPV 2020, Fig. 6, p.9
	electricity, medium voltage, at grid	US	0	kWh	0	3.20E+1	0	0	1	1.22	(2,2,1,2,1,5); ITRPV 2020, Fig. 6, p.9
	electricity, medium voltage, at grid	KR	0	kWh	0	0	3.20E+1	0	1	1.22	(2,2,1,2,1,5); ITRPV 2020, Fig. 6, p.9
	electricity, medium voltage, production ENTSO, at grid	ENTSO	0	kWh	0	0	0	3.20E+1	1	1.22	(2,2,1,2,1,5); ITRPV 2020, Fig. 6, p.9
	natural gas, burned in industrial furnace low-NOx >100kW	RER	0	MJ	6.82E+1	6.82E+1	6.82E+1	6.82E+1	1	1.32	(1,4,4,2,1,5); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (table 9)
	water, deionised, water balance according to MoeK 2013, at plant	CN	0	kg	4.01E+0	0	0	0	1	1.32	(1,4,4,2,1,5); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (table 9)
	water, deionised, water balance according to MoeK 2013, at plant	US	0	kg	0	4.01E+0	0	0	1	1.32	(1,4,4,2,1,5); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (table 9)
	water, deionised, water balance according to MoeK 2013, at plant	KR	0	kg	0	0	4.01E+0	0	1	1.32	(1,4,4,2,1,5); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (table 9)
	water, deionised, water balance according to MoeK 2013, at plant	RER	0	kg	0	0	0	4.01E+0	1	1.32	(1,4,4,2,1,5); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (table 9)
resource, in water	Water, cooling, unspecified natural origin, CN	-	-	m3	5.09E+0	0	0	0	1	1.32	(1,4,4,2,1,5); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (table 9)
	Water, cooling, unspecified natural origin, US	-	-	m3	0	5.09E+0	0	0	1	1.32	(1,4,4,2,1,5); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (table 9)
	Water, cooling, unspecified natural origin, KR	-	-	m3	0	0	5.09E+0	0	1	1.32	(1,4,4,2,1,5); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (table 9)
	Water, cooling, unspecified natural origin, RER	-	-	m3	0	0	0	5.09E+0	1	1.32	(1,4,4,2,1,5); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (table 9)
transport	transport, freight, lorry, fleet average	RER	0	tkm	1.13E+0	1.13E+0	1.13E+0	1.13E+0	1	2.09	(4,5,na,na,na,na); Transport distance: 100km; silicon: 1000km
	transport, freight, rail	RER	0	tkm	1.41E+0	1.41E+0	1.41E+0	1.41E+0	1	2.09	(4,5,na,na,na,na); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (table 9)
infrastructure	silicone plant	RER	1	unit	1.00E-11	1.00E-11	1.00E-11	1.00E-11	1	3.09	(1,2,4,1,3,3); Estimation
disposal	disposal, waste, Si waferprod., inorg, 9.4% water, to residual material landfill	CH	0	kg	1.67E-1	1.67E-1	1.67E-1	1.67E-1	1	1.32	(1,4,4,2,1,5); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (table 9)
	treatment, sewage, to wastewater treatment, class 2	CH	0	m3	4.84E+0	4.84E+0	4.84E+0	4.84E+0	1	1.63	(4,3,5,3,1,5); Calculation based on water withdrawal and water emissions
emission air	Heat, waste	-	-	MJ	1.15E+2	1.15E+2	1.15E+2	1.15E+2	1	1.58	(3,3,5,3,1,5); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (table 9)
	Water, CN	-	-	kg	2.55E+2	0	0	0	1	1.88	(4,3,5,3,1,5); Assumption: 5% evaporation of cooling water, 10% evaporation of process water; Frischknecht & Büsser Knöpfel (2013)
	Water, US	-	-	kg	0	2.55E+2	0	0	1	1.88	(4,3,5,3,1,5); Assumption: 5% evaporation of cooling water, 10% evaporation of process water; Frischknecht & Büsser Knöpfel (2013)
	Water, KR	-	-	kg	0	0	2.55E+2	0	1	1.88	(4,3,5,3,1,5); Assumption: 5% evaporation of cooling water, 10% evaporation of process water; Frischknecht & Büsser Knöpfel (2013)
	Water, RER	-	-	kg	0	0	0	2.55E+2	1	1.88	(4,3,5,3,1,5); Assumption: 5% evaporation of cooling water, 10% evaporation of process water; Frischknecht & Büsser Knöpfel (2013)
	Nitrogen oxides	-	-	kg	3.39E-2	3.39E-2	3.39E-2	3.39E-2	1	1.85	(3,4,5,3,1,5); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (table 9)
emission water, river	Hydroxide	-	-	kg	4.42E-3	4.42E-3	4.42E-3	4.42E-3	1	3.30	(3,4,5,3,1,5); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (table 9)
	BOD5, Biological Oxygen Demand	-	-	kg	1.30E-1	1.30E-1	1.30E-1	1.30E-1	1	3.33	(5,4,4,1,1,5); Extrapolation for sum parameter
	COD, Chemical Oxygen Demand	-	-	kg	1.30E-1	1.30E-1	1.30E-1	1.30E-1	1	3.33	(5,4,4,1,1,5); Extrapolation for sum parameter
	DOC, Dissolved Organic Carbon	-	-	kg	4.05E-2	4.05E-2	4.05E-2	4.05E-2	1	3.33	(5,4,4,1,1,5); Extrapolation for sum parameter
	TOC, Total Organic Carbon	-	-	kg	4.05E-2	4.05E-2	4.05E-2	4.05E-2	1	3.33	(5,4,4,1,1,5); Extrapolation for sum parameter
	Nitrate	-	-	kg	8.35E-2	8.35E-2	8.35E-2	8.35E-2	1	1.85	(3,4,5,3,1,5); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (table 9)

Table 10: Unit process LCI data of the multi-crystalline silicon production in Europe (RER), China (CN), North America (US) and Asia & Pacific (APAC)

	Name	Location	InfrastructureProcess	Unit	silicon, multi-Si, casted, at plant	silicon, multi-Si, casted, at plant	silicon, multi-Si, casted, at plant	silicon, multi-Si, casted, at plant	UncertaintyType	StandardDeviation95%	GeneralComment
	Location				CN	US	APAC	RER			
	InfrastructureProcess				0	0	0	0			
	Unit				kg	kg	kg	kg			
product	silicon, multi-Si, casted, at plant	CN	0	kg	1	0	0	0			
	silicon, multi-Si, casted, at plant	US	0	kg	0	1	0	0			
	silicon, multi-Si, casted, at plant	APAC	0	kg	0	0	1	0			
	silicon, multi-Si, casted, at plant	RER	0	kg	0	0	0	1			
technosphere	silicon, production mix, photovoltaics, at plant	CN	0	kg	1.00E+0	0	0	0	1	1.33	(2,4,4,2,1,5); Estimation
	silicon, production mix, photovoltaics, at plant	US	0	kg	0	1.00E+0	0	0	1	1.33	(2,4,4,2,1,5); Estimation
	silicon, production mix, photovoltaics, at plant	APAC	0	kg	0	0	1.00E+0	0	1	1.33	(2,4,4,2,1,5); Estimation
	silicon, production mix, photovoltaics, at plant	GLO	0	kg	0	0	0	1.00E+0	1	1.33	(2,4,4,2,1,5); Estimation
	argon, liquid, at plant	RER	0	kg	2.52E-1	2.52E-1	2.52E-1	2.52E-1	1	1.22	(1,2,4,1,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (table 12)
	helium, at plant	GLO	0	kg	7.76E-5	7.76E-5	7.76E-5	7.76E-5	1	1.22	(1,2,4,1,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (table 12)
	sodium hydroxide, 50% in H2O, production mix, at plant	RER	0	kg	5.00E-3	5.00E-3	5.00E-3	5.00E-3	1	1.58	(3,3,5,3,1,5); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (table 12)
	nitrogen, liquid, at plant	RER	0	kg	3.04E-2	3.04E-2	3.04E-2	3.04E-2	1	1.22	(1,2,4,1,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (table 12)
	ceramic tiles, at regional storage	CH	0	kg	2.14E-1	2.14E-1	2.14E-1	2.14E-1	1	1.22	(1,2,4,1,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (table 12)
	electricity, medium voltage, at grid	CN	0	kWh	7.00E+0	0	0	0	1	1.22	(2,2,1,2,1,5); ITRPV 2020, Fig. 6, p.9
	electricity, medium voltage, at grid	US	0	kWh	0	7.00E+0	0	0	1	1.22	(2,2,1,2,1,5); ITRPV 2020, Fig. 6, p.9
	electricity, medium voltage, at grid	KR	0	kWh	0	0	7.00E+0	0	1	1.22	(2,2,1,2,1,5); ITRPV 2020, Fig. 6, p.9
	electricity, medium voltage, production ENTSO, at grid	ENTSO	0	kWh	0	0	0	7.00E+0	1	1.22	(2,2,1,2,1,5); ITRPV 2020, Fig. 6, p.9
resource, in water	Water, cooling, unspecified natural origin, CN	-	-	m3	9.43E-1	0	0	0	1	1.60	(3,4,5,3,1,5); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (table 12)
	Water, cooling, unspecified natural origin, US	-	-	m3	0	9.43E-1	0	0	1	1.34	(3,4,4,3,1,5); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (table 12)
	Water, cooling, unspecified natural origin, KR	-	-	m3	0	0	9.43E-1	0	1	1.34	(3,4,4,3,1,5); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (table 12)
	Water, cooling, unspecified natural origin, RER	-	-	m3	0	0	0	9.43E-1	1	1.34	(3,4,4,3,1,5); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (table 12)
transport	transport, freight, lorry, fleet average	RER	0	tkm	1.05E+0	1.05E+0	1.05E+0	1.05E+0	1	2.09	(4,5,na,na,na,na); Transport distance: 100km; silicon: 1000km
	transport, freight, rail	RER	0	tkm	2.00E-1	2.00E-1	2.00E-1	2.00E-1	1	2.09	(4,5,na,na,na,na); Standard distances 100km
infrastructure	silicone plant	RER	1	unit	1.00E-11	1.00E-11	1.00E-11	1.00E-11	1	3.09	(1,2,4,1,3,3); Estimation
disposal	treatment, sewage, to wastewater treatment, class 2	CH	0	m3	8.96E-1	8.96E-1	8.96E-1	8.96E-1	1	1.63	(4,3,5,3,1,5); Calculation based on water withdrawal and water emissions
emission air	Heat, waste	-	-	MJ	2.52E+1	2.52E+1	2.52E+1	2.52E+1	1	1.58	(3,3,5,3,1,5); Calculation
	Water, CN	-	-	kg	4.72E+1	0	0	0	1	1.88	(4,3,5,3,1,5); Assumption: 5% evaporation of cooling water; Frischknecht & Büsser Knöpfel (2013)
	Water, US	-	-	kg	0	4.72E+1	0	0	1	1.88	(4,3,5,3,1,5); Assumption: 5% evaporation of cooling water; Frischknecht & Büsser Knöpfel (2013)
	Water, KR	-	-	kg	0	0	4.72E+1	0	1	1.88	(4,3,5,3,1,5); Assumption: 5% evaporation of cooling water; Frischknecht & Büsser Knöpfel (2013)
	Water, RER	-	-	kg	0	0	0	4.72E+1	1	1.88	(4,3,5,3,1,5); Assumption: 5% evaporation of cooling water; Frischknecht & Büsser Knöpfel (2013)

3.2.6 Silicon Wafer Production

Table 12 and Table 13 show the unit process data of the single- and multi-crystalline silicon wafer production in Europe (RER), China (CN), North America (US) and Asia & Pacific (APAC). The Korean electricity mix is selected for the APAC region, because Korea produces the highest share of the single-and multi-crystalline wafers in the APAC region [2]. The US electricity mix is chosen to model electricity consumption in the North American production. The data used to update the wafer manufacture life cycle inventory is shown in Table 11.

The consumption of deionised water is based on the water footprint of photovoltaic electricity described in section 3.12. Silicon carbide and triethylene glycol are no more used in wafer manufacturing [2].

Table 11: Key characteristics of crystalline silicon wafers and key parameters of wafer manufacturing (silicon density: 2.33 g/cm³); gross silicon demand, wafer dimension and wafer thicknesses from [7]
[1]): this includes losses from pot scrap in the crucibles (see Section 3.2.5)
[2]): wire demand (1.1-1.5m per wafer) and wire dimensions (70mm) from [2]
[3]): approximated with chromium steel (lack of LCI data on industrial diamond manufacture)

	unit	mono-Si	multi-Si
Gross silicon demand	g	15	16
Length	mm	158.75	158.75
Width	mm	158.75	158.75
Area	cm^2	252	252
Thickness	µm	170	180
Kerf loss	µm	65	65
Additional losses [1])	µm	20.5	27.5
Silicon content	g/m^2	396.1	419.4
Silicon losses	g/m^2	199.1	215.5
Total silicon demand	g/m^2	595.2	634.9
Electricity demand	kWh/m^2	4.92	5.69
Diamond wire demand [2])	m/m^2	52.6	52.2
Diamond wire demand [3])	g/m^2	1.56	1.55
Water demand	litre	57.4	56.9

Table 12: Unit process LCI data of the single- and multi-crystalline silicon wafer production in China (CN) and North America (US)

	Name	Location	InfrastructureProcess	Unit	single-Si wafer, photovoltaics, at plant	multi-Si wafer, at plant	single-Si wafer, photovoltaics, at plant	multi-Si wafer, at plant	UncertaintyType	StandardDeviation95%	GeneralComment
	Location				CN	CN	US	US			
	InfrastructureProcess				0	0	0	0			
	Unit				m2	m2	m2	m2			
product	single-Si wafer, photovoltaics, at plant	CN	0	m2	1	0	0	0			
	multi-Si wafer, at plant	CN	0	m2	0	1	0	0			
	single-Si wafer, photovoltaics, at plant	US	0	m2	0	0	1	0			
	multi-Si wafer, at plant	US	0	m2	0	0	0	1			
	single-Si wafer, photovoltaics, at plant	APAC	0	m2	0	0	0	0			
	multi-Si wafer, at plant	APAC	0	m2	0	0	0	0			
	single-Si wafer, photovoltaics, at plant	RER	0	m2	0	0	0	0			
	multi-Si wafer, at plant	RER	0	m2	0	0	0	0			
technosphere	CZ single crystalline silicon, photovoltaics, at plant	CN	0	kg	5.95E-1	0	0	0	1	1.22	(2,2,1,2,1,5); Wafer thickness: 170 um, kerf loss: 65 um, additional losses: 20.5 um; silicon density: 2330 kg/m3; ITRPV 2020; Woodhouse et al. (2019): c-Si PV Manufacturing Costs 2018
	silicon, multi-Si, casted, at plant	CN	0	kg	0	6.35E-1	0	0	1	1.22	(2,2,1,2,1,5); Wafer thickness: 180 um, kerf loss: 65 um, additional losses: 27.5 um; silicon density: 2330 kg/m3; ITRPV 2020; Woodhouse et al. (2019): c-Si PV Manufacturing Costs 2018
	CZ single crystalline silicon, photovoltaics, at plant	US	0	kg	0	0	5.95E-1	0	1	1.22	(2,2,1,2,1,5); Wafer thickness: 170 um, kerf loss: 65 um, additional losses: 20.5 um; silicon density: 2330 kg/m3; ITRPV 2020; Woodhouse et al. (2019): c-Si PV Manufacturing Costs 2018
	silicon, multi-Si, casted, at plant	US	0	kg	0	0	0	6.35E-1	1	1.22	(2,2,1,2,1,5); Wafer thickness: 180 um, kerf loss: 65 um, additional losses: 27.5 um; silicon density: 2330 kg/m3; ITRPV 2020; Woodhouse et al. (2019): c-Si PV Manufacturing Costs 2018
	CZ single crystalline silicon, photovoltaics, at plant	APAC	0	kg	0	0	0	0	1	1.22	(2,2,1,2,1,5); Wafer thickness: 170 um, kerf loss: 65 um, additional losses: 20.5 um; silicon density: 2330 kg/m3; ITRPV 2020; Woodhouse et al. (2019): c-Si PV Manufacturing Costs 2018
	silicon, multi-Si, casted, at plant	APAC	0	kg	0	0	0	0	1	1.22	(2,2,1,2,1,5); Wafer thickness: 180 um, kerf loss: 65 um, additional losses: 27.5 um; silicon density: 2330 kg/m3; ITRPV 2020; Woodhouse et al. (2019): c-Si PV Manufacturing Costs 2018
	CZ single crystalline silicon, photovoltaics, at plant	RER	0	kg	0	0	0	0	1	1.22	(2,2,1,2,1,5); Wafer thickness: 170 um, kerf loss: 65 um, additional losses: 20.5 um; silicon density: 2330 kg/m3; ITRPV 2020; Woodhouse et al. (2019): c-Si PV Manufacturing Costs 2018
	silicon, multi-Si, casted, at plant	RER	0	kg	0	0	0	0	1	1.22	(2,2,1,2,1,5); Wafer thickness: 180 um, kerf loss: 65 um, additional losses: 27.5 um; silicon density: 2330 kg/m3; ITRPV 2020; Woodhouse et al. (2019): c-Si PV Manufacturing Costs 2018
	flat glass, uncoated, at plant	RER	0	kg	9.99E-3	4.08E-2	9.99E-3	4.08E-2	1	1.26	(3,4,2,3,1,5); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 19,25)
	sodium hydroxide, 50% in H2O, production mix, at plant	RER	0	kg	1.50E-2	1.50E-2	1.50E-2	1.50E-2	1	1.22	(1,2,4,1,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 19,25)
	hydrochloric acid, 30% in H2O, at plant	RER	0	kg	2.70E-3	2.70E-3	2.70E-3	2.70E-3	1	1.22	(1,2,4,1,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 19,25)
	acetic acid, 98% in H2O, at plant	RER	0	kg	3.90E-2	3.90E-2	3.90E-2	3.90E-2	1	1.22	(1,2,4,1,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 19,25)
	dipropylene glycol monomethyl ether, at plant	RER	0	kg	3.00E-1	3.00E-1	3.00E-1	3.00E-1	1	1.22	(1,2,4,1,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 19,25)
	alkylbenzene sulfonate, linear, petrochemical, at plant	RER	0	kg	2.40E-1	2.40E-1	2.40E-1	2.40E-1	1	1.22	(1,2,4,1,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 19,25)
	acrylic binder, 34% in H2O, at plant	RER	0	kg	2.00E-3	3.85E-3	2.00E-3	3.85E-3	1	1.22	(1,2,4,1,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 19,25)
	brass, at plant	CH	0	kg	7.44E-3	7.44E-3	7.44E-3	7.44E-3	1	1.22	(1,2,4,1,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 19,25)
	chromium steel 18/8, at plant	RER	0	kg	1.51E-3	1.51E-3	1.51E-3	1.51E-3	1	1.32	(3,2,1,1,3,5); Proxy for diamond wire; Woodhouse et al. (2019): c-Si PV Manufacturing Costs 2018
	wire drawing, steel	RER	0	kg	8.95E-3	8.95E-3	8.95E-3	8.95E-3	1	1.32	(3,2,1,1,3,5); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 19,25)
	electricity, medium voltage, at grid	CN	0	kWh	4.76E+0	5.56E+0	0	0	1	2.05	(2,2,1,2,1,5); Woodhouse et al. (2019): c-Si PV Manufacturing Costs 2018
	electricity, medium voltage, at grid	US	0	kWh	0	0	4.76E+0	5.56E+0	1	2.05	(2,2,1,2,1,5); Woodhouse et al. (2019): c-Si PV Manufacturing Costs 2018
	electricity, medium voltage, at grid	KR	0	kWh	0	0	0	0	1	2.05	(2,2,1,2,1,5); Woodhouse et al. (2019): c-Si PV Manufacturing Costs 2018
	electricity, medium voltage, production ENTSO, at grid	ENTSO	0	kWh	0	0	0	0	1	2.05	(2,2,1,2,1,5); Woodhouse et al. (2019): c-Si PV Manufacturing Costs 2018
	natural gas, burned in industrial furnace low-NOx >100kW	RER	0	MJ	4.00E+0	4.00E+0	4.00E+0	4.00E+0	1	1.22	(1,2,4,1,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 19,25)
water	water, deionised, water balance according to MoeK 2013, at plant	CN	0	kg	5.56E+1	5.56E+1	0	0	1	1.26	(3,4,2,3,1,5); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 19,25)
	water, deionised, water balance according to MoeK 2013, at plant	US	0	kg	0	0	5.56E+1	5.56E+1	1	1.26	(3,4,2,3,1,5); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 19,25)
	water, deionised, water balance according to MoeK 2013, at plant	KR	0	kg	0	0	0	0	1	1.26	(3,4,2,3,1,5); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 19,25)
	water, deionised, water balance according to MoeK 2013, at plant	RER	0	kg	0	0	0	0	1	1.26	(3,4,2,3,1,5); China photovoltaic cell industry cleaner production evaluation index system
disposal	disposal, waste, silicon wafer production, 0% water, to underground deposit	DE	0	kg	1.10E-1	1.70E-1	1.10E-1	1.70E-1	1	1.22	(1,2,4,1,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 19,25)
	treatment, sewage, to wastewater treatment, class 2	CH	0	m3	5.00E-2	5.00E-2	5.00E-2	5.00E-2	1	1.26	(3,4,2,3,1,5); Calculation based on water withdrawal and water emissions
transport	transport, freight, lorry, fleet average	RER	0	tkm	2.36E-1	2.77E-1	2.36E-1	2.77E-1	1	2.09	(4,5,na,na,na,na); Transport distance: 100km; silicon: 200km
	transport, freight, rail	RER	0	tkm	1.25E+0	1.27E+0	1.25E+0	1.27E+0	1	2.09	(4,5,na,na,na,na); Transport distance: 100-600km
infrastructure	wafer factory	DE	1	unit	4.00E-6	4.00E-6	4.00E-6	4.00E-6	1	3.05	(1,2,4,1,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 19,25)
emission air	Heat, waste	-	-	MJ	1.71E+1	2.00E+1	1.71E+1	2.00E+1	1	1.34	(3,4,4,3,1,5); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 19,25)
	Water, CN	-	-	kg	5.56E+0	5.56E+0	0	0	1	1.65	(3,4,4,3,1,5); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 19,25)
	Water, US	-	-	kg	0	0	5.56E+0	5.56E+0	1	1.65	(3,4,4,3,1,5); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 19,25)
	Water, KR	-	-	kg	0	0	0	0	1	1.65	(3,4,4,3,1,5); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 19,25)
	Water, RER	-	-	kg	0	0	0	0	1	1.65	(3,4,4,3,1,5); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 19,25)
emission water, river	COD, Chemical Oxygen Demand	-	-	kg	2.95E-2	2.95E-2	2.95E-2	2.95E-2	1	1.64	(2,4,4,3,1,5); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 19,25)
	BOD5, Biological Oxygen Demand	-	-	kg	2.95E-2	2.95E-2	2.95E-2	2.95E-2	1	1.85	(3,4,5,3,1,5); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 19,25)
	COD, Chemical Oxygen Demand	-	-	kg	1.11E-2	1.11E-2	1.11E-2	1.11E-2	1	1.85	(3,4,5,3,1,5); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 19,25)
	TOC, Total Organic Carbon	-	-	kg	1.11E-2	1.11E-2	1.11E-2	1.11E-2	1	1.85	(3,4,5,3,1,5); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 19,25)

Table 13: Unit process LCI data of the single- and multi-crystalline silicon wafer production in Europe (RER) and Asia & Pacific (APAC)

	Name	Location	InfrastructureProcess	Unit	single-Si wafer, photovoltaics, at plant	multi-Si wafer, at plant	single-Si wafer, photovoltaics, at plant	multi-Si wafer, at plant	UncertaintyType	StandardDeviation95%	GeneralComment
	Location				APAC	APAC	RER	RER			
	InfrastructureProcess				0	0	0	0			
	Unit				m2	m2	m2	m2			
product	single-Si wafer, photovoltaics, at plant	CN	0	m2	0	0	0	0			
	multi-Si wafer, at plant	CN	0	m2	0	0	0	0			
	single-Si wafer, photovoltaics, at plant	US	0	m2	0	0	0	0			
	multi-Si wafer, at plant	US	0	m2	0	0	0	0			
	single-Si wafer, photovoltaics, at plant	APAC	0	m2	1	0	0	0			
	multi-Si wafer, at plant	APAC	0	m2	0	1	0	0			
	single-Si wafer, photovoltaics, at plant	RER	0	m2	0	0	1	0			
	multi-Si wafer, at plant	RER	0	m2	0	0	0	1			
technosphere	CZ single crystalline silicon, photovoltaics, at plant	CN	0	kg	0	0	0	0	1	1.22	(2,2,1,2,1,5); Wafer thickness: 170 um, kerf loss: 65 um, additional losses: 20.5 um; silicon density: 2330 kg/m3; ITRPV 2020; Woodhouse et al. (2019): c-Si PV Manufacturing Costs 2018
	silicon, multi-Si, casted, at plant	CN	0	kg	0	0	0	0	1	1.22	(2,2,1,2,1,5); Wafer thickness: 180 um, kerf loss: 65 um, additional losses: 27.5 um; silicon density: 2330 kg/m3; ITRPV 2020; Woodhouse et al. (2019): c-Si PV Manufacturing Costs 2018
	CZ single crystalline silicon, photovoltaics, at plant	US	0	kg	0	0	0	0	1	1.22	(2,2,1,2,1,5); Wafer thickness: 170 um, kerf loss: 65 um, additional losses: 20.5 um; silicon density: 2330 kg/m3; ITRPV 2020; Woodhouse et al. (2019): c-Si PV Manufacturing Costs 2018
	silicon, multi-Si, casted, at plant	US	0	kg	0	0	0	0	1	1.22	(2,2,1,2,1,5); Wafer thickness: 180 um, kerf loss: 65 um, additional losses: 27.5 um; silicon density: 2330 kg/m3; ITRPV 2020; Woodhouse et al. (2019): c-Si PV Manufacturing Costs 2018
	CZ single crystalline silicon, photovoltaics, at plant	APAC	0	kg	5.95E-1	0	0	0	1	1.22	(2,2,1,2,1,5); Wafer thickness: 170 um, kerf loss: 65 um, additional losses: 20.5 um; silicon density: 2330 kg/m3; ITRPV 2020; Woodhouse et al. (2019): c-Si PV Manufacturing Costs 2018
	silicon, multi-Si, casted, at plant	APAC	0	kg	0	6.35E-1	0	0	1	1.22	(2,2,1,2,1,5); Wafer thickness: 180 um, kerf loss: 65 um, additional losses: 27.5 um; silicon density: 2330 kg/m3; ITRPV 2020; Woodhouse et al. (2019): c-Si PV Manufacturing Costs 2018
	CZ single crystalline silicon, photovoltaics, at plant	RER	0	kg	0	0	5.95E-1	0	1	1.22	(2,2,1,2,1,5); Wafer thickness: 170 um, kerf loss: 65 um, additional losses: 20.5 um; silicon density: 2330 kg/m3; ITRPV 2020; Woodhouse et al. (2019): c-Si PV Manufacturing Costs 2018
	silicon, multi-Si, casted, at plant	RER	0	kg	0	0	0	6.35E-1	1	1.22	(2,2,1,2,1,5); Wafer thickness: 180 um, kerf loss: 65 um, additional losses: 27.5 um; silicon density: 2330 kg/m3; ITRPV 2020; Woodhouse et al. (2019): c-Si PV Manufacturing Costs 2018
	flat glass, uncoated, at plant	RER	0	kg	9.99E-3	4.08E-2	9.99E-3	4.08E-2	1	1.26	(3,4,2,3,1,5); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 19,25)
	sodium hydroxide, 50% in H2O, production mix, at plant	RER	0	kg	1.50E-2	1.50E-2	1.50E-2	1.50E-2	1	1.22	(1,2,4,1,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 19,25)
	hydrochloric acid, 30% in H2O, at plant	RER	0	kg	2.70E-3	2.70E-3	2.70E-3	2.70E-3	1	1.22	(1,2,4,1,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 19,25)
	acetic acid, 98% in H2O, at plant	RER	0	kg	3.90E-2	3.90E-2	3.90E-2	3.90E-2	1	1.22	(1,2,4,1,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 19,25)
	dipropylene glycol monomethyl ether, at plant	RER	0	kg	3.00E-1	3.00E-1	3.00E-1	3.00E-1	1	1.22	(1,2,4,1,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 19,25)
	alkylbenzene sulfonate, linear, petrochemical, at plant	RER	0	kg	2.40E-1	2.40E-1	2.40E-1	2.40E-1	1	1.22	(1,2,4,1,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 19,25)
	acrylic binder, 34% in H2O, at plant	RER	0	kg	3.85E-3	3.85E-3	2.00E-3	3.85E-3	1	1.22	(1,2,4,1,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 19,25)
	brass, at plant	CH	0	kg	7.44E-3	7.44E-3	7.44E-3	7.44E-3	1	1.22	(1,2,4,1,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 19,25)
	chromium steel 18/8, at plant	RER	0	kg	1.51E-3	1.51E-3	1.51E-3	1.51E-3	1	1.32	(3,2,1,1,3,5); Proxy for diamond wire; Woodhouse et al. (2019): c-Si PV Manufacturing Costs 2018
	wire drawing, steel	RER	0	kg	8.95E-3	8.95E-3	8.95E-3	8.95E-3	1	1.32	(3,2,1,1,3,5); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 19,25)
	electricity, medium voltage, at grid	CN	0	kWh	0	0	0	0	1	2.05	(2,2,1,2,1,5); Woodhouse et al. (2019): c-Si PV Manufacturing Costs 2018
	electricity, medium voltage, at grid	US	0	kWh	0	0	0	0	1	2.05	(2,2,1,2,1,5); Woodhouse et al. (2019): c-Si PV Manufacturing Costs 2018
	electricity, medium voltage, at grid	KR	0	kWh	4.76E+0	5.56E+0	0	0	1	2.05	(2,2,1,2,1,5); Woodhouse et al. (2019): c-Si PV Manufacturing Costs 2018
	electricity, medium voltage, production ENTSO, at grid	ENTSO	0	kWh	0	0	4.76E+0	5.56E+0	1	2.05	(2,2,1,2,1,5); Woodhouse et al. (2019): c-Si PV Manufacturing Costs 2018
	natural gas, burned in industrial furnace low-NOx >100kW	RER	0	MJ	4.00E+0	4.00E+0	4.00E+0	4.00E+0	1	1.22	(1,2,4,1,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 19,25)
water	water, deionised, water balance according to MoeK 2013, at plant	CN	0	kg	0	0	0	0	1	1.26	(3,4,2,3,1,5); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 19,25)
	water, deionised, water balance according to MoeK 2013, at plant	US	0	kg	0	0	0	0	1	1.26	(3,4,2,3,1,5); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 19,25)
	water, deionised, water balance according to MoeK 2013, at plant	KR	0	kg	5.56E+1	5.56E+1	0	0	1	1.26	(3,4,2,3,1,5); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 19,25)
	water, deionised, water balance according to MoeK 2013, at plant	RER	0	kg	0	0	5.56E+1	5.56E+1	1	1.26	(3,4,2,3,1,5); China photovoltaic cell industry cleaner production evaluation index system
disposal	disposal, waste, silicon wafer production, 0% water, to underground deposit	DE	0	kg	1.70E-1	1.70E-1	1.10E-1	1.70E-1	1	1.22	(1,2,4,1,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 19,25)
	treatment, sewage, to wastewater treatment, class 2	CH	0	m3	5.00E-2	5.00E-2	5.00E-2	5.00E-2	1	1.26	(3,4,2,3,1,5); Calculation based on water withdrawal and water emissions
transport	transport, freight, lorry, fleet average	RER	0	tkm	2.36E-1	2.77E-1	2.36E-1	2.77E-1	1	2.09	(4,5,na,na,na,na); Transport distance: 100km; silicon: 200km
	transport, freight, rail	RER	0	tkm	1.25E+0	1.27E+0	1.25E+0	1.27E+0	1	2.09	(4,5,na,na,na,na); Transport distance: 100-600km
infrastructure	wafer factory	DE	1	unit	4.00E-6	4.00E-6	4.00E-6	4.00E-6	1	3.05	(1,2,4,1,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 19,25)
emission air	Heat, waste	-	-	MJ	1.71E+1	2.00E+1	1.71E+1	2.00E+1	1	1.34	(3,4,4,3,1,5); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 19,25)
	Water, CN	-	-	kg	0	0	0	0	1	1.65	(3,4,4,3,1,5); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 19,25)
	Water, US	-	-	kg	0	0	0	0	1	1.65	(3,4,4,3,1,5); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 19,25)
	Water, KR	-	-	kg	5.56E+0	5.56E+0	0	0	1	1.65	(3,4,4,3,1,5); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 19,25)
	Water, RER	-	-	kg	0	0	5.56E+0	5.56E+0	1	1.65	(3,4,4,3,1,5); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 19,25)
emission water, river	COD, Chemical Oxygen Demand	-	-	kg	2.95E-2	2.95E-2	2.95E-2	2.95E-2	1	1.64	(2,4,4,3,1,5); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 19,25)
	BOD5, Biological Oxygen Demand	-	-	kg	2.95E-2	2.95E-2	2.95E-2	2.95E-2	1	1.85	(3,4,5,3,1,5); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 19,25)
	COD, Chemical Oxygen Demand	-	-	kg	1.11E-2	1.11E-2	1.11E-2	1.11E-2	1	1.85	(3,4,5,3,1,5); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 19,25)
	TOC, Total Organic Carbon	-	-	kg	1.11E-2	1.11E-2	1.11E-2	1.11E-2	1	1.85	(3,4,5,3,1,5); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 19,25)

Table 14 shows the unit process data of the silicon wafer market mixes in Europe (RER), North America (US) and Asia & Pacific (APAC). The values correspond to the shares given in Tab. 3.1.2.2. The transport distances with freight ships depend on the world region. Distances of 19'994 km, 20'755 km and 4584 km are assumed for the transport from China (Shanghai) to Europe (Rotterdam), from China (Shanghai) to North America (New York) and from China (Shanghai) to APAC (Port Klang), respectively. Furthermore, 50 km transport by lorry and 200 km transport by train are assumed independent of the region.

Table 14: Unit process LCI data of the silicon wafer market mixes 2018 in Europe (RER), North America (US) and Asia & Pacific (APAC)

	Name	Location	InfrastructureProcess	Unit	multi-Si wafer, at regional storage	single-Si wafer, photovoltaics, at regional storage	multi-Si wafer, at regional storage	single-Si wafer, photovoltaics, at regional storage	multi-Si wafer, at regional storage	single-Si wafer, photovoltaics, at regional storage	UncertaintyType	StandardDeviation95%	GeneralComment
	Location				RER	RER	US	US	APAC	APAC			
	InfrastructureProcess				0	0	0	0	0	0			
	Unit				m2	m2	m2	m2	m2	m2			
product	multi-Si wafer, at regional storage	RER	0	m2	1	0	0	0	0	0			
	single-Si wafer, photovoltaics, at regional storage	RER	0	m2	0	1	0	0	0	0			
	multi-Si wafer, at regional storage	US	0	m2	0	0	1	0	0	0			
	single-Si wafer, photovoltaics, at regional storage	US	0	m2	0	0	0	1	0	0			
	multi-Si wafer, at regional storage	APAC	0	m2	0	0	0	0	1	0			
	single-Si wafer, photovoltaics, at regional storage	APAC	0	m2	0	0	0	0	0	1			
wafers	multi-Si wafer, at plant	RER	0	m2	7.98E-1	0	0	0	0	0	1	1.56	(5,1,1,1,1,5); Market share European wafers
	single-Si wafer, photovoltaics, at plant	RER	0	m2	0	7.98E-1	0	0	0	0	1	1.56	(5,1,1,1,1,5); Market share European wafers
	multi-Si wafer, at plant	CN	0	m2	2.02E-1	0	1.00E+0	0	8.67E-1	0	1	1.56	(5,1,1,1,1,5); Market share Chinese wafers
	single-Si wafer, photovoltaics, at plant	CN	0	m2	0	2.02E-1	0	1.00E+0	0	8.67E-1	1	1.56	(5,1,1,1,1,5); Market share Chinese wafers
	multi-Si wafer, at plant	US	0	m2	0	0	0	0	0	0	1	1.56	(5,1,1,1,1,5); Market share US wafers
	single-Si wafer, photovoltaics, at plant	US	0	m2	0	0	0	0	0	0	1	1.56	(5,1,1,1,1,5); Market share US wafers
	multi-Si wafer, at plant	APAC	0	m2	0	0	0	0	1.33E-1	0	1	1.56	(5,1,1,1,1,5); Market share APAC wafers
	single-Si wafer, photovoltaics, at plant	APAC	0	m2	0	0	0	0	0	1.33E-1	1	1.56	(5,1,1,1,1,5); Market share APAC wafers
transport	transport, transoceanic freight ship	OCE	0	tkm	1.69E+0	1.60E+0	8.70E+0	8.22E+0	1.67E+0	1.57E+0	1	2.09	(4,5,na,na,na,na); Transport distance CN-EU: 19994 km, CN-US: 20755 km, CN-APAC: 4584 km
	transport, freight, rail	RER	0	tkm	8.39E-2	7.92E-2	8.39E-2	7.92E-2	8.39E-2	7.92E-2	1	2.09	(4,5,na,na,na,na); Standard distance 200km
	transport, freight, lorry, fleet average	RER	0	tkm	2.10E-2	1.98E-2	2.10E-2	1.98E-2	2.10E-2	1.98E-2	1	2.09	(4,5,na,na,na,na); Standard distance 50km

3.2.7 Photovoltaic cell, laminate and panel production

Photovoltaic cells

The LCI data on material and energy consumption as well as about emissions are updated based on LCI data of single- and multi-crystalline cells published by de Wild-Scholten [10]. Data on "tap water, at user" refers to city water for facility and manufacturing process use.

Table 15 and Table 16 show the unit process data of the photovoltaic cell production in Europe (RER), China (CN), North America (US) and Asia & Pacific (APAC). The Korean electricity mix is selected for the APAC region, because Korea produces the highest share of single-and multi-crystalline cells in the APAC region. The US electricity mix is chosen to model electricity consumption in the North American production.

The LCI data on material and energy consumption as well as about emissions are updated based on LCI data of single- and multi-crystalline cells published in [19]. The data used to update the cell manufacture life cycle inventory is shown in Table 15.

Table 15: Key characteristics of crystalline silicon cells and key parameters of cell manufacturing (silicon density: 2.33 g/cm^3)

	unit	mono-Si	multi-Si
Wafer area	cm^2	252	252
Wafer weight	kg/m^2	0.396	0.419
Wafer thickness	µm	170	180
Cell weight	kg/m^2	0.470	0.498
Electricity demand	kWh/m^2	17.7	17.7
Metallization paste, front	g/m^2	3.37	3.37
Metallization paste, back	g/m^2	1.11	1.11
Metallization paste, back, Al	g/m^2	57.2	56.8
Silver demand	g/m^2	3.70	3.67
Aluminium demand	g/m^2	46.2	45.9

Table 16: Unit process data of the photovoltaic cell production in China (CN) and North America (US)

	Name	Location	InfrastructureProcess	Unit	photovoltaic cell, single-Si, at plant	photovoltaic cell, multi-Si, at plant	photovoltaic cell, single-Si, at plant	photovoltaic cell, multi-Si, at plant	UncertaintyType	StandardDeviation95%	GeneralComment
	Location				CN	CN	US	US			
	InfrastructureProcess				0	0	0	0			
	Unit				m2	m2	m2	m2			
product	photovoltaic cell, single-Si, at plant	CN	0	m2	1	0	0	0			
	photovoltaic cell, multi-Si, at plant	CN	0	m2	0	1	0	0			
	photovoltaic cell, single-Si, at plant	US	0	m2	0	0	1	0			
	photovoltaic cell, multi-Si, at plant	US	0	m2	0	0	0	1			
	photovoltaic cell, single-Si, at plant	APAC	0	m2	0	0	0	0			
	photovoltaic cell, multi-Si, at plant	APAC	0	m2	0	0	0	0			
	photovoltaic cell, single-Si, at plant	RER	0	m2	0	0	0	0			
	photovoltaic cell, multi-Si, at plant	RER	0	m2	0	0	0	0			
wafers	single-Si wafer, photovoltaics, at plant	CN	0	m2	1.03E+0	0	0	0	1	1.10	(2,2,2,1,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 30,31)
	multi-Si wafer, at plant	CN	0	m2	0	1.04E+0	0	0	1	1.10	(2,2,2,1,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 30,31)
	single-Si wafer, photovoltaics, at regional storage	US	0	m2	0	0	1.03E+0	0	1	3.01	(2,2,2,1,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 30,31)
	multi-Si wafer, at regional storage	US	0	m2	0	0	0	1.04E+0	1	3.01	(2,2,2,1,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 30,31)
	single-Si wafer, photovoltaics, at regional storage	APAC	0	m2	0	0	0	0	1	3.01	(2,2,2,1,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 30,31)
	multi-Si wafer, at regional storage	APAC	0	m2	0	0	0	0	1	3.01	(2,2,2,1,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 30,31)
	single-Si wafer, photovoltaics, at regional storage	RER	0	m2	0	0	0	0	1	3.01	(2,2,2,1,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 30,31)
	multi-Si wafer, at regional storage	RER	0	m2	0	0	0	0	1	3.01	(2,2,2,1,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 30,31)
materials	metallization paste, front side, at plant	RER	0	kg	3.37E-3	3.37E-3	3.37E-3	3.37E-3	1	1.09	(2,2,1,1,1,3); Woodhouse et al. (2019): c-Si PV Manufacturing Costs 2018
	metallization paste, back side, at plant	RER	0	kg	1.11E-3	1.11E-3	1.11E-3	1.11E-3	1	1.09	(2,2,1,1,1,3); Woodhouse et al. (2019): c-Si PV Manufacturing Costs 2018
	metallization paste, back side, aluminium, at plant	RER	0	kg	5.54E-2	5.54E-2	5.54E-2	5.54E-2	1	1.09	(2,2,1,1,1,3); Woodhouse et al. (2019): c-Si PV Manufacturing Costs 2018
chemicals	ammonia, liquid, at regional storehouse	RER	0	kg	2.19E-2	8.92E-3	2.19E-2	8.92E-3	1	1.22	(2,2,4,1,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 30,31)
	phosphoric acid, fertiliser grade, 70% in H2O, at plant	GLO	0	kg	0	8.63E-3	0	8.63E-3	1	1.22	(2,2,4,1,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 30,31)
	phosphoryl chloride, at plant	RER	0	kg	1.33E-2	2.74E-2	1.33E-2	2.74E-2	1	1.22	(2,2,4,1,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 30,31)
	isopropanol, at plant	RER	0	kg	1.77E-1	8.10E-4	1.77E-1	8.10E-4	1	1.22	(2,2,4,1,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 30,31)
	solvents, organic, unspecified, at plant	GLO	0	kg	0	1.13E-2	0	1.13E-2	1	1.22	(2,2,4,1,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 30,31)
	calcium chloride, CaCl2, at regional storage	CH	0	kg	0	3.15E-2	0	3.15E-2	1	1.22	(2,2,4,1,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 30,31)
	hydrochloric acid, 30% in H2O, at plant	RER	0	kg	6.29E-4	8.59E-3	6.29E-4	8.59E-3	1	1.22	(2,2,4,1,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 30,31)
	hydrogen fluoride, at plant	GLO	0	kg	6.45E-4	4.03E-1	6.45E-4	4.03E-1	1	1.22	(2,2,4,1,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 30,31)
	nitric acid, 50% in H2O, at plant	RER	0	kg	0	2.93E-1	0	2.93E-1	1	1.22	(2,2,4,1,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 30,31)
	sodium hydroxide, 50% in H2O, production mix, at plant	RER	0	kg	6.04E-1	7.07E-2	6.04E-1	7.07E-2	1	1.22	(2,2,4,1,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 30,31)
	lime, hydrated, packed, at plant	CH	0	kg	1.51E-2	2.18E-1	1.51E-2	2.18E-1	1	1.22	(2,2,4,1,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 30,31)
	hydrogen peroxide, 50% in H2O, at plant	RER	0	kg	0	4.52E-4	0	4.52E-4	1	1.22	(2,2,4,1,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 30,31)
	sulphuric acid, liquid, at plant	RER	0	kg	0	1.01E-1	0	1.01E-1	1	1.22	(2,2,4,1,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 30,31)
	refrigerant R134a, at plant	RER	0	kg	3.12E-5	2.73E-5	3.12E-5	2.73E-5	1	1.22	(2,2,4,1,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 30,31)
	potassium hydroxide, at regional storage	RER	0	kg	0	3.00E-2	0	3.00E-2	1	1.22	(2,2,4,1,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 30,31)
	ammonium sulphate, as N, at regional storehouse	RER	0	kg	0	2.10E-2	0	2.10E-2	1	1.22	(2,2,4,1,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 30,31)
gases	oxygen, liquid, at plant	RER	0	kg	0	8.22E-3	0	8.22E-3	1	1.22	(2,2,4,1,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 30,31)
	nitrogen, liquid, at plant	RER	0	kg	1.15E+0	1.35E+0	1.15E+0	1.35E+0	1	1.22	(2,2,4,1,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 30,31)
	silane, at plant	RER	0	kg	2.91E-3	2.61E-3	2.91E-3	2.61E-3	1	1.22	(2,2,4,1,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 30,31)
	tap water, water balance according to MoeK 2013, at user	CN	0	kg	1.71E+2	2.51E+2	0	0	1	1.22	(2,2,4,1,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 30,31)
	tap water, water balance according to MoeK 2013, at user	US	0	kg	0	0	1.71E+2	2.51E+2	1	1.22	(2,2,4,1,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 30,31)
	tap water, water balance according to MoeK 2013, at user	KR	0	kg	0	0	0	0	1	1.22	(2,2,4,1,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 30,31)
	tap water, water balance according to MoeK 2013, at user	RER	0	kg	0	0	0	0	1	1.22	(2,2,4,1,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 30,31)
energy	electricity, medium voltage, at grid	CN	0	kWh	1.77E+1	1.77E+1	0	0	1	1.09	(2,2,1,1,1,3); Woodhouse et al. (2019): c-Si PV Manufacturing Costs 2018
	electricity, medium voltage, at grid	US	0	kWh	0	0	1.77E+1	1.77E+1	1	1.09	(2,2,1,1,1,3); Woodhouse et al. (2019): c-Si PV Manufacturing Costs 2018
	electricity, medium voltage, at grid	KR	0	kWh	0	0	0	0	1	1.09	(2,2,1,1,1,3); Woodhouse et al. (2019): c-Si PV Manufacturing Costs 2018
	electricity, medium voltage, production ENTSO, at grid	ENTSO	0	kWh	0	0	0	0	1	1.09	(2,2,1,1,1,3); Woodhouse et al. (2019): c-Si PV Manufacturing Costs 2018
	natural gas, burned in industrial furnace low-NOx >100kW	RER	0	MJ	6.08E-2	2.47E-1	6.08E-2	2.47E-1	1	1.22	(2,2,4,1,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 30,31)
	light fuel oil, burned in industrial furnace 1MW, non-modulating	RER	0	MJ	0	2.70E-3	0	2.70E-3	1	1.22	(2,2,4,1,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 30,31)
infrastructure	photovoltaic cell factory	DE	1	unit	4.00E-7	4.00E-7	4.00E-7	4.00E-7	1	3.05	(2,2,4,1,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 30,31)
transport	transport, freight, lorry, fleet average	RER	0	tkm	2.74E-1	5.22E-1	2.74E-1	5.22E-1	1	2.09	(4,5,na,na,na,na); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 30,31)
	transport, freight, rail	RER	0	tkm	1.52E+0	3.94E-1	1.52E+0	3.94E-1	1	2.09	(4,5,na,na,na,na); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 30,31)
disposal	treatment, PV cell production effluent, to wastewater treatment, class 3	CH	0	m3	1.54E-1	2.26E-1	1.54E-1	2.26E-1	1	1.22	(2,2,4,1,1,3); Calculation based on water withdrawal and water emissions
	disposal, waste, Si waferprod., inorg, 9.4% water, to residual material landfill	CH	0	kg	2.33E+0	2.74E+0	2.33E+0	2.74E+0	1	1.22	(2,2,4,1,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 30,31)
	disposal, solvents mixture, 16.5% water, to hazardous waste incineration	CH	0	kg	1.72E-1	1.08E-2	1.72E-1	1.08E-2	1	1.22	(2,2,4,1,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 30,31)
emission air, high population density	Heat, waste	-	-	MJ	5.18E+1	5.18E+1	5.18E+1	5.18E+1	1	1.22	(2,2,4,1,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 30,31)
	Water, CN	-	-	kg	1.71E+1	2.51E+1	0	0	1	1.63	(2,3,4,3,1,5); Assumption: 10% evaporation of process water; Frischknecht & Büsser Knöpfel (2013)
	Water, US	-	-	kg	0	0	1.71E+1	2.51E+1	1	1.63	(2,3,4,3,1,5); Assumption: 10% evaporation of process water; Frischknecht & Büsser Knöpfel (2013)
	Water, KR	-	-	kg	0	0	0	0	1	1.63	(2,3,4,3,1,5); Assumption: 10% evaporation of process water; Frischknecht & Büsser Knöpfel (2013)
	Water, RER	-	-	kg	0	0	0	0	1	1.63	(2,3,4,3,1,5); Assumption: 10% evaporation of process water; Frischknecht & Büsser Knöpfel (2013)
	Aluminium	-	-	kg	7.73E-6	7.73E-6	7.73E-6	7.73E-6	1	5.06	(2,2,4,1,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 30,31)
	Hydrogen fluoride	-	-	kg	1.38E-4	6.90E-4	1.38E-4	6.90E-4	1	1.57	(2,2,4,1,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 30,31)
	Lead	-	-	kg	7.73E-6	7.73E-6	7.73E-6	7.73E-6	1	5.06	(2,2,4,1,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 30,31)
	Silicon	-	-	kg	3.17E-8	3.17E-8	3.17E-8	3.17E-8	1	5.06	(2,2,4,1,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 30,31)
	Silver	-	-	kg	7.73E-6	7.73E-6	7.73E-6	7.73E-6	1	5.06	(2,2,4,1,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 30,31)
	Tin	-	-	kg	7.73E-6	7.73E-6	7.73E-6	7.73E-6	1	5.06	(2,2,4,1,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 30,31)
	Ammonia	-	-	kg	3.73E-5	5.22E-4	3.73E-5	5.22E-4	1	1.31	(2,2,4,1,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 30,31)
	Carbon dioxide, fossil	-	-	kg	1.67E-1	6.82E-1	1.67E-1	6.82E-1	1	1.22	(2,2,4,1,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 30,31)
	Chlorine	-	-	kg	4.60E-5	0	4.60E-5	0	1	1.57	(2,2,4,1,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 30,31)
	Hydrogen	-	-	kg	1.10E-2	4.44E-4	1.10E-2	4.44E-4	1	1.57	(2,2,4,1,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 30,31)
	2-Propanol	-	-	kg	1.47E-2	0	1.47E-2	0	1	1.57	(2,2,4,1,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 30,31)
	Acetaldehyde	-	-	kg	6.33E-4	0	6.33E-4	0	1	1.57	(2,2,4,1,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 30,31)
	Ethane, 1,1,1,2-tetrafluoro-, HFC-134a	-	-	kg	3.12E-5	2.73E-5	3.12E-5	2.73E-5	1	1.57	(2,2,4,1,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 30,31)
	Silicon	-	-	kg	3.33E-4	1.47E-4	3.33E-4	1.47E-4	1	5.06	(2,2,4,1,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 30,31)
	Silicon	-	-	kg	2.63E-3	6.00E-6	2.63E-3	6.00E-6	1	5.06	(2,2,4,1,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 30,31)
	NMVOC, non-methane volatile organic compounds, unspecified origin	-	-	kg	1.26E-2	3.53E-4	1.26E-2	3.53E-4	1	1.57	(2,2,4,1,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 30,31)
	Nitric acid	-	-	kg	0	1.19E-4	0	1.19E-4	1	1.57	(2,2,4,1,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 30,31)
	Nitrogen oxides	-	-	kg	0	1.24E-2	0	1.24E-2	1	1.57	(2,2,4,1,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 30,31)
	Nitrogen oxides	-	-	kg	0	3.64E-3	0	3.64E-3	1	1.57	(2,2,4,1,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 30,31)

Table 17: Unit process LCA data of the photovoltaic cell production in Europe (RER) and Asia & Pacific (APAC)

	Name	Location	InfrastructureProcess	Unit	photovoltaic cell, single-Si, at plant	photovoltaic cell, multi-Si, at plant	photovoltaic cell, single-Si, at plant	photovoltaic cell, multi-Si, at plant	UncertaintyType	StandardDeviation95 %	GeneralComment
	Location				APAC	APAC	RER	RER			
	InfrastructureProcess				0	0	0	0			
	Unit				m2	m2	m2	m2			
product	photovoltaic cell, single-Si, at plant	CN	0	m2	0	0	0	0			
	photovoltaic cell, multi-Si, at plant	CN	0	m2	0	0	0	0			
	photovoltaic cell, single-Si, at plant	US	0	m2	0	0	0	0			
	photovoltaic cell, multi-Si, at plant	US	0	m2	0	0	0	0			
	photovoltaic cell, single-Si, at plant	APAC	0	m2	1	0	0	0			
	photovoltaic cell, multi-Si, at plant	APAC	0	m2	0	1	0	0			
	photovoltaic cell, single-Si, at plant	RER	0	m2	0	0	1	0			
	photovoltaic cell, multi-Si, at plant	RER	0	m2	0	0	0	1			
wafers	single-Si wafer, photovoltaics, at plant	CN	0	m2	0	0	0	0	1	1.10	(2,2,2,1,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 30,31)
	multi-Si wafer, at plant	CN	0	m2	0	0	0	0	1	1.10	(2,2,2,1,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 30,31)
	single-Si wafer, photovoltaics, at regional storage	US	0	m2	0	0	0	0	1	3.01	(2,2,2,1,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 30,31)
	multi-Si wafer, at regional storage	US	0	m2	0	0	0	0	1	3.01	(2,2,2,1,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 30,31)
	single-Si wafer, photovoltaics, at regional storage	APAC	0	m2	1.03E+0	0	0	0	1	3.01	(2,2,2,1,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 30,31)
	multi-Si wafer, at regional storage	APAC	0	m2	0	1.04E+0	0	0	1	3.01	(2,2,2,1,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 30,31)
	single-Si wafer, photovoltaics, at regional storage	RER	0	m2	0	0	1.03E+0	0	1	3.01	(2,2,2,1,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 30,31)
	multi-Si wafer, at regional storage	RER	0	m2	0	0	0	1.04E+0	1	3.01	(2,2,2,1,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 30,31)
materials	metallization paste, front side, at plant	RER	0	kg	3.37E-3	3.37E-3	3.37E-3	3.37E-3	1	1.09	(2,2,1,1,1,3); Woodhouse et al. (2019): c-Si PV Manufacturing Costs 2018
	metallization paste, back side, at plant	RER	0	kg	1.11E-3	1.11E-3	1.11E-3	1.11E-3	1	1.09	(2,2,1,1,1,3); Woodhouse et al. (2019): c-Si PV Manufacturing Costs 2018
	metallization paste, back side, aluminium, at plant	RER	0	kg	5.54E-2	5.54E-2	5.54E-2	5.54E-2	1	1.09	(2,2,1,1,1,3); Woodhouse et al. (2019): c-Si PV Manufacturing Costs 2018
chemicals	ammonia, liquid, at regional storehouse	RER	0	kg	2.19E-2	8.92E-3	2.19E-2	8.92E-3	1	1.22	(2,2,4,1,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 30,31)
	phosphoric acid, fertiliser grade, 70% in H2O, at plant	GLO	0	kg	0	8.63E-3	0	8.63E-3	1	1.22	(2,2,4,1,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 30,31)
	phosphoryl chloride, at plant	RER	0	kg	1.33E-2	2.74E-2	1.33E-2	2.74E-2	1	1.22	(2,2,4,1,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 30,31)
	isopropanol, at plant	RER	0	kg	1.77E-1	8.10E-4	1.77E-1	8.10E-4	1	1.22	(2,2,4,1,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 30,31)
	solvents, organic, unspecified, at plant	GLO	0	kg	0	1.13E-2	0	1.13E-2	1	1.22	(2,2,4,1,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 30,31)
	calcium chloride, CaCl2, at regional storage	CH	0	kg	0	3.15E-2	0	3.15E-2	1	1.22	(2,2,4,1,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 30,31)
	hydrochloric acid, 30% in H2O, at plant	RER	0	kg	6.29E-4	8.59E-3	6.29E-4	8.59E-3	1	1.22	(2,2,4,1,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 30,31)
	hydrogen fluoride, at plant	GLO	0	kg	6.45E-4	4.03E-1	6.45E-4	4.03E-1	1	1.22	(2,2,4,1,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 30,31)
	nitric acid, 50% in H2O, at plant	RER	0	kg	0	2.93E-1	0	2.93E-1	1	1.22	(2,2,4,1,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 30,31)
	sodium hydroxide, 50% in H2O, production mix, at plant	RER	0	kg	6.04E-1	7.07E-2	6.04E-1	7.07E-2	1	1.22	(2,2,4,1,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 30,31)
	lime, hydrated, packed, at plant	CH	0	kg	1.51E-2	2.18E-1	1.51E-2	2.18E-1	1	1.22	(2,2,4,1,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 30,31)
	hydrogen peroxide, 50% in H2O, at plant	RER	0	kg	0	4.52E-4	0	4.52E-4	1	1.22	(2,2,4,1,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 30,31)
	sulphuric acid, liquid, at plant	RER	0	kg	0	1.01E-1	0	1.01E-1	1	1.22	(2,2,4,1,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 30,31)
	refrigerant R134a, at plant	RER	0	kg	3.12E-5	2.73E-5	3.12E-5	2.73E-5	1	1.22	(2,2,4,1,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 30,31)
	potassium hydroxide, at regional storage	RER	0	kg	0	3.00E-2	0	3.00E-2	1	1.22	(2,2,4,1,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 30,31)
	ammonium sulphate, as N, at regional storehouse	RER	0	kg	0	2.10E-2	0	2.10E-2	1	1.22	(2,2,4,1,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 30,31)
gases	oxygen, liquid, at plant	RER	0	kg	0	8.22E-3	0	8.22E-3	1	1.22	(2,2,4,1,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 30,31)
	nitrogen, liquid, at plant	RER	0	kg	1.15E+0	1.35E+0	1.15E+0	1.35E+0	1	1.22	(2,2,4,1,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 30,31)
	silane, at plant	RER	0	kg	2.91E-3	2.61E-3	2.91E-3	2.61E-3	1	1.22	(2,2,4,1,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 30,31)
	tap water, water balance according to MoeK 2013, at user	CN	0	kg	0	0	0	0	1	1.22	(2,2,4,1,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 30,31)
	tap water, water balance according to MoeK 2013, at user	US	0	kg	0	0	0	0	1	1.22	(2,2,4,1,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 30,31)
	tap water, water balance according to MoeK 2013, at user	KR	0	kg	1.71E+2	2.51E+2	0	0	1	1.22	(2,2,4,1,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 30,31)
	tap water, water balance according to MoeK 2013, at user	RER	0	kg	0	0	1.71E+2	2.51E+2	1	1.22	(2,2,4,1,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 30,31)
energy	electricity, medium voltage, at grid	CN	0	kWh	0	0	0	0	1	1.09	(2,2,1,1,1,3); Woodhouse et al. (2019): c-Si PV Manufacturing Costs 2018
	electricity, medium voltage, at grid	US	0	kWh	0	0	0	0	1	1.09	(2,2,1,1,1,3); Woodhouse et al. (2019): c-Si PV Manufacturing Costs 2018
	electricity, medium voltage, at grid	KR	0	kWh	1.77E+1	1.77E+1	0	0	1	1.09	(2,2,1,1,1,3); Woodhouse et al. (2019): c-Si PV Manufacturing Costs 2018
	electricity, medium voltage, production ENTSO, at grid	ENTSO	0	kWh	0	0	1.77E+1	1.77E+1	1	1.09	(2,2,1,1,1,3); Woodhouse et al. (2019): c-Si PV Manufacturing Costs 2018
	natural gas, burned in industrial furnace low-NOx >100kW	RER	0	MJ	6.08E-2	2.47E-1	6.08E-2	2.47E-1	1	1.22	(2,2,4,1,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 30,31)
	light fuel oil, burned in industrial furnace 1MW, non-modulating	RER	0	MJ	0	2.70E-3	0	2.70E-3	1	1.22	(2,2,4,1,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 30,31)
infrastructure	photovoltaic cell factory	DE	1	unit	4.00E-7	4.00E-7	4.00E-7	4.00E-7	1	3.05	(2,2,4,1,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 30,31)
transport	transport, freight, lorry, fleet average	RER	0	tkm	2.74E-1	5.22E-1	2.74E-1	5.22E-1	1	2.09	(4,5,na,na,na,na); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 30,31)
	transport, freight, rail	RER	0	tkm	1.52E+0	3.94E-1	1.52E+0	3.94E-1	1	2.09	(4,5,na,na,na,na); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 30,31)
disposal	treatment, PV cell production effluent, to wastewater treatment, class 3	CH	0	m3	1.54E-1	2.26E-1	1.54E-1	2.26E-1	1	1.22	(2,2,4,1,1,3); Calculation based on water withdrawal and water emissions
	disposal, waste, Si waferprod., inorg, 9.4% water, to residual material landfill	CH	0	kg	2.33E+0	2.74E+0	2.33E+0	2.74E+0	1	1.22	(2,2,4,1,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 30,31)
	disposal, solvents mixture, 16.5% water, to hazardous waste incineration	CH	0	kg	1.72E-1	1.08E-2	1.72E-1	1.08E-2	1	1.22	(2,2,4,1,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 30,31)
emission air, high population density	Heat, waste	-	-	MJ	5.18E+1	5.18E+1	5.18E+1	5.18E+1	1	1.22	(2,2,4,1,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 30,31)
	Water, CN	-	-	kg	0	0	0	0	1	1.63	(2,3,4,3,1,5); Assumption: 10% evaporation of process water; Frischknecht & Büsser Knöpfel (2013)
	Water, US	-	-	kg	0	0	0	0	1	1.63	(2,3,4,3,1,5); Assumption: 10% evaporation of process water; Frischknecht & Büsser Knöpfel (2013)
	Water, KR	-	-	kg	1.71E+1	2.51E+1	0	0	1	1.63	(2,3,4,3,1,5); Assumption: 10% evaporation of process water; Frischknecht & Büsser Knöpfel (2013)
	Water, RER	-	-	kg	0	0	1.71E+1	2.51E+1	1	1.63	(2,3,4,3,1,5); Assumption: 10% evaporation of process water; Frischknecht & Büsser Knöpfel (2013)
	Aluminium	-	-	kg	7.73E-6	7.73E-6	7.73E-6	7.73E-6	1	5.06	(2,2,4,1,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 30,31)
	Hydrogen fluoride	-	-	kg	1.38E-4	6.90E-4	1.38E-4	6.90E-4	1	1.57	(2,2,4,1,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 30,31)
	Lead	-	-	kg	7.73E-6	7.73E-6	7.73E-6	7.73E-6	1	5.06	(2,2,4,1,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 30,31)
	Silicon	-	-	kg	3.17E-8	3.17E-8	3.17E-8	3.17E-8	1	5.06	(2,2,4,1,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 30,31)
	Silver	-	-	kg	7.73E-6	7.73E-6	7.73E-6	7.73E-6	1	5.06	(2,2,4,1,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 30,31)
	Tin	-	-	kg	7.73E-6	7.73E-6	7.73E-6	7.73E-6	1	5.06	(2,2,4,1,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 30,31)
	Ammonia	-	-	kg	3.73E-5	5.22E-4	3.73E-5	5.22E-4	1	1.31	(2,2,4,1,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 30,31)
	Carbon dioxide, fossil	-	-	kg	1.67E-1	6.82E-1	1.67E-1	6.82E-1	1	1.22	(2,2,4,1,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 30,31)
	Chlorine	-	-	kg	4.60E-5	0	4.60E-5	0	1	1.57	(2,2,4,1,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 30,31)
	Hydrogen	-	-	kg	1.10E-2	4.44E-4	1.10E-2	4.44E-4	1	1.57	(2,2,4,1,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 30,31)
	2-Propanol	-	-	kg	1.47E-2	0	1.47E-2	0	1	1.57	(2,2,4,1,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 30,31)
	Acetaldehyde	-	-	kg	6.33E-4	0	6.33E-4	0	1	1.57	(2,2,4,1,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 30,31)
	Ethane, 1,1,1,2-tetrafluoro-, HFC-134a	-	-	kg	3.12E-5	2.73E-5	3.12E-5	2.73E-5	1	1.57	(2,2,4,1,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 30,31)
	Silicon	-	-	kg	3.33E-4	1.47E-4	3.33E-4	1.47E-4	1	5.06	(2,2,4,1,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 30,31)
	Silicon	-	-	kg	2.63E-3	6.00E-6	2.63E-3	6.00E-6	1	5.06	(2,2,4,1,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 30,31)
	NMVOC, non-methane volatile organic compounds, unspecified origin	-	-	kg	1.26E-2	3.53E-4	1.26E-2	3.53E-4	1	1.57	(2,2,4,1,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 30,31)
	Nitric acid	-	-	kg	0	1.19E-4	0	1.19E-4	1	1.57	(2,2,4,1,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 30,31)
	Nitrogen oxides	-	-	kg	0	1.24E-2	0	1.24E-2	1	1.57	(2,2,4,1,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 30,31)
	Nitrogen oxides	-	-	kg	0	3.64E-3	0	3.64E-3	1	1.57	(2,2,4,1,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 30,31)

The cells used in panel production in China and Asia & Pacific are produced domestically. Panel manufacturers in Europe and the Americas import a large share of the cells from Asia & Pacific and from China. Table 18 shows the LCI datasets representing the cell market mixes in Europe and the Americas.

Table 18: Unit process LCI data of the photovoltaic cell market mix 2018 in Europe (RER) and the Americas (US)

	Name	Location	InfrastructureProcess	Unit	photovoltaic cell, multi-Si, at regional storage	photovoltaic cell, single-Si, at regional storage	photovoltaic cell, multi-Si, at regional storage	photovoltaic cell, single-Si, at regional storage	UncertaintyType	StandardDeviation95%	GeneralComment
	Location				RER	RER	US	US			
	InfrastructureProcess				0	0	0	0			
	Unit				m2	m2	m2	m2			
product	photovoltaic cell, multi-Si, at regional storage	RER	0	m2	1	0	0	0			
	photovoltaic cell, single-Si, at regional storage	RER	0	m2	0	1	0	0			
	photovoltaic cell, multi-Si, at regional storage	US	0	m2	0	0	1	0			
	photovoltaic cell, single-Si, at regional storage	US	0	m2	0	0	0	1			
cells	photovoltaic cell, multi-Si, at plant	RER	0	m2	1.61E-1	0	0	0	1	1.56	(5,1,1,1,1,5); Market share European cells
	photovoltaic cell, single-Si, at plant	RER	0	m2	0	1.61E-1	0	0	1	1.56	(5,1,1,1,1,5); Market share European cells
	photovoltaic cell, multi-Si, at plant	CN	0	m2	0	0	0	0	1	1.56	(5,1,1,1,1,5); Market share Chinese cells
	photovoltaic cell, single-Si, at plant	CN	0	m2	0	0	0	0	1	1.56	(5,1,1,1,1,5); Market share Chinese cells
	photovoltaic cell, multi-Si, at plant	US	0	m2	0	0	7.19E-2	0	1	1.56	(5,1,1,1,1,5); Market share US cells
	photovoltaic cell, single-Si, at plant	US	0	m2	0	0	0	7.19E-2	1	1.56	(5,1,1,1,1,5); Market share US cells
	photovoltaic cell, multi-Si, at plant	APAC	0	m2	8.39E-1	0	9.28E-1	0	1	1.56	(5,1,1,1,1,5); Market share APAC cells
	photovoltaic cell, single-Si, at plant	APAC	0	m2	0	8.39E-1	0	9.28E-1	1	1.56	(5,1,1,1,1,5); Market share APAC cells
transport	transport, transoceanic freight ship	OCE	0	tkm	6.27E+0	5.92E+0	8.50E+0	8.03E+0	1	2.09	(4,5,na,na,na,na); Transport distance CN-EU: 19994 km, CN-US: 20755 km, APAC-EU: 15026 km, APAC-US: 18411 km
	transport, freight, rail	RER	0	tkm	9.95E-2	9.40E-2	9.95E-2	9.40E-2	1	2.09	(4,5,na,na,na,na); Standard distance 200km
	transport, freight, lorry, fleet average	RER	0	tkm	2.49E-2	2.35E-2	2.49E-2	2.35E-2	1	2.09	(4,5,na,na,na,na); Standard distance 50km

Photovoltaic laminate and panels

Tables 19-22 show the unit process data of the photovoltaic laminate and panel production in China (CN), North America (US), Asia & Pacific (APAC) and in Europe (RER).

The Japanese electricity mix is selected for the APAC region, because Japan produces the highest share of single- and multi-crystalline laminate and panel in the APAC region. The US electricity mix is chosen to model electricity consumption in the North American production.

The LCI data on material and energy consumption as well as about emissions are updated based on LCI data of single- and multi-crystalline modules published by de Wild-Scholten [10].

Table 19: Unit process LCI data of the photovoltaic laminate and panel production in China (CN)

	Name	Location	InfrastructureProcess	Unit	photovoltaic panel, single-Si, at plant	photovoltaic panel, multi-Si, at plant	photovoltaic laminate, single-Si, at plant	photovoltaic laminate, multi-Si, at plant	UncertaintyType	StandardDeviation95%	GeneralComment
	Location				CN	CN	CN	CN			
	InfrastructureProcess				1	1	1	1			
	Unit				m2	m2	m2	m2			
product	photovoltaic panel, single-Si, at plant	CN	1	m2	1	0	0	0			
	photovoltaic panel, multi-Si, at plant	CN	1	m2	0	1	0	0			
	photovoltaic laminate, single-Si, at plant	CN	1	m2	0	0	1	0			
	photovoltaic laminate, multi-Si, at plant	CN	1	m2	0	0	0	1			
	photovoltaic panel, single-Si, at plant	US	1	m2	0	0	0	0			
	photovoltaic panel, multi-Si, at plant	US	1	m2	0	0	0	0			
	photovoltaic laminate, single-Si, at plant	US	1	m2	0	0	0	0			
	photovoltaic laminate, multi-Si, at plant	US	1	m2	0	0	0	0			
	photovoltaic panel, single-Si, at plant	APAC	1	m2	0	0	0	0			
	photovoltaic panel, multi-Si, at plant	APAC	1	m2	0	0	0	0			
	photovoltaic laminate, single-Si, at plant	APAC	1	m2	0	0	0	0			
	photovoltaic laminate, multi-Si, at plant	APAC	1	m2	0	0	0	0			
	photovoltaic panel, single-Si, at plant	RER	1	m2	0	0	0	0			
	photovoltaic panel, multi-Si, at plant	RER	1	m2	0	0	0	0			
	photovoltaic laminate, single-Si, at plant	RER	1	m2	0	0	0	0			
	photovoltaic laminate, multi-Si, at plant	RER	1	m2	0	0	0	0			
materials	photovoltaic cell, single-Si, at plant	CN	0	m2	9.35E-1	0	9.35E-1	0	1	1.24	(1,4,4,3,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 37)
	photovoltaic cell, multi-Si, at plant	CN	0	m2	0	9.35E-1	0	9.35E-1	1	1.24	(1,4,4,3,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 37)
	photovoltaic cell, single-Si, at regional storage	US	0	m2	0	0	0	0	1	3.06	(1,4,4,3,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 37)
	photovoltaic cell, multi-Si, at regional storage	US	0	m2	0	0	0	0	1	3.06	(1,4,4,3,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 37)
	photovoltaic cell, single-Si, at plant	APAC	0	m2	0	0	0	0	1	1.24	(1,4,4,3,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 37)
	photovoltaic cell, multi-Si, at plant	APAC	0	m2	0	0	0	0	1	1.24	(1,4,4,3,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 37)
	photovoltaic cell, single-Si, at regional storage	RER	0	m2	0	0	0	0	1	3.06	(1,4,4,3,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 37)
	photovoltaic cell, multi-Si, at regional storage	RER	0	m2	0	0	0	0	1	3.06	(1,4,4,3,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 37)
	aluminium alloy, AlMg3, at plant	RER	0	kg	2.13E+0	2.13E+0	0	0	1	1.24	(1,4,4,3,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 37)
	copper, at regional storage	RER	0	kg	1.03E-1	1.03E-1	1.03E-1	1.03E-1	1	1.24	(1,4,4,3,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 37)
	wire drawing, copper	RER	0	kg	1.03E-1	1.03E-1	1.03E-1	1.03E-1	1	1.24	(1,4,4,3,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 37)
	diode, unspecified, at plant	GLO	0	kg	2.81E-3	2.81E-3	2.81E-3	2.81E-3	1	1.34	(3,4,4,3,1,5); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 37)
	silicone product, at plant	RER	0	kg	1.22E-1	1.22E-1	1.22E-1	1.22E-1	1	1.24	(1,4,4,3,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 37)
	tin, at regional storage	RER	0	kg	1.29E-2	1.29E-2	1.29E-2	1.29E-2	1	1.34	(3,4,4,3,1,5); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 37)
	lead, at regional storage	RER	0	kg	7.25E-4	7.25E-4	7.25E-4	7.25E-4	1	1.34	(3,4,4,3,1,5); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 37)
	solar glass, low-iron, at regional storage	RER	0	kg	8.81E+0	8.81E+0	8.81E+0	8.81E+0	1	1.33	(1,4,4,3,3,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 37)
	tempering, flat glass	RER	0	kg	8.81E+0	8.81E+0	8.81E+0	8.81E+0	1	1.24	(1,4,4,3,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 37)
	glass fibre reinforced plastic, polyamide, injection moulding, at plant	RER	0	kg	2.95E-1	2.95E-1	2.95E-1	2.95E-1	1	1.24	(1,4,4,3,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 37)
	polyethylene terephthalate, granulate, amorphous, at plant	RER	0	kg	3.46E-1	3.46E-1	3.46E-1	3.46E-1	1	1.24	(1,4,4,3,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 37)
	polyethylene, HDPE, granulate, at plant	RER	0	kg	2.38E-2	2.38E-2	2.38E-2	2.38E-2	1	1.34	(3,4,4,3,1,5); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 37)
	ethylvinylacetate, foil, at plant	RER	0	kg	8.75E-1	8.75E-1	8.75E-1	8.75E-1	1	1.24	(1,4,4,3,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 37)
	polyvinylfluoride film, at plant	US	0	kg	1.12E-1	1.12E-1	1.12E-1	1.12E-1	1	1.24	(1,4,4,3,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 37)
auxiliaries	tap water, water balance according to MoeK 2013, at user	CN	0	kg	5.03E+0	5.03E+0	5.03E+0	5.03E+0	1	1.24	(1,4,4,3,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 37)
	tap water, water balance according to MoeK 2013, at user	US	0	kg	0	0	0	0	1	1.24	(1,4,4,3,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 37)
	tap water, water balance according to MoeK 2013, at user	KR	0	kg	0	0	0	0	1	1.24	(1,4,4,3,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 37)
	tap water, water balance according to MoeK 2013, at user	RER	0	kg	0	0	0	0	1	1.24	(1,4,4,3,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 37)
	hydrogen fluoride, at plant	GLO	0	kg	6.24E-2	6.24E-2	6.24E-2	6.24E-2	1	1.34	(3,4,4,3,1,5); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 37)
	1-propanol, at plant	RER	0	kg	1.59E-2	1.59E-2	1.59E-2	1.59E-2	1	1.24	(1,4,4,3,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 37)
	isopropanol, at plant	RER	0	kg	1.47E-4	1.47E-4	1.47E-4	1.47E-4	1	1.34	(3,4,4,3,1,5); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 37)
	potassium hydroxide, at regional storage	RER	0	kg	5.14E-2	5.14E-2	5.14E-2	5.14E-2	1	1.34	(3,4,4,3,1,5); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 37)
	soap, at plant	RER	0	kg	1.16E-2	1.16E-2	1.16E-2	1.16E-2	1	1.34	(3,4,4,3,1,5); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 37)
	corrugated board, mixed fibre, single wall, at plant	RER	0	kg	7.63E-1	7.63E-1	7.63E-1	7.63E-1	1	1.24	(1,4,4,3,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 37)
	EUR-flat pallet	RER	0	unit	5.00E-2	5.00E-2	5.00E-2	5.00E-2	1	1.34	(3,4,4,3,1,5); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 37)
energy	electricity, medium voltage, at grid	CN	0	kWh	1.40E+1	1.40E+1	1.40E+1	1.40E+1	1	1.09	(2,2,1,1,1,3); Woodhouse et al. (2019): c-Si PV Manufacturing Costs 2018
	electricity, medium voltage, at grid	US	0	kWh	0	0	0	0	1	1.09	(2,2,1,1,1,3); Woodhouse et al. (2019): c-Si PV Manufacturing Costs 2018
	electricity, medium voltage, at grid	KR	0	kWh	0	0	0	0	1	1.09	(2,2,1,1,1,3); Woodhouse et al. (2019): c-Si PV Manufacturing Costs 2018
	electricity, medium voltage, production ENTSO, at grid	ENTSO	0	kWh	0	0	0	0	1	1.09	(2,2,1,1,1,3); Woodhouse et al. (2019): c-Si PV Manufacturing Costs 2018
	diesel, burned in building machine, average	CH	0	MJ	8.75E-3	8.75E-3	8.75E-3	8.75E-3	1	2.12	(3,4,4,3,1,5); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 37)
infrastructure	photovoltaic panel factory	GLO	1	unit	4.00E-6	4.00E-6	4.00E-6	4.00E-6	1	3.06	(1,4,4,3,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 37)
transport	transport, freight, lorry, fleet average	RER	0	tkm	2.77E+0	3.01E+0	2.56E+0	2.79E+0	1	2.09	(4,5,na,na,na,na); Standard distance 100km, cells 500km
	transport, freight, rail	RER	0	tkm	1.66E+1	1.66E+1	1.54E+1	1.54E+1	1	2.09	(4,5,na,na,na,na); Standard distance 600km
disposal	disposal, municipal solid waste, 22.9% water, to municipal incineration	CH	0	kg	3.00E-2	3.00E-2	3.00E-2	3.00E-2	1	1.24	(1,4,4,3,1,3); Alsema (personal communication) 2007, production waste
	disposal, polyvinylfluoride, 0.2% water, to municipal incineration	CH	0	kg	4.29E-3	4.29E-3	4.29E-3	4.29E-3	1	1.24	(1,4,4,3,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 37)
	disposal, plastics, mixture, 15.3% water, to municipal incineration	CH	0	kg	2.81E-2	2.81E-2	2.81E-2	2.81E-2	1	1.24	(1,4,4,3,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 37)
	disposal, used mineral oil, 10% water, to hazardous waste incineration	CH	0	kg	1.61E-3	1.61E-3	1.61E-3	1.61E-3	1	1.24	(1,4,4,3,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 37)
	treatment, sewage, from residence, to wastewater treatment, class 2	CH	0	m3	4.53E-3	4.53E-3	4.53E-3	4.53E-3	1	1.24	(1,4,4,3,1,3); Calculation, water use
emissions air	Heat, waste	-	-	MJ	5.03E+1	5.03E+1	5.03E+1	5.03E+1	1	1.60	(3,4,5,3,1,5); Calculation, electricity use
	NMVOC, non-methane volatile organic compounds, unspecified origin	-	-	kg	8.06E-3	8.06E-3	8.06E-3	8.06E-3	1	1.85	(3,4,5,3,1,5); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 37)
	Carbon dioxide, fossil	-	-	kg	2.18E-2	2.18E-2	2.18E-2	2.18E-2	1	1.60	(3,4,5,3,1,5); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 37)
	Water, CN	-	-	kg	5.03E-1	5.03E-1	5.03E-1	5.03E-1	1	1.85	(3,4,5,3,1,5); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 37)
	Water, US	-	-	kg	0	0	0	0	1	1.85	(3,4,5,3,1,5); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 37)
	Water, KR	-	-	kg	0	0	0	0	1	1.85	(3,4,5,3,1,5); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 37)
	Water, RER	-	-	kg	0	0	0	0	1	1.85	(3,4,5,3,1,5); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 37)

Table 20: Unit process LCI data of the photovoltaic laminate and panel production in North America (US)

	Name	Location	InfrastructureProcess	Unit	photovoltaic panel, single-Si, at plant	photovoltaic panel, multi-Si, at plant	photovoltaic laminate, single-Si, at plant	photovoltaic laminate, multi-Si, at plant	UncertaintyType	StandardDeviation95%	GeneralComment
	Location				US	US	US	US			
	InfrastructureProcess				1	1	1	1			
	Unit				m2	m2	m2	m2			
product	photovoltaic panel, single-Si, at plant	CN	1	m2	0	0	0	0			
	photovoltaic panel, multi-Si, at plant	CN	1	m2	0	0	0	0			
	photovoltaic laminate, single-Si, at plant	CN	1	m2	0	0	0	0			
	photovoltaic laminate, multi-Si, at plant	CN	1	m2	0	0	0	0			
	photovoltaic panel, single-Si, at plant	US	1	m2	1	0	0	0			
	photovoltaic panel, multi-Si, at plant	US	1	m2	0	1	0	0			
	photovoltaic laminate, single-Si, at plant	US	1	m2	0	0	1	0			
	photovoltaic laminate, multi-Si, at plant	US	1	m2	0	0	0	1			
	photovoltaic panel, single-Si, at plant	APAC	1	m2	0	0	0	0			
	photovoltaic panel, multi-Si, at plant	APAC	1	m2	0	0	0	0			
	photovoltaic laminate, single-Si, at plant	APAC	1	m2	0	0	0	0			
	photovoltaic laminate, multi-Si, at plant	APAC	1	m2	0	0	0	0			
	photovoltaic panel, single-Si, at plant	RER	1	m2	0	0	0	0			
	photovoltaic panel, multi-Si, at plant	RER	1	m2	0	0	0	0			
	photovoltaic laminate, single-Si, at plant	RER	1	m2	0	0	0	0			
	photovoltaic laminate, multi-Si, at plant	RER	1	m2	0	0	0	0			
materials	photovoltaic cell, single-Si, at plant	CN	0	m2	0	0	0	0	1	1.24	(1,4,4,3,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 37)
	photovoltaic cell, multi-Si, at plant	CN	0	m2	0	0	0	0	1	1.24	(1,4,4,3,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 37)
	photovoltaic cell, single-Si, at regional storage	US	0	m2	9.35E-1	0	9.35E-1	0	1	3.06	(1,4,4,3,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 37)
	photovoltaic cell, multi-Si, at regional storage	US	0	m2	0	9.35E-1	0	9.35E-1	1	3.06	(1,4,4,3,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 37)
	photovoltaic cell, single-Si, at plant	APAC	0	m2	0	0	0	0	1	1.24	(1,4,4,3,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 37)
	photovoltaic cell, multi-Si, at plant	APAC	0	m2	0	0	0	0	1	1.24	(1,4,4,3,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 37)
	photovoltaic cell, single-Si, at regional storage	RER	0	m2	0	0	0	0	1	3.06	(1,4,4,3,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 37)
	photovoltaic cell, multi-Si, at regional storage	RER	0	m2	0	0	0	0	1	3.06	(1,4,4,3,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 37)
	aluminium alloy, AlMg3, at plant	RER	0	kg	2.13E+0	2.13E+0	0	0	1	1.24	(1,4,4,3,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 37)
	copper, at regional storage	RER	0	kg	1.03E-1	1.03E-1	1.03E-1	1.03E-1	1	1.24	(1,4,4,3,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 37)
	wire drawing, copper	RER	0	kg	1.03E-1	1.03E-1	1.03E-1	1.03E-1	1	1.24	(1,4,4,3,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 37)
	diode, unspecified, at plant	GLO	0	kg	2.81E-3	2.81E-3	2.81E-3	2.81E-3	1	1.34	(3,4,4,3,1,5); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 37)
	silicone product, at plant	RER	0	kg	1.22E-1	1.22E-1	1.22E-1	1.22E-1	1	1.24	(1,4,4,3,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 37)
	tin, at regional storage	RER	0	kg	1.29E-2	1.29E-2	1.29E-2	1.29E-2	1	1.34	(3,4,4,3,1,5); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 37)
	lead, at regional storage	RER	0	kg	7.25E-4	7.25E-4	7.25E-4	7.25E-4	1	1.34	(3,4,4,3,1,5); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 37)
	solar glass, low-iron, at regional storage	RER	0	kg	8.81E+0	8.81E+0	8.81E+0	8.81E+0	1	1.33	(1,4,4,3,3,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 37)
	tempering, flat glass	RER	0	kg	8.81E+0	8.81E+0	8.81E+0	8.81E+0	1	1.24	(1,4,4,3,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 37)
	glass fibre reinforced plastic, polyamide, injection moulding, at plant	RER	0	kg	2.95E-1	2.95E-1	2.95E-1	2.95E-1	1	1.24	(1,4,4,3,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 37)
	polyethylene terephthalate, granulate, amorphous, at plant	RER	0	kg	3.46E-1	3.46E-1	3.46E-1	3.46E-1	1	1.24	(1,4,4,3,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 37)
	polyethylene, HDPE, granulate, at plant	RER	0	kg	2.38E-2	2.38E-2	2.38E-2	2.38E-2	1	1.34	(3,4,4,3,1,5); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 37)
	ethylvinylacetate, foil, at plant	RER	0	kg	8.75E-1	8.75E-1	8.75E-1	8.75E-1	1	1.24	(1,4,4,3,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 37)
	polyvinylfluoride film, at plant	US	0	kg	1.12E-1	1.12E-1	1.12E-1	1.12E-1	1	1.24	(1,4,4,3,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 37)
auxiliaries	tap water, water balance according to MoeK 2013, at user	CN	0	kg	0	0	0	0	1	1.24	(1,4,4,3,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 37)
	tap water, water balance according to MoeK 2013, at user	US	0	kg	5.03E+0	5.03E+0	5.03E+0	5.03E+0	1	1.24	(1,4,4,3,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 37)
	tap water, water balance according to MoeK 2013, at user	KR	0	kg	0	0	0	0	1	1.24	(1,4,4,3,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 37)
	tap water, water balance according to MoeK 2013, at user	RER	0	kg	0	0	0	0	1	1.24	(1,4,4,3,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 37)
	hydrogen fluoride, at plant	GLO	0	kg	6.24E-2	6.24E-2	6.24E-2	6.24E-2	1	1.34	(3,4,4,3,1,5); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 37)
	1-propanol, at plant	RER	0	kg	1.59E-2	1.59E-2	1.59E-2	1.59E-2	1	1.24	(1,4,4,3,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 37)
	isopropanol, at plant	RER	0	kg	1.47E-4	1.47E-4	1.47E-4	1.47E-4	1	1.34	(3,4,4,3,1,5); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 37)
	potassium hydroxide, at regional storage	RER	0	kg	5.14E-2	5.14E-2	5.14E-2	5.14E-2	1	1.34	(3,4,4,3,1,5); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 37)
	soap, at plant	RER	0	kg	1.16E-2	1.16E-2	1.16E-2	1.16E-2	1	1.34	(3,4,4,3,1,5); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 37)
	corrugated board, mixed fibre, single wall, at plant	RER	0	kg	7.63E-1	7.63E-1	7.63E-1	7.63E-1	1	1.24	(1,4,4,3,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 37)
	EUR-flat pallet	RER	0	unit	5.00E-2	5.00E-2	5.00E-2	5.00E-2	1	1.34	(3,4,4,3,1,5); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 37)
energy	electricity, medium voltage, at grid	CN	0	kWh	0	0	0	0	1	1.09	(2,2,1,1,1,3); Woodhouse et al. (2019): c-Si PV Manufacturing Costs 2018
	electricity, medium voltage, at grid	US	0	kWh	1.40E+1	1.40E+1	1.40E+1	1.40E+1	1	1.09	(2,2,1,1,1,3); Woodhouse et al. (2019): c-Si PV Manufacturing Costs 2018
	electricity, medium voltage, at grid	KR	0	kWh	0	0	0	0	1	1.09	(2,2,1,1,1,3); Woodhouse et al. (2019): c-Si PV Manufacturing Costs 2018
	electricity, medium voltage, production ENTSO, at grid	ENTSO	0	kWh	0	0	0	0	1	1.09	(2,2,1,1,1,3); Woodhouse et al. (2019): c-Si PV Manufacturing Costs 2018
	diesel, burned in building machine, average	CH	0	MJ	8.75E-3	8.75E-3	8.75E-3	8.75E-3	1	2.12	(3,4,4,3,1,5); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 37)
infrastructure	photovoltaic panel factory	GLO	1	unit	4.00E-6	4.00E-6	4.00E-6	4.00E-6	1	3.06	(1,4,4,3,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 37)
transport	transport, freight, lorry, fleet average	RER	0	tkm	2.99E+0	3.01E+0	2.78E+0	2.79E+0	1	2.09	(4,5,na,na,na,na); Standard distance 100km, cells 500km
	transport, freight, rail	RER	0	tkm	1.66E+1	1.66E+1	1.54E+1	1.54E+1	1	2.09	(4,5,na,na,na,na); Standard distance 600km
disposal	disposal, municipal solid waste, 22.9% water, to municipal incineration	CH	0	kg	3.00E-2	3.00E-2	3.00E-2	3.00E-2	1	1.24	(1,4,4,3,1,3); Alsema (personal communication) 2007, production waste
	disposal, polyvinylfluoride, 0.2% water, to municipal incineration	CH	0	kg	4.29E-3	4.29E-3	4.29E-3	4.29E-3	1	1.24	(1,4,4,3,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 37)
	disposal, plastics, mixture, 15.3% water, to municipal incineration	CH	0	kg	2.81E-2	2.81E-2	2.81E-2	2.81E-2	1	1.24	(1,4,4,3,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 37)
	disposal, used mineral oil, 10% water, to hazardous waste incineration	CH	0	kg	1.61E-3	1.61E-3	1.61E-3	1.61E-3	1	1.24	(1,4,4,3,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 37)
	treatment, sewage, from residence, to wastewater treatment, class 2	CH	0	m3	4.53E-3	4.53E-3	4.53E-3	4.53E-3	1	1.24	(1,4,4,3,1,3); Calculation, water use
emissions air	Heat, waste	-	-	MJ	5.03E+1	5.03E+1	5.03E+1	5.03E+1	1	1.60	(3,4,5,3,1,5); Calculation, electricity use
	NMVOC, non-methane volatile organic compounds, unspecified origin	-	-	kg	8.06E-3	8.06E-3	8.06E-3	8.06E-3	1	1.85	(3,4,5,3,1,5); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 37)
	Carbon dioxide, fossil	-	-	kg	2.18E-2	2.18E-2	2.18E-2	2.18E-2	1	1.60	(3,4,5,3,1,5); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 37)
	Water, CN	-	-	kg	0	0	0	0	1	1.85	(3,4,5,3,1,5); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 37)
	Water, US	-	-	kg	5.03E-1	5.03E-1	5.03E-1	5.03E-1	1	1.85	(3,4,5,3,1,5); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 37)
	Water, KR	-	-	kg	0	0	0	0	1	1.85	(3,4,5,3,1,5); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 37)
	Water, RER	-	-	kg	0	0	0	0	1	1.85	(3,4,5,3,1,5); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 37)

Table 21: Unit process LCI data of the photovoltaic laminate and panel production in Asia & Pacific (APAC)

	Name	Location	InfrastructureProcess	Unit	photovoltaic panel, single-Si, at plant	photovoltaic panel, multi-Si, at plant	photovoltaic laminate, single-Si, at plant	photovoltaic laminate, multi-Si, at plant	UncertaintyType	StandardDeviation95%	GeneralComment
	Location				APAC	APAC	APAC	APAC			
	InfrastructureProcess				1	1	1	1			
	Unit				m2	m2	m2	m2			
product	photovoltaic panel, single-Si, at plant	CN	1	m2	0	0	0	0			
	photovoltaic panel, multi-Si, at plant	CN	1	m2	0	0	0	0			
	photovoltaic laminate, single-Si, at plant	CN	1	m2	0	0	0	0			
	photovoltaic laminate, multi-Si, at plant	CN	1	m2	0	0	0	0			
	photovoltaic panel, single-Si, at plant	US	1	m2	0	0	0	0			
	photovoltaic panel, multi-Si, at plant	US	1	m2	0	0	0	0			
	photovoltaic laminate, single-Si, at plant	US	1	m2	0	0	0	0			
	photovoltaic laminate, multi-Si, at plant	US	1	m2	0	0	0	0			
	photovoltaic panel, single-Si, at plant	APAC	1	m2	1	0	0	0			
	photovoltaic panel, multi-Si, at plant	APAC	1	m2	0	1	0	0			
	photovoltaic laminate, single-Si, at plant	APAC	1	m2	0	0	1	0			
	photovoltaic laminate, multi-Si, at plant	APAC	1	m2	0	0	0	1			
	photovoltaic panel, single-Si, at plant	RER	1	m2	0	0	0	0			
	photovoltaic panel, multi-Si, at plant	RER	1	m2	0	0	0	0			
	photovoltaic laminate, single-Si, at plant	RER	1	m2	0	0	0	0			
	photovoltaic laminate, multi-Si, at plant	RER	1	m2	0	0	0	0			
materials	photovoltaic cell, single-Si, at plant	CN	0	m2	0	0	0	0	1	1.24	(1,4,4,3,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 37)
	photovoltaic cell, multi-Si, at plant	CN	0	m2	0	0	0	0	1	1.24	(1,4,4,3,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 37)
	photovoltaic cell, single-Si, at regional storage	US	0	m2	0	0	0	0	1	3.06	(1,4,4,3,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 37)
	photovoltaic cell, multi-Si, at regional storage	US	0	m2	0	0	0	0	1	3.06	(1,4,4,3,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 37)
	photovoltaic cell, single-Si, at plant	APAC	0	m2	9.35E-1	0	9.35E-1	0	1	1.24	(1,4,4,3,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 37)
	photovoltaic cell, multi-Si, at plant	APAC	0	m2	0	9.35E-1	0	9.35E-1	1	1.24	(1,4,4,3,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 37)
	photovoltaic cell, single-Si, at regional storage	RER	0	m2	0	0	0	0	1	3.06	(1,4,4,3,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 37)
	photovoltaic cell, multi-Si, at regional storage	RER	0	m2	0	0	0	0	1	3.06	(1,4,4,3,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 37)
	aluminium alloy, AlMg3, at plant	RER	0	kg	2.13E+0	2.13E+0	0	0	1	1.24	(1,4,4,3,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 37)
	copper, at regional storage	RER	0	kg	1.03E-1	1.03E-1	1.03E-1	1.03E-1	1	1.24	(1,4,4,3,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 37)
	wire drawing, copper	RER	0	kg	1.03E-1	1.03E-1	1.03E-1	1.03E-1	1	1.24	(1,4,4,3,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 37)
	diode, unspecified, at plant	GLO	0	kg	2.81E-3	2.81E-3	2.81E-3	2.81E-3	1	1.34	(3,4,4,3,1,5); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 37)
	silicone product, at plant	RER	0	kg	1.22E-1	1.22E-1	1.22E-1	1.22E-1	1	1.24	(1,4,4,3,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 37)
	tin, at regional storage	RER	0	kg	1.29E-2	1.29E-2	1.29E-2	1.29E-2	1	1.34	(3,4,4,3,1,5); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 37)
	lead, at regional storage	RER	0	kg	7.25E-4	7.25E-4	7.25E-4	7.25E-4	1	1.34	(3,4,4,3,1,5); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 37)
	solar glass, low-iron, at regional storage	RER	0	kg	8.81E+0	8.81E+0	8.81E+0	8.81E+0	1	1.33	(1,4,4,3,3,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 37)
	tempering, flat glass	RER	0	kg	8.81E+0	8.81E+0	8.81E+0	8.81E+0	1	1.24	(1,4,4,3,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 37)
	glass fibre reinforced plastic, polyamide, injection moulding, at plant	RER	0	kg	2.95E-1	2.95E-1	2.95E-1	2.95E-1	1	1.24	(1,4,4,3,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 37)
	polyethylene terephthalate, granulate, amorphous, at plant	RER	0	kg	3.46E-1	3.46E-1	3.46E-1	3.46E-1	1	1.24	(1,4,4,3,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 37)
	polyethylene, HDPE, granulate, at plant	RER	0	kg	2.38E-2	2.38E-2	2.38E-2	2.38E-2	1	1.34	(3,4,4,3,1,5); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 37)
	ethylvinylacetate, foil, at plant	RER	0	kg	8.75E-1	8.75E-1	8.75E-1	8.75E-1	1	1.24	(1,4,4,3,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 37)
	polyvinylfluoride film, at plant	US	0	kg	1.12E-1	1.12E-1	1.12E-1	1.12E-1	1	1.24	(1,4,4,3,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 37)
auxiliaries	tap water, water balance according to MoeK 2013, at user	CN	0	kg	0	0	0	0	1	1.24	(1,4,4,3,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 37)
	tap water, water balance according to MoeK 2013, at user	US	0	kg	0	0	0	0	1	1.24	(1,4,4,3,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 37)
	tap water, water balance according to MoeK 2013, at user	KR	0	kg	5.03E+0	5.03E+0	5.03E+0	5.03E+0	1	1.24	(1,4,4,3,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 37)
	tap water, water balance according to MoeK 2013, at user	RER	0	kg	0	0	0	0	1	1.24	(1,4,4,3,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 37)
	hydrogen fluoride, at plant	GLO	0	kg	6.24E-2	6.24E-2	6.24E-2	6.24E-2	1	1.34	(3,4,4,3,1,5); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 37)
	1-propanol, at plant	RER	0	kg	1.59E-2	1.59E-2	1.59E-2	1.59E-2	1	1.24	(1,4,4,3,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 37)
	isopropanol, at plant	RER	0	kg	1.47E-4	1.47E-4	1.47E-4	1.47E-4	1	1.34	(3,4,4,3,1,5); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 37)
	potassium hydroxide, at regional storage	RER	0	kg	5.14E-2	5.14E-2	5.14E-2	5.14E-2	1	1.34	(3,4,4,3,1,5); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 37)
	soap, at plant	RER	0	kg	1.16E-2	1.16E-2	1.16E-2	1.16E-2	1	1.34	(3,4,4,3,1,5); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 37)
	corrugated board, mixed fibre, single wall, at plant	RER	0	kg	7.63E-1	7.63E-1	7.63E-1	7.63E-1	1	1.24	(1,4,4,3,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 37)
	EUR-flat pallet	RER	0	unit	5.00E-2	5.00E-2	5.00E-2	5.00E-2	1	1.34	(3,4,4,3,1,5); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 37)
energy	electricity, medium voltage, at grid	CN	0	kWh	0	0	0	0	1	1.09	(2,2,1,1,1,3); Woodhouse et al. (2019): c-Si PV Manufacturing Costs 2018
	electricity, medium voltage, at grid	US	0	kWh	0	0	0	0	1	1.09	(2,2,1,1,1,3); Woodhouse et al. (2019): c-Si PV Manufacturing Costs 2018
	electricity, medium voltage, at grid	KR	0	kWh	1.40E+1	1.40E+1	1.40E+1	1.40E+1	1	1.09	(2,2,1,1,1,3); Woodhouse et al. (2019): c-Si PV Manufacturing Costs 2018
	electricity, medium voltage, production ENTSO, at grid	ENTSO	0	kWh	0	0	0	0	1	1.09	(2,2,1,1,1,3); Woodhouse et al. (2019): c-Si PV Manufacturing Costs 2018
	diesel, burned in building machine, average	CH	0	MJ	8.75E-3	8.75E-3	8.75E-3	8.75E-3	1	2.12	(3,4,4,3,1,5); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 37)
infrastructure	photovoltaic panel factory	GLO	1	unit	4.00E-6	4.00E-6	4.00E-6	4.00E-6	1	3.06	(1,4,4,3,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 37)
transport	transport, freight, lorry, fleet average	RER	0	tkm	2.99E+0	3.01E+0	2.78E+0	2.79E+0	1	2.09	(4,5,na,na,na,na); Standard distance 100km, cells 500km
	transport, freight, rail	RER	0	tkm	1.66E+1	1.66E+1	1.54E+1	1.54E+1	1	2.09	(4,5,na,na,na,na); Standard distance 600km
disposal	disposal, municipal solid waste, 22.9% water, to municipal incineration	CH	0	kg	3.00E-2	3.00E-2	3.00E-2	3.00E-2	1	1.24	(1,4,4,3,1,3); Alsema (personal communication) 2007, production waste
	disposal, polyvinylfluoride, 0.2% water, to municipal incineration	CH	0	kg	4.29E-3	4.29E-3	4.29E-3	4.29E-3	1	1.24	(1,4,4,3,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 37)
	disposal, plastics, mixture, 15.3% water, to municipal incineration	CH	0	kg	2.81E-2	2.81E-2	2.81E-2	2.81E-2	1	1.24	(1,4,4,3,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 37)
	disposal, used mineral oil, 10% water, to hazardous waste incineration	CH	0	kg	1.61E-3	1.61E-3	1.61E-3	1.61E-3	1	1.24	(1,4,4,3,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 37)
	treatment, sewage, from residence, to wastewater treatment, class 2	CH	0	m3	4.53E-3	4.53E-3	4.53E-3	4.53E-3	1	1.24	(1,4,4,3,1,3); Calculation, water use
emissions air	Heat, waste	-	-	MJ	5.03E+1	5.03E+1	5.03E+1	5.03E+1	1	1.60	(3,4,5,3,1,5); Calculation, electricity use
	NMVOC, non-methane volatile organic compounds, unspecified origin	-	-	kg	8.06E-3	8.06E-3	8.06E-3	8.06E-3	1	1.85	(3,4,5,3,1,5); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 37)
	Carbon dioxide, fossil	-	-	kg	2.18E-2	2.18E-2	2.18E-2	2.18E-2	1	1.60	(3,4,5,3,1,5); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 37)
	Water, CN	-	-	kg	0	0	0	0	1	1.85	(3,4,5,3,1,5); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 37)
	Water, US	-	-	kg	0	0	0	0	1	1.85	(3,4,5,3,1,5); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 37)
	Water, KR	-	-	kg	5.03E-1	5.03E-1	5.03E-1	5.03E-1	1	1.85	(3,4,5,3,1,5); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 37)
	Water, RER	-	-	kg	0	0	0	0	1	1.85	(3,4,5,3,1,5); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 37)

Table 22: Unit process LCI data of the photovoltaic laminate and panel production in Europe (RER)

	Name	Location	InfrastructureProcess	Unit	photovoltaic panel, single-Si, at plant	photovoltaic panel, multi-Si, at plant	photovoltaic laminate, single-Si, at plant	photovoltaic laminate, multi-Si, at plant	UncertaintyType	StandardDeviation95%	GeneralComment
	Location				RER	RER	RER	RER			
	InfrastructureProcess				1	1	1	1			
	Unit				m2	m2	m2	m2			
product	photovoltaic panel, single-Si, at plant	CN	1	m2	0	0	0	0			
	photovoltaic panel, multi-Si, at plant	CN	1	m2	0	0	0	0			
	photovoltaic laminate, single-Si, at plant	CN	1	m2	0	0	0	0			
	photovoltaic laminate, multi-Si, at plant	CN	1	m2	0	0	0	0			
	photovoltaic panel, single-Si, at plant	US	1	m2	0	0	0	0			
	photovoltaic panel, multi-Si, at plant	US	1	m2	0	0	0	0			
	photovoltaic laminate, single-Si, at plant	US	1	m2	0	0	0	0			
	photovoltaic laminate, multi-Si, at plant	US	1	m2	0	0	0	0			
	photovoltaic panel, single-Si, at plant	APAC	1	m2	0	0	0	0			
	photovoltaic panel, multi-Si, at plant	APAC	1	m2	0	0	0	0			
	photovoltaic laminate, single-Si, at plant	APAC	1	m2	0	0	0	0			
	photovoltaic laminate, multi-Si, at plant	APAC	1	m2	0	0	0	0			
	photovoltaic panel, single-Si, at plant	RER	1	m2	1	0	0	0			
	photovoltaic panel, multi-Si, at plant	RER	1	m2	0	1	0	0			
	photovoltaic laminate, single-Si, at plant	RER	1	m2	0	0	1	0			
	photovoltaic laminate, multi-Si, at plant	RER	1	m2	0	0	0	1			
materials	photovoltaic cell, single-Si, at plant	CN	0	m2	0	0	0	0	1	1.24	(1,4,4,3,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 37)
	photovoltaic cell, multi-Si, at plant	CN	0	m2	0	0	0	0	1	1.24	(1,4,4,3,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 37)
	photovoltaic cell, single-Si, at regional storage	US	0	m2	0	0	0	0	1	3.06	(1,4,4,3,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 37)
	photovoltaic cell, multi-Si, at regional storage	US	0	m2	0	0	0	0	1	3.06	(1,4,4,3,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 37)
	photovoltaic cell, single-Si, at plant	APAC	0	m2	0	0	0	0	1	1.24	(1,4,4,3,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 37)
	photovoltaic cell, multi-Si, at plant	APAC	0	m2	0	0	0	0	1	1.24	(1,4,4,3,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 37)
	photovoltaic cell, single-Si, at regional storage	RER	0	m2	9.35E-1	0	9.35E-1	0	1	3.06	(1,4,4,3,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 37)
	photovoltaic cell, multi-Si, at regional storage	RER	0	m2	0	9.35E-1	0	9.35E-1	1	3.06	(1,4,4,3,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 37)
	aluminium alloy, AlMg3, at plant	RER	0	kg	2.13E+0	2.13E+0	0	0	1	1.24	(1,4,4,3,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 37)
	copper, at regional storage	RER	0	kg	1.03E-1	1.03E-1	1.03E-1	1.03E-1	1	1.24	(1,4,4,3,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 37)
	wire drawing, copper	RER	0	kg	1.03E-1	1.03E-1	1.03E-1	1.03E-1	1	1.24	(1,4,4,3,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 37)
	diode, unspecified, at plant	GLO	0	kg	2.81E-3	2.81E-3	2.81E-3	2.81E-3	1	1.34	(3,4,4,3,1,5); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 37)
	silicone product, at plant	RER	0	kg	1.22E-1	1.22E-1	1.22E-1	1.22E-1	1	1.24	(1,4,4,3,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 37)
	tin, at regional storage	RER	0	kg	1.29E-2	1.29E-2	1.29E-2	1.29E-2	1	1.34	(3,4,4,3,1,5); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 37)
	lead, at regional storage	RER	0	kg	7.25E-4	7.25E-4	7.25E-4	7.25E-4	1	1.34	(3,4,4,3,1,5); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 37)
	solar glass, low-iron, at regional storage	RER	0	kg	8.81E+0	8.81E+0	8.81E+0	8.81E+0	1	1.33	(1,4,4,3,3,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 37)
	tempering, flat glass	RER	0	kg	8.81E+0	8.81E+0	8.81E+0	8.81E+0	1	1.24	(1,4,4,3,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 37)
	glass fibre reinforced plastic, polyamide, injection moulding, at plant	RER	0	kg	2.95E-1	2.95E-1	2.95E-1	2.95E-1	1	1.24	(1,4,4,3,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 37)
	polyethylene terephthalate, granulate, amorphous, at plant	RER	0	kg	3.46E-1	3.46E-1	3.46E-1	3.46E-1	1	1.24	(1,4,4,3,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 37)
	polyethylene, HDPE, granulate, at plant	RER	0	kg	2.38E-2	2.38E-2	2.38E-2	2.38E-2	1	1.34	(3,4,4,3,1,5); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 37)
	ethylvinylacetate, foil, at plant	RER	0	kg	8.75E-1	8.75E-1	8.75E-1	8.75E-1	1	1.24	(1,4,4,3,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 37)
	polyvinylfluoride film, at plant	US	0	kg	1.12E-1	1.12E-1	1.12E-1	1.12E-1	1	1.24	(1,4,4,3,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 37)
auxiliaries	tap water, water balance according to MoeK 2013, at user	CN	0	kg	0	0	0	0	1	1.24	(1,4,4,3,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 37)
	tap water, water balance according to MoeK 2013, at user	US	0	kg	0	0	0	0	1	1.24	(1,4,4,3,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 37)
	tap water, water balance according to MoeK 2013, at user	KR	0	kg	0	0	0	0	1	1.24	(1,4,4,3,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 37)
	tap water, water balance according to MoeK 2013, at user	RER	0	kg	5.03E+0	5.03E+0	5.03E+0	5.03E+0	1	1.24	(1,4,4,3,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 37)
	hydrogen fluoride, at plant	GLO	0	kg	6.24E-2	6.24E-2	6.24E-2	6.24E-2	1	1.34	(3,4,4,3,1,5); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 37)
	1-propanol, at plant	RER	0	kg	1.59E-2	1.59E-2	1.59E-2	1.59E-2	1	1.24	(1,4,4,3,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 37)
	isopropanol, at plant	RER	0	kg	1.47E-4	1.47E-4	1.47E-4	1.47E-4	1	1.34	(3,4,4,3,1,5); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 37)
	potassium hydroxide, at regional storage	RER	0	kg	5.14E-2	5.14E-2	5.14E-2	5.14E-2	1	1.34	(3,4,4,3,1,5); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 37)
	soap, at plant	RER	0	kg	1.16E-2	1.16E-2	1.16E-2	1.16E-2	1	1.34	(3,4,4,3,1,5); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 37)
	corrugated board, mixed fibre, single wall, at plant	RER	0	kg	7.63E-1	7.63E-1	7.63E-1	7.63E-1	1	1.24	(1,4,4,3,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 37)
	EUR-flat pallet	RER	0	unit	5.00E-2	5.00E-2	5.00E-2	5.00E-2	1	1.34	(3,4,4,3,1,5); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 37)
energy	electricity, medium voltage, at grid	CN	0	kWh	0	0	0	0	1	1.09	(2,2,1,1,1,3); Woodhouse et al. (2019): c-Si PV Manufacturing Costs 2018
	electricity, medium voltage, at grid	US	0	kWh	0	0	0	0	1	1.09	(2,2,1,1,1,3); Woodhouse et al. (2019): c-Si PV Manufacturing Costs 2018
	electricity, medium voltage, at grid	KR	0	kWh	0	0	0	0	1	1.09	(2,2,1,1,1,3); Woodhouse et al. (2019): c-Si PV Manufacturing Costs 2018
	electricity, medium voltage, production ENTSO, at grid	ENTSO	0	kWh	1.40E+1	1.40E+1	1.40E+1	1.40E+1	1	1.09	(2,2,1,1,1,3); Woodhouse et al. (2019): c-Si PV Manufacturing Costs 2018
	diesel, burned in building machine, average	CH	0	MJ	8.75E-3	8.75E-3	8.75E-3	8.75E-3	1	2.12	(3,4,4,3,1,5); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 37)
infrastructure	photovoltaic panel factory	GLO	1	unit	4.00E-6	4.00E-6	4.00E-6	4.00E-6	1	3.06	(1,4,4,3,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 37)
transport	transport, freight, lorry, fleet average	RER	0	tkm	2.77E+0	2.77E+0	2.56E+0	2.56E+0	1	2.09	(4,5,na,na,na,na); Standard distance 100km, cells 500km
	transport, freight, rail	RER	0	tkm	1.66E+1	1.66E+1	1.54E+1	1.54E+1	1	2.09	(4,5,na,na,na,na); Standard distance 600km
disposal	disposal, municipal solid waste, 22.9% water, to municipal incineration	CH	0	kg	3.00E-2	3.00E-2	3.00E-2	3.00E-2	1	1.24	(1,4,4,3,1,3); Alsema (personal communication) 2007, production waste
	disposal, polyvinylfluoride, 0.2% water, to municipal incineration	CH	0	kg	4.29E-3	4.29E-3	4.29E-3	4.29E-3	1	1.24	(1,4,4,3,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 37)
	disposal, plastics, mixture, 15.3% water, to municipal incineration	CH	0	kg	2.81E-2	2.81E-2	2.81E-2	2.81E-2	1	1.24	(1,4,4,3,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 37)
	disposal, used mineral oil, 10% water, to hazardous waste incineration	CH	0	kg	1.61E-3	1.61E-3	1.61E-3	1.61E-3	1	1.24	(1,4,4,3,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 37)
	treatment, sewage, from residence, to wastewater treatment, class 2	CH	0	m3	4.53E-3	4.53E-3	4.53E-3	4.53E-3	1	1.24	(1,4,4,3,1,3); Calculation, water use
emissions air	Heat, waste	-	-	MJ	5.03E+1	5.03E+1	5.03E+1	5.03E+1	1	1.60	(3,4,5,3,1,5); Calculation, electricity use
	NMVOC, non-methane volatile organic compounds, unspecified origin	-	-	kg	8.06E-3	8.06E-3	8.06E-3	8.06E-3	1	1.85	(3,4,5,3,1,5); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 37)
	Carbon dioxide, fossil	-	-	kg	2.18E-2	2.18E-2	2.18E-2	2.18E-2	1	1.60	(3,4,5,3,1,5); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 37)
	Water, CN	-	-	kg	0	0	0	0	1	1.85	(3,4,5,3,1,5); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 37)
	Water, US	-	-	kg	0	0	0	0	1	1.85	(3,4,5,3,1,5); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 37)
	Water, KR	-	-	kg	0	0	0	0	1	1.85	(3,4,5,3,1,5); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 37)
	Water, RER	-	-	kg	5.03E-1	5.03E-1	5.03E-1	5.03E-1	1	1.85	(3,4,5,3,1,5); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 37)

Tables 23-25 show the unit process data of the photovoltaic laminate and panel market mix in Europe (RER), North America (US), and APAC countries, respectively. The market shares for laminate and panels in the different regions of the world are shown in Table 5. The European market shares are extrapolated to 100 % because supply in 2018 did not fully match with the installed capacity in the same year.

Table 23: Unit process LCI data of the photovoltaic laminate and panel market mix 2018 in Europe (RER)

	Name	Location	InfrastructureProcess	Unit	photovoltaic laminate, multi-Si, at regional storage	photovoltaic laminate, single-Si, at regional storage	photovoltaic panel, multi-Si, at regional storage	photovoltaic panel, single-Si, at regional storage	UncertaintyType	StandardDeviation95%	GeneralComment
	Location				RER	RER	RER	RER			
	InfrastructureProcess				1	1	1	1			
	Unit				m2	m2	m2	m2			
product	photovoltaic laminate, multi-Si, at regional storage	RER	1	m2	1	0	0	0			
	photovoltaic laminate, single-Si, at regional storage	RER	1	m2	0	1	0	0			
	photovoltaic panel, multi-Si, at regional storage	RER	1	m2	0	0	1	0			
	photovoltaic panel, single-Si, at regional storage	RER	1	m2	0	0	0	1			
modules	photovoltaic panel, multi-Si, at plant	RER	1	m2	0	0	2.76E-1	0	1	3.27	(5,1,1,1,1,5); Market share European modules
	photovoltaic panel, single-Si, at plant	RER	1	m2	0	0	0	2.76E-1	1	3.27	(5,1,1,1,1,5); Market share European modules
	photovoltaic laminate, multi-Si, at plant	RER	1	m2	2.76E-1	0	0	0	1	3.27	(5,1,1,1,1,5); Market share European modules
	photovoltaic laminate, single-Si, at plant	RER	1	m2	0	2.76E-1	0	0	1	3.27	(5,1,1,1,1,5); Market share European modules
	photovoltaic panel, multi-Si, at plant	US	1	m2	0	0	0	0	1	3.27	(5,1,1,1,1,5); Market share US modules
	photovoltaic panel, single-Si, at plant	US	1	m2	0	0	0	0	1	3.27	(5,1,1,1,1,5); Market share US modules
	photovoltaic laminate, multi-Si, at plant	US	1	m2	0	0	0	0	1	3.27	(5,1,1,1,1,5); Market share US modules
	photovoltaic laminate, single-Si, at plant	US	1	m2	0	0	0	0	1	3.27	(5,1,1,1,1,5); Market share US modules
	photovoltaic panel, multi-Si, at plant	CN	1	m2	0	0	7.24E-1	0	1	3.27	(5,1,1,1,1,5); Market share Chinese modules
	photovoltaic panel, single-Si, at plant	CN	1	m2	0	0	0	7.24E-1	1	3.27	(5,1,1,1,1,5); Market share Chinese modules
	photovoltaic laminate, multi-Si, at plant	CN	1	m2	7.24E-1	0	0	0	1	3.27	(5,1,1,1,1,5); Market share Chinese modules
	photovoltaic laminate, single-Si, at plant	CN	1	m2	0	7.24E-1	0	0	1	3.27	(5,1,1,1,1,5); Market share Chinese modules
	photovoltaic panel, multi-Si, at plant	APAC	1	m2	0	0	0	0	1	3.27	(5,1,1,1,1,5); Market share APAC modules
	photovoltaic panel, single-Si, at plant	APAC	1	m2	0	0	0	0	1	3.27	(5,1,1,1,1,5); Market share APAC modules
	photovoltaic laminate, multi-Si, at plant	APAC	1	m2	0	0	0	0	1	3.27	(5,1,1,1,1,5); Market share APAC modules
	photovoltaic laminate, single-Si, at plant	APAC	1	m2	0	0	0	0	1	3.27	(5,1,1,1,1,5); Market share APAC modules
transport	transport, transoceanic freight ship	OCE	0	tkm	1.62E+2	1.61E+2	1.92E+2	1.92E+2	1	2.09	(4,5,na,na,na,na); Transport distance CN-EU: 19994 km, APAC-EU: 15026 km
	transport, freight, lorry, fleet average	RER	0	tkm	1.05E+1	1.05E+1	1.25E+1	1.25E+1	1	2.09	(4,5,na,na,na,na); Transport distance 943 km

Table 24: Unit process LCI data of the photovoltaic laminate and panel market mix 2018 in North America (US)

	Name	Location	InfrastructureProcess	Unit	photovoltaic laminate, multi-Si, at regional storage	photovoltaic laminate, single-Si, at regional storage	photovoltaic panel, multi-Si, at regional storage	photovoltaic panel, single-Si, at regional storage	UncertaintyType	StandardDeviation95%	GeneralComment
	Location				US	US	US	US			
	InfrastructureProcess				1	1	1	1			
	Unit				m2	m2	m2	m2			
product	photovoltaic laminate, multi-Si, at regional storage	US	1	m2	1	0	0	0			
	photovoltaic laminate, single-Si, at regional storage	US	1	m2	0	1	0	0			
	photovoltaic panel, multi-Si, at regional storage	US	1	m2	0	0	1	0			
	photovoltaic panel, single-Si, at regional storage	US	1	m2	0	0	0	1			
modules	photovoltaic panel, multi-Si, at plant	RER	1	m2	0	0	0	0	1	3.27	(5,1,1,1,1,5); Market share European modules
	photovoltaic panel, single-Si, at plant	RER	1	m2	0	0	0	0	1	3.27	(5,1,1,1,1,5); Market share European modules
	photovoltaic laminate, multi-Si, at plant	RER	1	m2	0	0	0	0	1	3.27	(5,1,1,1,1,5); Market share European modules
	photovoltaic laminate, single-Si, at plant	RER	1	m2	0	0	0	0	1	3.27	(5,1,1,1,1,5); Market share European modules
	photovoltaic panel, multi-Si, at plant	US	1	m2	0	0	2.53E-1	0	1	3.27	(5,1,1,1,1,5); Market share US modules
	photovoltaic panel, single-Si, at plant	US	1	m2	0	0	0	2.53E-1	1	3.27	(5,1,1,1,1,5); Market share US modules
	photovoltaic laminate, multi-Si, at plant	US	1	m2	2.53E-1	0	0	0	1	3.27	(5,1,1,1,1,5); Market share US modules
	photovoltaic laminate, single-Si, at plant	US	1	m2	0	2.53E-1	0	0	1	3.27	(5,1,1,1,1,5); Market share US modules
	photovoltaic panel, multi-Si, at plant	CN	1	m2	0	0	7.47E-1	0	1	3.27	(5,1,1,1,1,5); Market share Chinese modules
	photovoltaic panel, single-Si, at plant	CN	1	m2	0	0	0	7.47E-1	1	3.27	(5,1,1,1,1,5); Market share Chinese modules
	photovoltaic laminate, multi-Si, at plant	CN	1	m2	7.47E-1	0	0	0	1	3.27	(5,1,1,1,1,5); Market share Chinese modules
	photovoltaic laminate, single-Si, at plant	CN	1	m2	0	7.47E-1	0	0	1	3.27	(5,1,1,1,1,5); Market share Chinese modules
	photovoltaic panel, multi-Si, at plant	APAC	1	m2	0	0	0	0	1	3.27	(5,1,1,1,1,5); Market share APAC modules
	photovoltaic panel, single-Si, at plant	APAC	1	m2	0	0	0	0	1	3.27	(5,1,1,1,1,5); Market share APAC modules
	photovoltaic laminate, multi-Si, at plant	APAC	1	m2	0	0	0	0	1	3.27	(5,1,1,1,1,5); Market share APAC modules
	photovoltaic laminate, single-Si, at plant	APAC	1	m2	0	0	0	0	1	3.27	(5,1,1,1,1,5); Market share APAC modules
transport	transport, transoceanic freight ship	OCE	0	tkm	2.17E+2	2.17E+2	2.17E+2	2.17E+2	1	2.09	(4,5,na,na,na,na); Transport distance CN-US: 20755 km, APAC-US: 18411 km
	transport, freight, rail	RER	0	tkm	2.80E+0	2.80E+0	2.80E+0	2.80E+0	1	2.09	(4,5,na,na,na,na); Standard distance 200km
	transport, freight, lorry, fleet average	RER	0	tkm	6.99E-1	6.99E-1	6.99E-1	6.99E-1	1	2.09	(4,5,na,na,na,na); Standard distance 50km

Table 25: Unit process LCI data of the photovoltaic laminate and panel market mix 2018 in APAC countries

	Name	Location	InfrastructureProcess	Unit	photovoltaic laminate, multi-Si, at regional storage	photovoltaic laminate, single-Si, at regional storage	photovoltaic panel, multi-Si, at regional storage	photovoltaic panel, single-Si, at regional storage	UncertaintyType	StandardDeviation95%	GeneralComment
	Location				APAC	APAC	APAC	APAC			
	InfrastructureProcess				1	1	1	1			
	Unit				m2	m2	m2	m2			
product	photovoltaic laminate, multi-Si, at regional storage	APAC	1	m2	1	0	0	0			
	photovoltaic laminate, single-Si, at regional storage	APAC	1	m2	0	1	0	0			
	photovoltaic panel, multi-Si, at regional storage	APAC	1	m2	0	0	1	0			
	photovoltaic panel, single-Si, at regional storage	APAC	1	m2	0	0	0	1			
modules	photovoltaic panel, multi-Si, at plant	RER	1	m2	0	0	0	0	1	3.27	(5,1,1,1,1,5); Market share European modules
	photovoltaic panel, single-Si, at plant	RER	1	m2	0	0	0	0	1	3.27	(5,1,1,1,1,5); Market share European modules
	photovoltaic laminate, multi-Si, at plant	RER	1	m2	0	0	0	0	1	3.27	(5,1,1,1,1,5); Market share European modules
	photovoltaic laminate, single-Si, at plant	RER	1	m2	0	0	0	0	1	3.27	(5,1,1,1,1,5); Market share European modules
	photovoltaic panel, multi-Si, at plant	US	1	m2	0	0	0	0	1	3.27	(5,1,1,1,1,5); Market share US modules
	photovoltaic panel, single-Si, at plant	US	1	m2	0	0	0	0	1	3.27	(5,1,1,1,1,5); Market share US modules
	photovoltaic laminate, multi-Si, at plant	US	1	m2	0	0	0	0	1	3.27	(5,1,1,1,1,5); Market share US modules
	photovoltaic laminate, single-Si, at plant	US	1	m2	0	0	0	0	1	3.27	(5,1,1,1,1,5); Market share US modules
	photovoltaic panel, multi-Si, at plant	CN	1	m2	0	0	1.26E-1	0	1	3.27	(5,1,1,1,1,5); Market share Chinese modules
	photovoltaic panel, single-Si, at plant	CN	1	m2	0	0	0	1.26E-1	1	3.27	(5,1,1,1,1,5); Market share Chinese modules
	photovoltaic laminate, multi-Si, at plant	CN	1	m2	1.26E-1	0	0	0	1	3.27	(5,1,1,1,1,5); Market share Chinese modules
	photovoltaic laminate, single-Si, at plant	CN	1	m2	0	1.26E-1	0	0	1	3.27	(5,1,1,1,1,5); Market share Chinese modules
	photovoltaic panel, multi-Si, at plant	APAC	1	m2	0	0	8.74E-1	0	1	3.27	(5,1,1,1,1,5); Market share APAC modules
	photovoltaic panel, single-Si, at plant	APAC	1	m2	0	0	0	8.74E-1	1	3.27	(5,1,1,1,1,5); Market share APAC modules
	photovoltaic laminate, multi-Si, at plant	APAC	1	m2	8.74E-1	0	0	0	1	3.27	(5,1,1,1,1,5); Market share APAC modules
	photovoltaic laminate, single-Si, at plant	APAC	1	m2	0	8.74E-1	0	0	1	3.27	(5,1,1,1,1,5); Market share APAC modules
transport	transport, transoceanic freight ship	OCE	0	tkm	6.34E+0	6.32E+0	7.54E+0	7.53E+0	1	2.09	(4,5,na,na,na,na); Transport distance CN-APAC: 4500 km
	transport, freight, rail	RER	0	tkm	2.23E+0	2.23E+0	2.66E+0	2.65E+0	1	2.09	(4,5,na,na,na,na); Standard distance 200km
	transport, freight, lorry, fleet average	RER	0	tkm	5.58E-1	5.57E-1	6.65E-1	6.63E-1	1	2.09	(4,5,na,na,na,na); Standard distance 50km

3.3 CdTe PV

Table 26a shows the unit process data of the integrated CdTe photovoltaic cell, laminate, and panel production in USA and Malaysia. The data on material, energy consumption and emissions are from the life cycle inventory data in Sinha and Wade [8].

The production mix of CdTe PV panels is shown in Tab. 3.2.2 based on transport assumptions for the European market. CdTe PV panels are transported from the US and Malaysia by freight ship, rail and lorry to the European regional storage. Around 13 % are imported from the US, and the remaining 87 % are imported from Malaysia. It is assumed that Rotterdam is the import-port for Europe. From Rotterdam the panels are transported by lorry to the regional storage. The three main countries with installed PV capacity in Europe are Germany (60 %), Italy (31 %) and Spain (9 %). The average weighted transport distance to these countries is about 943 km.

The production mix in Table 26b is based on data for 2018 and includes the relative proportion of Series 4 and Series 6 panels. Since Series 6 panel production is ramping through 2020 [20], the relative proportion of Series 6 panels is likely to be higher than shown in Table 26b after 2018.

Table 26a: Unit process LCI data of the integrated CdTe photovoltaic cell, laminate, and panel production in Asia & Pacific (Malaysia, MY) and North America (United States of America, US)

	Name	Location	Infrastructure-Process	Unit	photovoltaic laminate, CdTe, First Solar Series 4, at plant	photovoltaic laminate, CdTe, First Solar Series 4, at plant	photovoltaic laminate, CdTe, First Solar Series 6, at plant	photovoltaic laminate, CdTe, First Solar Series 6, at plant	uncertaintyType	StandardDeviation 95%	GeneralComment
	Location				MY	US	MY	US			
	InfrastructureProcess				1	1	1	1			
	Unit				m2	m2	m2	m2			
product	photovoltaic laminate, CdTe, First Solar Series 4, at plant	MY	1	m2	1	0	0	0			
	photovoltaic laminate, CdTe, First Solar Series 4, at plant	US	1	m2	0	1	0	0			
	photovoltaic laminate, CdTe, First Solar Series 6, at plant	MY	1	m2	0	0	1	0			
	photovoltaic laminate, CdTe, First Solar Series 6, at plant	US	1	m2	0	0	0	1			
materials	cadmium telluride, semiconductor-grade, at plant	US	0	kg	2.29E-2	2.37E-2	2.21E-2	2.29E-2	1	1.07	(1,1,1,1,1,3,BU:1.05); 2015 and 2017-2018 (estimated) data for First Solar in US and Malaysia
	cadmium sulphide, semiconductor-grade, at plant	US	0	kg	5.73E-4	5.92E-4	0	0	1	1.07	(1,1,1,1,1,3,BU:1.05); 2015 and 2017-2018 (estimated) data for First Solar in US and Malaysia
	copper, at regional storage	RER	0	kg	1.46E-2	1.48E-2	3.22E-3	3.27E-3	1	1.07	(1,1,1,1,1,3,BU:1.05); 2015 and 2017-2018 (estimated) data for First Solar in US and Malaysia
	aluminium alloy, AlMg3, at plant	RER	0	kg	0	0	1.67E+0	1.69E+0	1	1.07	(1,1,1,1,1,3,BU:1.05); 2015 and 2017-2018 (estimated) data for First Solar in US and Malaysia
	chromium steel 18/8, at plant	RER	0	kg	0	0	1.11E-2	1.13E-2	1	1.07	(1,1,1,1,1,3,BU:1.05); 2015 and 2017-2018 (estimated) data for First Solar in US and Malaysia
	flat glass, uncoated, at plant	RER	0	kg	7.99E+0	8.11E+0	5.34E+0	5.42E+0	1	1.07	(1,1,1,1,1,3,BU:1.05); 2015 and 2017-2018 (estimated) data for First Solar in US and Malaysia
	tempering, flat glass	RER	0	kg	7.99E+0	8.11E+0	0	0	1	1.07	(1,1,1,1,1,3,BU:1.05); 2015 and 2017-2018 (estimated) data for First Solar in US and Malaysia
	solar glass, low-iron, at regional storage	RER	0	kg	8.17E+0	8.44E+0	6.94E+0	7.18E+0	1	1.07	(1,1,1,1,1,3,BU:1.05); 2015 and 2017-2018 (estimated) data for First Solar in US and Malaysia
	ethylvinylacetate, foil, at plant	RER	0	kg	3.79E-1	3.85E-1	3.85E-1	3.91E-1	1	1.07	(1,1,1,1,1,3,BU:1.05); 2015 and 2017-2018 (estimated) data for First Solar in US and Malaysia
	glass fibre reinforced plastic, polyamide, injection moulding, at plant	RER	0	kg	1.08E-1	1.08E-1	1.08E-1	1.08E-1	1	1.16	(1,4,3,3,1,3,BU:1.05); Fthenakis, literature, sum up of several materials
	silicone product, at plant	RER	0	kg	1.77E-2	1.80E-2	1.17E-1	1.19E-1	1	1.08	(1,2,2,3,1,3,BU:1.05); 2015 and 2017-2018 (estimated) data for First Solar in US and Malaysia
auxiliaries	tap water, water balance according to MoeK 2013, at user	MY	0	kg	2.07E+2	0	2.07E+2	0	1	1.07	(1,1,1,1,1,3,BU:1.05); 2015 and 2017-2018 (estimated) data for First Solar in US and Malaysia
	tap water, water balance according to MoeK 2013, at user	US	0	kg	0	1.93E+2	0	1.93E+2	1	1.07	(1,1,1,1,1,3,BU:1.05); 2015 and 2017-2018 (estimated) data for First Solar in US and Malaysia
	nitric acid, 50% in H2O, at plant	RER	0	kg	5.72E-2	5.72E-2	5.72E-2	5.72E-2	1	1.16	(1,4,3,3,1,3,BU:1.05); Fthenakis, literature
	sulphuric acid, liquid, at plant	RER	0	kg	3.93E-2	3.93E-2	3.93E-2	3.93E-2	1	1.16	(1,4,3,3,1,3,BU:1.05); Fthenakis, literature
	silica sand, at plant	DE	0	kg	4.68E-2	4.68E-2	0	0	1	1.16	(1,4,3,3,1,3,BU:1.05); Fthenakis, literature
	sodium chloride, powder, at plant	RER	0	kg	4.53E-2	4.53E-2	4.53E-2	4.53E-2	1	1.16	(1,4,3,3,1,3,BU:1.05); Fthenakis, literature
	hydrogen peroxide, 50% in H2O, at plant	RER	0	kg	1.67E-2	1.67E-2	1.67E-2	1.67E-2	1	1.16	(1,4,3,3,1,3,BU:1.05); Fthenakis, literature
	isopropanol, at plant	RER	0	kg	2.08E-3	2.08E-3	2.08E-3	2.08E-3	1	1.16	(1,4,3,3,1,3,BU:1.05); Fthenakis, literature
	sodium hydroxide, 50% in H2O, production mix, at plant	RER	0	kg	4.93E-2	4.93E-2	4.93E-2	4.93E-2	1	1.16	(1,4,3,3,1,3,BU:1.05); Fthenakis, literature
	chemicals inorganic, at plant	GLO	0	kg	7.55E-3	7.62E-3	9.26E-3	1.06E-2	1	1.07	(1,1,1,1,1,3,BU:1.05); 2015 and 2017-2018 (estimated) data for First Solar in US and Malaysia
	chemicals organic, at plant	GLO	0	kg	8.65E-2	8.53E-2	2.68E-2	3.35E-2	1	1.16	(1,4,3,3,1,3,BU:1.05); 2015 and 2017-2018 (estimated) data for First Solar in US and Malaysia
	nitrogen, liquid, at plant	RER	0	kg	7.32E-2	7.32E-2	7.32E-2	7.32E-2	1	1.16	(1,4,3,3,1,3,BU:1.05); Fthenakis, literature
	corrugated board, mixed fibre, single wall, at plant	RER	0	kg	5.22E-1	5.22E-1	0	0	1	1.07	(1,1,1,1,1,3,BU:1.05); 2015 and 2017-2018 (estimated) data for First Solar in US and Malaysia
	EUR-flat pallet	RER	0	unit	2.78E-2	2.78E-2	1.45E-2	1.45E-2	1	1.07	(1,1,1,1,1,3,BU:1.05); 2015 and 2017-2018 (estimated) data for First Solar in US and Malaysia
infrastructure	photovoltaic panel factory CdTe	US	1	unit	4.00E-6	4.00E-6	4.00E-6	4.00E-6	1	3.01	(2,1,1,1,1,3,BU:3); Assumption
energy	electricity, medium voltage, at grid	MY	0	kWh	3.34E+1	0	3.34E+1	0	1	1.07	(1,1,1,1,1,3,BU:1.05); 2010 data for First Solar in Malaysia
	electricity, medium voltage, at grid	US	0	kWh	0	3.48E+1	0	3.48E+1	1	1.07	(1,1,1,1,1,3,BU:1.05); 2015 and 2017-2018 (estimated) data for First Solar in US
	natural gas, burned in boiler modulating >100kW	RER	0	MJ	0	2.08E+1	0	2.08E+1	1	1.07	(1,1,1,1,1,3,BU:1.05); 2015 and 2017-2018 (estimated) data for First Solar in US
transport	transport, freight, lorry, fleet average	RER	0	tkm	1.44E-1	9.30E+0	1.02E-1	6.95E+0	1	2.00	(1,1,1,1,1,3,BU:2); 2015 and 2017-2018 (estimated) data for First Solar in US and Malaysia
	transport, freight, rail	RER	0	tkm	2.48E+0	0	2.11E+0	0	1	2.00	(1,1,1,1,1,3,BU:2); 2015 and 2017-2018 (estimated) data for First Solar in Malaysia
	transport, transoceanic freight ship	OCE	0	tkm	4.17E+1	0	3.12E+1	0	1	2.00	(1,1,1,1,1,3,BU:2); 2015 and 2017-2018 (estimated) data for First Solar in Malaysia
disposal	disposal, municipal solid waste, 22.9% water, to municipal incineration	CH	0	kg	2.52E-1	4.75E-1	2.52E-1	4.75E-1	1	1.16	(1,4,3,3,1,3,BU:1.05); 2015 and 2017-2018 (estimated) data for First Solar in US and Malaysia
	treatment, sewage, unpolluted, to wastewater treatment, class 3	CH	0	m3	0	8.63E-2	-	8.63E-2	1	1.07	(1,1,1,1,1,3,BU:1.05); 2015 and 2017-2018 (estimated) data for First Solar in US
emissions air	Heat, waste	-	-	MJ	1.20E+2	1.25E+2	1.20E+2	1.25E+2	1	1.29	(3,4,3,3,1,5,BU:1.05); Calculation
	Water, MY	-	-	kg	9.51E+1	0	9.51E+1	0	1	1.61	(3,4,3,3,1,5,BU:1.5); 46% evaporation of tap water; Personal communication Parikhit Sinha, FirstSolar
	Water, US	-	-	kg	0	1.07E+2	0	1.07E+2	1	1.61	(3,4,3,3,1,5,BU:1.5); Difference of tap water supply and wastewater outflow
	Cadmium	-	-	kg	9.56E-9	9.56E-9	9.56E-9	9.56E-9	1	5.00	(1,1,1,1,1,3,BU:5); 2015 and 2017-2018 (estimated) data for First Solar in US
	Copper	-	-	kg	7.39E-9	7.39E-9	7.39E-9	7.39E-9	1	5.00	(1,1,1,1,1,3,BU:5); 2015 and 2017-2018 (estimated) data for First Solar in US
	Lead	-	-	kg	4.35E-9	4.35E-9	4.35E-9	4.35E-9	1	5.00	(1,1,1,1,1,3,BU:5); 2015 and 2017-2018 (estimated) data for First Solar in US
	Nitric acid	-	-	kg	3.00E-4	3.00E-4	3.00E-4	3.00E-4	1	1.50	(1,1,1,1,1,3,BU:1.5); 2015 and 2017-2018 (estimated) data for First Solar in US
emissions water	Cadmium	-	-	kg	3.62E-8	3.62E-8	3.62E-8	3.62E-8	1	3.00	(1,1,1,1,1,3,BU:3); 2015 and 2017-2018 (estimated) data for First Solar in US
	Copper	-	-	kg	1.76E-7	1.76E-7	1.76E-7	1.76E-7	1	3.00	(1,1,1,1,1,3,BU:3); 2015 and 2017-2018 (estimated) data for First Solar in US
	Lead	-	-	kg	2.58E-8	2.58E-8	2.58E-8	2.58E-8	1	5.00	(1,1,1,1,1,3,BU:5); 2015 and 2017-2018 (estimated) data for First Solar in US
	Nitrate	-	-	kg	2.59E-2	2.59E-2	2.59E-2	2.59E-2	1	1.50	(1,1,1,1,1,3,BU:1.5); 2015 and 2017-2018 (estimated) data for First Solar in US
	Zinc	-	-	kg	1.34E-7	1.34E-7	1.34E-7	1.34E-7	1	5.00	(1,1,1,1,1,3,BU:5); 2015 and 2017-2018 (estimated) data for First Solar in US

Table 26b: Unit process LCI data for cadmium-telluride photovoltaic panels at the European regional storage

	Name	Location	InfrastructureProcess	Unit	photovoltaic laminate, CdTe, mix, at regional storage	UncertaintyType	StandardDeviation 95%	GeneralComment
	Location				RER			
	InfrastructureProcess				1			
	Unit				m2			
product	photovoltaic laminate, CdTe, mix, at regional storage	RER	1	m2	1			
materials	photovoltaic laminate, CdTe, First Solar Series 4, at plant	MY	1	m2	7.52E-1	1	3.00	(1,1,1,1,1,3); CdTe module import from Malaysia
	photovoltaic laminate, CdTe, First Solar Series 4, at plant	US	1	m2	5.44E-2	1	3.00	(1,1,1,1,1,3); CdTe module import from US
	photovoltaic laminate, CdTe, First Solar Series 6, at plant	MY	1	m2	1.19E-1	1	3.00	(1,1,1,1,1,3); CdTe module import from Malaysia
	photovoltaic laminate, CdTe, First Solar Series 6, at plant	US	1	m2	7.51E-2	1	3.00	(1,1,1,1,1,3); CdTe module import from US
transport	transport, transoceanic freight ship	OCE	0	tkm	2.18E+2	1	2.09	(4,5,na,na,na,na); Import of modules from the US 6469 km, from Malaysia 14783 km
	transport, freight, lorry, fleet average	RER	0	tkm	1.56E+1	1	2.09	(4,5,na,na,na,na); Average transport distance from Rotterdam to Europe is 943 km

3.4 CI(G)S modules

Table 27 shows the unit process data of the CI(G)S photovoltaic laminate and cell production in Europe (Germany, DE).

The data on material, energy consumption and emissions correspond to the life cycle inventory data of CI(G)S laminate and panels published by Jungbluth et al. [9] updated with information published by de Wild-Scholten [10].

Table 27: Unit process LCI data of the CI(G)S photovoltaic laminate and cell production in Europe (Germany, DE)

	Name	Location	InfrastructureProcess	Unit	photovoltaic laminate, CIS, at plant	photovoltaic panel, CIS, at plant	UncertaintyType	StandardDeviation95%	GeneralComment
	Location				DE	DE			
	InfrastructureProcess				1	1			
	Unit				m2	m2			
product	photovoltaic laminate, CIS, at plant	DE	1	m2	1	0			
	photovoltaic panel, CIS, at plant	DE	1	m2	0	1			
energy	electricity, medium voltage, at grid	DE	0	kWh	45	0	1	1.07	(1,1,1,1,1,3); company information, coating, air-conditioning, water purification, etc.
	natural gas, burned in boiler condensing modulating >100kW	RER	0	MJ	0	0	1	1.07	(1,1,1,1,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011
	light fuel oil, burned in industrial furnace 1MW, non-modulating	RER	0	MJ	0	1.55E+1	1	1.07	(1,1,1,1,1,3); Raugei, literature
infrastructure	photovoltaic panel factory	GLO	1	unit	4.00E-6	0	1	3.02	(1,4,1,3,1,3); Assumption
materials	photovoltaic laminate, CIS, at plant	DE	1	m2	0	1.00E+0	1	3.00	(1,1,1,1,1,3); Assumption
	aluminium alloy, AlMg3, at plant	RER	0	kg	0	2.20E+0	1	1.07	(1,1,1,1,1,3); company information
	copper, at regional storage	RER	0	kg	9.77E-3	0	1	1.07	(1,1,1,1,1,3); company information
	wire drawing, copper	RER	0	kg	9.77E-3	0	1	1.07	(1,1,1,1,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 46)
	aluminium, production mix, at plant	RER	0	kg	4.44E-2	0	1	1.07	(1,1,1,1,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 46)
	flat glass, uncoated, at plant	RER	0	kg	5.27E+0	0	1	1.07	(1,1,1,1,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 46)
	diode, unspecified, at plant	GLO	0	kg	1.44E-3	0	1	1.07	(1,1,1,1,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 46)
	silicone product, at plant	RER	0	kg	4.04E-1	0	1	1.07	(1,1,1,1,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 46)
coating	molybdenum, at regional storage	RER	0	kg	6.06E-3	0	1	1.13	(3,2,2,1,1,3); company information and assumption for share of metals
	indium, at regional storage	RER	0	kg	2.82E-3	0	1	1.13	(3,2,2,1,1,3); company information and assumption for share of metals
	cadmium sulphide, semiconductor-grade, at plant	US	0	kg	2.69E-4	0	1	1.07	(1,1,1,1,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 46)
	cadmium sulphide, semiconductor-grade, at plant	US	0	kg	0	0	1	1.13	(3,2,2,1,1,3); company information and assumption for share of metals
	gallium, semiconductor-grade, at regional storage	RER	0	kg	8.99E-4	0	1	1.13	(3,2,2,1,1,3); company information and assumption for share of metals
	selenium, at plant	RER	0	kg	5.60E-3	0	1	1.13	(3,2,2,1,1,3); company information and assumption for share of metals
	zinc, primary, at regional storage	RER	0	kg	0	0	1	1.13	(3,2,2,1,1,3); company information and assumption for share of metals
	tin, at regional storage	RER	0	kg	1.23E-2	0	1	1.13	(3,2,2,1,1,3); company information and assumption for share of metals
	solar glass, low-iron, at regional storage	RER	0	kg	7.70E+0	0	1	1.07	(1,1,1,1,1,3); company information
	tempering, flat glass	RER	0	kg	7.70E+0	0	1	1.07	(1,1,1,1,1,3); Assumption
	glass fibre reinforced plastic, polyamide, injection moulding, at plant	RER	0	kg	0	4.00E-2	1	1.07	(1,1,1,1,1,3); Raugei, literature
	ethylvinylacetate, foil, at plant	RER	0	kg	7.51E-1	0	1	1.07	(1,1,1,1,1,3); company information
	flux, wave soldering, at plant	GLO	0	kg	1.23E-2	0	1	1.07	(1,1,1,1,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 46)
	zinc oxide, at plant	RER	0	kg	9.09E-3	0	1	1.07	(1,1,1,1,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 46)
	polyethylene terephthalate, granulate, amorphous, at plant	RER	0	kg	3.36E-1	0	1	1.07	(1,1,1,1,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 46)
	polyethylene, HDPE, granulate, at plant	RER	0	kg	4.84E-2	0	1	1.07	(1,1,1,1,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 46)
	polyvinylbutyral foil, at plant	RER	0	kg	1.89E-1	0	1	1.07	(1,1,1,1,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 46)
	polyphenylene sulfide, at plant	GLO	0	kg	8.59E-2	0	1	1.07	(1,1,1,1,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 46)
auxiliaries	tap water, at user	RER	0	kg	1.31E+2	0	1	1.07	(1,1,1,1,1,3); company information
	acetone, liquid, at plant	RER	0	kg	0	0	1	1.16	(3,1,3,1,1,3); Cleaning agent, Ampenberg 1998
	argon, liquid, at plant	RER	0	kg	1.90E-2	0	1	1.07	(1,1,1,1,1,3); protection gas, company information
	butyl acrylate, at plant	RER	0	kg	1.01E-1	0	1	1.07	(1,1,1,1,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 46)
	diborane, at plant	GLO	0	kg	2.01E-4	0	1	1.07	(1,1,1,1,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 46)
	sulphuric acid, liquid, at plant	RER	0	kg	3.31E-2	0	1	1.07	(1,1,1,1,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 46)
	hydrogen sulphide, H2S, at plant	RER	0	kg	1.91E-1	0	1	1.07	(1,1,1,1,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 46)
	sodium hydroxide, 50% in H2O, production mix, at plant	RER	0	kg	3.34E-2	0	1	1.07	(1,1,1,1,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 46)
	hydrogen peroxide, 50% in H2O, at plant	RER	0	kg	2.31E-2	0	1	1.07	(1,1,1,1,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 46)
	hydrochloric acid, 30% in H2O, at plant	RER	0	kg	9.94E-2	0	1	1.07	(1,1,1,1,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 46)
	nitrogen, liquid, at plant	RER	0	kg	1.57E+1	0	1	1.07	(1,1,1,1,1,3); protection gas, company information
	ammonia, liquid, at regional storehouse	RER	0	kg	9.29E-2	0	1	1.07	(1,1,1,1,1,3); dip coating for CdS, company information
	urea, as N, at regional storehouse	RER	0	kg	1.15E-3	0	1	1.16	(3,1,3,1,1,3); dip coating for CdS, Ampenberg 1998
	EUR-flat pallet	RER	0	unit	5.00E-2	0	1	1.07	(1,1,1,1,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 46)
transport	transport, freight, lorry, fleet average	RER	0	tkm	1.70E+1	2.24E-1	1	2.09	(4,5,na,na,na,na); Standard distance 100km
	transport, freight, rail	RER	0	tkm	1.02E+2	1.34E+0	1	2.09	(4,5,na,na,na,na); Standard distance 600km
disposal	disposal, waste, Si waferprod., inorg, 9.4% water, to residual material landfill	CH	0	kg	2.02E-2	0	1	1.24	(3,1,1,1,3,3); company information, amount of deposited waste, own estimation for type
	disposal, inert waste, 5% water, to inert material landfill	CH	0	kg	6.50E-1	0	1	1.07	(1,1,1,1,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 46)
	disposal, glass, 0% water, to municipal incineration	CH	0	kg	3.44E+0	0	1	1.07	(1,1,1,1,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 46)
	treatment, glass production effluent, to wastewater treatment, class 2	CH	0	m3	0	0	1	1.07	(1,1,1,1,1,3); company information
	treatment, sewage, unpolluted, to wastewater treatment, class 3	CH	0	m3	1.31E-1	0	1	1.07	(1,1,1,1,1,3); de Wild-Scholten (2014) Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection (Table 46)
emissions air	Heat, waste	-	-	MJ	1.61E+2	0	1	1.07	(1,1,1,1,1,3); Calculation
	Cadmium	-	-	kg	2.10E-8	0	1	5.09	(3,4,3,3,1,5); Rough estimation

3.5 Perovskite silicon tandem PV

Table 28 shows the unit process data of a perovskite silicon tandem PV panel produced in Germany. The data on material, energy consumption and emissions are from the life cycle inventory data in de Wild-Scholten [11] with adaptations by Ramseier et al (2019) [21]. Note: theoretical prospective life cycle inventory (not yet commercialized).

Table 28: Unit process LCI data of perovskite silicon tandem PV panel production in Germany

	Name	Location	Infrastructure Process	Unit	photovoltaic panel, perovskite-Si-tandem, at plant	Uncertainty Type	Standard Deviation 95%	General Comment
	Location				DE			
	Infrastructure Process				1			
	Unit				m2			
product	photovoltaic panel, perovskite-Si-tandem, at plant	DE	1	m2	1			
resource, in water	Water, cooling, unspecified natural origin, DE	-	-	m3	7.31E-1	1	1.22	(2,3,1,1,1,5,BU:1.05); cooling water, from natural origin; de Wild-Scholten, M. 2017. Deliverable 3.1 Life Cycle Analysis of CHEOPS technologies and benchmarking: Screening. Available online.
technosphere	photovoltaic cell, single-Si, at plant	CN	0	m2	9.35E-1	1	1.22	(2,3,1,1,1,5,BU:1.05); Monocrystalline silicone solar cell without the grid, 156mm x 156mm; de Wild-Scholten, M. 2017. Deliverable 3.1 Life Cycle Analysis of CHEOPS technologies and benchmarking: Screening. Available online.
	photovoltaic panel factory	GLO	1	unit	4.00E-6	1	3.05	(2,3,1,1,1,5,BU:3); Factory; de Wild-Scholten, M. 2017. Deliverable 3.1 Life Cycle Analysis of CHEOPS technologies and benchmarking: Screening. Available online.
	electricity, medium voltage, at grid	DE	0	kWh	2.34E+1	1	1.22	(2,3,1,1,1,5,BU:1.05); electricity from external supply; de Wild-Scholten, M. 2017. Deliverable 3.1 Life Cycle Analysis of CHEOPS technologies and benchmarking: Screening. Available online.
	lead, at regional storage	RER	0	kg	1.62E-3	1	1.22	(2,3,1,1,1,5,BU:1.05); Lead iodide; de Wild-Scholten, M. 2017. Deliverable 3.1 Life Cycle Analysis of CHEOPS technologies and benchmarking: Screening. Available online.
	methyl iodide	RER	0	kg	3.94E-4	1	1.22	(2,3,1,1,1,5,BU:1.05); Methyl iodide; de Wild-Scholten, M. 2017. Deliverable 3.1 Life Cycle Analysis of CHEOPS technologies and benchmarking: Screening. Available online.
	ethylene bromide, at plant	RER	0	kg	3.94E-4	1	1.22	(2,3,1,1,1,5,BU:1.05); Ethylene bromide; de Wild-Scholten, M. 2017. Deliverable 3.1 Life Cycle Analysis of CHEOPS technologies and benchmarking: Screening. Available online.
	chemicals organic, at plant	GLO	0	kg	8.13E-5	1	1.22	(2,3,1,1,1,5,BU:1.05); C60 fullerene; de Wild-Scholten, M. 2017. Deliverable 3.1 Life Cycle Analysis of CHEOPS technologies and benchmarking: Screening. Available online.
	chemicals organic, at plant	GLO	0	kg	3.82E-5	1	1.22	(2,3,1,1,1,5,BU:1.05); Spiro-OMeTAD: 2,2',7,7'-Tetrakis-(N,N-di-4-methoxyphenylamino)-9,9'-spirobifluorene; de Wild-Scholten, M. 2017. Deliverable 3.1 Life Cycle Analysis of CHEOPS technologies and benchmarking: Screening. Available online.
	solvents, organic, unspecified, at plant	GLO	0	kg	4.24E-1	1	1.22	(2,3,1,1,1,5,BU:1.05); Solvent 1, organic, no halogen containing; de Wild-Scholten, M. 2017. Deliverable 3.1 Life Cycle Analysis of CHEOPS technologies and benchmarking: Screening. Available online.
	solvents, organic, unspecified, at plant	GLO	0	kg	3.94E-2	1	1.22	(2,3,1,1,1,5,BU:1.05); Solvent 2, organic, halogen containing; de Wild-Scholten, M. 2017. Deliverable 3.1 Life Cycle Analysis of CHEOPS technologies and benchmarking: Screening. Available online.
	indium, at regional storage	RER	0	kg	7.50E-3	1	1.22	(2,3,1,1,1,5,BU:1.05); Indium Tin Oxide; de Wild-Scholten, M. 2017. Deliverable 3.1 Life Cycle Analysis of CHEOPS technologies and benchmarking: Screening. Available online.
	tin, at regional storage	RER	0	kg	7.50E-3	1	1.22	(2,3,1,1,1,5,BU:1.05); Indium Tin Oxide; de Wild-Scholten, M. 2017. Deliverable 3.1 Life Cycle Analysis of CHEOPS technologies and benchmarking: Screening. Available online.
	silver, at regional storage	RER	0	kg	3.52E-3	1	1.22	(2,3,1,1,1,5,BU:1.05); Conductive Adhesive: NAMICS H9455: 85-95% Ag, <5% resins (phenolyc/epoxy), <5% additives, 5-10% ethylene glycol monophenyl ether (MSDS H9455-21); de Wild-Scholten, M. 2017. Deliverable 3.1 Life Cycle Analysis of CHEOPS technologies and benchmarking: Screening. Available online.
	phenolic resin, at plant	RER	0	kg	9.27E-5	1	1.22	(2,3,1,1,1,5,BU:1.05); Conductive Adhesive: NAMICS H9455: 85-95% Ag, <5% resins (phenolyc/epoxy), <5% additives, 5-10% ethylene glycol monophenyl ether (MSDS H9455-21); de Wild-Scholten, M. 2017. Deliverable 3.1 Life Cycle Analysis of CHEOPS technologies and benchmarking: Screening. Available online.
	epoxy resin, liquid, at plant	RER	0	kg	9.27E-5	1	1.22	(2,3,1,1,1,5,BU:1.05); Conductive Adhesive: NAMICS H9455: 85-95% Ag, <5% resins (phenolyc/epoxy), <5% additives, 5-10% ethylene glycol monophenyl ether (MSDS H9455-21); de Wild-Scholten, M. 2017. Deliverable 3.1 Life Cycle Analysis of CHEOPS technologies and benchmarking: Screening. Available online.
	diphenylether-compounds, at regional storehouse	RER	0	kg	3.71E-4	1	1.22	(2,3,1,1,1,5,BU:1.05); Conductive Adhesive: NAMICS H9455: 85-95% Ag, <5% resins (phenolyc/epoxy), <5% additives, 5-10% ethylene glycol monophenyl ether (MSDS H9455-21); de Wild-Scholten, M. 2017. Deliverable 3.1 Life Cycle Analysis of CHEOPS technologies and benchmarking: Screening. Available online.
	metallization paste, front side, at plant	RER	0	kg	9.38E-3	1	1.22	(2,3,1,1,1,5,BU:1.05); Silver paste; de Wild-Scholten, M. 2017. Deliverable 3.1 Life Cycle Analysis of CHEOPS technologies and benchmarking: Screening. Available online.
	solar glass, low-iron, at regional storage	RER	0	kg	8.13E+0	1	1.22	(2,3,1,1,1,5,BU:1.05); Front glass; de Wild-Scholten, M. 2017. Deliverable 3.1 Life Cycle Analysis of CHEOPS technologies and benchmarking: Screening. Available online.
	tempering, flat glass	RER	0	kg	8.00E+0	1	1.22	(2,3,1,1,1,5,BU:1.05); Tempering, flat glass; de Wild-Scholten, M. 2017. Deliverable 3.1 Life Cycle Analysis of CHEOPS technologies and benchmarking: Screening. Available online.
	flat glass, uncoated, at plant	RER	0	kg	5.08E+0	1	1.22	(2,3,1,1,1,5,BU:1.05); Backside glass; de Wild-Scholten, M. 2017. Deliverable 3.1 Life Cycle Analysis of CHEOPS technologies and benchmarking: Screening. Available online.
	ethylvinylacetate, foil, at plant	RER	0	kg	9.75E-1	1	1.22	(2,3,1,1,1,5,BU:1.05); Ethylvinylacetate foil; de Wild-Scholten, M. 2017. Deliverable 3.1 Life Cycle Analysis of CHEOPS technologies and benchmarking: Screening. Available online.
	copper, at regional storage	RER	0	kg	1.03E-1	1	1.22	(2,3,1,1,1,5,BU:1.05); String copper; de Wild-Scholten, M. 2017. Deliverable 3.1 Life Cycle Analysis of CHEOPS technologies and benchmarking: Screening. Available online.
	wire drawing, copper	RER	0	kg	1.03E-1	1	1.22	(2,3,1,1,1,5,BU:1.05); String copper; de Wild-Scholten, M. 2017. Deliverable 3.1 Life Cycle Analysis of CHEOPS technologies and benchmarking: Screening. Available online.
	tin, at regional storage	RER	0	kg	1.29E-2	1	1.22	(2,3,1,1,1,5,BU:1.05); String tin; de Wild-Scholten, M. 2017. Deliverable 3.1 Life Cycle Analysis of CHEOPS technologies and benchmarking: Screening. Available online.
	lead, at regional storage	RER	0	kg	7.25E-4	1	1.22	(2,3,1,1,1,5,BU:1.05); String lead; de Wild-Scholten, M. 2017. Deliverable 3.1 Life Cycle Analysis of CHEOPS technologies and benchmarking: Screening. Available online.
	1-propanol, at plant	RER	0	kg	1.59E-2	1	1.22	(2,3,1,1,1,5,BU:1.05); Soldering flux: propanol; de Wild-Scholten, M. 2017. Deliverable 3.1 Life Cycle Analysis of CHEOPS technologies and benchmarking: Screening. Available online.
	glass fibre reinforced plastic, polyamide, injection moulding, at plant	RER	0	kg	2.95E-1	1	1.22	(2,3,1,1,1,5,BU:1.05); Junction box; de Wild-Scholten, M. 2017. Deliverable 3.1 Life Cycle Analysis of CHEOPS technologies and benchmarking: Screening. Available online.
	diode, unspecified, at plant	GLO	0	kg	2.81E-3	1	1.22	(2,3,1,1,1,5,BU:1.05); Bypass diode; de Wild-Scholten, M. 2017. Deliverable 3.1 Life Cycle Analysis of CHEOPS technologies and benchmarking: Screening. Available online.
	silicone product, at plant	RER	0	kg	1.22E-1	1	1.22	(2,3,1,1,1,5,BU:1.05); Silicone; de Wild-Scholten, M. 2017. Deliverable 3.1 Life Cycle Analysis of CHEOPS technologies and benchmarking: Screening. Available online.
	aluminium alloy, AlMg3, at plant	RER	0	kg	2.13E+0	1	1.22	(2,3,1,1,1,5,BU:1.05); Module frame: aluminium; de Wild-Scholten, M. 2017. Deliverable 3.1 Life Cycle Analysis of CHEOPS technologies and benchmarking: Screening. Available online.
	corrugated board, mixed fibre, single wall, at plant	RER	0	kg	7.63E-1	1	1.22	(2,3,1,1,1,5,BU:1.05); Cardboard for packaging; de Wild-Scholten, M. 2017. Deliverable 3.1 Life Cycle Analysis of CHEOPS technologies and benchmarking: Screening. Available online.
	EUR-flat pallet	RER	0	unit	3.13E-2	1	1.22	(2,3,1,1,1,5,BU:1.05); wooden pallet; de Wild-Scholten, M. 2017. Deliverable 3.1 Life Cycle Analysis of CHEOPS technologies and benchmarking: Screening. Available online.
	transport, freight, lorry, fleet average	RER	0	tkm	4.61E+0	1	2.05	(2,3,1,1,1,5,BU:2); Transport lorry; de Wild-Scholten, M. 2017. Deliverable 3.1 Life Cycle Analysis of CHEOPS technologies and benchmarking: Screening. Available online.
	transport, transoceanic freight ship	OCE	0	tkm	6.14E+1	1	2.05	(2,3,1,1,1,5,BU:2); Transport ship; de Wild-Scholten, M. 2017. Deliverable 3.1 Life Cycle Analysis of CHEOPS technologies and benchmarking: Screening. Available online.
	disposal, plastics, mixture, 15.3% water, to municipal incineration	CH	0	kg	3.02E-2	1	1.22	(2,3,1,1,1,5,BU:1.05); EVA cutting loss; de Wild-Scholten, M. 2017. Deliverable 3.1 Life Cycle Analysis of CHEOPS technologies and benchmarking: Screening. Available online.
	disposal, solvents mixture, 16.5% water, to hazardous waste incineration	CH	0	kg	8.86E-1	1	1.22	(2,3,1,1,1,5,BU:1.05); organic solvent (halogen free), halogen contatining solvent, PB + halogen contating solvent; de Wild-Scholten, M. 2017. Deliverable 3.1 Life Cycle Analysis of CHEOPS technologies and benchmarking: Screening. Available online.
emission air, high population density	Lead	-	-	kg	1.16E-5	1	5.06	(2,3,1,1,1,5,BU:5); Lead to air; de Wild-Scholten, M. 2017. Deliverable 3.1 Life Cycle Analysis of CHEOPS technologies and benchmarking: Screening. Available online.
emission water, unspecified	Lead	-	-	kg	1.16E-5	1	5.06	(2,3,1,1,1,5,BU:5); Lead to water; de Wild-Scholten, M. 2017. Deliverable 3.1 Life Cycle Analysis of CHEOPS technologies and benchmarking: Screening. Available online.
emission air, high population density	Water	-	-	kg	3.66E+1	1	1.58	(3,3,1,1,1,5,BU:1.5); Cooling water emissions (5% of used cooling water); Estmated based Frischknecht and Büsser (2013)

3.6 PV module recycling

Life cycle inventories of current PV module recycling have been compiled for c-Si and CdTe PV technologies [22-24]. Due to limited waste volumes, c-Si PV modules are mainly treated in recycling plants designed for treatment of laminated glass, metals or electronic waste. Only the bulk materials (glass, aluminium and copper) are recovered, while the cells and other materials such as plastics are incinerated. CdTe PV modules have been treated in dedicated recycling plants for many years and life cycle inventories of this process have been published, with the semiconductor recovered in addition to glass and copper. Regarding the outputs of the recycling processes, yield for glass and nonferrous metal for c-Si PV is 59-75% and 13.5-21.8%, respectively [23]. Yield for glass, semiconductor, and copper in CdTe PV recycling is over 90% [24]. Under the EU WEEE Directive, recycling of end-of-life PV modules is mandatory in the European Union and the current status of global policy and technology related to PV module recycling has been reviewed by IEA PVPS Task 12 [25][26].

Name	**c-Si and CdTe PV module recycling**
Time period	2015-2016 for c-Si PV and 2012 for CdTe PV
Geography	Europe, Western
Technology	Average technology
Representativeness	Data from commercial operations
Approaches	**cut-off approach**: treatment efforts and emissions are allocated based on economic revenue received from selling the treatment service and the materials recovered; to be used in LCA of PV electricity and the assessment of the full life cycle (from cradle to grave) of PV panels. **end-of-life approach**: treatment efforts and emissions are fully attributed to the treatment service; potential environmental benefits are included due to avoiding primary material supply; may be applied in the LCA of different end of life treatment options for PV panels and systems.
Date	10/3/2016
Collection method	Data For c-Si PV collected from four European recycling plants (3 laminated glass recyclers, 1 metal recycler) [22-23]. Data for CdTe PV from publicly available information on first generation CdTe PV recycling in First Solar's PV recycling facility in Germany [22][24].
Data treatment	Scaled to 1 kg of module

Table 29: Unit process LCI data of the treatment of used c-Si PV modules in a first generation recycling process and of the recovered materials according to the cut-off approach

	Name	Location	InfrastructureProcess	Unit	treatment, c-Si PV module	glass cullets, recovered from c-Si PV module treatment	aluminium scrap, recovered from c-Si PV module treatment	copper scrap, recovered from c-Si PV module treatment	UncertaintyType	StandardDeviation95%	GeneralComment
	Location				RER	RER	RER	RER			
	InfrastructureProcess				0	0	0	0			
	Unit				kg	kg	kg	kg			
product	treatment, c-Si PV module	RER	0	kg	1	0	0	0			
	glass cullets, recovered from c-Si PV module treatment	RER	0	kg	0	1	0	0			
	aluminium scrap, recovered from c-Si PV module treatment	RER	0	kg	0	0	1	0			
	copper scrap, recovered from c-Si PV module treatment	RER	0	kg	0	0	0	1			
technosphere	electricity, medium voltage, production ENTSO, at grid	ENTSO	0	kWh	5.56E-2	4.05E-3	1.42E-1	8.09E-1	1	1.25	(2,3,1,1,3,4,BU:1.05); Weighted average of data from recyclers; Economic allocation;
	diesel, burned in building machine, average	CH	0	MJ	3.24E-2	2.36E-3	8.25E-2	4.71E-1	1	2.07	(2,3,1,1,3,4,BU:2); Weighted average of data from recyclers; Economic allocation;
	disposal, plastics, mixture, 15.3% water, to municipal incineration	CH	0	kg	7.34E-2	5.34E-3	1.87E-1	1.07E+0	1	1.25	(2,3,1,1,3,4,BU:1.05); Weighted average of data from recyclers; Economic allocation;
	disposal, plastics, mixture, 15.3% water, to sanitary landfill	CH	0	kg	1.28E-2	9.33E-4	3.26E-2	1.87E-1	1	1.25	(2,3,1,1,3,4,BU:1.05); Weighted average of data from recyclers; Economic allocation;
	transport, freight, lorry 3.5-7.5 metric ton, EURO 5	RER	0	tkm	5.00E-2	3.64E-3	1.27E-1	7.27E-1	1	2.09	(4,5,na,na,na,na,BU:2); Assumed transport distance to collection point: 100 km; Economic allocation; Latunussa et al. 2016
	transport, freight, lorry, fleet average	RER	0	tkm	2.00E-1	1.45E-2	5.09E-1	2.91E+0	1	2.09	(4,5,na,na,na,na,BU:2); Assumed transport distance to recycling site: 400 km; Economic allocation; Latunussa et al. 2016

Table 30: Unit process LCI data of the takeback and recycling of used c-Si PV modules in a first generation recycling process according to the end-of-life approach

	Name	Location	InfrastructureProcess	Unit	takeback and recycling, c-Si PV module	UncertaintyType	StandardDeviation95%	GeneralComment
	Location				RER			
	InfrastructureProcess				0			
	Unit				kg			
product	takeback and recycling, c-Si PV module	RER	0	kg	1			
technosphere	electricity, medium voltage, production ENTSO, at grid	ENTSO	0	kWh	1.11E-1	1	1.25	(2,3,1,1,3,4,BU:1.05); Weighted average of data from recyclers;
	diesel, burned in building machine, average	CH	0	MJ	6.48E-2	1	2.07	(2,3,1,1,3,4,BU:2); Weighted average of data from recyclers;
	disposal, plastics, mixture, 15.3% water, to municipal incineration	CH	0	kg	1.47E-1	1	1.25	(2,3,1,1,3,4,BU:1.05); Weighted average of data from recyclers;
	disposal, plastics, mixture, 15.3% water, to sanitary landfill	CH	0	kg	2.57E-2	1	1.25	(2,3,1,1,3,4,BU:1.05); Weighted average of data from recyclers;
	transport, freight, lorry 3.5-7.5 metric ton, EURO 5	RER	0	tkm	1.00E-1	1	2.09	(4,5,na,na,na,na,BU:2); Assumed transport distance to collection point: 100 km; Latunussa et al. 2016
	transport, freight, lorry, fleet average	RER	0	tkm	4.00E-1	1	2.09	(4,5,na,na,na,na,BU:2); Assumed transport distance to recycling site: 400 km; Latunussa et al. 2016

Table 31: Unit process LCI data of the avoided burdens due to materials recovered from used c-Si PV modules in a first generation recycling process according to the end-of-life approach

	Name	Location	InfrastructureProcess	Unit	avoided burden from recycling, c-Si PV module	UncertaintyType	StandardDeviation95%	GeneralComment
	Location				RER			
	InfrastructureProcess				0			
	Unit				kg			
product	avoided burden from recycling, c-Si PV module	RER	0	kg	1			
technosphere	natural gas, burned in industrial furnace >100kW	RER	0	MJ	-8.15E-1	1	1.14	(2,4,1,1,1,3,BU:1.05); Avoided primary glass production materials; Weighted average of data from recyclers; Held and Ilg 2011; KBOB LCI data DQRv2:2016
	heavy fuel oil, burned in industrial furnace 1MW, non-modulating	RER	0	MJ	-5.28E-1	1	1.14	(2,4,1,1,1,3,BU:1.05); Avoided primary glass production materials; Weighted average of data from recyclers; Held and Ilg 2011; KBOB LCI data DQRv2:2016
	silica sand, at plant	DE	0	kg	-3.44E-1	1	1.14	(2,4,1,1,1,3,BU:1.05); Avoided primary glass production materials; Weighted average of data from recyclers; Held and Ilg 2011; KBOB LCI data DQRv2:2016
	soda, powder, at plant	RER	0	kg	-1.36E-1	1	1.14	(2,4,1,1,1,3,BU:1.05); Avoided primary glass production materials; Weighted average of data from recyclers; Held and Ilg 2011; KBOB LCI data DQRv2:2016
	limestone, milled, packed, at plant	CH	0	kg	-2.38E-1	1	1.14	(2,4,1,1,1,3,BU:1.05); Avoided primary glass production materials; Weighted average of data from recyclers; Held and Ilg 2011; KBOB LCI data DQRv2:2016
	copper, at regional storage	RER	0	kg	-2.48E-2	1	1.14	(2,4,1,1,1,3,BU:1.05); Avoided primary copper production materials from junction box and cables; Recycling content of copper is 44 % according to KBOB-list; Weighted average of data from recyclers; KBOB LCI data DQRv2:2016
	copper, secondary, at refinery	RER	0	kg	2.48E-2	1	1.14	(2,4,1,1,1,3,BU:1.05); Efforts for making secondary copper from scrap;
	aluminium, primary, at plant	RER	0	kg	-5.34E-2	1	1.14	(2,4,1,1,1,3,BU:1.05); Avoided primary aluminium production materials from frame; Recycling content of AlMg3 alloy is 77 % according to KBOB-list; Weighted average of data from recyclers; KBOB LCI data DQRv2:2016
	aluminium, secondary, from old scrap, at plant	RER	0	kg	5.34E-2	1	1.14	(2,4,1,1,1,3,BU:1.05); Efforts for making secondary aluminium from scrap;
emission air, unspecified	Carbon dioxide, fossil	-	-	kg	-1.24E-1	1	1.14	(2,4,1,1,1,3,BU:1.05); Avoided primary glass production materials; Weighted average of data from recyclers; Held and Ilg 2011; KBOB LCI data DQRv2:2016

Table 32: Unit process LCI data of the treatment of used CdTe PV modules in a first generation recycling process and of the recovered materials according to the cut-off approach

	Name	Location	InfrastructureProcess	Unit	treatment, CdTe PV module	glass cullets, recovered from CdTe PV module treatment	copper scrap, recovered from CdTe PV module treatment	cadmium sludge, recovered from CdTe PV module treatment	copper telluride cement, recovered from CdTe PV module treatment	UncertaintyType	StandardDeviation95%	GeneralComment
	Location				DE	DE	DE	DE	DE			
	InfrastructureProcess				0	0	0	0	0			
	Unit				kg	kg	kg	kg	kg			
product	treatment, CdTe PV module	DE	0	kg	1	0	0	0	0			
	glass cullets, recovered from CdTe PV module treatment	DE	0	kg	0	1	0	0	0			
	copper scrap, recovered from CdTe PV module treatment	DE	0	kg	0	0	1	0	0			
	cadmium sludge, recovered from CdTe PV module treatment	DE	0	kg	0	0	0	1	0			
	copper telluride cement, recovered from CdTe PV module treatment	DE	0	kg	0	0	0	0	1			
technosphere	electricity, medium voltage, at grid	DE	0	kWh	2.24E-1	1.51E-2	3.02E+0	6.95E-2	5.89E+0	1	1.14	(2,4,1,1,1,3,BU:1.05); ; Sinha et al. 2012
	water, deionised, at plant	CH	0	kg	2.78E-1	1.87E-2	3.74E+0	8.60E-2	7.29E+0	1	1.14	(2,4,1,1,1,3,BU:1.05); ; Sinha et al. 2012
	sulphuric acid, liquid, at plant	RER	0	kg	4.28E-3	2.87E-4	5.75E-2	1.32E-3	1.12E-1	1	1.14	(2,4,1,1,1,3,BU:1.05); ; Sinha et al. 2012
	hydrogen peroxide, 50% in H2O, at plant	RER	0	kg	2.93E-2	1.97E-3	3.94E-1	9.07E-3	7.68E-1	1	1.14	(2,4,1,1,1,3,BU:1.05); ; Sinha et al. 2012
	sodium hydroxide, 50% in H2O, production mix, at plant	RER	0	kg	5.34E-3	3.59E-4	7.18E-2	1.65E-3	1.40E-1	1	1.14	(2,4,1,1,1,3,BU:1.05); ; Sinha et al. 2012
	transport, freight, lorry 3.5-7.5 metric ton, EURO 5	RER	0	tkm	8.47E-2	5.69E-3	1.14E+0	2.62E-2	2.22E+0	1	2.09	(4,5,na,na,na,na,BU:2); Assumed transport distance to collection point: km; Sinha et al. 2012; Latanussa et al. 2016
	transport, freight, lorry, fleet average	RER	0	tkm	4.90E-1	3.29E-2	6.59E+0	1.52E-1	1.29E+1	1	2.09	(4,5,na,na,na,na,BU:2); Assumed transport distance to recycling site: km; Sinha et al. 2012; Latanussa et al. 2016
	treatment, PV cell production effluent, to wastewater treatment, class 3	CH	0	m3	2.46E-4	1.65E-5	3.30E-3	7.61E-5	6.45E-3	1	1.14	(2,4,1,1,1,3,BU:1.05); ; Sinha et al. 2012
	disposal, plastics, mixture, 15.3% water, to sanitary landfill	CH	0	kg	3.16E-2	2.12E-3	4.25E-1	9.78E-3	8.29E-1	1	1.14	(2,4,1,1,1,3,BU:1.05); ; Sinha et al. 2012
	disposal, inert waste, 5% water, to inert material landfill	CH	0	kg	6.59E-3	4.43E-4	8.86E-2	2.04E-3	1.73E-1	1	1.14	(2,4,1,1,1,3,BU:1.05); ; Sinha et al. 2012
emission air, unspecified	Cadmium	-	-	kg	3.02E-10	2.03E-11	4.06E-9	9.35E-11	7.93E-9	1	5.02	(2,4,1,1,1,3,BU:5); ; Sinha et al. 2012
emission water, unspecified	Cadmium	-	-	kg	4.58E-9	3.08E-10	6.15E-8	1.42E-9	1.20E-7	1	3.02	(2,4,1,1,1,3,BU:3); ; Sinha et al. 2012

Table 33: Unit process LCI data of the takeback and recycling of used CdTe PV modules in a first generation recycling process according to the end-of-life approach

	Name	Location	InfrastructureProcess	Unit	takeback and recycling, CdTe PV module	UncertaintyType	StandardDeviation95%	GeneralComment
	Location				DE			
	InfrastructureProcess				0			
	Unit				kg			
product	takeback and recycling, CdTe PV module	DE	0	kg	1			
technosphere	electricity, medium voltage, at grid	DE	0	kWh	2.65E-1	1	1.14	(2,4,1,1,1,3,BU:1.05); ; Sinha et al. 2012
	water, deionised, at plant	CH	0	kg	3.28E-1	1	1.14	(2,4,1,1,1,3,BU:1.05); ; Sinha et al. 2012
	sulphuric acid, liquid, at plant	RER	0	kg	5.05E-3	1	1.14	(2,4,1,1,1,3,BU:1.05); ; Sinha et al. 2012
	hydrogen peroxide, 50% in H2O, at plant	RER	0	kg	3.46E-2	1	1.14	(2,4,1,1,1,3,BU:1.05); ; Sinha et al. 2012
	sodium hydroxide, 50% in H2O, production mix, at plant	RER	0	kg	6.31E-3	1	1.14	(2,4,1,1,1,3,BU:1.05); ; Sinha et al. 2012
	transport, freight, lorry 3.5-7.5 metric ton, EURO 5	RER	0	tkm	1.00E-1	1	2.09	(4,5,na,na,na,na,BU:2); Assumed transport distance to collection point: 100 km; Sinha et al. 2012; Latanussa et al. 2016
	transport, freight, lorry, fleet average	RER	0	tkm	5.78E-1	1	2.09	(4,5,na,na,na,na,BU:2); Assumed transport distance to recycling site: 400 km; Sinha et al. 2012; Latanussa et al. 2016
	treatment, PV cell production effluent, to wastewater treatment, class 3	CH	0	m3	2.90E-4	1	1.14	(2,4,1,1,1,3,BU:1.05); ; Sinha et al. 2012
	disposal, plastics, mixture, 15.3% water, to sanitary landfill	CH	0	kg	3.73E-2	1	1.14	(2,4,1,1,1,3,BU:1.05); ; Sinha et al. 2012
	disposal, inert waste, 5% water, to inert material landfill	CH	0	kg	7.78E-3	1	1.14	(2,4,1,1,1,3,BU:1.05); ; Sinha et al. 2012
emission air, unspecified	Cadmium	-	-	kg	3.57E-10	1	5.02	(2,4,1,1,1,3,BU:5); ; Sinha et al. 2012
emission water, unspecified	Cadmium	-	-	kg	5.40E-9	1	3.02	(2,4,1,1,1,3,BU:3); ; Sinha et al. 2012

Table 34: Unit process LCI data of the avoided burdens due to materials recovered from used CdTe PV modules in a first generation recycling process according to the end-of-life approach

	Name	Location	InfrastructureProcess	Unit	avoided burden from recycling, CdTe PV module	UncertaintyType	StandardDeviation95%	GeneralComment
	Location				DE			
	InfrastructureProcess				0			
	Unit				kg			
product	avoided burden from recycling, CdTe PV module	DE	0	kg	1			
technosphere	natural gas, burned in industrial furnace >100kW	RER	0	MJ	-1.19E+0	1	1.14	(2,4,1,1,1,3,BU:1.05); Avoided primary glass production materials; Held and Ilg 2011; KBOB LCI data DQRv2:2016
	heavy fuel oil, burned in industrial furnace 1MW, non-modulating	RER	0	MJ	-7.67E-1	1	1.14	(2,4,1,1,1,3,BU:1.05); Avoided primary glass production materials; Held and Ilg 2011; KBOB LCI data DQRv2:2016
	silica sand, at plant	DE	0	kg	-5.01E-1	1	1.14	(2,4,1,1,1,3,BU:1.05); Avoided primary glass production materials; Held and Ilg 2011; KBOB LCI data DQRv2:2016
	soda, powder, at plant	RER	0	kg	-1.98E-1	1	1.14	(2,4,1,1,1,3,BU:1.05); Avoided primary glass production materials; Held and Ilg 2011; KBOB LCI data DQRv2:2016
	limestone, milled, packed, at plant	CH	0	kg	-3.47E-1	1	1.14	(2,4,1,1,1,3,BU:1.05); Avoided primary glass production materials; Held and Ilg 2011; KBOB LCI data DQRv2:2016
	copper, at regional storage	RER	0	kg	-2.68E-3	1	1.14	(2,4,1,1,1,3,BU:1.05); Avoided primary copper production materials from junction box; Recycling content of copper is 44 % according to KBOB-list; Personal communication Parikhit Sinha, 06.10.2014; KBOB LCI data DQRv2:2016
	copper, secondary, at refinery	RER	0	kg	2.68E-3	1	1.14	(2,4,1,1,1,3,BU:1.05); Efforts for making secondary copper from scrap; Personal communication Parikhit Sinha, 06.10.2014
	cadmium sludge, from zinc electrolysis, at plant	GLO	0	kg	-1.72E-3	1	1.14	(2,4,1,1,1,3,BU:1.05); Avoided unrefined semiconductor materials; Sinha et al. 2012
	copper telluride cement, from copper production	GLO	0	kg	-1.95E-3	1	1.14	(2,4,1,1,1,3,BU:1.05); Avoided unrefined semiconductor materials; Sinha et al. 2012
emission air, unspecified	Carbon dioxide, fossil	-	-	kg	-1.80E-1	1	1.14	(2,4,1,1,1,3,BU:1.05); Avoided primary glass production materials; Held and Ilg 2011; KBOB LCI data DQRv2:2016

3.7 Mounting Structures of PV Modules

Table 35 shows the unit process data of PV mounting systems in Europe. The data correspond to the life cycle inventory data of mounting systems published by Jungbluth et al. [9]. Data includes materials, packaging, and transport of mounting structures and disposal of packaging materials.

Table 35: Unit process LCI data of different rooftop PV mounting systems

	Name	Location	InfrastructureProcess	Unit	facade construction, mounted, at building	facade construction, integrated, at building	flat roof construction, on roof	slanted-roof construction, mounted, on roof	slanted-roof construction, integrated, on roof	UncertaintyType	StandardDeviation 95%	GeneralComment
	Location				RER	RER	RER	RER	RER			
	InfrastructureProcess				1	1	1	1	1			
	Unit				m2	m2	m2	m2	m2			
product	facade construction, mounted, at building	RER	1	m2	1	0	0	0	0			
	facade construction, integrated, at building	RER	1	m2	-	1	0	0	0			
	flat roof construction, on roof	RER	1	m2	-	-	1	0	0			
	slanted-roof construction, mounted, on roof	RER	1	m2	-	-	-	1	0			
	slanted-roof construction, integrated, on roof	RER	1	m2	-	-	-	-	1.00E+0			
	open ground construction, on ground	RER	1	m2	-	-	-	-	0			
	slanted-roof construction, mounted, on roof, Stade de Suisse	CH	1	m2	-	-	-	-	0			
materials	aluminium, production mix, wrought alloy, at plant	RER	0	kg	2.64E+0	3.27E+0	2.52E+0	2.84E+0	2.25E+0	1	2.05	(1,2,1,1,1,na); Literature and own estimations
	corrugated board, mixed fibre, single wall, at plant	RER	0	kg	4.03E-2	0	1.83E-2	1.33E-1	1.14E-1	1	2.18	(3,4,3,1,3,5); Schwarz et al. 1992
	polyethylene, HDPE, granulate, at plant	RER	0	kg	7.32E-4	0	1.92E+0	1.40E-3	2.82E-2	1	2.05	(1,2,1,1,1,na); Literature and own estimations, recycled PE
	polystyrene, high impact, HIPS, at plant	RER	0	kg	3.66E-3	0	8.30E-3	7.02E-3	6.02E-3	1	2.18	(3,4,3,1,3,5); Schwarz et al. 1992
	polyurethane, flexible foam, at plant	RER	0	kg	0	0	0	0	1.84E-2	1	2.048	(1,2,1,1,1,na); Literature and own estimations
	synthetic rubber, at plant	RER	0	kg	0	0	0	0	1.24E+0	1	2.048	(1,2,1,1,1,na); Literature and own estimations
	steel, low-alloyed, at plant	RER	0	kg	1.80E+0	0	2.67E-1	1.50E+0	2.00E-1	1	2.048	(1,2,1,1,1,na); Literature and own estimations
	chromium steel 18/8, at plant	RER	0	kg	0	0	0	0	0	1	2.102	(2,3,1,1,1,5); Literature and own estimations
	gravel, unspecified, at mine	CH	0	kg	0	0	0	0	0	1	2.18	(3,4,3,1,3,5); not accounted
	reinforcing steel, at plant	RER	0	kg	-	0	-	-	-	1	2.102	(2,3,1,1,1,5); Literature and own estimations
	concrete, normal, at plant	CH	0	m3	-	0	0	0	-	1	2.18	(3,4,3,1,3,5); Fence foundation
	section bar extrusion, aluminium	RER	0	kg	2.64E+0	3.27E+0	2.52E+0	2.84E+0	2.25E+0	1	2.18	(3,4,3,1,3,5); Estimation
	sheet rolling, steel	RER	0	kg	1.10E-1	0	2.67E-1	1.50E+0	0	1	2.18	(3,4,3,1,3,5); Estimation
	section bar rolling, steel	RER	0	kg	1.69E+0	0	0	0	2.00E-1	1	2.18	(3,4,3,1,3,5); Brunschweiler 1993
	wire drawing, steel	RER	0	kg	-	0	0	0	-	1	2.18	(3,4,3,1,3,5); Mesh wire fence
	zinc coating, pieces	RER	0	m2	-	0	0	0	-	1	2.18	(3,4,3,1,3,5); Estimation
	zinc coating, coils	RER	0	m2	-	0	0	0	-	1	2.18	(3,4,3,1,3,5); Fence
transport	transport, freight, lorry, fleet average	RER	0	tkm	2.24E-1	1.64E-1	2.56E-1	2.25E-1	2.07E-1	1	2.142	(4,5,na,na,na,na); Standard distance 50km
	transport, freight, rail	RER	0	tkm	1.61E+0	6.54E-1	1.05E+0	1.50E+0	8.52E-1	1	2.142	(4,5,na,na,na,na); Standard distances 200km, 600km
	transport, freight, light commercial vehicle	RER	0	tkm	4.44E-1	3.27E-1	4.72E-1	4.34E-1	3.75E-1	1	2.18	(3,4,3,1,3,5); 100km to construction place
disposal	disposal, packaging cardboard, 19.6% water, to municipal incineration	CH	0	kg	4.03E-2	0	1.83E-2	1.33E-1	1.14E-1	1	2.18	(3,4,3,1,3,5); Calculated with use
	disposal, building, polyethylene/polypropylene products, to final disposal	CH	0	kg	7.32E-4	0	1.92E+0	1.40E-3	1.29E+0	1	2.18	(3,4,3,1,3,5); Disposal of plastics parts at end of life
	disposal, building, polystyrene isolation, flame-retardant, to final disposal	CH	0	kg	3.66E-3	0	8.30E-3	7.02E-3	6.02E-3	1	2.18	(3,4,3,1,3,5); Disposal of plastics parts at end of life
resources	Transformation, from pasture and meadow	-	-	m2	-	0	-	-	-	1	2.18	(3,4,3,1,3,5); Tucson Electric Power
	Transformation, to industrial area, built up	-	-	m2	-	0	-	-	-	1	2.147	(1,3,2,3,3,5); Literature and own estimations
	Transformation, to industrial area, vegetation	-	-	m2	-	0	-	-	-	1	2.16	(3,3,2,3,3,5); Literature and own estimations
	Occupation, industrial area, built up	-	-	m2a	-	0	-	-	-	1	2.16	(3,3,2,3,3,5); Assumed life time: 30 a
	Occupation, industrial area, vegetation	-	-	m2a	-	0	-	-	-	1	2.16	(3,3,2,3,3,5); Assumed life time: 30 a

Table 36: Unit process LCI data of ground-mount PV mounting systems

	Name	Location	Infrastructure Process	Unit	open ground construction, on ground, Mont Soleil	UncertaintyType	StandardDeviation95%	GeneralComment
	Location				CH			
	InfrastructureProcess				1			
	Unit				m2			
product	open ground construction, on ground, Mont Soleil	CH	1	m2	1			
materials	gravel, round, at mine	CH	0	kg	350	1	1.89	(2,1,5,1,1,5); gravel for access route
	excavation, hydraulic digger, average	CH	0	m3	0	1	3.21	(2,1,5,1,1,5); for access route
	zinc, primary, at regional storage	RER	0	kg	3	1	1.89	(2,1,5,1,1,5);
	concrete, normal, at plant	CH	0	m3	2.05E-2	1	1.89	(2,1,5,1,1,5); foundation and building
	reinforcing steel, at plant	RER	0	kg	3.95E+1	1	1.89	(2,1,5,1,1,5); for foundation
	steel, low-alloyed, at plant	RER	0	kg	2.51E+0	1	1.89	(2,1,5,1,1,5); for fence and building
	particleboard, average glue mix, uncoated, at plant	RER	0	m3	9.98E-4	1	1.89	(2,1,5,1,1,5); for building
	roof tile, at plant	RER	0	kg	5.41E-1	1	1.89	(2,1,5,1,1,5); for building
	polyurethane, flexible foam, at plant	RER	0	kg	9.94E-2	1	1.89	(2,1,5,1,1,5); for building insulation
	zinc coating, coils	RER	0	m2	1.83E-1	1	1.89	(2,1,5,1,1,5); coating of fence and building steel
	polyethylene, HDPE, granulate, at plant	RER	0	kg	4.17E-2	1	1.89	(2,1,5,1,1,5); for building
	acetone, liquid, at plant	RER	0	kg	4.57E-2	1	1.89	(2,1,5,1,1,5); for cleaning of profiles
	polyvinylchloride, at regional storage	RER	0	kg	1.11E-2	1	1.89	(2,1,5,1,1,5); for building
	bitumen, at refinery	CH	0	kg	2.03E-2	1	1.89	(2,1,5,1,1,5); for building
	rock wool, packed, at plant	CH	0	kg	1.92E-2	1	1.89	(2,1,5,1,1,5); for building
	flat glass, coated, at plant	RER	0	kg	7.21E-3	1	1.89	(2,1,5,1,1,5); for building
	acrylic binder, 34% in H2O, at plant	RER	0	kg	5.20E-3	1	1.89	(2,1,5,1,1,5); assumed for acryl tape
	silicone product, at plant	RER	0	kg	4.79E-2	1	1.89	(2,1,5,1,1,5); silicone glue
transport	transport, freight, lorry 7.5-16 metric ton, fleet average	CH	0	tkm	9.45E+0	1	2.85	(4,5,na,na,na,na); Literature
	transport, freight, lorry 16-32 metric ton, fleet average	CH	0	tkm	2.95E+0	1	2.85	(4,5,na,na,na,na); Literature
disposal	disposal, concrete, 5% water, to inert material landfill	CH	0	kg	4.87E+1	1	1.91	(3,1,5,1,1,5); Literature and own estimations
	disposal, building, reinforcement steel, to sorting plant	CH	0	kg	3.95E+1	1	1.91	(3,1,5,1,1,5); Literature and own estimations
	disposal, building, fibre board, to final disposal	CH	0	kg	6.79E-1	1	1.91	(3,1,5,1,1,5); Literature and own estimations
	disposal, building, polyurethane foam, to final disposal	CH	0	kg	9.94E-2	1	1.91	(3,1,5,1,1,5); Literature and own estimations
	disposal, building, polyethylene/polypropylene products, to final disposal	CH	0	kg	4.17E-2	1	1.91	(3,1,5,1,1,5); Literature and own estimations
	disposal, building, polyethylene/polypropylene products, to final disposal	CH	0	kg	1.11E-2	1	1.91	(3,1,5,1,1,5); Literature and own estimations
	disposal, building, polyvinylchloride products, to final disposal	CH	0	kg	1.11E-2	1	1.91	(3,1,5,1,1,5); Literature and own estimations
	disposal, building, mineral wool, to sorting plant	CH	0	kg	1.92E-2	1	1.91	(3,1,5,1,1,5); Literature and own estimations
	disposal, building, glass pane (in burnable frame), to sorting plant	CH	0	kg	7.21E-3	1	1.91	(3,1,5,1,1,5); Literature and own estimations
resources	Transformation, from pasture and meadow	-	-	m2	4.72E+0	1	2.00	(3,1,5,1,1,5); Literature and own estimations
	Transformation, to industrial area, built up	-	-	m2	1.50E+0	1	3.23	(3,1,5,1,1,5); Literature and own estimations
	Transformation, to industrial area, vegetation	-	-	m2	3.22E+0	1	1.91	(3,1,5,1,1,5); Literature and own estimations
	Occupation, industrial area, built up	-	-	m2a	4.50E+1	1	5.37	(3,1,5,1,1,5); Assumed life time: 30 a
	Occupation, industrial area, vegetation	-	-	m2a	9.67E+1	1	2.37	(3,1,5,1,1,5); Assumed life time: 30 a
emission	Acetone	-	-	kg	4.57E-2	1	1.89	(2,1,5,1,1,5); Assumed life time: 30 a

3.8 Electrical Components

3.8.1 Roof Top Installations

This section has not been updated. Nowadays Aluminium may be used in sub-array and array cables.

Name	**Electrical cabling for module interconnection and AC-interface**
Time period	2006
Geography	Europe, Western
Technology	Average technology
Representativeness	Mixed data
Date	11/6/2006
Collection method	For roof top systems: 4 rows of 13 SolarWorld SW220 poly module with 6 x 10 multicrystalline cells of 156 mm x 156 mm.
Data treatment	Scaled to 1 m^2 of module area
Comment	For systems with modules in 150-170 Wp range and dimension of about 1 x 1.3 m^2, connected to a 4.6 kW inverter.

Table 37: LCI of DC Cable (1)

Type of system		on-roof or in-roof	ground PhönixSonnenstrom	ground Springerville	
Products	**Unit**	**Amount**	**Amount**	**Amount**	**Comment**
DC Cabling	m^2	1	1	1	per m^2 module area
Materials/fuels					
Copper	kg	0.10	0.62	0.64	2.2 m DC cable and 0.1 m AC cable
TPE = Thermoplastic elastomer	kg	0.06	0.25	0.48	
Electricity					
electricity, medium voltage	kWh	0.0	0.0	0.0	unknown
Emissions					unknown
Waste to treatment					Unknown

Note

1) Typical cable lengths for a roof top system are: 2.2 m DC cable and 0.1 m AC cable per m^2 of module/array area

Reference: [13]

Date 9/1/2006

Collection method http://www.helukabel.de/download.php?lang=en&im=pdf/english/datenblatt/&fid=78990.pdf

Comment Helukabel Solarflex 101, 4 mm^2, ROHS compliant.
In a typical rooftop system, comprising modules of 1x1.7 m^2, the DC cable length will be about 2.2 m per m^2 of module area

Table 38: LCI of DC Cable (2)

Products	**Unit**	**Amount**	**Comment**
Cable DC 4 mm^2	m	1	
Materials/fuels			
SOLIDS			
copper	kg	0.038	Cu, Sn coated
TPE = Thermoplastic elastomer	kg	0.030	TPE
Electricity			
electricity, medium voltage, total	kWh	0.0	unknown
Emissions			unknown
Waste to treatment			unknown

Reference [13]

Table 39: Unit process LCI data of 2.5-20 kW Inverter

Name	**Inverter 2.5-20 kW**
Time period	2016
Geography	Europe, Western
Technology	Average technology
Representativeness	Data from a specific component
Date	10/3/2016
Collection method	Based on survey of 3 major European inverter manufacturers [14]

	Name	Location	InfrastructureProcess	Unit	inverter, 2.5 kW, average, at plant	inverter, 5 kW, average, at plant	inverter, 10 kW, average, at plant	inverter, 20 kW, average, at plant	UncertaintyType	StandardDeviation95%	GeneralComment
	Location				RER	RER	RER	RER			
	InfrastructureProcess				1	1	1	1			
	Unit				unit	unit	unit	unit			
product	inverter, 2.5 kW, average, at plant	RER	1	unit	1	0	0	0			
	inverter, 5 kW, average, at plant	RER	1	unit	0	1	0	0			
	inverter, 10 kW, average, at plant	RER	1	unit	0	0	1	0			
	inverter, 20 kW, average, at plant	RER	1	unit	0	0	0	1			
energy use	electricity, medium voltage, production ENTSO, at grid	ENTSO	0	kWh	1.06E+1	1.69E+1	2.71E+1	4.34E+1	1	1.31	(2,3,1,3,3,5,BU:1.05); Data from two European inverter manufacturers;
	light fuel oil, burned in industrial furnace 1MW, non-modulating	CH	0	MJ	2.26E-1	3.61E-1	5.79E-1	9.28E-1	1	1.34	(3,4,1,3,3,5,BU:1.05); Data from two European inverter manufacturers;
	natural gas, burned in power plant	DE	0	MJ	3.57E+0	5.72E+0	9.17E+0	1.47E+1	1	1.34	(3,4,1,3,3,5,BU:1.05); Data from two European inverter manufacturers;
	heat, natural gas, at industrial furnace >100kW	RER	0	MJ	9.21E+0	1.47E+1	2.36E+1	3.79E+1	1	1.34	(3,4,1,3,3,5,BU:1.05); Data from two European inverter manufacturers;
individual components	aluminium, production mix, cast alloy, at plant	RER	0	kg	4.77E+0	7.64E+0	1.22E+1	1.96E+1	1	1.31	(2,3,1,3,3,5,BU:1.05); Data from three European inverter manufacturers ; recycled after use;
	aluminium alloy, AlMg3, at plant	RER	0	kg	2.12E-1	3.39E-1	5.43E-1	8.70E-1	1	1.34	(3,4,1,3,3,5,BU:1.05); Data from three European inverter manufacturers ; recycled after use;
	copper, at regional storage	RER	0	kg	1.91E+0	3.06E+0	4.90E+0	7.86E+0	1	1.31	(2,3,1,3,3,5,BU:1.05); Data from three European inverter manufacturers ; recycled after use;
	steel, low-alloyed, at plant	RER	0	kg	9.07E-1	1.45E+0	2.33E+0	3.73E+0	1	1.31	(2,3,1,3,3,5,BU:1.05); Data from three European inverter manufacturers ; recycled after use; data on the production of three inverters by two European producers
	polypropylene, granulate, at plant	RER	0	kg	8.82E-1	1.41E+0	2.27E+0	3.63E+0	1	1.60	(3,4,1,3,4,5,BU:1.05); Data from three European inverter manufacturers ; recycled after use;
	polycarbonate, at plant	RER	0	kg	2.02E-1	3.24E-1	5.19E-1	8.32E-1	1	1.34	(3,4,1,3,3,5,BU:1.05); Data from three European inverter manufacturers ; recycled after use;
	cable, connector for computer, without plugs, at plant	GLO	0	m	1.31E-1	2.10E-1	3.37E-1	5.40E-1	1	1.34	(3,4,1,3,3,5,BU:1.05); Data from three European inverter manufacturers ; recycled after use;
	inductor, ring core choke type, at plant	GLO	0	kg	8.71E-1	1.40E+0	2.24E+0	3.58E+0	1	1.31	(2,3,1,3,3,5,BU:1.05); Data from three European inverter manufacturers ; recycled after use;
	integrated circuit, IC, logic type, at plant	GLO	0	kg	6.61E-2	1.06E-1	1.70E-1	2.72E-1	1	1.31	(2,3,1,3,3,5,BU:1.05); Data from three European inverter manufacturers ; recycled after use;
	ferrite, at plant	GLO	0	kg	3.49E-2	5.59E-2	8.96E-2	1.44E-1	1	1.31	(2,3,1,3,3,5,BU:1.05); Data from three European inverter manufacturers ; recycled after use;
	plugs, inlet and outlet, for network cable, at plant	GLO	0	unit	3.48E+0	5.58E+0	8.93E+0	1.43E+1	1	1.31	(2,3,1,3,3,5,BU:1.05); Data from three European inverter manufacturers ; recycled after use;
	glass fibre reinforced plastic, polyamide, injection moulding, at plant	RER	0	kg	1.31E-1	2.09E-1	3.35E-1	5.37E-1	1	1.31	(2,3,1,3,3,5,BU:1.05); Data from three European inverter manufacturers ; recycled after use;
printed board assembly	printed wiring board, surface mount, lead-free surface, at plant	GLO	0	m2	1.01E-1	1.62E-1	2.60E-1	4.16E-1	1	1.31	(2,3,1,3,3,5,BU:1.05); Data from three European inverter manufacturers ; recycled after use;
	tin, at regional storage	RER	0	kg	9.59E-3	1.54E-2	2.46E-2	3.94E-2	1	1.31	(2,3,1,3,3,5,BU:1.05); Data from three European inverter manufacturers ; recycled after use;
	connector, clamp connection, at plant	GLO	0	kg	2.44E-2	3.91E-2	6.26E-2	1.00E-1	1	1.31	(2,3,1,3,3,5,BU:1.05); Data from three European inverter manufacturers ; recycled after use;
	inductor, ring core choke type, at plant	GLO	0	kg	1.31E-1	2.09E-1	3.35E-1	5.37E-1	1	1.31	(2,3,1,3,3,5,BU:1.05); Data from three European inverter manufacturers ; recycled after use;
	inductor, miniature RF chip type, MRFI, at plant	GLO	0	kg	1.10E-3	1.77E-3	2.83E-3	4.53E-3	1	1.31	(2,3,1,3,3,5,BU:1.05); Data from three European inverter manufacturers ; recycled after use;
	integrated circuit, IC, logic type, at plant	GLO	0	kg	1.55E-1	2.49E-1	3.99E-1	6.39E-1	1	1.31	(2,3,1,3,3,5,BU:1.05); Data from three European inverter manufacturers ; recycled after use;
	integrated circuit, IC, memory type, at plant	GLO	0	kg	1.87E-3	3.00E-3	4.81E-3	7.70E-3	1	1.31	(2,3,1,3,3,5,BU:1.05); Data from three European inverter manufacturers ; recycled after use;
	transistor, unspecified, at plant	GLO	0	kg	1.92E-2	3.07E-2	4.92E-2	7.89E-2	1	1.31	(2,3,1,3,3,5,BU:1.05); Data from three European inverter manufacturers ; recycled after use;
	transistor, SMD type, surface mounting, at plant	GLO	0	kg	4.17E-2	6.69E-2	1.07E-1	1.72E-1	1	1.31	(2,3,1,3,3,5,BU:1.05); Data from three European inverter manufacturers ; recycled after use;
	diode, glass-, SMD type, surface mounting, at plant	GLO	0	kg	2.01E-3	3.22E-3	5.15E-3	8.25E-3	1	1.31	(2,3,1,3,3,5,BU:1.05); Data from three European inverter manufacturers ; recycled after use;
	light emitting diode, LED, at plant	GLO	0	kg	1.44E-5	2.31E-5	3.69E-5	5.92E-5	1	1.31	(2,3,1,3,3,5,BU:1.05); Data from three European inverter manufacturers ; recycled after use;
	capacitor, film, through-hole mounting, at plant	GLO	0	kg	1.66E-1	2.67E-1	4.27E-1	6.84E-1	1	1.31	(2,3,1,3,3,5,BU:1.05); Data from three European inverter manufacturers ; recycled after use;
	capacitor, electrolyte type, > 2cm height, at plant	GLO	0	kg	2.57E-1	4.12E-1	6.60E-1	1.06E+0	1	1.31	(2,3,1,3,3,5,BU:1.05); Data from three European inverter manufacturers ; recycled after use;
	capacitor, electrolyte type, < 2cm height, at plant	GLO	0	kg	6.71E-3	1.08E-2	1.72E-2	2.76E-2	1	1.31	(2,3,1,3,3,5,BU:1.05); Data from three European inverter manufacturers ; recycled after use;
	capacitor, SMD type, surface-mounting, at plant	GLO	0	kg	1.33E-3	2.14E-3	3.42E-3	5.49E-3	1	1.31	(2,3,1,3,3,5,BU:1.05); Data from three European inverter manufacturers ; recycled after use;

Table 39 (continued): Unit process LCI data of 2.5-20 kW Inverter

	Name	Location	InfrastructureProcess	Unit	inverter, 2.5 kW, average, at plant	inverter, 5 kW, average, at plant	inverter, 10 kW, average, at plant	inverter, 20 kW, average, at plant	UncertaintyType	StandardDeviation95%	GeneralComment
	Location				RER	RER	RER	RER			
	InfrastructureProcess				1	1	1	1			
	Unit				unit	unit	unit	unit			
	resistor, wirewound, through-hole mounting, at plant	GLO	0	kg	1.12E-3	1.79E-3	2.87E-3	4.60E-3	1	1.31	(2,3,1,3,3,5,BU:1.05); Data from three European inverter manufacturers ; recycled after use;
	resistor, SMD type, surface mounting, at plant	GLO	0	kg	4.57E-3	7.33E-3	1.17E-2	1.88E-2	1	1.31	(2,3,1,3,3,5,BU:1.05); Data from three European inverter manufacturers ; recycled after use;
	ferrite, at plant	GLO	0	kg	2.55E-5	4.09E-5	6.55E-5	1.05E-4	1	1.31	(2,3,1,3,3,5,BU:1.05); Data from three European inverter manufacturers ; recycled after use;
	transformer, low voltage use, at plant	GLO	0	kg	4.01E-2	6.43E-2	1.03E-1	1.65E-1	1	1.31	(2,3,1,3,3,5,BU:1.05); Data from three European inverter manufacturers ; recycled after use;
	plugs, inlet and outlet, for network cable, at plant	GLO	0	unit	2.79E-1	4.47E-1	7.16E-1	1.15E+0	1	1.31	(2,3,1,3,3,5,BU:1.05); Data from three European inverter manufacturers ; recycled after use;
	glass fibre reinforced plastic, polyamide, injection moulding, at plant	RER	0	kg	2.56E-2	4.10E-2	6.57E-2	1.05E-1	1	1.31	(2,3,1,3,3,5,BU:1.05); Data from three European inverter manufacturers ; recycled after use;
	cable, ribbon cable, 20-pin, with plugs, at plant	GLO	0	kg	2.40E-4	3.84E-4	6.16E-4	9.86E-4	1	1.31	(2,3,1,3,3,5,BU:1.05); Data from three European inverter manufacturers ; recycled after use;
processing	sheet rolling, steel	RER	0	kg	9.07E-1	1.45E+0	2.33E+0	3.73E+0	1	1.21	(1,1,1,1,1,5,BU:1.05); Data from three European inverter manufacturers ; recycled after use; Applied as well on the production data of an inverter of an European producer
	wire drawing, copper	RER	0	kg	1.91E+0	3.06E+0	4.90E+0	7.86E+0	1	1.21	(1,1,1,1,1,5,BU:1.05); Data from three European inverter manufacturers ; recycled after use; Applied as well on the production data of an inverter of an European producer
	section bar extrusion, aluminium	RER	0	kg	4.77E+0	7.64E+0	1.22E+1	1.96E+1	1	1.21	(1,1,1,1,1,5,BU:1.05); Data from three European inverter manufacturers ; recycled after use; Applied as well on the production data of an inverter of an European producer
	steel product manufacturing, average metal working	RER	0	kg	1.92E-2	3.08E-2	4.93E-2	7.90E-2	1	1.34	(3,4,1,3,3,5,BU:1.05); data on the production of an inverter by a European producer;
infrastructure	metal working factory	RER	1	unit	1.10E-8	1.76E-8	2.82E-8	4.51E-8	1	3.05	(1,1,1,1,1,5,BU:3); Calculation, based on annual production of electronic component production plant; taken from the ecoinvent v2.2 inverter dataset;
packaging	corrugated board, mixed fibre, single wall, at plant	RER	0	kg	6.60E-1	1.06E+0	1.69E+0	2.71E+0	1	1.21	(1,1,1,1,1,5,BU:1.05); data on the production of an inverter by a European producer;
	folding boxboard, FBB, at plant	RER	0	kg	1.16E+0	1.85E+0	2.97E+0	4.75E+0	1	1.34	(3,4,1,3,3,5,BU:1.05); data on the production of an inverter by a European producer;
	packaging film, LDPE, at plant	RER	0	kg	1.15E-2	1.84E-2	2.95E-2	4.73E-2	1	1.34	(3,4,1,3,3,5,BU:1.05); data on the production of an inverter by a European producer;
transport	transport, freight, lorry, fleet average	RER	0	tkm	6.76E-1	1.08E+0	1.74E+0	2.78E+0	1	2.09	(4,5,na,na,na,na,BU:2); Standard distance 60km incl. disposal;
	transport, freight, rail	RER	0	tkm	2.25E+0	3.61E+0	5.79E+0	9.27E+0	1	2.09	(4,5,na,na,na,na,BU:2); Standard distances 200km;
	transport, transoceanic freight ship	OCE	0	tkm	2.03E+1	3.25E+1	5.21E+1	8.34E+1	1	2.09	(4,5,na,na,na,na,BU:2); Estimation: 18000km;
emission air, unspecified	Heat, waste	-	-	MJ	3.80E+1	6.09E+1	9.75E+1	1.56E+2	1	1.22	(2,3,1,1,1,5,BU:1.05); Calculation;
technosphere	tap water, at user	RER	0	kg	1.99E+1	3.18E+1	5.10E+1	8.17E+1	1	1.34	(3,4,1,3,3,5,BU:1.05); data on the production of an inverter by a European producer;
resource, in water	Water, unspecified natural origin, DE	-	-	m3	3.78E-2	6.06E-2	9.71E-2	1.56E-1	1	1.34	(3,4,1,3,3,5,BU:1.05); data on the production of an inverter by a European producer;
disposal	treatment, sewage, unpolluted, to wastewater treatment, class 3	CH	0	m3	1.99E-2	3.18E-2	5.10E-2	8.17E-2	1	1.34	(3,4,1,3,3,5,BU:1.05); data on the production of an inverter by a European producer;
	disposal, packaging cardboard, 19.6% water, to municipal incineration	CH	0	kg	1.82E+0	2.91E+0	4.66E+0	7.47E+0	1	1.25	(2,3,1,5,1,5,BU:1.05); disposal of the packaging materials;
	disposal, polyethylene, 0.4% water, to municipal incineration	CH	0	kg	1.15E-2	1.84E-2	2.95E-2	4.73E-2	1	1.25	(2,3,1,5,1,5,BU:1.05); disposal of the packaging materials;
	disposal, treatment of printed wiring boards	GLO	0	kg	1.22E+0	1.96E+0	3.14E+0	5.02E+0	1	1.25	(2,3,1,5,1,5,BU:1.05); Data from three European inverter manufacturers ; recycled after use;
	disposal, municipal solid waste, 22.9% water, to municipal incineration	CH	0	kg	2.43E-1	3.89E-1	6.23E-1	9.98E-1	1	1.34	(3,4,1,3,3,5,BU:1.05); data on the production of an inverter by a European producer;
	disposal, hazardous waste, 25% water, to hazardous waste incineration	CH	0	kg	1.28E-2	2.06E-2	3.30E-2	5.28E-2	1	1.34	(3,4,1,3,3,5,BU:1.05); data on the production of an inverter by a European producer;

3.8.2 Ground mount installations

This section has not been updated. The amount of copper per MW may be overestimated and should be crosschecked in the next update.

Name	**Inverters + transformers 1 MW**
Time period	2000-2004
Geography	Europe, Western
Technology	Average technology
Representativeness	Data from a specific component
Date	9/21/2006
Data treatment	Data scaled to 1 MW DC
Comment	Based on data collected at the 4.6 MWp Springerville plant (Tucson, USA), scaled to 1 MW DC power. Inverters: Xantrex PV-150 [15]. Includes material for step-up transformers.

Table 40: LCI of 1 MW Inverters + Transformers for Ground Mount Installation

Products	**Unit**	**Amount**	**Comment**
Inverters + Transformers	p	1.00	Nominal input power 1 MW DC
Materials			
Steels	kg	9792	
aluminum	kg	894	
copper	kg	2277	
polyamide injection molded	kg	485	
polyester	Kg	300	
Polyethylene, HD	Kg	150	
Paint	Kg	150	
Transformer oil (vegetable)	Kg	6001	

3.8.3 Li-ion Battery Storage

Name	**Li-ion battery storage system**
Time period	2014
Geography	Europe, Western
Technology	Average technology
Representativeness	Data from a specific component
Date	12/6/2016
Data treatment	Data scaled to 1 MW DC
Comment	Life cycle inventory of nickel-cobalt-manganese (NCM) Li-ion battery pack including single cell, battery management system, battery cooling system, and battery packing. The assembly process takes place in Norway (NO) but the battery cells are produced in East Asia (RAS). These data correspond to the data published by Ager-Wick Ellingsen et al. [27]. Further documentation: see Appendix A of Stolz et al. [28].

Table 41: Life cycle inventory of 1 kg NCM Li-ion battery pack.

	Name	Location	InfrastructureProcess	Unit	battery, rechargeable, prismatic, LiNCM, at plant	UncertaintyType	StandardDeviation95%	GeneralComment
	Location				NO			
	InfrastructureProcess				0			
	Unit				kg			
product	battery, rechargeable, prismatic, LiNCM, at plant	NO	0	kg	1			
technosphere	single cell, lithium-ion battery,NCM, at plant	RAS	0	kg	6.00E-1	1	1.34	(1,4,1,5,3,5,BU:1.05); ; Ellingsen, 2014 supporting information
	battery-managment-system, at plant	RAS	0	kg	3.70E-2	1	1.34	(1,4,1,5,3,5,BU:1.05); ; Ellingsen, 2014 supporting information
	battery-cooling-system, passive, at plant	RAS	0	kg	4.10E-2	1	1.34	(1,4,1,5,3,5,BU:1.05); ; Ellingsen, 2014 supporting information
	electricity, medium voltage, at grid	NO	0	kWh	4.00E-4	1	1.34	(1,4,1,5,3,5,BU:1.05); ; Ellingsen, 2014 supporting information
	steel, low-alloyed, at plant	RER	0	kg	1.15E-1	1	1.34	(1,4,1,5,3,5,BU:1.05); ; Ellingsen, 2014 supporting information
	nylon 6, at plant	RER	0	kg	7.79E-4	1	1.34	(1,4,1,5,3,5,BU:1.05); ; Ellingsen, 2014 supporting information
	nylon 66, at plant	RER	0	kg	5.36E-2	1	1.34	(1,4,1,5,3,5,BU:1.05); ; Ellingsen, 2014 supporting information
	steel product manufacturing, average metal working	RER	0	kg	1.15E-1	1	1.34	(1,4,1,5,3,5,BU:1.05); ; Ellingsen, 2014 supporting information
	injection moulding	RER	0	kg	8.22E-2	1	1.34	(1,4,1,5,3,5,BU:1.05); ; Ellingsen, 2014 supporting information
	aluminium, production mix, at plant	RER	0	kg	1.14E-1	1	1.34	(1,4,1,5,3,5,BU:1.05); ; Ellingsen, 2014 supporting information
	anodising, aluminium sheet	RER	0	m2	4.98E-3	1	1.34	(1,4,1,5,3,5,BU:1.05); ; Ellingsen, 2014 supporting information
	sheet rolling, aluminium	RER	0	kg	1.13E-1	1	1.34	(1,4,1,5,3,5,BU:1.05); ; Ellingsen, 2014 supporting information
	copper, primary, at refinery	GLO	0	kg	3.90E-3	1	1.34	(1,4,1,5,3,5,BU:1.05); ; Ellingsen, 2014 supporting information
	copper, secondary, at refinery	RER	0	kg	6.91E-4	1	1.34	(1,4,1,5,3,5,BU:1.05); ; Ellingsen, 2014 supporting information
	acrylonitrile-butadiene-styrene copolymer, ABS, at plant	RER	0	kg	6.43E-3	1	1.34	(1,4,1,5,3,5,BU:1.05); ; Ellingsen, 2014 supporting information
	copper product manufacturing, average metal working	RER	0	kg	4.56E-3	1	1.34	(1,4,1,5,3,5,BU:1.05); ; Ellingsen, 2014 supporting information
	aluminium product manufacturing, average metal working	RER	0	kg	1.88E-3	1	1.34	(1,4,1,5,3,5,BU:1.05); ; Ellingsen, 2014 supporting information
	synthetic rubber, at plant	RER	0	kg	3.52E-3	1	1.34	(1,4,1,5,3,5,BU:1.05); ; Ellingsen, 2014 supporting information
	polypropylene, granulate, at plant	RER	0	kg	2.13E-2	1	1.34	(1,4,1,5,3,5,BU:1.05); ; Ellingsen, 2014 supporting information
	butyl acrylate, at plant	RER	0	kg	3.94E-5	1	1.34	(1,4,1,5,3,5,BU:1.05); ; Ellingsen, 2014 supporting information
	transport, freight, rail	RER	0	tkm	1.27E-1	1	2.12	(1,4,1,5,3,5,BU:2); ; Ellingsen, 2014 supporting information
	transport, lorry >32t, EURO3	RER	0	tkm	2.24E-1	1	2.12	(1,4,1,5,3,5,BU:2); ; Ellingsen, 2014 supporting information
	transport, lorry >16t, fleet average	RER	0	tkm	4.80E-2	1	2.12	(1,4,1,5,3,5,BU:2); ; Ellingsen, 2014 supporting information
	transport, transoceanic freight ship	OCE	0	tkm	6.44E+0	1	2.12	(1,4,1,5,3,5,BU:2); ; Ellingsen, 2014 supporting information
	facilities precious metal refinery	SE	1	unit	2.26E-8	1	3.12	(1,4,1,5,3,5,BU:3); ; Ellingsen, 2014 supporting information
	aluminium casting, plant	RER	1	unit	1.76E-11	1	3.12	(1,4,1,5,3,5,BU:3); ; Ellingsen, 2014 supporting information
	plastics processing factory	RER	1	unit	5.99E-11	1	3.12	(1,4,1,5,3,5,BU:3); ; Ellingsen, 2014 supporting information
	metal working factory	RER	1	unit	6.12E-11	1	3.12	(1,4,1,5,3,5,BU:3); ; Ellingsen, 2014 supporting information
emission air, high population density	Heat, waste	-	-	MJ	1.40E-3	1	1.34	(1,4,1,5,3,5,BU:1.05); ; Ellingsen, 2014 supporting information

Table 42: Life cycle inventory of the manufacture of single cells.

	Name	Location	InfrastructureProcess	Unit	single cell, lithium-ion battery,NCM, at plant	UncertaintyType	StandardDeviation95%	GeneralComment
	Location				RAS			
	InfrastructureProcess				0			
	Unit				kg			
product	single cell, lithium-ion battery,NCM, at plant	RAS	0	kg	1			
technosphere	anode, lithium-ion battery, graphite, at plant	RAS	0	kg	3.90E-1	1	1.34	(1,4,1,5,3,5,BU:1.05); ; Ellingsen, 2014 supporting information
	electrolyte, LiPF6, at plant	RAS	0	kg	1.60E-1	1	1.34	(1,4,1,5,3,5,BU:1.05); ; Ellingsen, 2014 supporting information
	cathode, lithium-ion battery, NCM, at plant	RAS	0	kg	4.30E-1	1	1.34	(1,4,1,5,3,5,BU:1.05); ; Ellingsen, 2014 supporting information
	separator, lithium-ion battery, at plant	RAS	0	kg	2.20E-2	1	1.34	(1,4,1,5,3,5,BU:1.05); ; Ellingsen, 2014 supporting information
	electricity, medium voltage, production Eastern Asia, at grid	RAS	0	kWh	2.27E+1	1	1.34	(1,4,1,5,3,5,BU:1.05); Due energy efficiency and the development of the battery manufacture electricity consumption was reduced by 20%; Ellingsen, 2014 supporting information
	water, decarbonised, at plant	RER	0	kg	3.80E+2	1	1.34	(1,4,1,5,3,5,BU:1.05); ; Ellingsen, 2014 supporting information
	transport, freight, rail	RER	0	tkm	2.62E-1	1	2.12	(1,4,1,5,3,5,BU:2); ; Ellingsen, 2014 supporting information
	transport, lorry >32t, EURO3	RER	0	tkm	1.01E-1	1	2.12	(1,4,1,5,3,5,BU:2); ; Ellingsen, 2014 supporting information
	facilities precious metal refinery	SE	1	unit	1.90E-8	1	3.12	(1,4,1,5,3,5,BU:3); ; Ellingsen, 2014 supporting information
	sheet rolling, aluminium	RER	0	kg	2.81E-3	1	1.34	(1,4,1,5,3,5,BU:1.05); ; Ellingsen, 2014 supporting information
	aluminium casting, plant	RER	1	unit	4.27E-13	1	3.12	(1,4,1,5,3,5,BU:3); ; Ellingsen, 2014 supporting information
	copper, primary, at refinery	GLO	0	kg	2.16E-3	1	1.34	(1,4,1,5,3,5,BU:1.05); ; Ellingsen, 2014 supporting information
	copper, secondary, at refinery	RER	0	kg	3.82E-4	1	1.34	(1,4,1,5,3,5,BU:1.05); ; Ellingsen, 2014 supporting information
	sheet rolling, copper	RER	0	kg	2.55E-3	1	1.34	(1,4,1,5,3,5,BU:1.05); ; Ellingsen, 2014 supporting information
	metal working factory	RER	1	unit	1.17E-12	1	3.12	(1,4,1,5,3,5,BU:3); ; Ellingsen, 2014 supporting information
	polyethylene terephthalate, granulate, amorphous, at plant	RER	0	kg	2.09E-4	1	1.34	(1,4,1,5,3,5,BU:1.05); ; Ellingsen, 2014 supporting information
	nylon 6, at plant	RER	0	kg	2.14E-4	1	1.34	(1,4,1,5,3,5,BU:1.05); ; Ellingsen, 2014 supporting information
	polypropylene, granulate, at plant	RER	0	kg	8.58E-4	1	1.34	(1,4,1,5,3,5,BU:1.05); ; Ellingsen, 2014 supporting information
	polyethylene, LDPE, granulate, at plant	RER	0	kg	6.70E-5	1	1.34	(1,4,1,5,3,5,BU:1.05); ; Ellingsen, 2014 supporting information
	injection moulding	RER	0	kg	1.26E-3	1	1.34	(1,4,1,5,3,5,BU:1.05); ; Ellingsen, 2014 supporting information
	plastics processing factory	RER	1	unit	9.38E-13	1	3.12	(1,4,1,5,3,5,BU:3); ; Ellingsen, 2014 supporting information
emission air, high population density	Heat, waste	-	-	MJ	1.00E+2	1	1.34	(1,4,1,5,3,5,BU:1.05); ; Ellingsen, 2014 supporting information

Table 43: Life cycle inventory of the electricity mix of Eastern Asia (RAS) specific for single cell manufacture

	Name	Location	InfrastructureProcess	Unit	electricity, production mix Eastern Asia	UncertaintyType	StandardDeviation95%	GeneralComment
	Location				RAS			
	InfrastructureProcess				0			
	Unit				kWh			
product	electricity, production mix Eastern Asia	RAS	0	kWh	1.00E+0			
technosphere	electricity, peat, at power plant	NORDEL	0	kWh	0.000380490	1	1.05	(1,1,1,3,1,1); according to paper of L. Ager-Wick Ellingsen, 2014
	electricity, hard coal, at power plant	UCTE	0	kWh	0.459748349	1	1.05	(1,1,1,3,1,1); according to paper of L. Ager-Wick Ellingsen, 2014
	electricity, oil, at power plant	UCTE	0	kWh	0.043571590	1	1.05	(1,1,1,3,1,1); according to paper of L. Ager-Wick Ellingsen, 2014
	electricity, natural gas, at power plant	UCTE	0	kWh	0.154566868	1	1.05	(1,1,1,2,1,1); according to paper of L. Ager-Wick Ellingsen, 2014
	electricity from waste, at municipal waste incineration plant	CH	0	kWh	0.000439873	1	1.05	(1,1,1,3,1,1); according to paper of L. Ager-Wick Ellingsen, 2014
	electricity, nuclear, at power plant	UCTE	0	kWh	0.325002144	1	1.05	(1,1,1,3,1,1); according to paper of L. Ager-Wick Ellingsen, 2014
	electricity, hydropower, at power plant	CH	0	kWh	0.013539282	1	1.05	(1,1,1,1,1,1); according to paper of L. Ager-Wick Ellingsen, 2014
	electricity, production mix photovoltaic, at plant	US	0	kWh	0.001244840	1	1.05	(1,1,1,2,1,1); according to paper of L. Ager-Wick Ellingsen, 2014
	electricity, at wind power plant	RER	0	kWh	0.001506564	1	1.05	(1,1,1,2,1,1); according to paper of L. Ager-Wick Ellingsen, 2014

Table 44: Life cycle inventory of the anode

	Name	Location	InfrastructureProcess	Unit	anode, lithium-ion battery, graphite, at plant	UncertaintyType	StandardDeviation95%	GeneralComment
	Location				RAS			
	InfrastructureProcess				0			
	Unit				kg			
product	anode, lithium-ion battery, graphite, at plant	RAS	0	kg	1			
technosphere	transport, freight, rail	RER	0	tkm	9.87E-1	1	2.12	(1,4,1,5,3,5,BU:2); ; Ellingsen, 2014 supporting information
	transport, lorry >32t, EURO3	RER	0	tkm	2.40E-1	1	2.12	(1,4,1,5,3,5,BU:2); ; Ellingsen, 2014 supporting information
	copper, primary, at refinery	GLO	0	kg	4.88E-1	1	1.34	(1,4,1,5,3,5,BU:1.05); ; Ellingsen, 2014 supporting information
	copper, secondary, at refinery	RER	0	kg	8.60E-2	1	1.34	(1,4,1,5,3,5,BU:1.05); ; Ellingsen, 2014 supporting information
	sheet rolling, copper	RER	0	kg	5.74E-1	1	1.34	(1,4,1,5,3,5,BU:1.05); ; Ellingsen, 2014 supporting information
	metal working factory	RER	1	unit	2.63E-10	1	3.12	(1,4,1,5,3,5,BU:3); ; Ellingsen, 2014 supporting information
	graphite, battery grade, at plant	CN	0	kg	4.09E-1	1	1.34	(1,4,1,5,3,5,BU:1.05); ; Ellingsen, 2014 supporting information
	carboxymethyl cellulose, powder, at plant	RER	0	kg	1.09E-2	1	1.34	(1,4,1,5,3,5,BU:1.05); ; Ellingsen, 2014 supporting information
	acrylic acid, at plant	RER	0	kg	1.09E-2	1	1.34	(1,4,1,5,3,5,BU:1.05); ; Ellingsen, 2014 supporting information
	N-methyl-2-pyrrolidone, at plant	RER	0	kg	4.05E-1	1	1.34	(1,4,1,5,3,5,BU:1.05); ; Ellingsen, 2014 supporting information
	chemical plant, organics	RER	1	unit	1.71E-10	1	3.12	(1,4,1,5,3,5,BU:3); ; Ellingsen, 2014 supporting information

Table 45: Life cycle inventory of the cathode

	Name	Location	InfrastructureProcess	Unit	cathode, lithium-ion battery, NCM, at plant	UncertaintyType	StandardDeviation95%	GeneralComment
	Location				RAS			
	InfrastructureProcess				0			
	Unit				kg			
product	cathode, lithium-ion battery, NCM, at plant	RAS	0	kg	1			
technosphere	transport, freight, rail	RER	0	tkm	2.97E+0	1	2.12	(1,4,1,5,3,5,BU:2); ; Ellingsen, 2014 supporting information
	transport, lorry >32t, EURO3	RER	0	tkm	2.42E-1	1	2.12	(1,4,1,5,3,5,BU:2); ; Ellingsen, 2014 supporting information
	transport, lorry >16t, fleet average	RER	0	tkm	1.06E+0	1	2.12	(1,4,1,5,3,5,BU:2); ; Ellingsen, 2014 supporting information
	aluminium, production mix, at plant	RER	0	kg	1.14E-1	1	1.34	(1,4,1,5,3,5,BU:1.05); ; Ellingsen, 2014 supporting information
	sheet rolling, aluminium	RER	0	kg	1.14E-1	1	1.34	(1,4,1,5,3,5,BU:1.05); ; Ellingsen, 2014 supporting information
	aluminium casting, plant	RER	1	unit	1.76E-11	1	3.12	(1,4,1,5,3,5,BU:3); ; Ellingsen, 2014 supporting information
	polyvinylfluoride, at plant	US	0	kg	3.54E-2	1	1.34	(1,4,1,5,3,5,BU:1.05); ; Ellingsen, 2014 supporting information
	carbon black, at plant	GLO	0	kg	1.77E-2	1	1.34	(1,4,1,5,3,5,BU:1.05); ; Ellingsen, 2014 supporting information
	N-methyl-2-pyrrolidone, at plant	RER	0	kg	4.18E-1	1	1.34	(1,4,1,5,3,5,BU:1.05); ; Ellingsen, 2014 supporting information
	chemical plant, organics	RER	1	unit	1.00E-9	1	3.12	(1,4,1,5,3,5,BU:3); ; Ellingsen, 2014 supporting information
	lithium hydroxide, at plant	GLO	0	kg	2.07E-1	1	1.34	(1,4,1,5,3,5,BU:1.05); ; Ellingsen, 2014 supporting information
	heat, unspecific, in chemical plant	RER	0	MJ	4.58E-1	1	1.34	(1,4,1,5,3,5,BU:1.05); ; Ellingsen, 2014 supporting information
	soda, powder, at plant	RER	0	kg	6.92E-1	1	1.34	(1,4,1,5,3,5,BU:1.05); ; Ellingsen, 2014 supporting information
	ammonia, liquid, at regional storehouse	RER	0	kg	1.42E-2	1	1.34	(1,4,1,5,3,5,BU:1.05); ; Ellingsen, 2014 supporting information
	chemicals organic, at plant	GLO	0	kg	7.30E-3	1	1.34	(1,4,1,5,3,5,BU:1.05); ; Ellingsen, 2014 supporting information
	chemicals inorganic, at plant	GLO	0	kg	2.49E-2	1	1.34	(1,4,1,5,3,5,BU:1.05); ; Ellingsen, 2014 supporting information
	carbon monoxide, CO, at plant	RER	0	kg	4.96E-2	1	1.34	(1,4,1,5,3,5,BU:1.05); ; Ellingsen, 2014 supporting information
	hydrogen cyanide, at plant	RER	0	kg	1.14E-3	1	1.34	(1,4,1,5,3,5,BU:1.05); ; Ellingsen, 2014 supporting information
	hydrogen, liquid, at plant	RER	0	kg	4.31E-3	1	1.34	(1,4,1,5,3,5,BU:1.05); ; Ellingsen, 2014 supporting information
	limestone, milled, loose, at plant	CH	0	kg	3.35E-1	1	1.34	(1,4,1,5,3,5,BU:1.05); ; Ellingsen, 2014 supporting information
	portland calcareous cement, at plant	CH	0	kg	1.06E+0	1	1.34	(1,4,1,5,3,5,BU:1.05); ; Ellingsen, 2014 supporting information
	sand, at mine	CH	0	kg	1.34E+1	1	1.34	(1,4,1,5,3,5,BU:1.05); ; Ellingsen, 2014 supporting information
	silica sand, at plant	DE	0	kg	3.20E-1	1	1.34	(1,4,1,5,3,5,BU:1.05); ; Ellingsen, 2014 supporting information
	blasting	RER	0	kg	4.86E-2	1	1.34	(1,4,1,5,3,5,BU:1.05); ; Ellingsen, 2014 supporting information
	diesel, burned in building machine	GLO	0	MJ	3.43E+0	1	1.34	(1,4,1,5,3,5,BU:1.05); ; Ellingsen, 2014 supporting information
	electricity, high voltage, production ENTSO, at grid	ENTSO	0	kWh	4.48E-1	1	1.34	(1,4,1,5,3,5,BU:1.05); ; Ellingsen, 2014 supporting information
	electricity, hydropower, at run-of-river power plant	RER	0	kWh	6.71E-1	1	1.34	(1,4,1,5,3,5,BU:1.05); ; Ellingsen, 2014 supporting information
	electricity, medium voltage, production ENTSO, at grid	ENTSO	0	kWh	1.02E+0	1	1.34	(1,4,1,5,3,5,BU:1.05); ; Ellingsen, 2014 supporting information
	heat, at hard coal industrial furnace 1-10MW	RER	0	MJ	3.16E-1	1	1.34	(1,4,1,5,3,5,BU:1.05); ; Ellingsen, 2014 supporting information
	heavy fuel oil, burned in industrial furnace 1MW, non-modulating	RER	0	MJ	2.05E-1	1	1.34	(1,4,1,5,3,5,BU:1.05); ; Ellingsen, 2014 supporting information
	natural gas, burned in industrial furnace >100kW	RER	0	MJ	1.24E+0	1	1.34	(1,4,1,5,3,5,BU:1.05); ; Ellingsen, 2014 supporting information
	aluminium hydroxide, at plant	RER	0	kg	3.73E-10	1	1.34	(1,4,1,5,3,5,BU:1.05); ; Ellingsen, 2014 supporting information
	conveyor belt, at plant	RER	1	m	1.23E-6	1	3.12	(1,4,1,5,3,5,BU:3); ; Ellingsen, 2014 supporting information
	non-ferrous metal mine, underground	GLO	1	unit	1.61E-9	1	3.12	(1,4,1,5,3,5,BU:3); ; Ellingsen, 2014 supporting information
	non-ferrous metal smelter	GLO	1	unit	5.67E-12	1	3.12	(1,4,1,5,3,5,BU:3); ; Ellingsen, 2014 supporting information
	disposal, nickel smelter slag, 0% water, to residual material landfill	CH	0	kg	1.62E+0	1	1.34	(1,4,1,5,3,5,BU:1.05); ; Ellingsen, 2014 supporting information
	disposal, sulfidic tailings, off-site	GLO	0	kg	1.23E+1	1	1.34	(1,4,1,5,3,5,BU:1.05); ; Ellingsen, 2014 supporting information
	disposal, non-sulfidic tailings, off-site	GLO	0	kg	1.14E+1	1	1.34	(1,4,1,5,3,5,BU:1.05); ; Ellingsen, 2014 supporting information
	disposal, non-sulfidic overburden, off-site	GLO	0	kg	5.93E+0	1	1.34	(1,4,1,5,3,5,BU:1.05); ; Ellingsen, 2014 supporting information
	manganese concentrate, at beneficiation	GLO	0	kg	4.66E-1	1	1.34	(1,4,1,5,3,5,BU:1.05); ; Ellingsen, 2014 supporting information
	sulphuric acid, liquid, at plant	RER	0	kg	2.83E-1	1	1.34	(1,4,1,5,3,5,BU:1.05); ; Ellingsen, 2014 supporting information
	natural gas, high pressure, at consumer	CH	0	MJ	1.58E-2	1	1.34	(1,4,1,5,3,5,BU:1.05); ; Ellingsen, 2014 supporting information
	hard coal coke, at plant	RER	0	MJ	6.23E-1	1	1.34	(1,4,1,5,3,5,BU:1.05); ; Ellingsen, 2014 supporting information

Table 45: Life cycle inventory of the cathode (continued)

	Name	Location	InfrastructureProcess	Unit	cathode, lithium-ion battery, NCM, at plant	UncertaintyType	StandardDeviation95%	GeneralComment
	Location				RAS			
	InfrastructureProcess				0			
	Unit				kg			
product	cathode, lithium-ion battery, NCM, at plant	RAS	0	kg	1			
resource, in ground	Nickel, 1.13% in sulfide, Ni 0.76% and Cu 0.76% in crude ore, in ground	-	-	kg	2.13E-1	1	1.34	(1,4,1,5,3,5,BU:1.05); ; Ellingsen, 2014 supporting information
	Cobalt, in ground	-	-	kg	2.24E-1	1	1.34	(1,4,1,5,3,5,BU:1.05); ; Ellingsen, 2014 supporting information
resource, in water	Water, river	-	-	m3	1.12E-2	1	1.34	(1,4,1,5,3,5,BU:1.05); ; Ellingsen, 2014 supporting information
	Water, well, in ground	-	-	m3	6.44E-2	1	1.34	(1,4,1,5,3,5,BU:1.05); ; Ellingsen, 2014 supporting information
emission air, unspecified	Aluminium	-	-	kg	2.48E-4	1	5.13	(1,4,1,5,3,5,BU:5); ; Ellingsen, 2014 supporting information
	Arsenic	-	-	kg	9.01E-7	1	5.13	(1,4,1,5,3,5,BU:5); ; Ellingsen, 2014 supporting information
	Calcium	-	-	kg	1.74E-4	1	5.13	(1,4,1,5,3,5,BU:5); ; Ellingsen, 2014 supporting information
	Carbon dioxide, fossil	-	-	kg	1.44E-1	1	1.34	(1,4,1,5,3,5,BU:1.05); ; Ellingsen, 2014 supporting information
	Carbon disulfide	-	-	kg	3.22E-3	1	1.65	(1,4,1,5,3,5,BU:1.5); ; Ellingsen, 2014 supporting information
	Cobalt	-	-	kg	1.88E-4	1	5.13	(1,4,1,5,3,5,BU:5); ; Ellingsen, 2014 supporting information
	Copper	-	-	kg	5.59E-5	1	5.13	(1,4,1,5,3,5,BU:5); ; Ellingsen, 2014 supporting information
	Dioxins, measured as 2,3,7,8-tetrachlorodibenzo-p-dioxin	-	-	kg	1.54E-12	1	3.12	(1,4,1,5,3,5,BU:3); ; Ellingsen, 2014 supporting information
	Heat, waste	-	-	MJ	1.18E+1	1	1.34	(1,4,1,5,3,5,BU:1.05); ; Ellingsen, 2014 supporting information
	Lead	-	-	kg	5.31E-6	1	5.13	(1,4,1,5,3,5,BU:5); ; Ellingsen, 2014 supporting information
	Magnesium	-	-	kg	1.49E-4	1	5.13	(1,4,1,5,3,5,BU:5); ; Ellingsen, 2014 supporting information
	Nickel	-	-	kg	6.60E-5	1	5.13	(1,4,1,5,3,5,BU:5); ; Ellingsen, 2014 supporting information
	NMVOC, non-methane volatile organic compounds, unspecified origin	-	-	kg	3.09E-5	1	1.65	(1,4,1,5,3,5,BU:1.5); ; Ellingsen, 2014 supporting information
	Particulates, < 2.5 um	-	-	kg	2.87E-3	1	3.12	(1,4,1,5,3,5,BU:3); ; Ellingsen, 2014 supporting information
	Particulates, > 10 um	-	-	kg	3.71E-3	1	1.65	(1,4,1,5,3,5,BU:1.5); ; Ellingsen, 2014 supporting information
	Particulates, > 2.5 um, and < 10um	-	-	kg	5.26E-3	1	2.12	(1,4,1,5,3,5,BU:2); ; Ellingsen, 2014 supporting information
	Silver	-	-	kg	2.14E-8	1	5.13	(1,4,1,5,3,5,BU:5); ; Ellingsen, 2014 supporting information
	Sulfur dioxide	-	-	kg	2.30E-1	1	1.34	(1,4,1,5,3,5,BU:1.05); ; Ellingsen, 2014 supporting information
	Tin	-	-	kg	1.01E-6	1	5.13	(1,4,1,5,3,5,BU:5); ; Ellingsen, 2014 supporting information
	Zinc	-	-	kg	1.56E-5	1	5.13	(1,4,1,5,3,5,BU:5); ; Ellingsen, 2014 supporting information
emission water, unspecified	Aluminium	-	-	kg	5.56E-6	1	5.13	(1,4,1,5,3,5,BU:5); ; Ellingsen, 2014 supporting information
	Arsenic, ion	-	-	kg	2.27E-7	1	5.13	(1,4,1,5,3,5,BU:5); ; Ellingsen, 2014 supporting information
	BOD5, Biological Oxygen Demand	-	-	kg	2.83E-4	1	1.65	(1,4,1,5,3,5,BU:1.5); ; Ellingsen, 2014 supporting information
	Cadmium, ion	-	-	kg	2.57E-8	1	3.12	(1,4,1,5,3,5,BU:3); ; Ellingsen, 2014 supporting information
	Calcium, ion	-	-	kg	3.14E-2	1	3.12	(1,4,1,5,3,5,BU:3); ; Ellingsen, 2014 supporting information
	Calcium, ion	-	-	kg	1.28E-2	1	3.12	(1,4,1,5,3,5,BU:3); ; Ellingsen, 2014 supporting information
	Chromium, ion	-	-	kg	9.12E-8	1	3.12	(1,4,1,5,3,5,BU:3); ; Ellingsen, 2014 supporting information
	Cobalt	-	-	kg	5.04E-8	1	3.12	(1,4,1,5,3,5,BU:3); ; Ellingsen, 2014 supporting information
	COD, Chemical Oxygen Demand	-	-	kg	6.74E-4	1	1.65	(1,4,1,5,3,5,BU:1.5); ; Ellingsen, 2014 supporting information
	Copper, ion	-	-	kg	6.15E-7	1	3.12	(1,4,1,5,3,5,BU:3); ; Ellingsen, 2014 supporting information
	Cyanide	-	-	kg	1.21E-4	1	3.12	(1,4,1,5,3,5,BU:3); ; Ellingsen, 2014 supporting information
	DOC, Dissolved Organic Carbon	-	-	kg	1.10E-4	1	1.65	(1,4,1,5,3,5,BU:1.5); ; Ellingsen, 2014 supporting information
	Iron, ion	-	-	kg	1.87E-5	1	5.13	(1,4,1,5,3,5,BU:5); ; Ellingsen, 2014 supporting information
	Lead	-	-	kg	2.12E-7	1	5.13	(1,4,1,5,3,5,BU:5); ; Ellingsen, 2014 supporting information
emission water, fossil-	Manganese	-	-	kg	1.59E-6	1	5.13	(1,4,1,5,3,5,BU:5); ; Ellingsen, 2014 supporting information
emission water, unspecified	Mercury	-	-	kg	2.99E-9	1	5.13	(1,4,1,5,3,5,BU:5); ; Ellingsen, 2014 supporting information
	Nickel, ion	-	-	kg	1.61E-6	1	5.13	(1,4,1,5,3,5,BU:5); ; Ellingsen, 2014 supporting information
	Nitrogen, organic bound	-	-	kg	6.16E-4	1	1.65	(1,4,1,5,3,5,BU:1.5); ; Ellingsen, 2014 supporting information
	Nitrogen	-	-	kg	8.53E-4	1	1.65	(1,4,1,5,3,5,BU:1.5); ; Ellingsen, 2014 supporting information
	Suspended solids, unspecified	-	-	kg	3.34E-4	1	1.65	(1,4,1,5,3,5,BU:1.5); ; Ellingsen, 2014 supporting information
	Sulfate	-	-	kg	1.52E-1	1	1.65	(1,4,1,5,3,5,BU:1.5); ; Ellingsen, 2014 supporting information
	Tin, ion	-	-	kg	5.58E-8	1	5.13	(1,4,1,5,3,5,BU:5); ; Ellingsen, 2014 supporting information
	TOC, Total Organic Carbon	-	-	kg	1.10E-4	1	1.65	(1,4,1,5,3,5,BU:1.5); ; Ellingsen, 2014 supporting information
	Zinc, ion	-	-	kg	5.08E-6	1	5.13	(1,4,1,5,3,5,BU:5); ; Ellingsen, 2014 supporting information
emission air, high population density	Heat, waste	-	-	MJ	1.11E+0	1	1.34	(1,4,1,5,3,5,BU:1.05); ;

Table 46: Life cycle inventory of the electrolyte

	Name	Location	InfrastructureProcess	Unit	electrolyte, LiPF6, at plant	UncertaintyType	StandardDeviation95%	GeneralComment
	Location				RAS			
	InfrastructureProcess				0			
	Unit				kg			
product	electrolyte, LiPF6, at plant	RAS	0	kg	1			
technosphere	lithium hexafluorophosphate, at plant	CN	0	kg	1.20E-1	1	1.34	(1,4,1,5,3,5,BU:1.05); ; Ellingsen, 2014 supporting information
	ethylene carbonate, at plant	CN	0	kg	8.80E-1	1	1.34	(1,4,1,5,3,5,BU:1.05); ; Ellingsen, 2014 supporting information
	transport, freight, rail	RER	0	tkm	6.00E-1	1	2.12	(1,4,1,5,3,5,BU:2); ; Ellingsen, 2014 supporting information
	transport, lorry >32t, EURO3	RER	0	tkm	1.00E-1	1	2.12	(1,4,1,5,3,5,BU:2); ; Ellingsen, 2014 supporting information
	chemical plant, organics	RER	1	unit	4.10E-10	1	3.12	(1,4,1,5,3,5,BU:3); ; Ellingsen, 2014 supporting information

Table 47: Life cycle inventory of the separator

	Name	Location	InfrastructureProcess	Unit	separator, lithium-ion battery, at plant	UncertaintyType	StandardDeviation95%	GeneralComment
	Location				RAS			
	InfrastructureProcess				0			
	Unit				kg			
product	separator, lithium-ion battery, at plant	RAS	0	kg	1			
technosphere	polypropylene, granulate, at plant	RER	0	kg	1.00E+0	1	1.34	(1,4,1,5,3,5,BU:1.05); ; Ellingsen, 2014 supporting information
	injection moulding	RER	0	kg	1.00E+0	1	1.34	(1,4,1,5,3,5,BU:1.05); ; Ellingsen, 2014 supporting information
	transport, freight, rail	RER	0	tkm	2.00E-1	1	2.12	(1,4,1,5,3,5,BU:2); ; Ellingsen, 2014 supporting information
	transport, lorry >32t, EURO3	RER	0	tkm	1.00E-1	1	2.12	(1,4,1,5,3,5,BU:2); ; Ellingsen, 2014 supporting information
	plastics processing factory	RER	1	unit	7.40E-10	1	3.12	(1,4,1,5,3,5,BU:3); ; Ellingsen, 2014 supporting information

Table 48: Life cycle inventory of the battery management system

	Name	Location	InfrastructureProcess	Unit	battery-managment-system, at plant	UncertaintyType	StandardDeviation95%	GeneralComment
	Location				RAS			
	InfrastructureProcess				0			
	Unit				kg			
product	battery-managment-system, at plant	RAS	0	kg	1			
technosphere	printed wiring board, through-hole mounted, unspec., Pb free, at plant	GLO	0	kg	8.93E-2	1	1.34	(1,4,1,5,3,5,BU:1.05); ; Ellingsen, 2014 supporting information
	transport, freight, rail	RER	0	tkm	3.69E-1	1	2.12	(1,4,1,5,3,5,BU:2); ; Ellingsen, 2014 supporting information
	transport, lorry >32t, EURO3	RER	0	tkm	1.71E-1	1	2.12	(1,4,1,5,3,5,BU:2); ; Ellingsen, 2014 supporting information
	nylon 66, at plant	RER	0	kg	1.70E-2	1	1.34	(1,4,1,5,3,5,BU:1.05); ; Ellingsen, 2014 supporting information
	electronic component, passive, unspecified, at plant	GLO	0	kg	1.29E-1	1	1.34	(1,4,1,5,3,5,BU:1.05); ; Ellingsen, 2014 supporting information
	injection moulding	RER	0	kg	4.46E-2	1	1.34	(1,4,1,5,3,5,BU:1.05); ; Ellingsen, 2014 supporting information
	electronic component production plant	GLO	1	unit	1.82E-8	1	3.12	(1,4,1,5,3,5,BU:3); ; Ellingsen, 2014 supporting information
	steel, low-alloyed, at plant	RER	0	kg	3.40E-3	1	1.34	(1,4,1,5,3,5,BU:1.05); ; Ellingsen, 2014 supporting information
	aluminium, production mix, at plant	RER	0	kg	3.64E-2	1	1.34	(1,4,1,5,3,5,BU:1.05); ; Ellingsen, 2014 supporting information
	synthetic rubber, at plant	RER	0	kg	1.06E-3	1	1.34	(1,4,1,5,3,5,BU:1.05); ; Ellingsen, 2014 supporting information
	polyethylene terephthalate, granulate, amorphous, at plant	RER	0	kg	1.69E-2	1	1.34	(1,4,1,5,3,5,BU:1.05); ; Ellingsen, 2014 supporting information
	copper, primary, at refinery	GLO	0	kg	6.91E-2	1	1.34	(1,4,1,5,3,5,BU:1.05); ; Ellingsen, 2014 supporting information
	copper, secondary, at refinery	RER	0	kg	1.23E-2	1	1.34	(1,4,1,5,3,5,BU:1.05); ; Ellingsen, 2014 supporting information
	polyphenylene sulfide, at plant	GLO	0	kg	9.57E-3	1	1.34	(1,4,1,5,3,5,BU:1.05); ; Ellingsen, 2014 supporting information
	tin, at regional storage	RER	0	kg	5.02E-3	1	1.34	(1,4,1,5,3,5,BU:1.05); ; Ellingsen, 2014 supporting information
	cable, ribbon cable, 20-pin, with plugs, at plant	GLO	0	kg	1.34E-1	1	1.34	(1,4,1,5,3,5,BU:1.05); ; Ellingsen, 2014 supporting information
	steel product manufacturing, average metal working	RER	0	kg	3.40E-3	1	1.34	(1,4,1,5,3,5,BU:1.05); ; Ellingsen, 2014 supporting information
	aluminium product manufacturing, average metal working	RER	0	kg	3.64E-2	1	1.34	(1,4,1,5,3,5,BU:1.05); ; Ellingsen, 2014 supporting information
	copper product manufacturing, average metal working	RER	0	kg	8.14E-2	1	1.34	(1,4,1,5,3,5,BU:1.05); ; Ellingsen, 2014 supporting information
	metal product manufacturing, average metal working	RER	0	kg	5.02E-3	1	1.34	(1,4,1,5,3,5,BU:1.05); ; Ellingsen, 2014 supporting information

Table 49: Life cycle inventory of the battery cooling system

	Name	Location	InfrastructureProcess	Unit	battery-cooling-system, passive, at plant	UncertaintyType	StandardDeviation95%	GeneralComment
	Location				RAS			
	InfrastructureProcess				0			
	Unit				kg			
product	battery-cooling-system, passive, at plant	RAS	0	kg	1			
technosphere	ethylene glycol, at plant	RER	0	kg	4.78E-2	1	1.34	(1,4,1,5,3,5,BU:1.05); ; Ellingsen, 2014 supporting information
	transport, freight, rail	RER	0	tkm	4.10E-1	1	2.12	(1,4,1,5,3,5,BU:2); ; Ellingsen, 2014 supporting information
	transport, lorry >32t, EURO3	RER	0	tkm	1.95E-1	1	2.12	(1,4,1,5,3,5,BU:2); ; Ellingsen, 2014 supporting information
	aluminium, production mix, at plant	RER	0	kg	9.11E-1	1	1.34	(1,4,1,5,3,5,BU:1.05); ; Ellingsen, 2014 supporting information
	sheet rolling, aluminium	RER	0	kg	8.73E-1	1	1.34	(1,4,1,5,3,5,BU:1.05); ; Ellingsen, 2014 supporting information
	aluminium casting, plant	RER	1	unit	1.40E-10	1	3.12	(1,4,1,5,3,5,BU:3); ; Ellingsen, 2014 supporting information
	aluminium product manufacturing, average metal working	RER	0	kg	3.82E-2	1	1.34	(1,4,1,5,3,5,BU:1.05); ; Ellingsen, 2014 supporting information
	steel, low-alloyed, at plant	RER	0	kg	2.29E-2	1	1.34	(1,4,1,5,3,5,BU:1.05); ; Ellingsen, 2014 supporting information
	steel product manufacturing, average metal working	RER	0	kg	2.29E-2	1	1.34	(1,4,1,5,3,5,BU:1.05); ; Ellingsen, 2014 supporting information
	metal working factory	RER	1	unit	1.05E-11	1	3.12	(1,4,1,5,3,5,BU:3); ; Ellingsen, 2014 supporting information
	polyvinylchloride, at regional storage	RER	0	kg	7.16E-4	1	1.34	(1,4,1,5,3,5,BU:1.05); ; Ellingsen, 2014 supporting information
	synthetic rubber, at plant	RER	0	kg	2.39E-4	1	1.34	(1,4,1,5,3,5,BU:1.05); ; Ellingsen, 2014 supporting information
	injection moulding	RER	0	kg	2.08E-2	1	1.34	(1,4,1,5,3,5,BU:1.05); ; Ellingsen, 2014 supporting information
	plastics processing factory	RER	1	unit	1.56E-11	1	3.12	(1,4,1,5,3,5,BU:3); ; Ellingsen, 2014 supporting information
	glass fibre, at plant	RER	0	kg	1.99E-3	1	1.34	(1,4,1,5,3,5,BU:1.05); ; Ellingsen, 2014 supporting information
	silicon, electronic grade, at plant	DE	0	kg	5.96E-3	1	1.34	(1,4,1,5,3,5,BU:1.05); ; Ellingsen, 2014 supporting information
	acrylonitrile-butadiene-styrene copolymer, ABS, at plant	RER	0	kg	1.19E-2	1	1.34	(1,4,1,5,3,5,BU:1.05); ; Ellingsen, 2014 supporting information

3.9 Medium-Large PV installations In Europe

This section has not been updated.

Name	**Real photovoltaic power plants in Europe**
Time period	2004-2009
Geography	Europe
Technology	Mixed data
Representativeness	Individual real installations
Date	09.02.2010
Collection method	Data from system installers, operators and literature.
Comment	Photovoltaic power plants operating in Switzerland, Germany, and Spain Reference [17]

Table 50: LCI of PV Power Plants in Europe

capacity		93 kWp	280 kWp	156 kWp	1.3 MWp	324 kWp	450 kWp	569 kWp	570 kWp	
type of module		single-Si laminate	single-Si panel	multi-Si panel	multi-Si panel	multi-Si panel	single-Si panel	multi-Si panel	multi-Si panel	
type of mounting system:		Slanted roof integrate	Flat roof mounted	Flat roof mounted	Slanted roof mounted	Flat roof mounted	Flat roof mounted	Open ground	Open ground	
location		Switzerland	Switzerland	Switzerland	Switzerland	Germany	Germany	Spain	Spain	
Products	**Unit**	**Amount**	**Amount**	**Amount**	**Amount**	**Amount**	**Amount**	**Amount**	**Amount**	**Comment**
photovoltaic installation	unit	1	1	1	1	1	1	1	1	Refers to capacity above
electricity yield	kWh/ m^2*a	131	155	120	128	141	136	238	198	3.85 MJ converted solar energy per kWh
Components/fuels										
electricity consumption	kWh	7.13E+00	2.15E+01	1.19E+01	1.03E+02	2.48E+01	3.45E+01	3.60E+01	3.60E+01	Erection of plant

diesel consumption	MJ	0	0	0	0	0	0	7.66E+03	7.67E+03	
inverter weight	kg	123	2420	1590	6600	2600	3535	4675	4675	This amount is replaced every 15 years.
mounting system	m2	6.84E+02	2.08E+03	1.17E+03	1.01E+04	2.55E+03	3.38E+03	4.27E+03	4.27E+03	
photovoltaic module	m2	7.05E+02	2.14E+03	1.21E+03	1.04E+04	2.63E+03	3.48E+03	4.29E+03	4.40E+03	Including 2% replaces during life time and 1% rejects

Table 50: LCI of PV Power Plants in Europe (continued)

Electric installations (excluding inverter)		93 kWp	280 kWp	156 kWp	1.3 MWp	324 kWp	450 kWp	569 kWp	570 kWp	
copper	kg	7.06E+01	3.18E+02	3.03E+02	3.87E+03	3.77E+02	3.81E+02	7.41E+02	7.41E+02	Drawn to wire
brass	kg	5.46E-01	1.02E+00	6.82E-01	7.50E+00	1.36E+00	1.36E+00	1.36E+00	1.36E+00	
zinc	kg	1.09E+00	2.05E+00	1.36E+00	1.50E+01	2.73E+00	2.73E+00	2.73E+00	2.73E+00	
Steel	kg	2.24E+01	4.12E+01	2.81E+01	2.90E+02	5.29E+01	5.29E+01	5.29E+01	5.29E+01	
nylon 61	kg	6.28E+00	1.18E+01	7.84E+00	8.63E+01	1.57E+01	1.57E+01	1.57E+01	1.57E+01	
polyethylene1	kg	6.07E+01	3.15E+02	2.80E+02	3.73E+03	4.12E+02	4.17E+02	7.09E+02	7.09E+02	
polyvinylchloride1	kg	8.69E-01	2.61E+01	2.17E+01	2.36E+02	4.17E+01	4.35E+01	4.49E+01	4.49E+01	
polycarbonate1	kg	5.46E-02	1.02E-01	6.82E-02	7.50E-01	1.36E-01	1.36E-01	1.36E-01	1.36E-01	
epoxy resin1	kg	5.46E-02	1.02E-01	6.82E-02	7.50E-01	1.36E-01	1.36E-01	1.36E-01	1.36E-01	
Transport	tkm									
lorry	tkm	4.23E+03	1.82E+04	9.64E+03	8.34E+04	2.10E+04	2.96E+04	3.51E+04	3.52E+04	500 km modules
transoceanic freight ship	tkm	1.69E+04	7.28E+04	3.86E+04	3.34E+05	8.14E+04	1.18E+05	1.41E+05	1.41E+05	2’000 km modules
van	tkm	8.91E+02	4.12E+03	2.24E+03	1.80E+04	4.72E+03	6.62E+03	7.96E+03	7.98E+03	100 km system

3.10 Country specific photovoltaic mixes

Name	**Country-specific photovoltaic electricity mixes**
Time period	2016
Geography	World
Technology	Mixed data
Representativeness	Representative for selected countries
Date	4/5/2019
Collection method	National and international statistics.
Comment	Photovoltaic installations on buildings are considered with 3kWp installations, centralized installations are considered with open ground installations. More detailed documentation in: Stolz and Frischknecht (2019) [29].

Table 51: Unit process LCI data of country-specific photovoltaic mixes. Note: share refers to relative proportion with shares in a given country summing to 1.

Country	Code	Façade				Flat Roof				Slanted Roof Thin-Film					
		3kWp facade installation, single-Si, laminated, integrated, at building	3kWp facade installation, single-Si, panel, mounted, at building	3kWp facade installation, multi-Si, laminated, integrated, at building	3kWp facade installation, multi-Si, panel, mounted, at building	3kWp flat roof installation, single-Si, on roof	156 kWp flat-roof installation, single-Si, on roof	3kWp flat roof installation, multi-Si, on roof	156 kWp flat-roof installation, multi-Si, on roof	3kWp slanted-roof installation, CdTe, laminated, integrated, on roof	3kWp slanted-roof installation, CdTe, panel, mounted, on roof	3kWp slanted-roof installation, CIS, laminated, integrated, on roof	3kWp slanted-roof installation, CIS, panel, mounted, on roof	3kWp slanted-roof installation, micro-Si, laminated, integrated, on roof	3kWp slanted-roof installation, micro-Si, panel, mounted, on roof
		Share	Share	Share	Share	Share	Share	Share	Share	Share	Share	Share	Share	Share	Share
Australia	AU	2.55E-03	2.55E-03	4.82E-03	4.82E-03	3.83E-02	7.66E-02	7.23E-02	1.45E-01	9.84E-04	1.64E-02	8.13E-04	1.36E-02	1.28E-04	2.14E-03
Austria	AT	4.19E-04	0.00E+00	6.43E-03	0.00E+00	9.98E-03	2.00E-02	1.53E-01	3.06E-01	3.01E-04	9.92E-03	2.49E-04	8.20E-03	3.93E-05	1.29E-03
Belgium	BE	2.85E-03	2.85E-03	5.37E-03	5.37E-03	4.27E-02	8.54E-02	8.06E-02	1.61E-01	1.10E-03	1.83E-02	9.06E-04	1.51E-02	1.43E-04	2.39E-03
Canada	CA	1.21E-03	1.21E-03	2.29E-03	2.29E-03	1.82E-02	3.64E-02	3.44E-02	6.88E-02	4.68E-04	7.80E-03	3.87E-04	6.45E-03	6.11E-05	1.02E-03
Chile	CL	3.21E-05	3.21E-05	6.07E-05	6.07E-05	4.82E-04	9.64E-04	9.10E-04	1.82E-03	1.24E-05	2.06E-04	1.02E-05	1.71E-04	1.62E-06	2.69E-05
China	CN	1.00E-03	1.00E-03	1.89E-03	1.89E-03	1.50E-02	3.01E-02	2.84E-02	5.68E-02	1.68E-04	2.79E-03	1.38E-04	2.31E-03	2.19E-05	3.64E-04
Czech Republic	CZ	2.16E-03	2.16E-03	4.08E-03	4.08E-03	3.24E-02	6.48E-02	6.12E-02	1.22E-01	8.33E-04	1.39E-02	6.88E-04	1.15E-02	1.09E-04	1.81E-03
Denmark	DK	2.54E-03	2.54E-03	4.80E-03	4.80E-03	3.81E-02	7.62E-02	7.19E-02	1.44E-01	9.79E-04	1.63E-02	8.09E-04	1.35E-02	1.28E-04	2.13E-03
Finland	FI	3.46E-03	3.46E-03	6.54E-03	6.54E-03	5.19E-02	1.04E-01	9.81E-02	1.96E-01	1.34E-03	2.23E-02	1.10E-03	1.84E-02	1.74E-04	2.90E-03
France	FR	2.07E-03	2.07E-03	3.91E-03	3.91E-03	3.11E-02	6.21E-02	5.87E-02	1.17E-01	7.99E-04	1.33E-02	6.60E-04	1.10E-02	1.04E-04	1.74E-03
Germany	DE	2.58E-03	2.58E-03	4.87E-03	4.87E-03	3.87E-02	7.74E-02	7.31E-02	1.46E-01	9.95E-04	1.66E-02	8.22E-04	1.37E-02	1.30E-04	2.16E-03
Greece	GR	2.16E-03	2.16E-03	4.08E-03	4.08E-03	3.24E-02	6.48E-02	6.12E-02	1.22E-01	8.33E-04	1.39E-02	6.88E-04	1.15E-02	1.09E-04	1.81E-03
Hungary	HU	2.16E-03	2.16E-03	4.08E-03	4.08E-03	3.24E-02	6.48E-02	6.12E-02	1.22E-01	8.33E-04	1.39E-02	6.88E-04	1.15E-02	1.09E-04	1.81E-03
Ireland	IE	2.16E-03	2.16E-03	4.08E-03	4.08E-03	3.24E-02	6.48E-02	6.12E-02	1.22E-01	8.33E-04	1.39E-02	6.88E-04	1.15E-02	1.09E-04	1.81E-03
Israel	IL	1.34E-03	1.34E-03	2.52E-03	2.52E-03	2.00E-02	4.01E-02	3.78E-02	7.57E-02	5.15E-04	8.59E-03	4.26E-04	7.09E-03	6.72E-05	1.12E-03
Italy	IT	1.45E-03	1.45E-03	2.75E-03	2.75E-03	2.18E-02	4.36E-02	4.12E-02	8.24E-02	5.61E-04	9.35E-03	4.63E-04	7.72E-03	7.32E-05	1.22E-03
Japan	JP	2.32E-03	2.32E-03	4.34E-03	4.34E-03	3.48E-02	6.95E-02	6.51E-02	1.30E-01	0.00E+00	0.00E+00	3.39E-03	5.66E-02	7.54E-05	1.26E-03
Korea	KR	4.85E-04	4.85E-04	9.15E-04	9.15E-04	7.27E-03	1.45E-02	1.37E-02	2.75E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.55E-05	4.25E-04
Luxembourg	LU	2.16E-03	2.16E-03	4.08E-03	4.08E-03	3.24E-02	6.48E-02	6.12E-02	1.22E-01	8.33E-04	1.39E-02	6.88E-04	1.15E-02	1.09E-04	1.81E-03
Malaysia	MY	1.28E-03	1.28E-03	2.41E-03	2.41E-03	1.91E-02	3.83E-02	3.61E-02	7.23E-02	4.92E-04	8.20E-03	4.07E-04	6.78E-03	6.42E-05	1.07E-03
Mexico	MX	4.84E-04	4.84E-04	9.14E-04	9.14E-04	7.26E-03	1.45E-02	1.37E-02	2.74E-02	1.87E-04	3.11E-03	1.54E-04	2.57E-03	2.43E-05	4.06E-04
Netherlands	NL	1.81E-03	1.81E-03	3.42E-03	3.42E-03	2.71E-02	5.43E-02	5.13E-02	1.03E-01	6.98E-04	1.16E-02	5.77E-04	9.61E-03	9.10E-05	1.52E-03
New Zealand	NZ	2.55E-03	2.55E-03	4.82E-03	4.82E-03	3.83E-02	7.66E-02	7.23E-02	1.45E-01	9.84E-04	1.64E-02	8.13E-04	1.36E-02	1.28E-04	2.14E-03
Norway	NO	3.46E-03	3.46E-03	6.54E-03	6.54E-03	5.19E-02	1.04E-01	9.81E-02	1.96E-01	1.34E-03	2.23E-02	1.10E-03	1.84E-02	1.74E-04	2.90E-03
Portugal	PT	1.20E-03	1.20E-03	2.26E-03	2.26E-03	1.80E-02	3.59E-02	3.39E-02	6.78E-02	4.62E-04	7.70E-03	3.82E-04	6.36E-03	6.03E-05	1.00E-03
South Africa	ZA	4.96E-04	4.96E-04	9.36E-04	9.36E-04	7.44E-03	1.49E-02	1.40E-02	2.81E-02	1.91E-04	3.19E-03	1.58E-04	2.63E-03	2.49E-05	4.16E-04
Spain	ES	2.06E-04	2.06E-04	3.89E-04	3.89E-04	3.09E-03	6.18E-03	5.83E-03	1.17E-02	7.94E-05	1.32E-03	6.56E-05	1.09E-03	1.04E-05	1.73E-04
Sweden	SE	3.29E-03	3.29E-03	6.22E-03	6.22E-03	4.94E-02	9.88E-02	9.33E-02	1.87E-01	1.27E-03	2.12E-02	1.05E-03	1.75E-02	1.66E-04	2.76E-03
Switzerland	CH	3.85E-04	7.71E-04	7.27E-04	1.45E-03	6.36E-02	1.10E-01	1.20E-01	2.07E-01	9.33E-03	1.41E-02	7.71E-03	1.16E-02	1.22E-03	1.84E-03
Thailand	TH	6.05E-04	6.05E-04	1.14E-03	1.14E-03	9.08E-03	1.82E-02	1.71E-02	3.43E-02	2.33E-04	3.89E-03	1.93E-04	3.21E-03	3.05E-05	5.08E-04
Turkey	TR	4.85E-07	4.85E-07	9.16E-07	9.16E-07	7.27E-06	1.45E-05	1.37E-05	2.75E-05	1.87E-07	3.12E-06	1.54E-07	2.57E-06	2.44E-08	4.07E-07
United Kingdom	GB	2.16E-03	2.16E-03	4.08E-03	4.08E-03	3.24E-02	6.48E-02	6.12E-02	1.22E-01	8.33E-04	1.39E-02	6.88E-04	1.15E-02	1.09E-04	1.81E-03
USA	US	1.43E-03	1.43E-03	2.59E-03	2.59E-03	2.13E-02	4.27E-02	3.85E-02	7.70E-02	5.77E-05	1.39E-03	1.13E-04	2.71E-03	7.72E-05	1.85E-03

Country	Code	Slanted Roof c-Si >50kWp				Slanted Roof c-Si <50kWp				Centralized				
		93 kWp slanted-roof installation, single-Si, laminated, integrated, on roof	93 kWp slanted-roof installation, single-Si, panel, mounted, on roof	93 kWp slanted-roof installation, multi-Si, laminated, integrated, on roof	93 kWp slanted-roof installation, multi-Si, panel, mounted, on roof	3kWp slanted-roof installation, single-Si, laminated, integrated, on roof	3kWp slanted-roof installation, single-Si, panel, mounted, on roof	3kWp slanted-roof installation, multi-Si, laminated, integrated, on roof	3kWp slanted-roof installation, multi-Si, panel, mounted, on roof	570 kWp open ground installation, single-Si, on open ground	570 kWp open ground installation, multi-Si, on open ground	570 kWp open ground installation, CdTe, on open ground	570 kWp open ground installation, CIS, on open ground	570 kWp open ground installation, micro-Si, on open ground
		Share	Share	Share	Share	Share	Share	Share	Share	Share	Share	Share	Share	Share
Australia	AU	5.11E-03	8.51E-02	9.64E-03	1.61E-01	1.89E-03	3.14E-02	3.56E-03	5.93E-02	8.68E-02	1.64E-01	6.20E-03	5.12E-03	8.08E-04
Austria	AT	6.06E-04	2.00E-02	9.29E-03	3.06E-01	2.67E-04	8.79E-03	4.09E-03	1.35E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Belgium	BE	5.69E-03	9.48E-02	1.07E-02	1.79E-01	2.10E-03	3.50E-02	3.97E-03	6.62E-02	5.88E-02	1.11E-01	4.20E-03	3.47E-03	5.48E-04
Canada	CA	2.43E-03	4.05E-02	4.59E-03	7.64E-02	8.97E-04	1.49E-02	1.69E-03	2.82E-02	2.14E-01	4.05E-01	1.53E-02	1.27E-02	2.00E-03
Chile	CL	6.43E-05	1.07E-03	1.21E-04	2.02E-03	2.37E-05	3.96E-04	4.48E-05	7.47E-04	3.27E-01	6.18E-01	2.34E-02	1.93E-02	3.05E-03
China	CN	2.01E-03	3.34E-02	3.79E-03	6.31E-02	8.89E-04	1.48E-02	1.68E-03	2.80E-02	2.41E-01	4.55E-01	7.26E-03	6.00E-03	9.47E-04
Czech Republic	CZ	4.32E-03	7.20E-02	8.16E-03	1.36E-01	1.60E-03	2.66E-02	3.01E-03	5.02E-02	1.24E-01	2.35E-01	8.87E-03	7.33E-03	1.16E-03
Denmark	DK	5.08E-03	8.47E-02	9.59E-03	1.60E-01	1.88E-03	3.13E-02	3.54E-03	5.90E-02	8.80E-02	1.66E-01	6.29E-03	5.19E-03	8.20E-04
Finland	FI	6.92E-03	1.15E-01	1.31E-02	2.18E-01	2.56E-03	4.26E-02	4.83E-03	8.05E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
France	FR	4.14E-03	6.90E-02	7.82E-03	1.30E-01	1.53E-03	2.55E-02	2.89E-03	4.81E-02	1.33E-01	2.51E-01	9.48E-03	7.83E-03	1.24E-03
Germany	DE	5.16E-03	8.60E-02	9.74E-03	1.62E-01	1.91E-03	3.18E-02	3.60E-03	6.00E-02	8.41E-02	1.59E-01	6.01E-03	4.96E-03	7.84E-04
Greece	GR	4.32E-03	7.20E-02	8.16E-03	1.36E-01	1.60E-03	2.66E-02	3.01E-03	5.02E-02	1.24E-01	2.35E-01	8.87E-03	7.33E-03	1.16E-03
Hungary	HU	4.32E-03	7.20E-02	8.16E-03	1.36E-01	1.60E-03	2.66E-02	3.01E-03	5.02E-02	1.24E-01	2.35E-01	8.87E-03	7.33E-03	1.16E-03
Ireland	IE	4.32E-03	7.20E-02	8.16E-03	1.36E-01	1.60E-03	2.66E-02	3.01E-03	5.02E-02	1.24E-01	2.35E-01	8.87E-03	7.33E-03	1.16E-03
Israel	IL	2.67E-03	4.45E-02	5.05E-03	8.41E-02	9.87E-04	1.64E-02	1.86E-03	3.11E-02	2.03E-01	3.83E-01	1.45E-02	1.20E-02	1.89E-03
Italy	IT	2.91E-03	4.85E-02	5.49E-03	9.16E-02	1.07E-03	1.79E-02	2.03E-03	3.38E-02	1.91E-01	3.62E-01	1.37E-02	1.13E-02	1.78E-03
Japan	JP	4.64E-03	7.73E-02	8.69E-03	1.45E-01	1.11E-03	1.85E-02	2.08E-03	3.47E-02	1.06E-01	1.98E-01	0.00E+00	3.01E-02	6.68E-04
Korea	KR	9.70E-04	1.62E-02	1.83E-03	3.05E-02	4.76E-04	7.93E-03	8.99E-04	1.50E-02	2.97E-01	5.60E-01	0.00E+00	0.00E+00	2.77E-03
Luxembourg	LU	4.32E-03	7.20E-02	8.16E-03	1.36E-01	1.60E-03	2.66E-02	3.01E-03	5.02E-02	1.24E-01	2.35E-01	8.87E-03	7.33E-03	1.16E-03
Malaysia	MY	2.55E-03	4.25E-02	4.82E-03	8.03E-02	9.43E-04	1.57E-02	1.78E-03	2.97E-02	2.09E-01	3.94E-01	1.49E-02	1.23E-02	1.94E-03
Mexico	MX	9.68E-04	1.61E-02	1.83E-03	3.05E-02	3.58E-04	5.96E-03	6.75E-04	1.13E-02	2.84E-01	5.36E-01	2.03E-02	1.68E-02	2.65E-03
Netherlands	NL	3.62E-03	6.03E-02	6.83E-03	1.14E-01	1.34E-03	2.23E-02	2.52E-03	4.21E-02	1.58E-01	2.98E-01	1.13E-02	9.30E-03	1.47E-03
New Zealand	NZ	5.11E-03	8.51E-02	9.64E-03	1.61E-01	1.89E-03	3.14E-02	3.56E-03	5.93E-02	8.68E-02	1.64E-01	6.20E-03	5.12E-03	8.08E-04
Norway	NO	6.92E-03	1.15E-01	1.31E-02	2.18E-01	2.56E-03	4.26E-02	4.83E-03	8.05E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Portugal	PT	2.40E-03	3.99E-02	4.52E-03	7.54E-02	8.85E-04	1.47E-02	1.67E-03	2.78E-02	2.16E-01	4.08E-01	1.54E-02	1.27E-02	2.01E-03
South Africa	ZA	9.92E-04	1.65E-02	1.87E-03	3.12E-02	3.66E-04	6.11E-03	6.92E-04	1.15E-02	2.83E-01	5.34E-01	2.02E-02	1.67E-02	2.64E-03
Spain	ES	4.12E-04	6.87E-03	7.78E-04	1.30E-02	1.52E-04	2.54E-03	2.87E-04	4.79E-03	3.11E-01	5.86E-01	2.22E-02	1.83E-02	2.89E-03
Sweden	SE	6.59E-03	1.10E-01	1.24E-02	2.07E-01	2.43E-03	4.06E-02	4.60E-03	7.66E-02	1.60E-02	3.03E-02	1.15E-03	9.46E-04	1.49E-04
Switzerland	CH	4.27E-02	6.46E-02	8.06E-02	1.22E-01	1.84E-02	2.78E-02	3.48E-02	5.25E-02	2.26E-03	4.28E-03	1.62E-04	1.34E-04	2.11E-05
Thailand	TH	1.21E-03	2.02E-02	2.29E-03	3.81E-02	4.47E-04	7.45E-03	8.44E-04	1.41E-02	2.73E-01	5.15E-01	1.95E-02	1.61E-02	2.54E-03
Turkey	TR	9.70E-07	1.62E-05	1.83E-06	3.05E-05	3.58E-07	5.97E-06	6.76E-07	1.13E-05	3.30E-01	6.24E-01	2.36E-02	1.95E-02	3.08E-03
United Kingdom	GB	4.32E-03	7.20E-02	8.16E-03	1.36E-01	1.60E-03	2.66E-02	3.01E-03	5.02E-02	1.24E-01	2.35E-01	8.87E-03	7.33E-03	1.16E-03
USA	US	2.04E-03	4.90E-02	3.68E-03	8.84E-02	9.33E-04	2.24E-02	1.68E-03	4.04E-02	1.38E-01	2.60E-01	1.95E-01	5.06E-03	0.00E+00

3.11 Country specific electricity grid mixes

This section of the report has not been updated. More recent information e.g. for Germany is provided by the AG Energiebilanzen[1].

Tables 52-61 show the electricity grid mixes of the leading PV manufacturing countries globally: China, Japan, Germany, Taiwan, Malaysia, USA, Korea, Spain, India, Mexico (de Wild-Scholten, 2013) [30].

The data correspond to the electricity grid mixes published by Itten et al. [31], except where indicated otherwise. Entries in red indicate data not available.

[1] https://ag-energiebilanzen.de/index.php?article _id=29&fileName=ageb _ strerz _ 20200921_a10 _.pdf, access on 3.9.2020

Table 52: Electricity supply mix of China

China	Supply Mix
	%
Fossil fuels	**78.75**
Hard coal	**76.61**
Lignite	**0.00**
Peat	**0.00**
Industrial Gases	**0.61**
Coke gases	*0.00*
Blast furnace gases	*0.00*
Petroleum products	**0.66**
Fuel oil	*0.00*
Diesel	*0.00*
other petroleum products	*0.00*
Natural Gas	**0.88**
Other fossil	**0.00**
Hydro	**18.57**
Reservoir power plants	**13.93**
Run-of-river power plants	**4.64**
Pumped storage power plants	**0.00**
Nuclear	**2.06**
Pressurised-water reactor (PWR)	**2.06**
Boiling-water reactor (BWR)	**0.00**
Renewables	**0.49**
Geothermal	**0.00**
Solar	**0.00**
Photovoltaic	*0.01*
Solar thermal	*0.00*
Wave and tidal energy	**0.00**
Wind	**0.42**
Wood	**0.07**
Biogas	**0.00**
Waste	**0.00**
Municipal waste	**0.00**
Industrial waste	**0.00**
Sewage sludge and landfill gases	**0.00**
Other	**0.00**
Total domestic	**99.88**
Imports	**0.12**
Chinese Taipeh	**0.12**
Total	**100.00**

Table 53: Electricity supply mix of Japan

Japan	Supply Mix
	%
Fossil fuels	**65.38**
Hard coal	**24.26**
Lignite	**0.00**
Peat	**0.00**
Industrial Gases	**2.96**
Coke gases	*0.76*
Blast furnace gases	*2.20*
Petroleum products	**12.11**
Fuel oil	*10.03*
Diesel	*0.29*
other petroleum products	*1.78*
Natural Gas	**26.06**
Other fossil	**0.00**
Hydro	**8.07**
Reservoir power plants	**1.48**
Run-of-river power plants	**5.91**
Pumped storage power plants	**0.68**
Nuclear	**23.76**
Pressurised-water reactor (PWR)	**10.36**
Boiling-water reactor (BWR)	**13.40**
Renewables	**2.11**
Geothermal	**0.26**
Solar	**0.21**
Photovoltaic	*0.21*
Solar thermal	*0.00*
Wave and tidal energy	**0.00**
Wind	**0.26**
Wood	**1.39**
Biogas	**0.00**
Waste	**0.67**
Municipal waste	**0.63**
Industrial waste	**0.04**
Sewage sludge and landfill gases	**0.00**
Other	**0.00**
Total domestic	**100.00**
Imports	**0.00**
Total	**100.00**

Table 54: Electricity supply mix of Germany [32]

Germany	Supply Mix
	%
Fossil fuels	**58.30**
Hard coal	**18.00**
Lignite	**25.60**
Peat	*0.00*
Industrial Gases	*0.00*
Coke gases	*0.00*
Blast furnace gases	*0.00*
Petroleum products	**0.80**
Fuel oil	*0.00*
Diesel	*0.00*
other petroleum products	*0.00*
Natural Gas	**9.60**
Other fossil	**4.30**
Hydro	**3.40**
Reservoir power plants	
Run-of-river power plants	
Pumped storage power plants	
Nuclear	**15.90**
Pressurised-water reactor (PWR)	
Boiling-water reactor (BWR)	
Renewables	**21.40**
Geothermal	*0.00*
Solar	**5.80**
Photovoltaic	*5.80*
Solar thermal	*0.00*
Wave and tidal energy	*0.00*
Wind	**8.60**
Wood	**7.00**
Biogas	
Waste	**1.00**
Municipal waste	
Industrial waste	
Sewage sludge and landfill gases	
Other	**0.00**
Total	**100.00**

Table 55: Electricity supply mix of Taiwan

Taiwan	Supply Mix
	%
Fossil fuels	**77.35**
Hard coal	**46.82**
Lignite	**4.43**
Peat	**0.00**
Industrial Gases	**0.85**
Coke gases	*0.00*
Blast furnace gases	*0.00*
Petroleum products	**5.94**
Fuel oil	*0.00*
Diesel	*0.00*
other petroleum products	*0.00*
Natural Gas	**19.30**
Other fossil	**0.00**
Hydro	**3.49**
Reservoir power plants	**0.00**
Run-of-river power plants	**3.49**
Pumped storage power plants	**0.00**
Nuclear	**17.43**
Pressurised-water reactor (PWR)	**6.44**
Boiling-water reactor (BWR)	**10.99**
Renewables	**0.49**
Geothermal	**0.00**
Solar	**0.00**
Photovoltaic	*0.00*
Solar thermal	*0.00*
Wave and tidal energy	**0.00**
Wind	**0.27**
Wood	**0.22**
Biogas	**0.00**
Waste	**1.24**
Municipal waste	**1.24**
Industrial waste	**0.00**
Sewage sludge and landfill gases	**0.00**
Other	**0.00**
Total domestic	**100.00**
Imports	**0.00**
Total	**100.00**

Table 56: Electricity supply mix of Malaysia

Malaysia	Supply Mix
	%
Fossil fuels	**92.28**
Hard coal	**26.86**
Lignite	**0.00**
Peat	**0.00**
Industrial Gases	**0.00**
Coke gases	*0.00*
Blast furnace gases	*0.00*
Petroleum products	**1.89**
Fuel oil	*0.00*
Diesel	*0.00*
other petroleum products	*0.00*
Natural Gas	**63.52**
Other fossil	**0.00**
Hydro	**7.72**
Reservoir power plants	**7.72**
Run-of-river power plants	**0.00**
Pumped storage power plants	**0.00**
Nuclear	**0.00**
Pressurised-water reactor (PWR)	**0.00**
Boiling-water reactor (BWR)	**0.00**
Renewables	**0.00**
Geothermal	**0.00**
Solar	**0.00**
Photovoltaic	*0.00*
Solar thermal	*0.00*
Wave and tidal energy	**0.00**
Wind	**0.00**
Wood	**0.00**
Biogas	**0.00**
Waste	**0.00**
Municipal waste	**0.00**
Industrial waste	**0.00**
Sewage sludge and landfill gases	**0.00**
Other	**0.00**
Total domestic	**100.00**
Imports	**0.00**
Total	**100.00**

Table 57: Electricity supply mix of USA

United States of America	Supply Mix
	%
Fossil fuels	**69.31**
Hard coal	**45.62**
Lignite	**1.95**
Peat	**0.00**
Industrial Gases	**0.09**
Coke gases	*0.01*
Blast furnace gases	*0.07*
Petroleum products	**1.30**
Fuel oil	*0.56*
Diesel	*0.19*
other petroleum products	*0.55*
Natural Gas	**20.35**
Other fossil	**0.00**
Hydro	**6.77**
Reservoir power plants	**1.23**
Run-of-river power plants	**4.93**
Pumped storage power plants	**0.61**
Nuclear	**19.10**
Pressurised-water reactor (PWR)	**12.68**
Boiling-water reactor (BWR)	**6.42**
Renewables	**2.75**
Geothermal	**0.40**
Solar	**0.06**
Photovoltaic	*0.04*
Solar thermal	*0.02*
Wave and tidal energy	**0.00**
Wind	**1.35**
Wood	**0.93**
Biogas	**0.02**
Waste	**0.67**
Municipal waste	**0.38**
Industrial waste	**0.12**
Sewage sludge and landfill gases	**0.17**
Other	**0.02**
Total domestic	**98.62**
Imports	**1.38**
Canada	**1.35**
Mexico	**0.03**
Total	**100.00**

Table 58: Electricity supply mix of Korea

South Korea	Supply Mix
	%
Fossil fuels	**64.83**
Hard coal	**39.71**
Lignite	**0.00**
Peat	**0.00**
Industrial Gases	**3.39**
Coke gases	*0.36*
Blast furnace gases	*3.02*
Petroleum products	**3.45**
Fuel oil	*2.59*
Diesel	*0.10*
other petroleum products	*0.76*
Natural Gas	**18.28**
Other fossil	**0.00**
Hydro	**1.30**
Reservoir power plants	**0.14**
Run-of-river power plants	**0.57**
Pumped storage power plants	**0.58**
Nuclear	**33.54**
Pressurised-water reactor (PWR)	**33.54**
Boiling-water reactor (BWR)	**0.00**
Renewables	**0.18**
Geothermal	**0.00**
Solar	**0.06**
Photovoltaic	*0.06*
Solar thermal	*0.00*
Wave and tidal energy	**0.00**
Wind	**0.10**
Wood	**0.01**
Biogas	**0.00**
Waste	**0.14**
Municipal waste	**0.04**
Industrial waste	**0.00**
Sewage sludge and landfill gases	**0.10**
Other	**0.02**
Total domestic	**100.00**
Imports	**0.00**
Total	**100.00**

Table 59: Electricity supply mix of Spain [33]

Spain	Supply Mix
	%
Fossil fuels	**36.60**
Hard coal	**14.60**
Lignite	*0.00*
Peat	*0.00*
Industrial Gases	*0.00*
Coke gases	*0.00*
Blast furnace gases	*0.00*
Petroleum products	*0.00*
Fuel oil	*0.00*
Diesel	*0.00*
other petroleum products	*0.00*
Natural Gas	**9.50**
Other fossil	**12.50**
Hydro	**14.20**
Reservoir power plants	
Run-of-river power plants	
Pumped storage power plants	
Nuclear	**21.20**
Pressurised-water reactor (PWR)	
Boiling-water reactor (BWR)	
Renewables	**28.00**
Geothermal	*0.00*
Solar	**4.80**
Photovoltaic	*3.10*
Solar thermal	*1.70*
Wave and tidal energy	*0.00*
Wind	**21.20**
Wood	**2.00**
Biogas	*0.00*
Waste	**0.00**
Municipal waste	*0.00*
Industrial waste	*0.00*
Sewage sludge and landfill gases	*0.00*
Other	**0.00**
Total	**100.00**

Table 60: Electricity supply mix of India

India	Supply Mix
	%
Fossil fuels	**80.83**
Hard coal	**64.84**
Lignite	**2.14**
Peat	**0.00**
Industrial Gases	**0.17**
Coke gases	*0.00*
Blast furnace gases	*0.00*
Petroleum products	**4.03**
Fuel oil	*0.00*
Diesel	*0.00*
other petroleum products	*0.00*
Natural Gas	**9.66**
Other fossil	**0.00**
Hydro	**14.28**
Reservoir power plants	**11.01**
Run-of-river power plants	**1.52**
Pumped storage power plants	**1.76**
Nuclear	**1.75**
Pressurised-water reactor (PWR)	**1.63**
Boiling-water reactor (BWR)	**0.12**
Renewables	**1.97**
Geothermal	**0.00**
Solar	**0.00**
Photovoltaic	*0.00*
Solar thermal	*0.00*
Wave and tidal energy	**0.00**
Wind	**1.73**
Wood	**0.23**
Biogas	**0.00**
Waste	**0.00**
Municipal waste	**0.00**
Industrial waste	**0.00**
Sewage sludge and landfill gases	**0.00**
Other	**0.00**
Total domestic	**98.83**
Imports	**1.17**
Bhutan	**1.17**
Total	**100.00**

Table 61: Electricity supply mix of Mexico

Mexico	Supply Mix
	%
Fossil fuels	**77.22**
Hard coal	**8.00**
Lignite	**0.00**
Peat	**0.00**
Industrial Gases	**0.19**
Coke gases	*0.03*
Blast furnace gases	*0.17*
Petroleum products	**18.87**
Fuel oil	*17.77*
Diesel	*0.33*
other petroleum products	*0.77*
Natural Gas	**50.16**
Other fossil	**0.00**
Hydro	**15.73**
Reservoir power plants	**0.00**
Run-of-river power plants	**15.73**
Pumped storage power plants	**0.00**
Nuclear	**3.74**
Pressurised-water reactor (PWR)	**0.00**
Boiling-water reactor (BWR)	**3.74**
Renewables	**3.14**
Geothermal	**2.75**
Solar	**0.00**
Photovoltaic	*0.00*
Solar thermal	*0.00*
Wave and tidal energy	**0.00**
Wind	**0.11**
Wood	**0.28**
Biogas	**0.00**
Waste	**0.03**
Municipal waste	**0.00**
Industrial waste	**0.00**
Sewage sludge and landfill gases	**0.03**
Other	**0.00**
Total domestic	**99.86**
Imports	**0.14**
United States of America	**0.14**
Total	**100.00**

3.12 Water footprint

The water consumption and water withdrawal of electricity generated by PV systems can be assessed by considering all life cycle stages. This analysis can be performed using the data presented in this report. The IEA PVPS Task 12 report by Stolz et al. [34] demonstrates the application of the AWARE (Available WAter REmaining) method to assess the water stress impact caused by water consumption and water withdrawal.

REFERENCES

1. TS PEF Pilot PV, *Product Environmental Footprint Category Rules (PEFCR): Photovoltaic Modules used in Photovoltaic Power Systems for Electricity Generation*, commissioned by the Technical Secretariat of the PEF Pilot "Photovoltaic Electricity Generation", treeze Ltd., Uster, Switzerland, 2019.
2. M. Woodhouse, B. Smith, A. Ramdas, and R. Margolis, *Crystalline Silicon Photovoltaic Module Manufacturing Costs and Sustainable Pricing: 1H 2018 Benchmark and Cost Reduction Road Map*, NREL, Golden, CO, USA, 2019.
3. R. Frischknecht, et al., *Methodology Guidelines on Life Cycle Assessment of Photovoltaic Electricity, 4th edition,* IEA PVPS Task 12, 2020.
4. M. Raugei, R. Frischknecht, C. Olson, P. Sinha, and G. Heath, *Methodological guidelines on Net Energy Analysis of Photovoltaic Electricity*, IEA-PVPS Task 12, Report T12-07: 2016.
5. Fraunhofer ISE, *Photovoltaics Report (16 September 2020)*, Freiburg, Germany, 2020.
6. G. Masson and I. Kaizuka, *Trends in Photovoltaic Applications 2019*, IEA PVPS Task 1, Report T1-36:2019, 2019.
7. VDMA, *International Technology Roadmap for Photovoltaic (ITRPV) - 2019 Results*, Vol. Eleventh Edition, VDMA Photovoltaic equipment, 2020.
8. P. Sinha and A. Wade, *Addressing Hotspots in the Product Environmental Footprint of CdTe Photovoltaics*, IEEE J. Photovoltaics, 8(3), 793-797, 2018.
9. N. Jungbluth, M. Stucki, K. Flury, R. Frischknecht, and S. Büsser, *Life Cycle Inventories of Photovoltaics*, ESU-services Ltd., Uster, Switzerland, 2012.
10. M. de Wild-Scholten, *Life Cycle Assessment of Photovoltaics Status 2011, Part 1 Data Collection*, SmartGreenScans, Groet, NL, 2014.
11. M. de Wild-Scholten, *Deliverable 3.1 - Life Cycle Analysis of CHEOPS technologies and bench-marking: Screening*, SmartGreenScans, Groet, NL, 2017.
12. R. Frischknecht, et al., *Overview and Methodology*, Swiss Centre for Life Cycle Inventories, Dübendorf, Switzerland, 2007.
13. M. de Wild-Scholten, E. A. Alsema, E. W. ter Horst, M. Bächler, and V. M. Fthenakis, *A Cost and Environmental Impact Comparison of Grid-connected Rooftop and Ground-based PV Systems*, 21st EU PVSEC, Dresden, Germany, pp. 3167-73, 2006.
14. L. Tschümperlin, P. Stolz, R. Frischknecht, *Life cycle assessment of low power solar inverters (2.5 to 20 kW)*, treeze, Uster, Switzerland, 2016.
15. Mason, J.E., V. M. Fthenakis, T. Hansen, and H. C. Kim, Energy Payback and Life-cycle CO2 Emissions of the BOS in an Optimized 3.5 MW PV Installation, *Progress in Photovoltaics: Research and Applications*, 14:179-190, 2006.
16. KBOB, eco-bau, and IPB, *UVEK Ökobilanzdatenbestand DQRv2:2018*, Koordinationskonferenz der Bau- und Liegenschaftsorgane der öffentlichen Bauherren c/o BBL Bundesamt für Bauten und Logistik, 2018.
17. N. Jungbluth, M. Stucki, and R. Frischknecht, *Photovoltaics. In: Sachbilanzen von Energiesystemen: Grundlagen für den ökologischen Vergleich von Energiesystemen und den Einbezug von Energiesystemen in Ökobilanzen für die Schweiz. Ecoinvent report No. 6-XII, v2.2+,* Swiss Centre for Life Cycle Inventories, Dübendorf, Switzerland, 2010.
18. EPIA, *Global Market Outlook for photovoltaics 2013-2017*, European Photovoltaic Industry Association, Brussels, Belgium, 2013.
19. R. Frischknecht, R. Itten, P. Sinha, M. de Wild-Scholten, J. Zhang, V. Fthenakis, H. C. Kim, M. Raugei, and M. Stucki, *Life Cycle Inventories and Life Cycle Assessments of Photovoltaic Systems*, IEA PVPS Task 12, Report T12-04:2015, 2015.
20. T. de Jong, *Analyst Day Meeting – Operations Update*, First Solar, 2018.
21. L. Ramseier, P. Stolz, and R. Frischknecht. *Life Cycle Assessment of a Perovskite Silicon Tandem Photovoltaic Panel*, treeze Ltd., Uster, Switzerland, 2019.
22. P. Stolz, R. Frischknecht, K. Wambach, P. Sinha, and G. Heath, *Life Cycle Assessment of Current Photovoltaic Module Recycling*, IEA PVPS Task 12, Report T12-13:2018, 2018.
23. K. Wambach, G. Heath, and C. Libby, *Life Cycle Inventory of Current Photovoltaic Module Recycling Processes in Europe*, IEA-PVPS Task 12, Report T12-12:2017, 2017.
24. P. Sinha, M. Cossette, and J.-F. Ménard, *End-of-life CdTe PV Recycling with Semiconductor Refining*, 27th EU PVSEC, Frankfurt, Germany, pp. 4653 – 4656, 2012.
25. S. Weckend, A. Wade, and G. Heath, *End-of-Life-Management: Solar Photovoltaic Panels*, IRENA and IEA-PVPS Task 12, Report IEA-PVPS T12-06:2016, 2016.
26. K. Komoto, and J.S. Lee, *End-of-Life Management of Photovoltaic Panels: Trends in PV Module Recycling Technologies*, IEA PVPS Task 12, Report IEA-PVPS T12-10:2018, 2018.

27. L. Ager-Wick Ellingsen, G. Majeau-Bettez, B. Singh, A. Kumar Srivastava, L. O. Valøen, and A. Hammer Strømman, *Life Cycle Assessment of a Lithium-Ion Battery Vehicle Pack*, J. Industrial Ecology, 18(1), 113-124, 2014.
28. P. Stolz, A. Messmer, and R. Frischknecht, *Life Cycle Inventories of Road and Non-Road Transport Services*, treeze Ltd., Uster, Switzerland, 2016.
29. P. Stolz and R. Frischknecht, *Life Cycle Assessment of National PV Electricity Mixes*, treeze Ltd, Uster, Switzerland, 2019.
30. M. de Wild-Scholten and V. Cassagne, *Environmental Footprint of Photovoltaics*, 28th EU PVSEC, Paris, France, 2013.
31. R. Itten, R. Frischknecht, and M. Stucki, *Life Cycle Inventories of Electricity Mixes and Grid*, Version 1.3, treeze Ltd., Uster, Switzerland, 2014.
32. AG Energiebilanzen e.V., *Bruttostromerzeugung in Deutschland ab 1990 nach Energieträgern, Year 2014*, Berlin, Germany, 2014.
33. RED Eléctrica de España, *Informe del Sistema Eléctrico Español 2013, Documento resumen con nivel de accesibilidad AA*, Madrid, Spain, 2014.
34. P. Stolz, R. Frischknecht, G. Heath, K. Komoto, J. Macknick, P. Sinha, and A. Wade, *Water Footprint of European Rooftop Photovoltaic Electricity based on Regionalised Life Cycle Inventories*, IEA PVPS Task 12, Report T12-11:2017, 2017.

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