Life cycle assessment of different energy technologies
Environmental Analysis & Ecology

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1 Photovoltaic Park (Matteo)

1.1 Paper 1 [1]

Title: Estimating the environmental footprint of a grid-connected 20 MWp photovoltaic system
Authors: Artúr Szilágyi, Gyula Gróf
Year: 2020

The LCA in this paper is intended to support the planning and eco-design of photovoltaic plants by estimating their environmental impact during the early planning phase. The goal of the paper is twofold: first, to assess the environmental impacts of the power plant using the Product Environmental Footprint (PEF) methodology released by the Official Journal of the European Union [2] and second, to compare the results of the simplified life-cycle model with those of the detailed model.

The study is comparative because it compares the simplified LCA with the detailed LCA, as well as the PV power plant with the Hungarian grid mix.

The function of the system is to generate AC electricity and deliver it to the grid, and the functional unit is 1 kWh of AC electricity. The estimated lifetime of the plant is of 25 years, and the expected lifetime production is 550 GWh.

The system boundary is cradle-to-grave, but with two model variants. The detailed model applies a 99% cut-off criterion, meaning that it aims to include more than 99% of the total materials and energy required for the construction of the power plant, and includes PV modules, support structure, inverters, transformers, cables, auxiliary infrastructure such as roads, fence and buildings, transport to site, diesel and electricity for installation, packaging, site preparation, installation waste, operation and maintenance (O&M), replacement of faulty components, and end-of-life transport and waste treatment. The excluded processes are capital equipment and machinery life cycles, commuting, administration, marketing, R&D, and the energy needed for decommissioning, because it could not be reliably estimated. The simplified model takes into account only the dominant contributors of the environmental impact, which are PV panels, mounting structure, inverters, and cables. Installation, transport and most O&M processes are neglected; O&M is reduced to replacement of modules and inverters, and end-of-life is represented mainly by waste cable treatment. This simplified boundary still captures most impacts.

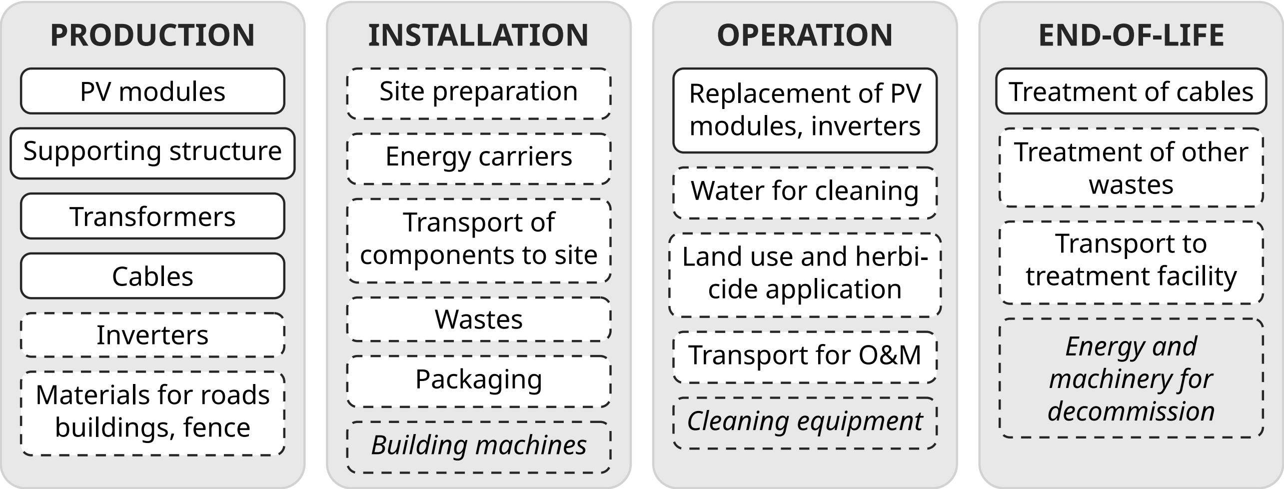

Figure 1: Life-cycle stages considered in the study. Processes with white background are considered in the detailed model, while processes with dashed borders are excluded from the simplified model. Processes with italic font are excluded from both models.

The inventory requires material quantities, component numbers, component masses, transport distances, diesel and electricity use, replacement rates, degradation rate, lifetime electricity generation and end-of-life treatment assumptions. Primary data is retrieved by the commissioner of the power plants, while the secondary data, mainly raw material, equipment, and fuels data, is taken from the latest available ecoinvent database version (v3.5) released in 2018. Most of the data is measured or calculated, while only transported quantity and end-of-life assumptions are estimated. The case study is located in Felsőzsolca, Hungary, and the data is representative of the Hungarian plant and European averages. Regarding the precision and the completeness of the data, the secondary PV-module dataset was checked against a review and found to be in the same range, but transport and end-of-life data remain uncertain. The study did not model the decarbonisation of the grid over the 25-year lifetime, limiting the comparison with the Hungarian grid mix.

The impact categories are grouped by damage type. Climate change is represented by global warming 100a. Ecosystem quality includes freshwater and terrestrial acidification, freshwater ecotoxicity, freshwater eutrophication, marine eutrophication, and terrestrial eutrophication. Human health includes carcinogenic effects, ionising radiation, non-carcinogenic effects, ozone layer depletion, photochemical ozone creation, and respiratory effects from inorganics. Resources include fossil fuel depletion, land use, minerals and metals depletion, and water depletion.

Table 1: Results of the case study vs. simplified model in PEF pts and impact coverage in (%) by damage category

Damage category	**A: Simplified model**	**B: Detailed model**	**Share (A/B)**
Climate change	8.67×10^3 PEF pt	9.47×10^3 PEF pt	92%
Ecosystem quality	2.67×10^4 PEF pt	2.95×10^4 PEF pt	91%
Human health	1.18×10^5 PEF pt	1.36×10^5 PEF pt	87%
Natural resources	2.23×10^5 PEF pt	2.38×10^5 PEF pt	94%
Total	3.76×10^5 PEF pt	4.13×10^5 PEF pt	91%

The total detailed result is equivalent to 7.5×10^{-4} PEF pt/kWh based on the 550 GWh lifetime output. The converted GWP is 6.57 g CO_2-eq/kWh for the detailed model and 6.02 g CO_2-eq/kWh for the simplified model.

The main contributors are PV production at 47.0% and steel structure at 24.3%, followed by the inverter production at 6.6%, cable production at 5.5%, and other smaller processes. Thus, PV modules and the mounting structure dominate the footprint.

1.2 Paper 2 [3]

Title: Life Cycle Assessment of a ground-mounted 1778 kW_p photovoltaic plant and comparison with traditional energy production systems
Authors: Umberto Desideri, Stefania Proietti, Francesco Zepparelli, Paolo Sdringola, Silvia Bini
Year: 2012

This paper is intended to assess the environmental impact of generating electricity using a large ground-mounted photovoltaic system. The purpose is merely publication-oriented and it is based on a comparative analysis, as electricity generated by the ground-mounted PV system is compared with electricity produced from conventional energy sources, namely the Italian electricity mix, natural-gas turbine electricity, oil-fired electricity, and hard-coal electricity. It also compares different end-of-life scenarios for PV modules and the PV plant with the Swiss PV mix.

The product function is electricity production from a ground-mounted photovoltaic plant. Two functional units are used: 1 kWp of installed power for the assembly inventory and 1 kWh of electricity produced for the full life-cycle comparison. The energy production is estimated over a 25-year lifetime, and the installed peak power of the plant is 1778 kWp.

The system boundary is cradle-to-grave. It includes land preparation, fence installation, electrical substations of precast concrete, support structures, wiring, instrumental apparatus for electrical network connection, PV module production, module transportation to the construction site, module installation, operation, maintenance, decommissioning and disposal/recycling. In particular, the study takes into account the soil preparation, the installation of fence and electrical substations of low and medium voltage, the mounting of support structures, also with reference to hot dip galvanizing process, the production of modules, their installation, the wiring apparatus and the network connection. The transport of all components to the installation site is considered for each stage that is examined. The end of life scenario of the plant is also evaluated.

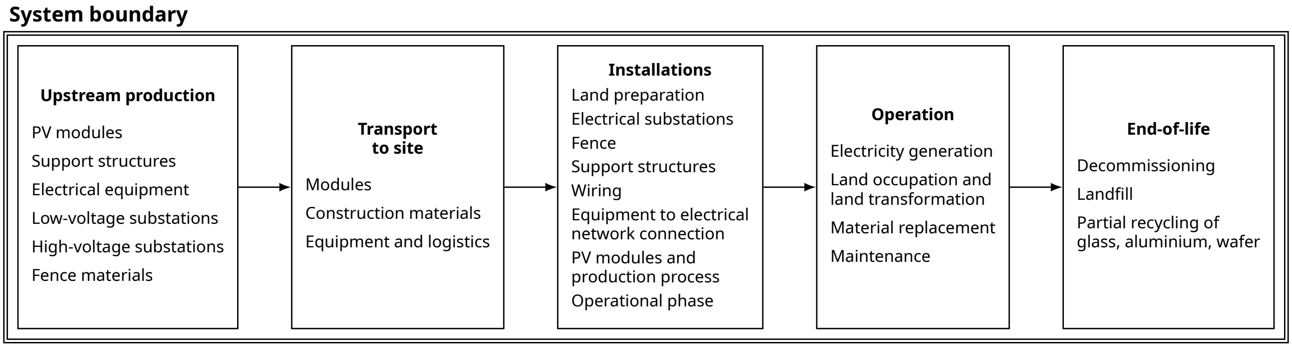

Figure 2: System boundary of the ground-mounted photovoltaic plant

The required inventory data include diesel consumption, transport distances, raw materials, component composition, module manufacturing data, inverter and transformer composition, cable material shares, construction-machine use, maintenance replacements, and end-of-life recycling/disposal assumptions. A large amount of the data is retrieved from the documentation of TerniEnergia, and some other is measured on-site. The secondary data is taken from literature and SimaPro databases. The plant was built in November 2009 and became operational in April 2010, when PV modules were still under study. The power plant is located in Marsciano, Italy, and the study mentions that the PV modules were manufactured in China and transported through France to Italy. The periodic monitoring of the construction site during the building and operating phases provides high data precision, resulting in no missing data and therefore no need to fill data gaps. The main uncertainty is the production data of the modules, as it is stated that the exact information of the modules was not directly provided so the literature was adapted relying on another publication.

The impact assessment method used is Eco-indicator 99, which groups impacts into three main damage categories: Human Health, Ecosystem Quality, and Resources. Human Health includes carcinogens, respiratory organics, respiratory inorganics, climate change, radiation, and ozone layer depletion. Ecosystem Quality includes ecotoxicity, acidification/eutrophication, and land use. Resources include minerals and fossil fuels.

With a total of 177 Pt, the LCIA shows that PV modules are the largest contributor in the assembly phase, scoring 118 Pt, followed by the electrical network connection apparatus with 31.4 Pt and wiring with 18 Pt.

For the full life cycle, the results differ based on the module end-of-life scenario. If the modules are landfilled the score is 7.79 mPt/kWh, if glass and aluminium are partially recovered the score is 7.68 mPt/kWh, and including the wafer recovery it is 7.34 mPt/kWh.

The main climate and energy indicator is GWP100, with a value of 88.743 g CO_2/kWh, or 0.106 kg CO_2-eq/kWh.

1.3 Comparison of Paper 1 and Paper 2

Despite the fact that both papers carry out the LCA of ground-mounted PV plants, each with a 25-year lifespan, and apply the cradle-to-grave approach, their LCA studies are partially comparable. They can be compared in terms of technological aspects as they analyse the same function, that is the production of electricity by PV panels, considering 1 kWh of electricity generated over the life cycle as the functional unit, including modules, structural elements, electrical equipment, transportation, operation and maintenance (O&M), and end-of-life management. However, their systems differ in terms of the applied boundaries, assumptions, and LCIA methods.

Paper 1 evaluates a 20 MWp plant installed in Hungary through the PEF method, applying the detailed and simplified models without machinery life cycle assessment and energy for decommissioning. On the other hand, Paper 2 estimates the environmental footprint of a 1778 kWp Italian plant using Eco-indicator 99, taking into account detailed construction site information, shipment of modules from China, O&M, decommissioning, and various recycling options. Moreover, the damage categories differ, as Paper 1 provides the PEF damage categories and Paper 2 presents Eco-indicator 99 damage categories and single score results. With appropriate calculations, the two LCAs can be compared and mainly for common indicators such as the GWP100.

2 Nuclear Power Plant (Yannik)

2.1 Introduction

The following two Life Cycle Assessments focus on the environmental impacts of nuclear power plants. The first report, titled “Life Cycle Assessment of Nuclear Power in Switzerland”, was published by Paul Scherrer Institut (PSI) in 2018 and analyses two Swiss power plants based in Gösgen and Leibstadt [4]. The second report, titled “Parametric Life Cycle Assessment of Nuclear Power for Simplified Models”, was published in the journal Environmental Science & Technology in 2023 and creates a simplified parametric LCA model [5]. Even though both reports have drastically different motivations and audiences, they share the same functional unit, and an interesting comparison can be made.

2.2 Paper 1 [4]

Title: Life Cycle Assessment (LCA) of Nuclear Power in Switzerland
Authors: Xiaojin Zhang, Christian Bauer
Year: 2018

The intended application of this report is to update and extend the existing life-cycle inventory data for Swiss nuclear electricity [4]. It is important to note that this report was funded by Swissnuclear which may present a bias. However, the rest of this analysis will show that the results closely align with those from the parametric LCA report. The report is primarily aimed at researchers, plant operators, and Swiss policy stakeholders.

The two reactors this report analyses are the pressurized water reactor (PWR) at Kernkraftwerk Gösgen (KKG) and the boiling water reactor (BWR) at Kernkraftwerk Leibstadt (KKL). The functional unit is 1 kWh of electricity generated at the power plant, and the system boundary is cradle-to-grave which means it covers uranium mining and milling, conversion, enrichment, fuel-element fabrication, plant construction, operation, decommissioning, and geological storage of radioactive waste. However, reprocessing is excluded as it has been banned in Switzerland under the Nuclear Energy Act since 2006.

The analysis for both reactors consists of primary data collected directly from KKG and KKL between the years 2014 and 2017, and secondary data taken mainly from ecoinvent 3.3 and a model ran on SimaPro 8. The data quality for the plant operation and decommissioning is described as high quality, but the data used for the analysis of the uranium supply chain is not as high quality, especially for KKL, as complete data was not publicly available due to the nature of the uranium source which can be highly confidential.

The report identifies seven environmental indicators: climate change, ionizing radiation, particulate matter formation, land use, acidification, freshwater ecotoxicity, and human toxicity. The main climate change results are 5.6 g CO_2-eq/kWh for KKG and 9.4 g CO_2-eq/kWh for KKL. The main contributor to these emissions is the upstream nuclear fuel cycle. This includes uranium mining, milling, conversion, enrichment, and fuel-element fabrication, which account for 58% of the KKG climate impact and 72% of the KKL climate impact. The difference between the two reactors can be explained by the differing origins of nuclear fuel. For example, KKL uses Russian enrichment at Seversk which emits 578 kg CO_2-eq per kg SWU and KKG uses the French Areva facility which emits 202 kg CO_2-eq per kg SWU.

2.3 Paper 2 [5]

Title: Parametric Life Cycle Assessment of Nuclear Power for Simplified Models
Authors: Thomas Gibon, Álvaro Hahn Menacho
Year: 2023

The second report takes a fundamentally different approach as it builds a parametric model of an average 1 GWe pressurized water reactor representative of the global 2020 situation [5]. This means that, on top of providing a default result, the report also provides the tools to calculate emissions for any input parameters. This means that the target audience includes the wider scientific community and policymakers. In contrast to the PSI report, the funding comes from UNECE and the Luxembourg National Research Fund which presents less risk of bias.

The functional unit is 1 kWh generated from a pressurized water reactor, and the system boundary covers the same areas as the PSI report: uranium mining and milling, conversion, enrichment, fuel-element fabrication, plant construction, operation, decommissioning, interim storage, and final disposal of spent fuel. The model assumes an open fuel cycle, meaning that reprocessing of the fuel is also not included. The analysis was modelled with Brightway2 and the lca_algebraic Python module and primarily used secondary data using ecoinvent 3.8 as the background database. Primary data consisted of direct input from World Nuclear Association experts. Compared to the PSI report which provided plant-specific LCAs, this report generated a parametric LCA with 20 modifiable parameters. These include uranium ore grade, extraction technique, enrichment technique, power plant lifetime, availability, construction intensity, and the energy input used for enrichment. The quality of the data is generally high, however, not all 20 variables could be supported with rich data.

The default model assumes a 1000 MWe plant with a 60-year lifetime, 34% thermal efficiency, 4.15% uranium enrichment, and an 80% centrifugation and 20% gaseous diffusion mix for the enrichment process. The report identifies nine environmental indicators: climate change, freshwater eutrophication, ionizing radiation, human toxicity, freshwater, ecotoxicity, land use, water resource depletion, mineral resource depletion, and non-renewable resource depletion. This default model results in 6.1 g CO_2-eq/kWh of greenhouse gas emissions. Once again, like in the PSI report, the main contributors to emissions are the upstream nuclear fuel processes. In the default model, mining and milling represent 46% of greenhouse gas emissions, and conversion, enrichment, and fuel fabrication 23%. Additionally, this report also shows how drastically the results can differ when the assumptions change. For example, the most pessimistic scenario assumes very low uranium ore grades combined with very inefficient enrichment processes which results in an emission of 122 g CO_2-eq/kWh.

2.4 Conclusion

Even though the two reports have drastically different motivations, audiences, and methodologies, the analysis above shows that they are comparable. They use the same functional unit of 1 kWh of electricity from a nuclear power plant, they both use a cradle-to-grave system boundary that covers the full nuclear fuel chain from uranium mining to waste storage, and they both ignore fuel reprocessing. Their climate change results are also very similar, the PSI report calculates 5.6 g CO_2-eq/kWh for KKG, while the parametric report calculates a default of 6.06 g CO_2-eq/kWh for an average global PWR.

However, there are still some differing assumptions which can be seen in Table 2 which must be noted. For example, PSI assumes a lifetime of 50 years for both reactors and centrifuge-based enrichment, while the parametric report assumes a 60-year lifetime with a default enrichment mix of 80% centrifugation and 20% gaseous diffusion. The 9.4 g CO_2-eq/kWh result for KKL is also higher than the parametric default, which can be explained by the Russian fuel source.

Table 2: Summary of the assumptions of the LCAs

Assumption	**KKG / KKL [4]**	**Parametric LCA [5]**
Functional unit	1 kWh at the power plant	1 kWh from a PWR power plant
Reactor type	PWR (KKG) + BWR (KKL)	Generic PWR
Geography	Switzerland (2014–17)	Global average (2020)
System boundary	Cradle-to-grave, open cycle	Cradle-to-grave, open cycle
Modelling approach	Deterministic, plant-specific	Parametric (20 variables)
Lifetime	50 years	60 years
Capacity	3002 / 3600 MWth	1000 MWe
Net efficiency	33.6% / 33.3%	34%
Enrichment level	4.95% / 4.50%	4.15%
Enrichment mix	100% centrifuge	80% centrifuge / 20% diffusion
Software / database	SimaPro 8 / ecoinvent 3.3	Brightway2 / ecoinvent 3.8
Climate change result	5.6 / 9.4 g CO_2-eq/kWh	6.06 g CO_2-eq/kWh (default model)

In conclusion, both reports show that nuclear electricity can have very low life-cycle emissions, but the parametric report shows that even with slight changes to the parameters, such as less efficient enrichment technologies, the emissions can drastically increase.

3 Coal-fired Power Plant (Anastasia)

The following section examines two Life Cycle Assessments of Coal-fired power plants. The first report focuses in Bangladesh and examines three different plants within the country [6], while the second looks at a single plant in Indonesia [7]. This diversity makes it harder to compare the LCAs with each other, but makes for an interesting examination of the different types of LCAs being published.

3.1 Paper 1 [6]

Title: Life cycle and environmental impact assessment of coal-fired power plants in Bangladesh
Authors: Khalid Shaifullah Mahmud, Md. Rasel Ahmed, Sajal Ahmed, Jahidul Islam Jihan, Mst. Tajnin Nahar Tonni, Md. Golam Kibria, Md. Rabiul Islam Sarker
Year: 2025

The first LCA looked at three plants across Bangladesh, making it a comparative analysis. The intended application of the LCA is to support sustainable energy policy in Bangladesh under growing electricity demand, with the purpose of evaluating resource use, emissions, and environmental impacts. The LCA is targeted at policy makers, energy engineers, and fellow researchers. Throughout the report, the functional unit of 1 MWh of electricity generated was used.

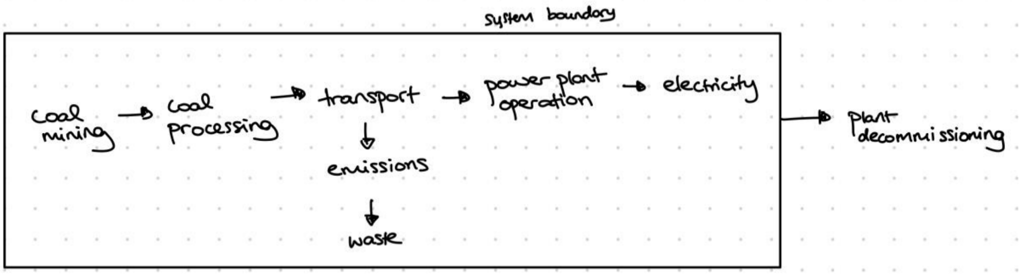

Figure 3: Summary of the plant boundaries

The figure above is a rough diagram of the LCA boundaries during the analysis. The LCA is Cradle-to-Gate.

This LCA has three geographical references, all in Bangladesh: Barapukuria (subcritical), Rampal (supercritical), and Payra (ultra-supercritical). It claims high precision and uses modern and state-of-the-art technologies and software that includes OpenLCA, ReCiPe 2016 Midpoint (H), CML-IA baseline, and ILCD 2011 Midpoint. The missing local plant data is substituted using the datasheets: Ecoinvent v3.8 database and ef_secondarydata_202202 for energy supply, material, transport and emission processes. The time reference used is 2020–2025 for plant data and 2015–2021 for datasheets. The report states that it follows ISO 14040/14044 transparency and reproducibility standards. As it is a Cradle-to-Gate analysis, no data for plant decommissioning is presented.

Below are the impact categories considered in this analysis and their results, where given in number format:

- Global Warming Potential (GWP): 765–767 kg CO_2-eq/MWh (Barapukuria), 826–828 kg CO_2-eq/MWh (Rampal), 841–843 kg CO_2-eq/MWh (Payra)
- Acidification Potential (AP): 1.5–3.2 kg SO_2-eq/MWh
- Eutrophication Potential (EP): 0.15–0.45 kg PO_4-eq/MWh
- Particulate Matter Formation: 0.8–1.5 kg $PM_{2.5}$-eq/MWh
- Human Toxicity
- Freshwater Ecotoxicity
- Water consumption / Resource depletion: 1.2–2.5 m^3/MWh

The goal and scope of this LCA was achieved, as the three planned power plants were assessed and evaluated with the same methods. The limitations of this LCA are that it excludes plant construction and its end-of-life (decommissioning), it relies heavily on secondary datasheets, and it is assumed that coal consumption across the three locations is the same.

3.2 Paper 2 [7]

Title: Environmental impact assessment of a remote coal-fired power plant in Central Kalimantan: A life cycle assessment approach and mitigation strategies
Authors: Yohanes Christda Batista, Subhan Hasisi, Muchamad Arief Dharmawan, Bagus Adi Putra, Sunu Herwi Pranolo, Muflih Arisa Adnan
Year: 2025

The second LCA examined a single plant in Indonesia, meaning it was not a comparative analysis. The intended application of the LCA is to support climate-related frameworks such as the Paris Agreement. Its purpose is to quantify existing emissions and identify strategies for reducing future emissions. The LCA is targeted at fellow researchers and engineers. Throughout the report, the functional unit of 1 kWh of electricity generated from the power plant was used.

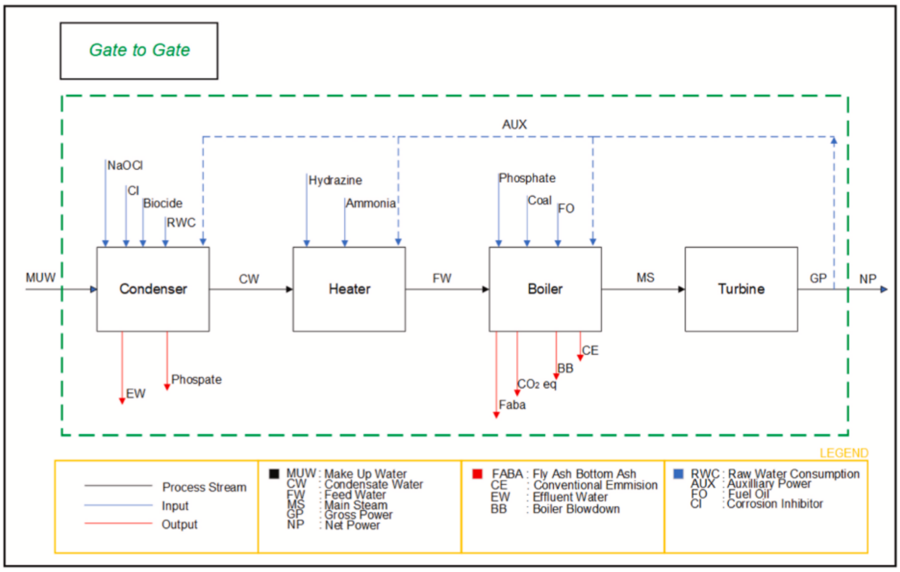

Figure 4: A diagram of the power plant and the system boundaries

The figure above is a diagram of the LCA boundaries during the analysis. The LCA is Gate-to-Gate.

This LCA looks solely into one power plant located in Central Kalimantan, Indonesia. It is precise for the plant itself, as it uses 99% of data from the power plant, in the years 2022–2024, but as such it is hard to use it as an estimate for another place. The data types needed are material inputs (water, coal, chemicals), their amounts, and operational parameters. Where data is missing, Ecoinvent databases are used, and OpenLCA is used as a tool to process the LCA. The assessment is Gate-to-Gate, and as such is missing upstream processes and infrastructure cycles, for which the gaps are not filled. This LCA can be reproduced in method for other plants, but for the data used only for this plant, as it relies heavily on existing datasheets.

Below are the impact categories considered in this analysis and their results, where given in number format:

- Global Warming Potential (GWP): 1.29 kg CO_2-eq/kWh
- Acidification Potential (AP): 2.21×10^{-3} kg SO_2-eq/kWh
- Eutrophication Potential (EP): 1.31×10^{-2} kg PO_4-eq/kWh
- Ozone Depletion: 3.04×10^{-8} kg-CFC-11-eq/kWh

The goal and scope of this LCA was achieved, as the results were measured and quantified in kWh. The limitations of this report are the missing parts of infrastructure, which limits full sustainability assessment. It is a good study for the particular power plant examined, but is not viable when looking at the industry in general.

3.3 Comparison of Paper 1 and Paper 2

Between both of the reports, the results are not comparable. While the units are different, MWh and kWh, the conversion between the units is easy, and as such it does not cause a problem when it comes to comparison. The main issue is that the first LCA considers Cradle-to-Gate and the second considered Gate-to-Gate. Also the first one considers more impact categories.

4 Comparison between the three technologies

When comparing various methods of electricity production, it is most crucial to look at the following categories: purpose, functional unit, system boundary, included/excluded life cycle stages, and GWP results. It ensures that the calculation of environmental impacts takes place using an equivalent level of service and life cycle coverage. Other categories such as geographic scope, databases, and software tools are also important, although only to the extent that they affect the underlying assumptions and data used by each study.

A detailed comparison for the 3 specific LCAs, solar PV in Hungary, nuclear power in Switzerland, and coal power in Indonesia, can be seen in Table 3.

Table 3: Comparison of selected LCA studies for solar PV, nuclear power, and coal power

Category	**Solar PV – LCA 1 [1]**	**Nuclear – LCA 1 [4]**	**Coal – LCA 2 [7]**
Study focus	20 MWp grid-connected PV plant in Hungary	Swiss nuclear power plants: Gösgen and Leibstadt	Remote coal-fired power plant in Central Kalimantan, Indonesia
Purpose	Electricity generation from a PV park	Electricity generation from nuclear power	Electricity generation from coal combustion
Functional unit	1 kWh AC electricity	1 kWh electricity generated at the power plant	1 kWh electricity generated
System boundary	Cradle-to-grave	Cradle-to-grave	Gate-to-gate
Included stages	PV module production, mounting structure, inverters, cables, transport, installation, operation, maintenance, end-of-life treatment	Uranium mining, milling, conversion, enrichment, fuel fabrication, construction, operation, decommissioning, radioactive waste storage	Plant operation, coal combustion, water and chemical inputs, operational emissions
Excluded stages	Capital equipment, commuting, administration, marketing, R&D, decommissioning energy	Fuel reprocessing	Coal mining, coal transport, plant construction, infrastructure, decommissioning, end-of-life
Main GWP result	6.57 g CO_2-eq/kWh	5.6 g CO_2-eq/kWh for KKG; 9.4 g CO_2-eq/kWh for KKL	1.29 kg CO_2-eq/kWh
Geography	Hungary / European data	Switzerland	Indonesia
Main data sources	Primary plant data + ecoinvent 3.5	Primary plant data + ecoinvent 3.3	99% plant data + ecoinvent for missing data
LCIA method / software	PEF methodology	SimaPro 8	OpenLCA

The three technologies can be partially compared since they assess the same function, which is electricity generation. Moreover, the same functional unit, which is 1 kWh of electricity generated, was used in all three LCAs. Nevertheless, these LCA analysis cannot be fully compared because of various system boundaries, assumptions, database, geographical location, and impact assessment techniques. Specifically, the study on coal uses cradle-to-gate or gate-to-gate system boundaries, whereas the studies on photovoltaics and nuclear power involve cradle-to-grave system boundaries.

A LCA Questionnaire

A.1 Goal and scope

A.1.1 Goal of LCA

a) What is the intended application of the LCA study?

b) What is the purpose of the LCA study?

c) Who is the intended audience of the LCA report?

d) Is the LCA study based on a comparative analysis?

A.1.2 Scope of LCA

e) What is the function(s) of the product and which functional unit has been applied?

f) Plan and describe the system boundaries of the LCAs using a process flow diagram showing the processes, their relationships, and the function of the system.

g) What data and type of data are needed to calculate inventory results and selected impact assessment categories?

   - Data quality requirements, assumptions and limitations
   - Data acquisition: Is the data measured, calculated or estimated? How much of the data required is primary data (in %) and how much data is taken from literature and databases (secondary data)?
   - Time-reference: When was the data obtained and have there been any major changes since the data collection that might affect the results?
   - Geographical reference: For what country or region is this data relevant?
   - Is the secondary data from literature or databases representative for state-of-the-art-technology or for older technology?
   - Precision: Is the data a precise representation of the system?
   - Completeness: Are any data missing? How are data gaps filled?
   - Representativeness, consistency, reproducibility: Is the data representative, consistent and can it be reproduced?

h) What impact categories are used?

A.2 Results of Life Cycle Impact Assessment (LCIA)

a) State the results of the different impact categories in numbers.

b) Interpret the two case studies by considering the following:
Results are checked and evaluated to check if they are consistent with the goal and scope definition. This includes: identification of significant issues (e.g. inventory elements or impact categories missing) and evaluation/interpretation of results (e.g. comparability)

B References

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