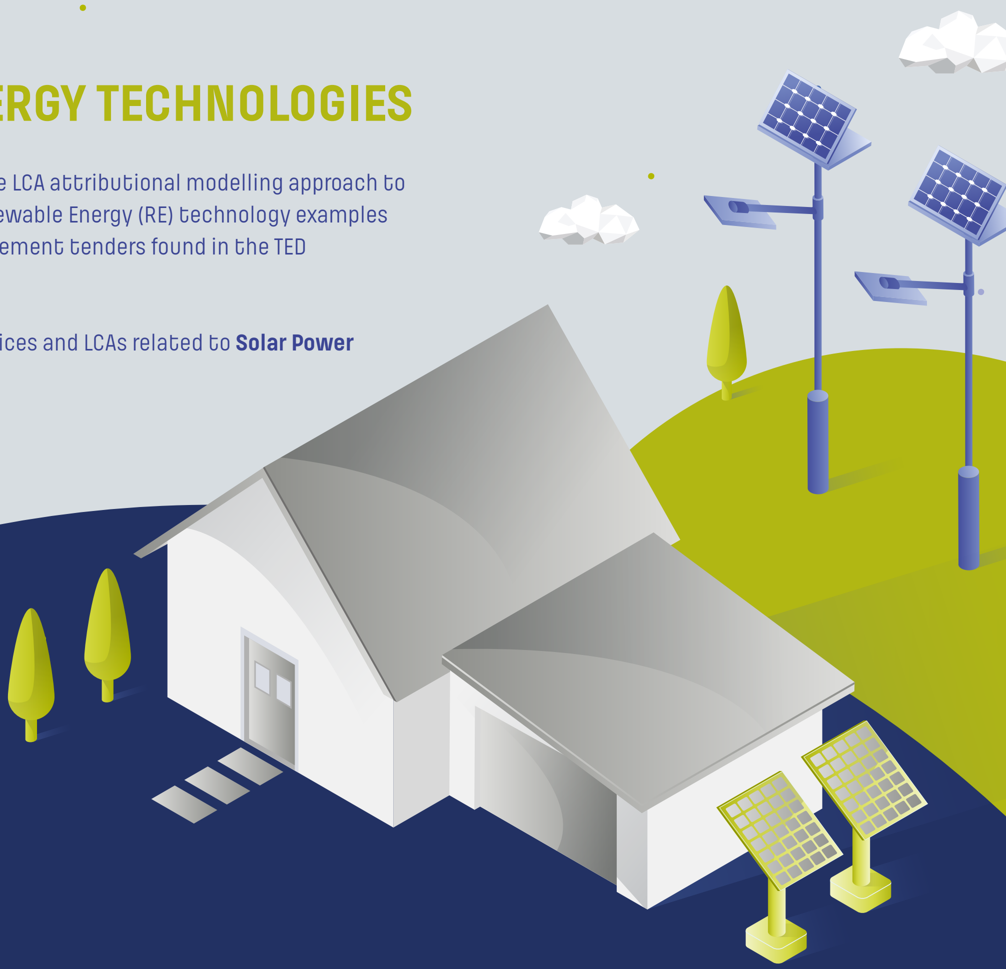
XPRESS

XPRESS LCA FACTSHEET (3/5)

RENEWABLE ENERGY TECHNOLOGIES

The XPRESS project has adopted the LCA attributional modelling approach to look at existing good practice Renewable Energy (RE) technology examples related to past Green Public Procurement tenders found in the TED (Tender Electronic Daily) database.

This factsheet outlines good practices and LCAs related to **Solar Power** technologies.



Solar Power

The growth in electricity from solar power has been dramatic and one of the sharpest of all RES, rising from 0.7% of all electricity generated in EU-28 in 2008 to 12.3% in 2017 (Eurostat, 2020). As a result, the quantity of electricity generated from solar in the EU-28 was 31.6 times as high in 2017 as in 2007, rising from just 3.8 TWh in 2007 to overtake geothermal energy in 2008, reaching a level of 119.5 TWh in 2017.

In the utility, single or mono-crystalline photovoltaic (PV) power plant sector, the fastest growing segment is PV systems with tracking systems. It is expected that the market share of utility scale PV plants with tracking will rise from approximately 20% in 2016 to over 40% in 2020. The tracking systems are relevant only for the PV installations that are mounted on the ground.

Regarding other solar power technologies, there are also thin-film PV cells, which are silicon-based and use either amorphous silicon or an amorphous/microcrystalline silicon structure. Their use has declined steeply in the last 5 years due to the low efficiencies, still at the bottom end of the scale.

Concentrated solar is a family of technologies using the thermal energy from the sun to heat up a fluid through different settings of mirrors. The fluid follows then a Rankine cycle in a closed loop, producing power after its expansion in the turbine. Despite of their demonstrated feasibility, these technologies are struggling to continue the reduction of costs to become competitive and the number of companies active in the field has declined sharply over the last years. Within CPV, there is a differentiation according to concentration factors and whether the system uses disk mirrors or trough mirrors. The economic viability of this RE technology in the future is a possibility, thus it will be analysed in the LCA dataset extension of prospective RE technologies.

Multi-crystalline

The LCI data for the electricity production with multi-crystalline PV systems are based on the main source of the Ecoinvent database (Jungbluth & Stucki, 2012). The selected dataset for XPRESS regards a unit process raw data for 1 m2 of a multi-crystalline PV panel. A solar panel consists of 60 solar cells of 156 x 156cm with a capacity of 210Wp. The assumed efficiency of solar irradiation to electricity is of 17% with a productivity of 150 Wp/m2, which represents more modern PV technology characteristics than the default values of Ecoinvent.). This assumption implies that we include a surface of 20 m2 of solar PV panels (instead of 23.4 m2 as considered in Ecoinvent) to have a 3 kWp installation module and 3800 m2 of solar PV panels (instead of 4400 m2) to have a 570 kWp installation module. The 3 kWp installation module is the basic PV module for which the raw LCI data is available. The infrastructure and auxiliary equipment impacts are then amortized over the expected lifetime of the PV panels, 30 years (Hsu et al., 2012; Wong et al., 2016). The dataset includes the repairing of 2% of the modules during the lifetime and 1% of rejects.

The location specific irradiation and the resulting annual yield of photovoltaic plants is one of the decisive factors for LCA results of photovoltaics (Jungbluth & Stucki, 2012). Here we have calculated the country-specific productivity through the European PVGIS database, where the specific solar irradiation per site can be extracted and converted into PV productivity via the optimal solar incidence angle, by inserting the cell module efficiency and the installed PV area. The estimated electricity output over the expected lifetime of the PV installation is finally used to derive the environmental footprint per kWh of this technology for each country assessed.

	H(h)	H(i_opt)	Lifetime power production estimate (MWh/ 3 kWp module)
Spain	1648.6	1863.5	190.1
Italy	1392.5	1597.6	163.0
Germany	995.1	1133.7	115.6
Portugal	1622.0	1863.9	190.1
Belgium	1157.2	1384.5	141.2
Norway	787.0	936.5	95.5
Sweeden	835.0	999.4	101.9
UK	886.0	998.4	101.8
Denmark	955.6	1132.5	115.5
Slovakia	1107.2	1236.3	126.1

Rooftop installations

In the next table the LCA results for the production of 1 kWh of electricity with a generic rooftop PV installation (multi-crystalline Si wafers, grid connected) are presented. The results include the variability of solar energy in the ten European countries where the PV is applied. The lowest environmental footprints belong to the southernmost countries (Spain and Portugal, closely followed by Italy), where the solar irradiation is highest, and vice versa. The lowest performing PV panels are those of UK, Norway and Sweden.

Impact Category	Unit	BE	DE	DK	ES	IT
Climate change	kg CO2 eq	4.11E-02	5.02E-02	5.02E-02	3.05E-02	3.56E-02
Ozone depletion	kg CFC11 eq	4.07E-09	4.96E-09	4.97E-09	3.02E-09	3.52E-09
Ionising radiation	kBq U-235 eq	3.68E-03	4.50E-03	4.50E-03	2.74E-03	3.19E-03
Photochemical ozone formation	kg NMVOC eq	1.76E-04	2.16E-04	2.16E-04	1.31E-04	1.53E-04
Particulate matter	disease inc.	2.73E-09	3.34E-09	3.34E-09	2.03E-09	2.37E-09
Human toxicity, non-cancer	CTUh	2.75E-09	3.36E-09	3.36E-09	2.04E-09	2.38E-09
Human toxicity, cancer	CTUh	5.55E-11	6.78E-11	6.79E-11	4.12E-11	4.81E-11
Acidification	mol H+ eq	3.51E-04	4.28E-04	4.29E-04	2.60E-04	3.04E-04
Eutrophication, freshwater	kg P eq	3.49E-05	4.27E-05	4.27E-05	2.60E-05	3.03E-05
Eutrophication, marine	kg N eq	5.17E-05	6.31E-05	6.32E-05	3.84E-05	4.48E-05
Eutrophication, terrestrial	mol N eq	5.30E-04	6.47E-04	6.47E-04	3.93E-04	4.59E-04
Ecotoxicity, freshwater	CTUe	2.51E+00	3.06E+00	3.07E+00	1.86E+00	2.17E+00
Water use	m3 depriv.	3.82E-02	4.66E-02	4.67E-02	2.84E-02	3.31E-02
Resource use, fossils	MJ	5.08E-01	6.20E-01	6.20E-01	3.77E-01	4.40E-01
Resource use, minerals and metals	kg Sb eq	5.75E-06	7.03E-06	7.04E-06	4.28E-06	4.99E-06

Impact Category	Unit	NO	PT	SK	SE	UK
Climate change	kg CO2 eq	6.07E-02	3.05E-02	4.60E-02	5.69E-02	5.70E-02
Ozone depletion	kg CFC11 eq	6.01E-09	3.02E-09	4.55E-09	5.63E-09	5.64E-09
Ionising radiation	kBq U-235 eq	5.45E-03	2.74E-03	4.13E-03	5.10E-03	5.11E-03
Photochemical ozone formation	kg NMVOC eq	2.61E-04	1.31E-04	1.98E-04	2.44E-04	2.45E-04
Particulate matter	disease inc.	4.04E-09	2.03E-09	3.06E-09	3.79E-09	3.79E-09
Human toxicity, non-cancer	CTUh	4.06E-09	2.04E-09	3.08E-09	3.81E-09	3.81E-09
Human toxicity, cancer	CTUh	8.21E-11	4.12E-11	6.22E-11	7.69E-11	7.70E-11
Acidification	mol H+ eq	5.18E-04	2.60E-04	3.93E-04	4.86E-04	4.86E-04
Eutrophication, freshwater	kg P eq	5.16E-05	2.59E-05	3.91E-05	4.84E-05	4.84E-05
Eutrophication, marine	kg N eq	7.64E-05	3.84E-05	5.79E-05	7.16E-05	7.17E-05
Eutrophication, terrestrial	mol N eq	7.83E-04	3.93E-04	5.93E-04	7.34E-04	7.34E-04
Ecotoxicity, freshwater	CTUe	3.71E+00	1.86E+00	2.81E+00	3.48E+00	3.48E+00
Water use	m3 depriv.	5.64E-02	2.84E-02	4.28E-02	5.29E-02	5.29E-02
Resource use, fossils	MJ	7.50E-01	3.77E-01	5.68E-01	7.03E-01	7.04E-01
Resource use, minerals and metals	kg Sb eq	8.51E-06	4.27E-06	6.44E-06	7.97E-06	7.98E-06

On ground installations

One of the main drawbacks of big solar plants is the large amount of land required to produce electricity. Unlike onshore wind plants, land transformed by PV plants becomes unavailable for other purposes. Furthermore, from an environmental perspective, impacts go beyond land occupation, given that soil is crucial for the supply of ecosystems services and to support biodiversity, for example. In the last decade, developments have been carried out to adequately incorporate such impacts on the LCA of production processes.

Within XPRESS, differences are expected for on ground PV installations among all considered countries. For these first models, the default value for land use included in the database has been kept. New insights are required to determine which type of inventory data would be the most relevant to address this impact assessment, as well as how to incorporate land characteristics that are not usually taking on consideration for LCA, such as current use (e.g. forest, fruit crops), location (e.g. ecoregions, countries), and land occupation intensiveness (Vidal-Legaz et al., 2016). Even without considering potential iLUC impacts, on ground PV installations perform slightly worse than their counterparts on rooftops, but in the range of wind power electricity. Regarding the indirect land use impacts that on ground PV installations could have, a study concluded that in the medium term, and with respect to more efficient land use, PV should be integrated into buildings and infrastructures (Lakhani et al., 2014).

Impact Category	Unit	BE	DE	DK	ES	IT
Climate change	kg CO2 eq	4.18E-02	5.10E-02	5.11E-02	3.10E-02	3.62E-02
Ozone depletion	kg CFC11 eq	4.10E-09	5.00E-09	5.01E-09	3.04E-09	3.55E-09
Ionising radiation	kBq U-235 eq	3.55E-03	4.34E-03	4.34E-03	2.64E-03	3.08E-03
Photochemical ozone formation	kg NMVOC eq	1.67E-04	2.04E-04	2.05E-04	1.24E-04	1.45E-04
Particulate matter	disease inc.	2.79E-09	3.40E-09	3.41E-09	2.07E-09	2.42E-09
Human toxicity, non-cancer	CTUh	1.92E-09	2.35E-09	2.35E-09	1.43E-09	1.66E-09
Human toxicity, cancer	CTUh	5.81E-11	7.09E-11	7.10E-11	4.32E-11	5.03E-11
Acidification	mol H+ eq	2.83E-04	3.45E-04	3.46E-04	2.10E-04	2.45E-04
Eutrophication, freshwater	kg P eq	2.49E-05	3.04E-05	3.04E-05	1.85E-05	2.16E-05
Eutrophication, marine	kg N eq	4.90E-05	5.98E-05	5.99E-05	3.64E-05	4.25E-05
Eutrophication, terrestrial	mol N eq	5.05E-04	6.17E-04	6.17E-04	3.75E-04	4.38E-04
Ecotoxicity, freshwater	CTUe	1.67E+00	2.04E+00	2.04E+00	1.24E+00	1.45E+00
Water use	m3 depriv.	3.82E-02	4.67E-02	4.67E-02	2.84E-02	3.31E-02
Resource use, fossils	MJ	5.09E-01	6.22E-01	6.22E-01	3.78E-01	4.41E-01
Resource use, minerals and metals	kg Sb eq	6.80E-06	8.31E-06	8.32E-06	5.06E-06	5.90E-06

Impact Category	Unit	NO	PT	SK	SE	UK
Climate change	kg CO2 eq	6.18E-02	3.10E-02	4.68E-02	5.79E-02	5.79E-02
Ozone depletion	kg CFC11 eq	6.06E-09	3.04E-09	4.59E-09	5.68E-09	5.68E-09
Ionising radiation	kBq U-235 eq	5.25E-03	2.64E-03	3.98E-03	4.92E-03	4.92E-03
Photochemical ozone formation	kg NMVOC eq	2.47E-04	1.24E-04	1.87E-04	2.32E-04	2.32E-04
Particulate matter	disease inc.	4.12E-09	2.07E-09	3.12E-09	3.86E-09	3.86E-09
Human toxicity, non-cancer	CTUh	2.84E-09	1.43E-09	2.15E-09	2.66E-09	2.66E-09
Human toxicity, cancer	CTUh	8.59E-11	4.32E-11	6.51E-11	8.05E-11	8.06E-11
Acidification	mol H+ eq	4.18E-04	2.10E-04	3.17E-04	3.92E-04	3.92E-04
Eutrophication, freshwater	kg P eq	3.68E-05	1.85E-05	2.79E-05	3.45E-05	3.45E-05
Eutrophication, marine	kg N eq	7.24E-05	3.64E-05	5.49E-05	6.79E-05	6.79E-05
Eutrophication, terrestrial	mol N eq	7.46E-04	3.75E-04	5.65E-04	6.99E-04	7.00E-04
Ecotoxicity, freshwater	CTUe	2.47E+00	1.24E+00	1.87E+00	2.31E+00	2.32E+00
Water use	m3 depriv.	5.65E-02	2.84E-02	4.28E-02	5.30E-02	5.30E-02
Resource use, fossils	MJ	7.53E-01	3.78E-01	5.70E-01	7.05E-01	7.06E-01
Resource use, minerals and metals	kg Sb eq	1.01E-05	5.05E-06	7.62E-06	9.43E-06	9.44E-06

Consortium

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