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HARMONISED LCA FOR WIND POWER

Environmental profiles of electricity generation from wind energy: Aims and needs for harmonised life cycle assessment

Authors:

Alena Frehner[1], Matthias Stucki[1], René Itten[1], Léa Braud[2], Vinit V. Dighe[3], Peter Garrett[4], Adrien Guilloré[5], Dominik Huber[6], Cristina-Maria Iordan[7], Samuel Kainz[5], Andrea Melet[8], Katerina Milerova[9], Nicholas Nenni[8], Aje Singh Rihel[10], Rosa Garcia Sanchez[9], Joanna Schlesinger[11], Karlien Wouters[12]

[1]Zurich University of Applied Sciences, Institute of Natural Resource Sciences, Grüentalstrasse 14, 8820 Wädenswil, Switzerland

[2] Department of Sustainable Development, Environmental Sciences, and Engineering (SEED), KTH Royal Institute of Technology, Stockholm, Sweden

[3]TNO, Wind Energy Department, The Netherlands

[4]BEng/MEng MRes CEng IMechE, Vestas Wind Systems

[5]Wind Energy Institute, School of Engineering and Design, Technical University of Munich (TUM), Germany

[6]Electric Vehicle and Energy Research Group (EVERGI), Vrije Universiteit Brussel, Belgium

[7]SINTEF Ocean, Climate and Environment Department, Trondheim, Norway

[8]GE Vernova, U.S.A. and Spain

[9]Ørsted A/S, Spain

[10]Esgian AS, Oslo, Norway

[11]Mines Paris – PSL University, France

[12]TNO, Circularity & Sustainability Impact Department, The Netherlands

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HARMONISED LCA FOR A ROBUST COMPARISON OF WIND POWER

Up-to-date and robust life cycle assessments (LCA) are an essential basis for the scientific and comprehensive comparison of the environmental impacts of electricity generated by different wind energy generation technologies. This comparison extends also to other renewable and non-renewable electricity generation technologies. Additionally, environmental impacts determined by LCAs are increasingly included as a requirement in the tender process for new offshore wind projects. The costs of wind energy have been massively decreased in the last two decades due to improved technology and supply chain maturity. It is therefore crucial to simultaneously improve the knowledge and performances on environmental impacts from technology design and system integration, using robust and well-adopted LCA methods. Currently, there is a great variation in the LCA results of wind power depending on considered technology and location, modelling choices, and background inventory databases used. The IEA Wind Task 11 Topical Expert Meeting #105 in September 2023 discussed the current state of LCA of electricity generation from wind energy and proposed recommendations for a more harmonised methodological approach.

Motivation

Based on the discussions during the IEA Wind Topical Expert Meeting TEM#105 on September 21st-22nd 2023 in Wädenswil, Switzerland, the 30 participants from 11 countries agreed on the need for more comparability of LCA studies in the context of wind energy though increased consistency and transparency.

In order to achieve increased consistency, harmonization of LCA could apply at different levels e.g., project, plant, turbine, technology, etc. and for different purposes (e.g. academic, product declaration, auction, etc.).

The objective to include non-price criteria for carbon-content (leading to decarbonisation) in the design of renewable energy auctions needs to be assessed. However, currently LCA methods in the wind energy industry are based on a non-harmonized approach, resulting in inconsistent and incomparable results. Therefore, it is advisable to enable the use of LCA in energy policy and auction design based on officially adopted international harmonised LCA guidelines in the wind industry, including guidelines for project-specific LCAs, as well as potential LCA at technology-level evaluations. Such guidelines should follow the LCA framework of ISO 14040 and ISO 104044 and could provide a platform in future for consistent and comparable non-price criteria, that rewards wind projects with lower environmental impact in government policy and auction design.

Main challenges regarding LCA studies of wind power

Conducting LCA studies of wind power is a complex task that comes with a variety of challenges. In order to establish harmonised and consistent approaches, it is crucial to identify such challenges. Based on the discussions during the TEM#105, Table 1 shows an overview of the frequent challenges identified when conducting LCA studies of wind power.

The main challenge is the lack of consistent approaches, which consequently impedes the comparability between LCAs of wind power. LCA studies generally show significant discrepancies regarding the main parameters of wind power plants. Consequently, an important challenge regarding harmonisation consists of establishing comparable but flexible LCA approaches to account for site-specific differences.

The lack of transparency describes another major general challenge to the harmonisation of LCA of wind power. In order to create consistency and ensure transparency, it is necessary to define a minimum set of parameters that need to be harmonised. These parameters encompass aspects of the goal and

scope, life cycle inventory, and impact assessment as well as communication of the LCA results. Depending on the specific LCA purpose, the set scope for parameters to be harmonized differs. Examples for different LCA scopes are project LCAs that are location specific and turbine LCAs that are product specific.

Depending on different use cases, another key challenge identified when conducting LCAs of wind power regards data availability. Issues with data collection due to limited access to information is mainly associated with primary data on individual components and their material composition, wind-specific manufacturing data for all supply-chain processes, energy yields, and general data regarding offshore installations, operation, maintenance and end-of-life treatment. When primary data cannot be collected, inventories for generic wind farm components (e.g., wind turbines, cables, foundations etc.) could be used and be adjusted to fill in the data gaps. One major challenge is also related to confidentiality concerns, which often impedes the disclosure of data and transparency of LCA studies. One possible solution is to aggregate the data, ideally at a process level.

Modelling the End-of-Life (EoL) phase, which often extends into the distant future, represents a specific point of uncertainty. EoL modelling heavily relies on methodological choices concerning system boundaries, open-loop or close-loop recycling approaches and allocation methods. There is a notable absence of consensus and uniformity regarding these decisions, including credit allocation for different LCA studies. This point might differ from who/why an LCA is conducted (design perspective, tender-process, etc.), but clear guidelines should be clarified.

What further complicates the performance of LCA of wind power is the wide technological diversity of wind power plants, concerning the general differences between onshore, offshore, and airborne wind power plants, as well as vast differences in foundation types and technological readiness levels (TRL). LCA studies that analyse projected wind energy installations which are not based on existing products face very high uncertainty as the wind turbine performance (e.g. driven by the aerodynamic blade profiles) is typically not available in detail, but has a substantial impact on the LCA results. The fast-moving change in wind technology also poses a relevant challenge, as with this arises the need for consideration of impacts over time (e.g., through prospective LCA). There is yet a lack of agreement on how to tackle these issues and whether a standardisation for prospective LCA of wind power would be needed.

Finally, there is a need to establish standardized reference cases for comparing LCA results in the field of wind power. Such a reference database should focus on well-established technologies including onshore and bottom-fixed offshore installations. Such fully published reference cases using generic data would be very useful for methodology guidelines as well as providing reference “default” inventory and processes data when no other case-specific detailed data can be obtained by LCA practitioners. Additionally, these reference cases could be useful such that significant variation of new LCA results compared to it would need to be justified, to increase reliability and transparency. Establishing reference cases for LCA studies of wind turbines and farms additionally inheres great collaboration opportunity with IEA Wind Task 55 (starting in November 2023) which focuses on reference turbine and farm definition.

An additional challenge with the mentioned issues is the need for primary data collection and exchange of information in the wind industry supply-chain across actors in the supply chain - starting from material extraction, through trading, processing, manufacturing, up until the wind developers. In order to move towards harmonisation and come to agreements regarding these topics, creating an intersectoral platform gathering actors from academia, industry, and governments across different regions and along the entire value chain would be crucial to ensure information exchange.

Table 1: Overview of the most frequent challenges encountered in LCA studies of wind power.

Challenge	Comment
Lack of consistent approach	• Lack of consistency and comparability ➔ within wind energy as well as between other energy generation technologies (e.g., solar energy) • Lack of industry standards • Discrepancy in main parameters • Variability of regulations between different countries • Inconsistent definition of the system boundaries of LCA studies on wind power • Lack of LCA guidance for tendering process
Limited data availability	• Regarding primary data, manufacturing data, yields, offshore data in general • Inventory databases tend to be outdated • Confidentiality or IP concerns regarding disclosure of data ➔ Aggregating data: ideally at process level
Lack of transparency	Minimum set of parameters and assumptions to meet reporting requirements: • Specified for Goal & Scope • Life Cycle Inventory • Life Cycle Impact Assessment • Communication
EoL modelling	Inconsistent modelling choices or system boundaries in the modelling of the End-of-Life (EoL) and between the modelling of recycled material as input and as output.
Technological diversity	• Offshore / onshore / airborne • Horizontal / vertical • Foundation types • Floating vs bottom-fixed for offshore • Technological Readiness Levels
Fast-moving technological change	LCA for projected future wind energy: Need for consideration of impacts over time. ➔ Standardisation of prospective LCA
Reference case	Lack of reference case(s) for standard comparison of LCA results ➔ General data that represent average wind power plants
Information exchange	Lack of intersectoral platform for information exchange ➔ Not all stakeholders in the supply chain are represented in TEM #105

Objective Statement TEM#105

With regard to the identified challenges of LCA of wind power, the conclusion of the TEM#105 is the following:

“There is a need for international collaboration in order to work towards harmonisation of environmental life cycle assessment of wind power. This collaboration shall include different actors and stakeholder groups such as industry, academia and regulators.”

Primary objectives of such a collaboration would be to:

“Provide a harmonised framework for LCA of electricity generation from wind energy, enabling consistent and transparent LCA results with increased comparability for sustainable long-term decision support.”

It is envisaged that a new IEA Wind TCP Task could deliver the following outcomes:

a) Produce documented Methodological guidance defining harmonised LCA of wind power with the purpose of consistent application of LCA including LCA use-cases at plant level, turbine level and technology level.
b) Ensure there is coordination and alignment with (or updates to) existing ISO standards and development of IEC standards under IEC/TC88, where relevant.
c) Build a platform for consistent and comparable decision support for use of LCA in government policy and energy auction design, including potential non-price criteria.
d) Support the scoping of LCA-related requirements for developing a digitalised platform for data exchange in the wind industry for the collection and sharing of primary data in the supply-chain.

Draft parameters for harmonisation

Within the identified challenges described above, a set of specific parameters can be identified that require harmonisation in order to create consistency and enable comparability between LCAs of wind power. Table 2 shows a draft overview of the relevant parameters in question. For site-specific LCA studies the inventory modelling should consider these parameters with site-specific data whereas for product-specific LCA studies that do not refer to a specific site, reference data for the most important wind energy types (onshore, offshore, etc.) may be applied.

The #TEM participants recommend to transparently declare these parameters in all LCA studies. Furthermore, each LCA should specifically declare its objectives, and target audience.

A new platform could facilitate the consistent use of LCA in policy and auction design.

Table 2: Draft overview of relevant parameters for harmonisation of LCA of wind power which will be further developed for different LCA use cases such as on project, turbine, and technology level.

		Harmonisation parameter
Target audience		Explicitly specify target audience and use case for each LCA study (e.g., policy makers, auctions, R&D, suppliers etc.)
Scope / system boundary	Modelling approach	• Cradle-to-grave • To include all infrastructure up to the grid connection
	Preparation	Site survey to be included
	Manufacturing	To be divided into: • Production and • Processing of materials
	Transportation	• Transportation to collection point (e.g., port) Transport infrastructure to be included.
	Installation	Offshore specific: • Transportation of components from port to farm area
	Operation & Maintenance	To be included but the how's are to be defined
	Decommissioning & EoL	• To be included, but the how's are to be defined. • Modelling of recycling to be consistent regarding input and output materials modelled (also consistent with modelling of manufacturing)
Functional unit		1 kWh AC electricity, delivered to the grid (onshore substation) For comparability report also per MW capacity.
Lifetime		• Turbine and electrical infrastructure to be addressed differently • Depends on the purpose / scope of the LCA ➔ Guidance can reflect these different purposes
Electricity yield & capacity factor		Measured/calculated data (electricity in kWh/year/turbine or park) Define standard assumptions, in case of lack of site-specific data
Inventory databases		Consensus needs to be found
Impact categories		Consensus needs to be found
Uncertainty		Include an uncertainty assessment of foreground and background data

Participants of the TEM#105, September 21st-22nd 2023

Surname	Name	Institution
Philipp	Beiter	National Renewable Energy Laboratory
Alicia Maria	Benitez Britos	IEK-STE Jülich Forschungzentrum
Léa	Braud	KTH Royal Institute of Technology
Jungchul	Choi	Korea Energy Technology Evaluation and Planning
Vinit	Dighe	TNO
Alena	Frehner	Zurich University of Applied Sciences
Rosa	Garcia Sanchez	Ørsted
Peter	Garrett	Vestas Wind Systems
Adrien	Guilloré	Technical University of Munich
Dominik	Huber	Vrije Universiteit Brussel
Cristina-Maria	Iordan	SINTEF Ocean
René	Itten	Zurich University of Applied Sciences
Samuel	Kainz	Technical University of Munich
Si-Jing	Liu	Shell
Andrea	Melet	GE Vernova – Offshore Wind
Benjamin	Metayer	Engie
Pascal	Müller	Elektrizitätswerk Der Stadt Zürich
Nicholas	Nenni	GE Vernova – Onshore Wind
Lionel	Perret	Planair SA
Aje Singh	Rihel	Esgian
Florian	Sayer	Fraunhofer IFAM
Joanna	Schlesinger	Mines Paris Engineering School
Oliver	Stephenson	Esgian
Matthias	Stucki	Zurich University of Applied Sciences
Karin	Treyer	Paul Scherrer Institut
Alexander	Vandenberghe	WindEurope
Karlien	Wouters	TNO