Power system sustainability and environmental performance
SPECIAL REPORT FOR SC C3

Special Reporters
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A few words about Session Papers

Session Papers are focussed on a number of Subjects, referred to as 'Preferential Subjects', selected in advance by the 16 Study Committees of CIGRE and available in the Call for Papers.

Session Papers are selected through a two-phase review process – abstracts and full Papers.

To gain an overview of subjects that will be discussed, have a look at the Technical Programme for a list of the Papers selected for the Session. It is updated as the Full Paper review proceeds.

CIGRE Sessions

At CIGRE Sessions authors are given the opportunity to present their Paper during half-day specific meetings – the Poster Sessions.

Four days are also dedicated to 'Group Discussion Meetings' organised by Study Committees. Four meetings run simultaneously each day from Tuesday to Friday, under the presidency of the Study Committee Chairs. The purpose of these meetings is the discussion of the "Special Reports" which incorporate the gist of the Session Papers and pose a number of questions for discussion: the questions and how to respond are below.

The Special Reports are available to all (from the end of May) on the Session page of the CIGRE website.

For fruitful discussions delegates are strongly encouraged to read the Papers before the Session.

The Session Papers are made available for downloading to all duly registered delegates before the Session through their private account on the registrations portal. Papers are also readable on the Session smartphone application while on site in Paris.
Follow the latest Session news and General Programme by regularly visiting our website!

The scope of **Study Committee C3** covers the identification, assessment, and management of the interactions between the natural and social environments and the electricity system throughout the life of the infrastructure (cradle to grave), recognising the importance and influence of stakeholders and communities and seeking to anticipate changes in the energy system and the environment.

SC C3 has selected 69 papers for the 2026 CIGRE session aligning with the three preferential subjects, all of them well aligned with the Strategic Directions of the SC C3:

- **PS1 - Biodiversity conservation & enhancement. Towards positive contribution (24 Papers)**
    - Mitigating the impact from power system infrastructure: new renewable generation facilities, transmission and distribution. Preventive and corrective measures: nature inclusive design, commissioning, asset management and end of life.
    - Offsetting measures & ecosystems restauration. Net Zero impact and positive impact. How to measure?
    - New standards regarding biodiversity. i.e. IPBES; TNFD
- **PS2 - Building a more sustainable power system for the future (33 papers)**
    - Identification, quantification and assessment of impacts. Tools and methodologies. LCA approach, considering climate change and beyond.
    - Eco-design to reduce impacts.
    - Innovative solutions to enhance circularity.
- **PS3 - Disclosing sustainability (12 papers)**
    - Reporting standards & regulation. Indicators.
    - Stakeholder reporting requirements. Impact of disclosure on social perception and acceptance.
    - Value chain information, strategies and methodologies to obtain complete and reliable information.

One out of the 69 selected papers were submitted as part of Next Generation Network (NGN) Young Member showcase competition.

PARTICIPATING IN THE 2026 PARIS SESSION

1. Group Discussion Meeting

You are invited to participate in discussing this Special Report at the **SC-C3** session held on **28th August 2026** starting at 08:45 in **352AB** at the Palais de Congress de Paris.

In the following sections, a summary of each PS is presented along with corresponding discussion questions that have been prepared by the Special Reporters. A summary of each paper is provided at the end of the report for completeness.

Responses and contributions to the questions offered throughout this Special Report are invited for presentation during the **SC-C3 GDM**. The questions compiled by the reporters are not specifically aimed at the papers 'authors but are synthesised from common issues and trends identified across the papers.
This provides the opportunity for a broader response and participation in the discussion session. We encourage you to share your views or experiences in response to the specific questions in this report.

During the Group Discussion Meeting, each prepared contribution will be allocated a time slot of two to three minutes for a presentation.

We encourage you to share your views or experiences in response to the specific questions in this report. During the Group Discussion Meeting, each prepared contribution will be allocated a time slot of three to four minutes for a presentation.

Procedure for contributions.

a) Contributors should upload contributions on the registrations portal – "Contributions to Group Discussion Meetings" section - using your existing account and own credentials before **7th August 2026**, for a prior screening and a good organization of the Group Discussion Meeting. Prepared contributions which are received after the deadline will not be considered for presentation at the GDM.

Important points:

b) Access to contribution uploading is given only to duly registered delegates.

- Therefore, registration to CIGRE Session should be finalized before uploading contribution(s) online.
- Register now for the Session registrations
- Contributions uploading will be open at start from early June 2026.

c) A guide for contributors as well as templates and sample pages is available on the Paris Session webpage: Contributors | Session CIGRE

d) Special Reporters will review the prepared contributions for readability, technical/scientific content (no commercial information is allowed) and relevance to the questions posed in this Special Report. (*Power point presentation with max **3-4** slides including the title slide and a written word file with max 1000 words pr contribution*).
Important notice: **No commercial names are to be included in presentation or the written summary (even TSO/DSO names)**.

e) Any recommendations or changes to the contributions will be provided to the contributors by the Special reporters directly on the Registration platform. Contributors are encouraged to visit their account on the registrations portal to see the result of this review.

f) All contributors with accepted/finalised contributions will be contacted by the Special reporters, to finalize the presentation and receive the instructions regarding the session.

g) Important note:
- All contributions must be uploaded prior to the Conference in Paris.
- Last minute changes to the contributions will not be granted.

It is expected that the questions relevant to the Preferential Subjects will attract many prepared contributions. The number of contributions for each Preferential Subject (PS1, PS2 and PS3) may need to be limited. The selection will be based on relevance, quality and time of submission of the contribution.

h) Please note that accepted contributors will be required to attend a short pre-session meeting with the Special Reporters, SC Chair and SC Secretary on **27th August 2026**. You can meet them at **08:45 to 13:00** in **Room 237** at the Palais des Congrès to finalise presentation arrangements. The purpose of this short meeting is to review the final details of their contribution and to receive the latest instructions (such as schedule).

i) During the GDM the Study Committee Chair may call for spontaneous contributions, which will only be verbal with no slides. All attendees are eligible to make such a contribution. Attendees who provide a spontaneous contribution are allowed to deliver a written contribution which will be included in the Session Proceedings. This text is required to be forwarded within a maximum delay of **two weeks after** the Study Committee GDM Session (**28th August 2026**) to the SC Secretary (asalinas@redeia.com)

2. Poster session

Authors of SC-C3 Session papers are required to present their papers during the **SC-C3 Poster Session scheduled on Thursday 27th August 2026 (14:00 to 18:00)** in Halle Ternes on level 1 **Room 2**. Template and instructions on poster preparation are available on the CIGRE 2026 Session website and Authors | Session CIGRE

Posters will be displayed on digital screens.

A draft copy of the poster must be uploaded on the ConfTool platform **from 20th May by 29th June** at the latest for review by the poster session convener.

Poster conveners may ask for a final version, incorporating any requested changes, must be uploaded by **August 14th**. It should be noted that authors will **not** have the possibility to upload their own file on the day of the Poster Session. If the author(s) cannot attend the Poster Session, he/she or the relevant National Committee is requested to send a substitute.

3. Tutorial

The following C3 tutorial and workshops will take place during the week:
• C3 tutorial: "Ecodesign methods for the power system", presented by **Michael Gatzsche**. **Monday 24th August (08:30 to 10:20)**. Bourdeaux Hall

SUMMARY OF KEY DATES

Date	Time	Action	Location
Monday 29th June 2026	End of day	Deadline for submission of posters for all accepted paper authors	ConfTool platform
Friday 7th August 2026	End of day	Deadline for uploading prepared contributions for the GDM	Registrations platform
Friday 14th August 2026	End of day	Deadline for submission of final versions of posters for all accepted paper authors (if changes are required)	ConfTool platform
		Deadline for uploading final prepared contributions for the GDM (if changes are required)	Registrations platform
Monday 24th August 2026	08:30 to 10:20	SC C3 Tutorial "Ecodesign methods for the power system"	**Bordeaux**
Thursday 27th August 2026	08:45 to 13:00	Authors of accepted prepared contributions: short pre-session meeting with the Special Reporters	**Room 237**
	14:00 to 18:00	SC C3 Poster session	**Halle Ternes (Level 1) Room 2**
Friday 28th August 2026	08:45 to 18 :00	SC C3 Group Discussion Meeting	**352AB**
Friday 11th September 2026	End of day	Deadline for submission of spontaneous contributions to be included in the Session Proceedings	**Email to SC-C3 Chair and SC C3 Secretary**

PS1: Biodiversity conservation & enhancement. Towards positive contribution

General

The energy transition is driving an unprecedented expansion of electricity infrastructure—renewable generation, transmission and distribution networks—that increasingly interacts with natural ecosystems. Within this context, the PS1 preferential subject highlights a shift from impact mitigation towards achieving a net positive contribution to biodiversity, requiring the integration of ecological considerations across the entire asset lifecycle.

The reviewed papers show a clear evolution from reactive approaches to more systemic strategies based on nature-inclusive design, spatial planning, adaptive management and targeted technical solutions. There is growing use of analytical tools—such as GIS mapping, biodiversity indicators and TNFD-aligned frameworks—to identify impacts, prioritise interventions and support more robust, evidence-based decision-making.

A key trend is the integration of biodiversity into operational and planning processes: from siting and design decisions to vegetation management, avifauna protection and offshore ecosystem enhancement. These approaches combine preventive, corrective and restorative measures, increasingly incorporating offsetting strategies and ecosystem restoration to deliver measurable ecological gains. At the same time, significant attention is being paid to the challenge of quantifying "net impact" and advancing from no net loss to biodiversity-positive outcomes, despite current methodological and standardisation gaps. International frameworks such as TNFD and IPBES are beginning to shape how companies assess dependencies, risks and opportunities, and how they align their strategies with global expectations.

Finally, the papers highlight that achieving a genuinely positive contribution requires an integrated perspective—technical, ecological and regulatory—supported by strong governance and stakeholder engagement, and covering the full lifecycle of assets, including design, commissioning, operation and end-of-life.

Paper description and discussion

24 papers were accepted for PS1, which can be divided into 3 groups:

1. Monitoring & indicators

The papers grouped under Monitoring & Indicators collectively address a key enabling dimension of biodiversity-positive grids: the ability to measure, understand and manage interactions between energy infrastructure and ecosystems in a consistent and actionable way. They move beyond descriptive monitoring towards structured, data-driven approaches that link observation, analysis and decision-making.

A central theme is the combination of field-based evidence—such as species behaviour, collision patterns or habitat use—with spatial and digital tools, including GIS mapping and modelling techniques, to identify high-risk areas and prioritise interventions across large networks. This integration significantly enhances the capacity to anticipate impacts rather than react to them.

Another common focus is the development and use of indicators and bioindicators capable of translating complex ecological responses into operational metrics. These tools enable grid

operators to track performance, assess the effectiveness of mitigation measures and progressively align with emerging reporting frameworks.
Importantly, the papers highlight that monitoring is not an end in itself, but a feedback mechanism that supports adaptive management, continuous improvement and scaling of best practices. Together, they illustrate the transition towards evidence-based biodiversity management, where robust metrics and monitoring systems become critical to demonstrating tangible progress towards nature-positive infrastructure.

- **C3-10900**. Biodiversity indicators or bioindicators: useful examples for transmission grid operators.

- **C3-10898**. Exploring the potential of remote sensing and digital tools for ecological vegetation management in power line corridors

- **C3-10899**. Birds & fishes: Monitoring strategies to identify and assess impacts of submarine and aerial power cables & substations

- **C3-11100**. Birds nesting on pylons of transmission lines in Portugal: results of the first national-scale survey with proposal of measures to promote and protect species of conservation concern

- **C3-10301**. Lights, Camera, Biodiversity! ROV video insights from an Offshore High-Voltage Station and NIDs in the Dutch North Sea

- **Question 1.1.** What level and type of monitoring is needed to effectively support decision-making in power system operations and planning? In particular, how can monitoring approaches (from field observations to advanced tools such as GIS, telemetry or eDNA) be designed so that results are reliable, proportionate and clearly linked to operational decisions?
- **Question 1.2** How can the sector move towards a robust and standardized set of biodiversity indicators? How can we ensure these indicators reflect real ecological outcomes (not just proxies), while dealing with uncertainty, data gaps and the limitations of large-scale models?

2. Nature-Inclusive Design, Planning & Management

The papers grouped under Nature-Inclusive Design, Planning & Management address how biodiversity considerations can be embedded directly into the design, location and operation of power system infrastructure. Rather than focusing only on impact reduction, they explore how infrastructure can actively contribute to ecological value across different environments, from terrestrial corridors to offshore systems.

A central theme is the integration of nature-inclusive principles from the earliest project stages, including siting, technology choices and design solutions that reduce risks for species and habitats. This is complemented by a wide range of technical and operational measures—such as species-specific mitigation devices, habitat management in rights-of-way, and adaptive operational practices in hydropower or wastewater management.

These papers also highlight the importance of spatial planning and risk mapping to identify conflict areas and guide preventive measures, particularly in relation to avifauna interactions and infrastructure placement. In parallel, they show how infrastructure can be adapted to provide ecological functions, for example through habitat enhancement, restoration or multi-functional land use.

A key takeaway is the need to manage biodiversity throughout the full lifecycle of assets, combining design, operation and maintenance decisions in a coherent way. Together, the papers illustrate a shift towards integrating engineering, ecological knowledge and planning tools to deliver infrastructure that is not only less harmful but increasingly aligned with biodiversity conservation objectives.

- **C3-10131**. Nature Inclusive Design for an artificial energy island – from ideation to implementation
- **C3-10340**. Powerlines and the Eastern Osprey: The challenges and opportunities of balancing a safe and reliable electricity distribution network with an iconic raptor species in New South Wales, Australia
- **C3-10471**. Integrating Nature-Inclusive Design and Lifecycle Management for Biodiversity-Positive Power System Infrastructure
- **C3-10892**. Offshore Experiment on biomimetic solutions aiming at limiting sediment erosion over submarine assets
- **C3-10901**. Submarine cables and marine biodiversity: Feedback on implementing avoidance and minimization measures as well as monitoring environmental impacts
- **C3-10959**. Application of Repellent Gel to the Surfaces of Transmission Towers for Wild Bird Management
- **C3-11080.** Hydropower Operation and Fish Conservation: Challenges of a Changing Energy Matrix
- **C3-11098.** Reconversion of Powerline Rights-of-Way: Biodiversity, Resilience and Local Value in the Face of Climate Change and Wildfires
- **C3-11256.** Placement of Renewable Energy Sources-Based Power Plants Considering Biodiversity Impact Mitigation
- **C3-11798.** Prevention of mortality and power outages on 22 kV lines related to mute swan collisions by using bird flight diverters in Slovakia
- **C3-12350**. Development of Collision Risk Maps Between Birds and Power Transmission Lines with an Assessment of Applicable Mitigation Measures
- **C3-12544**.Towards positive biodiversity contribution from transmission infrastructure: safe osprey nesting, fault reduction and 50+ year durable mitigation design

- **C3-10163.** Environmentally Sustainable Discharge of Treated Industrial Wastewaters in the Egyptian Power System: A Case Study of Assuit West Power Plant

- **Question 1.3** At what stage of project development does Nature-Inclusive Design have the greatest impact, and how can it be embedded as a standard practice rather than a project-specific approach? How do we balance biodiversity ambitions with technical constraints such as cost, safety and system reliability?
- **Question 1.4** To what extent existing infrastructure can be transformed into nature-inclusive assets, and how should retrofit actions be prioritised? What should define "success" for these interventions: reduced impacts (e.g. mortality), behavioural change, ecosystem improvement, or operational performance?
- **Question 1.5** Are we truly moving towards biodiversity-positive infrastructure at system level, or mainly improving mitigation practices? What role do planning tools, adaptive management and uncertainty play in avoiding unintended ecological effects and ensuring long-term effectiveness?

3. Frameworks (Strategy & Governance)

The papers grouped under Frameworks (Strategy & Governance) focus on how biodiversity is being integrated at a strategic level within the electricity sector, moving beyond individual projects towards structured, organisation-wide approaches. They address how companies assess, manage and report their impacts, dependencies, risks and opportunities related to nature in a more consistent and forward-looking way.

A central theme is the development of methodologies and frameworks—such as biodiversity footprinting, natural capital approaches and TNFD-aligned analyses—that allow operators to better understand their interaction with ecosystems across the value chain. These approaches support decision-making at strategic and portfolio levels, rather than only at project scale.

The papers also explore how the mitigation hierarchy (avoid–minimise–compensate/restore) can be operationalised through governance mechanisms, including offsetting schemes, compensation methodologies and structured asset management processes. In this context, the transition from "no net loss" towards "net gain" or biodiversity-positive outcomes emerges as a key ambition, although still with practical and methodological challenges.

Another important aspect is the role of governance, transparency and standardisation. The need for common metrics, comparable indicators and robust reporting frameworks is highlighted as essential to align the sector with emerging international expectations and to ensure credibility and comparability across the sector.
Overall, these papers illustrate a shift towards embedding biodiversity into corporate strategy and governance, linking technical actions on the ground with strategic planning, risk management and long-term accountability.

- **C3-10300**. Towards a nature-inclusive grid network: Identifying grounds for synergy in the Dutch grid operator sector.

- **C3-10341**.Biodiversity Offsetting: The Australian experience with case studies from the state of New South Wales.

- **C3-10889**. Forecasting Nature's Footprint: Co-Building Biodiversity Metrics for Tomorrow's Electricity Mix.

- **C3-11507**. Analysis and assessment of impacts, dependencies, risks and opportunities related to nature in electricity transmission.

- **C3-11505** Biodiversity compensation methodology based on natural capital & mitigation hierarchy.

- **C3-12545**. Wildlife-caused outages and mortality in substations: from wildlife mitigation to durable biodiversity-positive asset management.

- **Question 1.6** How can current biodiversity frameworks and methodologies (e.g. TNFD, footprinting, natural capital approaches) better support real decision-making across the full value chain of the electricity sector? Where do they add most value today, and where are the main gaps (e.g. indirect impacts, cumulative effects or practical applicability)?
- **Question 1.7** How do we ensure that biodiversity commitments—such as offsets, compensation or mitigation strategies—translate into real, measurable ecological outcomes on the ground? What factors most influence success or failure, and how can these approaches be improved or made more credible?
- **Question 1.8** What is currently the biggest challenge in scaling biodiversity-positive practices across the sector Is it mainly related to measurement, implementation, governance or coordination? How can better integration between strategy, monitoring and on-the-ground actions help scale best practices across different operators and regions?

PREFERENTIAL SUBJECT 2

PS2: Building a more sustainable power system for the future

General

The contributions to this preferential topic provide a comprehensive perspective on building a more sustainable and resilient power system.
A central theme is the growing use of structured methodologies – particularly Life Cycle Assessment (LCA) – to identify, quantify, and assess environmental impacts. Additional decision-relevant indicators are proposed include more environmental and social dimensions and open a broader perspective on sustainability.
In parallel, several contributions highlight the role of Eco-design in reducing impacts if used at early stages of equipment and infrastructure development, complemented by innovative solutions such as circular material strategies, asset refurbishment, and low-carbon technologies. Digitalisation emerges as an important enabler, supporting optimisation of environmental performance.
Several contributions regarding resilience to climate change have been made. Many papers demonstrate that sustainability and resilience are closely linked, requiring integrated approaches that combine environmental assessment, system planning, and long-term adaptation strategies.

Paper description and discussion

33 papers were accepted for PS2, which can be divided into 6 groups:

1. Circular Economy & Material Sustainability

The five papers in this group focus on the role of circular economy principles and address material criticality, supply risks, and sustainability challenges. The papers collectively highlight the increasing pressure on key materials – particularly copper and specialty metals – driven by grid expansion and electrification.
A central theme is the development of circular strategies such as closed-loop recycling, refurbishment, and reuse of components, which can significantly reduce environmental impacts and improve supply chain resilience. Case studies demonstrate tangible benefits, including reduced emissions, cost savings, and shorter lead times.
However, the research also identifies structural limitations of circularity. Recycling alone cannot fully meet future material demand due to growing infrastructure needs, technical constraints, and regulatory barriers. Therefore, a combination of circular design, improved asset management, and policy interventions is required.
Overall, the papers emphasize that circular economy approaches are essential but must be complemented by systemic changes in regulation, supply chains, and asset planning to ensure long-term material sustainability.

a) Circular Supply Chains & Critical Materials

- **C3-10132**, A closed loop business model: a significant contribution for European TSO's to face copper scarcity?
- **C3-10895**, Material Flow Analysis of Geo-Economic Tensions Affecting the Supply Chains of Low-Carbon Technologies: The Case of the Electric Grid

b) Circular Design Strategies & End-of-Life Technologies

- **C3-12313**, Advancing Circularity in Transformers: Update on recent Solutions and Impacts
- **C3-12122**, Circular Economy in Power Transformers: Financial Opportunity and Climate Solution in Colombia.
- **C3-10963**, Effect of the Fluorine Resource Conversion Process of SF6 Gas for a Circular Economy

- **Question 2.1.** C3-10132, C3-10895, C3-12313 and C3-12122 describe to what extent circular supply chains can realistically reduce dependency on primary materials in rapidly expanding power systems. Which additional proposals and alternatives can be made to derisk supply chains?

- **Question 2.2.** C3-12313, C3-12122 describe the challenges in maximizing circularity at end of life. Which established or innovative processes can be used for the treatment of materials with high impact? Which specific requirements for manufacturers and regulation should be raised? What could be channels to communicate these requirements?

2. Life Cycle Assessments & Evaluation Methodologies

The eight papers in this group address the development and application of Life Cycle Assessment (LCA) and related environmental evaluation methodologies. The contributions highlight LCA as a key decision-support tool for quantifying environmental impacts across the full lifecycle of equipment and infrastructure.
A major focus lies on methodological consistency, data quality, and comparability. Several studies emphasize that differences in system boundaries, assumptions, and data sources can lead to significantly divergent results, underscoring the need for harmonized standards and transparent reporting frameworks.
Beyond traditional carbon-focused assessments, the research expands environmental impact assessment toward integrated, multi-impact approaches that consider resource use, land impacts, and social dimensions. Case studies demonstrate that lifecycle impacts are often dominated by specific phases – such as material production or operational losses – while also revealing the importance of context factors like energy mix.

Overall, the papers demonstrate that while LCA is mature and widely applied, further standardization, improved data availability, and methodological refinement are essential to fully support robust decision-making and regulatory alignment.

a) LCA Harmonisation, Comparability & Standards

- **C3-10897**, Tools and methodologies to assess HV products' environmental impacts: state of the art and future trends.
- **C3-12455**, Application of new IEC TS 62271-320 for the Evaluation of Life Cycle Assessment (LCA) Methodologies in High-Voltage Switchgear
- **C3-12315**, Standardization of LCA for environmental Performance Assessment of High Voltage Switchgear: A critical Evaluation of current Challenges and Needs.
- **C3-10302**, A Life-Cycle-Based Environmental Passport for High-Voltage Substations.
- **C3-10961**, Impact of Evaluation Criteria of Power Loss in LCA.

b) Multi-Impact Assessments

- **C3-10962**, Life Cycle Impact Assessment and Weighting in Switching Station: Insights from a Case Study.
- **C3-11277**, Modular and regenerative life cycle assessment indicators for sustainable power systems
- **C3-11131**, Integrating marine archaeology into HVDC marine cable design and realization

- **Question 2.3.** C3-10897, C3-12455, and C3-10302 define requirements on harmonization and transparency beyond existing standardization frameworks, and several papers highlight the role of LCA as a tool for decision making. From the delegates' and authors' practical experience, what are the real-world decision-making cases? Derived from that, what are the standardized assumptions or project specific boundary conditions? How can environmental assessment methods balance simplicity and usability with the need for accuracy in decision-making?

- **Question 2.4.** C3-10962 and C3-11277 emphasize the need of using or even extending the full scope of LCA impact categories. What are the impact categories used today for decision making (e.g., which transformer has the lowest CO2eq, which substation has lowest land use)? How are they weighted or is there a structured approach to deal with conflicting conclusions?

3. Eco-Design, Sustainable Technologies & Innovation

The six papers in this group explore how eco-design principles and technological innovation can reduce environmental impacts across the lifecycle of power system assets. The

contributions emphasize the integration of sustainability considerations directly into design processes, supported by tools such as LCA, environmental passports, and decision frameworks.
A key contribution is the demonstration of practical applications, including the development of SF_6-free equipment, optimized conductor designs, and low-carbon fuel solutions. These innovations show significant potential to reduce emissions, material use, and operational impacts while maintaining system performance.
The research also highlights the importance of early-stage decision-making, where design choices have the greatest influence on long-term sustainability outcomes. In addition, the studies stress the need to balance environmental performance with technical feasibility, cost constraints, and system reliability.
Overall, the sub-topic illustrates that eco-design and innovation are critical levers for achieving sustainable power systems, requiring close integration of engineering, environmental assessment, and lifecycle thinking.

a) Application of Eco-Design

- **C3-10902**, An innovative Eco-design methodology for a sustainable switchgear: the case of the new 245kV GIS.

- **C3-10888**, Implementing Eco-Design at EDF HYDRO. Guidelines for Electrical Equipment.

b) Technology Assessment & Low-Carbon Solutions

- **C3-11083**, Conventional and Floating Photovoltaic Generation from a Life Cycle Perspective – Carbon and Water Footprint.

- **C3-10474**, Alternate Fuels in Thermal Power Plants: Pathways to Decarbonization and Energy Transition.

- **C3-12016**, Next Generation Overhead Lines with Carbon Core Conductors: Optimisation of Design Paradigm to meet the Needs of Energy Transition and reduced environmental Footprints.

- **C3-12622**, Life Cycle Assessment (LCA) for assessing the sustainability of high-voltage electrical infrastructure Application to the 150kV double-circuit overhead link of the Canino-Arlena power line to the Tuscania Power Station.

- **Question 2.5.** Are there more examples on how authors and delegates apply Eco-design methods on a system level, e.g., in designing a transmission system? How did the system level Eco-design affect choice or design of subsystems (e.g., substation) or equipment (e.g., transformers, switchgear)? Can we identify the common methodological, organizational and other key elements of a well-functioning Eco-design framework? Which technical information or guidelines would help the authors and delegates to apply Eco-design in their scope of work?

- **Question 2.6.** How should technology choices account for trade-offs across greenhouse gas emissions, resources use, land use, cost, and performance? How can

all these aspects be integrated into decision-making processes, e.g. by environmental cost indicators, carbon cost indicators or other methods? Are there any practical examples to share in the session?

4. Climate Change, Resilience & System Planning

The five papers in this group focus on the growing impact of climate change on power systems and the need to integrate resilience and climate considerations into planning and operation. The papers highlight both physical risks – such as extreme weather events – and systemic challenges arising from increased dependence on weather-driven renewable generation.
A key theme is the development of structured, data-driven frameworks to assess climate risks and prioritize adaptation measures. These approaches combine climate modelling, multi-criteria decision tools, and risk-based methodologies to support more resilient infrastructure planning.
The research also emphasizes the importance of high-quality, harmonized climate data and the integration of uncertainty into planning processes. Collaborative efforts and standardized datasets are identified as crucial enablers for consistent and robust system studies.
Overall, the papers demonstrate that climate resilience must become an integral part of system planning, requiring iterative, multidisciplinary approaches that balance short-term operational needs with long-term strategic adaptation.

- **C3-10111**, Enabling Efficient Integration of Renewable Energy Sources into the Grid: A Comprehensive Methodology for Assessing RES Site Suitability in Slovenia Based on Key Performance Indicators.

- **C3-10318**, Climate Adaptation in Dutch Grid Infrastructure: A Guideline Based Framework with Adaptive Feedback.

- **C3-10894**, Leveraging Climate Services to Build Climate Resilient Power Systems

- **C3-11883**, Climate Risk and Vulnerability Assessment for the Croatian Transmission Network

- **C3-12563**, Multi-Criteria Prioritization of Climate Resilience Strategies for Electric Power Networks

- **Question 2.7.** How far are resilience aspects, climate and other risks, considered in current planning processes in different organizations? What is state of the art and how mature are those processes compared to what has been presented in the studies? What practical guidance can be provided by the authors to other grid operators?

- **Question 2.8.** What are the key criteria to decide whether climate and other risk are addressed by either physical or operational measures? How is this related to existing regulations regarding capital and operation expenses?

5. Governance, Procurement & Strategy

The seven papers in this group examine how governance frameworks and procurement practices can drive sustainability across the value chain. They highlight procurement as a key

lever for embedding environmental and social criteria into project execution and supplier behaviours.
A central focus is the development of harmonized frameworks – such as CSR criteria, carbon accounting methods, and sustainability indicators – to improve transparency, comparability, and regulatory compliance. These approaches align with emerging policies and reporting requirements, enabling organizations to manage risks and access sustainable financing.
Broader governance themes such as SDG alignment and stakeholder engagement illustrate the strategic dimension of sustainability integration.
Overall, the contributions underline that achieving sustainable energy systems requires not only technical innovation but also coordinated governance, standardized methodologies, and strategic alignment across the entire value chain.

- **C3-11084**, The Role of SDGs in Shaping Sustainability in the Electric Power Sector
- **C3-11102**, Harmonizing EPD and CBAM methodologies for carbon footprinting of power transformers.
- **C3-10893**, Advancing Sustainability and CSR in Procurement: A Collaborative TSO Perspective.
- **C3-11611**, Sustainability in HVDC tenders and projects - A pathway to long-term value creation.
- **C3-12323,** A meta-analysis of Transformer Sustainability evaluations based on Customers Practices, national level policies and voluntary standards in major markets around the world.
- **C3-11161**, Environmental Controls and Lifecycle Assessment of Battery Energy Storage Systems (BESS) in South Africa: Lessons from Global Frameworks.
- **C3-12084**, Beyond 2050: Decommissioning Frameworks and Environmental Liabilities of the Electricity Sector in the EU and Latin America

- **Question 2.9.** What commonalities can be identified across current approaches to sustainable procurement, and what are the main challenges in achieving comparable environmental impact results for decision-making, particularly when such results are used as evaluation criteria in public tendering? What would be needed to move towards a harmonised and legally sound process?

- **Question 2.10.** How do the aspects of governance and sustainable procurement relate to the contributions presented in the group “Life Cycle Assessments & Evaluation Methodologies” regarding harmonization and data quality requirements?

- **Question 2.11.** What learnings from the group “Circular Economy & Material Sustainability” can be considered to develop a whole life cycle governance structure to close the gaps described in C3-12084?

6. Digitalisation

The two papers in this group explore how digitalization increasingly shapes sustainability in power systems. One paper highlights the use of machine learning to improve monitoring and prediction of emissions, enabling more efficient and environmentally informed operation. The other focuses on the sustainability of digital infrastructures themselves, proposing open-source standards to improve transparency, traceability, and eco-design.
Together, they show that Digitalisation is both an enabler of sustainability improvements and a domain that requires dedicated design principles to manage its own environmental impacts.

- **C3-11187**, A data-driven approach for predicting and monitoring nitrogen oxides emissions of natural gas CCGT in power plants with neural networks.

- **C3-10896**, Harnessing Open-Source Standards for Sustainable Digital Design in the Energy Transition.

- **Question 2.12.** How can digital tools such as machine learning be used to deliver measurable emission reductions and operational improvements in power systems?

- **Question 2.13.** As digitalisation expands, how should the sustainability of digital infrastructures themselves be assessed and integrated into overall grid sustainability strategies?

PREFERENTIAL SUBJECT 3

PS3: Disclosing Sustainability

General

Public acceptance of power system expansion and operation is increasingly dependent on quality engagement with affected stakeholders, and the reporting and disclosure of environmental performance and corporate sustainability goals.
For disclosure and reporting, many national and international requirements and frameworks exist, and transmission system operators are continually improving on their methodologies to meet and now exceed these minimum requirements. In addition, many operators are working to integrate these requirements deeper into their organizations to help educate design and procurement decisions.
At the same time, stakeholders are expecting increasing engagement and participation in how the expansion and operation of the power system will affect them, both with the physical assets, but also with direct and indirect environmental impacts. Transmission System Operators are looking beyond traditional engagement tools and practices to support these new expectations.

Paper description and discussion

A total of twelve papers were accepted for this Preferential Subject. They have been divided into two groups covering corporate reporting and stakeholder engagement, although most papers touch on multiple aspects of disclosure.

1. Corporate sustainability, including assessment, inventory, and reporting.

There are 7 papers in this group, C3-10133, C3-10470, C3-10480, C3-10481, C3-10890, C3-10891, and C3-12068, which discuss topics such as emissions accounting and inventory, material and facility passports, greenwashing, reporting, and corporate trust, credibility, and accountability.

- **C3-10133** Navigating scope 3 emissions in the context of increasing grid investments facilitating the energy transition.
- **C3-10470** Addressing Greenwashing in Sustainability Reports of Power Transmission Companies: Impacts and Solutions.
- **C3-10480** Towards Enhancing Sustainability Disclosures – A Comprehensive Analysis of SEBI's BRSR Framework.
- **C3-10481** Scientometric Analysis of Sustainability Disclosure and Stakeholder Perception Research.
- **C3-10890** Disclosing Sustainability: Throwback to First Sustainability Reporting – What Next?
- **C3-10891** Unlocking Resilience: Detailed Equipment Data for Future-proof Transmission Grids.

- **C3-12068** Enhancing the Stakeholders' Trust through a Transparent Sustainability Disclosure: A case study of a Power Company in Thailand.

- **Question 3.1.** What are the most critical barriers to achieving high quality data for reporting, and what practical approaches are showing the most promise to overcome them?
- **Question 3.2.** How do we balance the need for globally comparable, standardized reporting with the need for sector and region-specific approaches?
- **Question 3.3.** As sustainability disclosure is evolving beyond compliance how do we leverage reporting to become a decision-making tool rather than a regulatory exercise?

2. Stakeholder engagement, including land, livelihood, and environmental sustainability.

There are 5 papers in this group, C3-11081, C3-11082, C3-11264, C3-12277, and C3-12319, which discuss topics such as impact assessments and engagement methods, requirements, transparency, and tools.

- **C3-11081** Environmental Impact Assessment and Human Rights Due Diligence: Current State of the Art and Possible Convergences.

- **C3-11082** Effectiveness of Social Monitoring Forums: Comparative Analysis of Belo Monte HPP, Santo Antonio HPP and Sitio Grande SHP.

- **C3-11264** A Paradigm shift in constructing the Transmission Grid in Korea.

- **C3-12277** Stakeholder Reporting Requirements - Impact of Disclosure on Social Perception and Acceptance.

- **C3-12319** Improved Stakeholder Engagement process and transparency using geospatial cloud solutions.

- **Question 3.4.** When planning, designing and constructing power infrastructure, how can stakeholder engagement processes provide information that is both transparent and sufficiently detailed without overwhelming stakeholders? How should organizations balance simplified communication with technical accuracy? How can they clearly explain the rationale behind decisions, including when stakeholder requests or suggestions are not adopted?
- **Question 3.5.** How should the effectiveness of stakeholder engagement be assessed to ensure that it is meaningful rather than merely performative? Which indicators or practical approaches can demonstrate that stakeholder input has genuinely informed project development and decision-making?

PAPER SUMMARIES

PS1 - Biodiversity conservation & enhancement. Towards positive contribution

10131 – Nature Inclusive Design for an Artificial Energy Island – From Ideation to Implementation

The paper presents the application of Nature-Inclusive Design (NID) to the Princess Elisabeth energy island, integrating biodiversity features into large offshore infrastructure. A co-creation process with experts enabled the design of measures such as oyster modules, reef panels and habitat structures. Despite technical and safety constraints, key solutions were implemented to enhance marine ecosystems. The project demonstrates how infrastructure can deliver biodiversity gains through early design integration.

10163 – Environmentally Sustainable Discharge of Treated Industrial Wastewaters in the Egyptian Power System: A Case Study of Assuit West Power Plant

This study proposes the reuse of treated industrial wastewater for afforestation in arid environments using salt-tolerant species such as Jojoba and Casuarina. The approach improves water use efficiency, supports carbon sequestration and creates economic value through biomass production. Results show significant environmental benefits, including biodiversity recovery and air quality improvement. The project demonstrates a circular solution for wastewater management in power plants.

11080 – Hydropower Operation and Fish Conservation: Challenges of a Changing Energy Matrix

The paper analyses how increased renewable penetration alters hydropower operation, leading to hydropeaking and ecological impacts on fish populations. Operational changes such as start-ups, reduced generation and zero-generation increase risks of fish injury and mortality. Long-term monitoring shows rising impacts linked to operational variability. Adaptive management and mitigation measures are proposed to balance energy transition and aquatic biodiversity protection.

11098 – Reconversion of Powerline Rights-of-Way: Biodiversity, Resilience and Local Value in the Face of Climate Change and Wildfires

This paper presents REN's Integrated Vegetation Management strategy transforming ROWs into multifunctional ecological corridors. The approach replaces invasive species with native vegetation, enhancing wildfire resilience, biodiversity and ecosystem services. Over 4,800 ha have been restored through strong stakeholder engagement. Results highlight ROWs as key landscape-scale tools for climate adaptation and rural development.

11100 – Birds Nesting on Pylons of Transmission Lines in Portugal: Results of the First National-Scale Survey

The study reports the first national survey of bird nesting on transmission pylons, identifying 14 species and over 1,000 occupied structures. White stork nests play a key ecological role by supporting secondary nesting species, including threatened birds. Monitoring programs show

successful breeding of species such as Bonelli's eagle and osprey. Recommendations focus on improving monitoring, mitigation and habitat enhancement.

11256 – Placement of Renewable Energy Sources-Based Power Plants Considering Biodiversity Impact Mitigation

This paper proposes a GIS-based multi-criteria framework for siting renewable plants considering both energy yield and biodiversity impacts. A bi-objective optimization approach balances capacity factor with ecological performance, including potential net-positive effects. Case studies show that environmental impacts can be significantly reduced with limited energy trade-offs. The framework supports biodiversity-informed planning of renewable expansion.

11505 – Biodiversity Compensation Methodology Based on Natural Capital & Mitigation Hierarchy

The paper presents methodology for compensating residual biodiversity impacts using the mitigation hierarchy and a natural capital approach. It focuses on three key assets: habitat, species (birdlife), and atmosphere, with quantitative methods for impact calculation and offsetting. Compensation measures prioritise ecosystem restoration and management over simple reforestation. The framework aims to achieve net zero or positive biodiversity impact in new projects.

11507 – Analysis and Assessment of Impacts, Dependencies, Risks and Opportunities Related to Nature in Electricity Transmission

This study develops a TNFD-based methodology to assess nature-related impacts, dependencies, risks and opportunities in transmission infrastructure. Using the LEAP approach and geospatial analysis, assets are classified by ecological sensitivity and prioritised. Results highlight key risks such as habitat loss, collisions and fires, alongside ecosystem dependencies. The framework supports strategic decision-making towards a nature-positive grid.

11798 – Prevention of Mortality and Power Outages on 22 kV Lines Related to Mute Swan Collisions by Using Bird Flight Diverters in Slovakia

The study evaluates bird flight diverters to reduce swan collisions and associated power outages on a 22 kV line. Behavioural monitoring shows strong avoidance responses, with most birds crossing safely above the line. Extreme weather conditions were identified as a key factor influencing residual mortality. Results confirm diverters as an effective mitigation when combined with field observations.

12350 – Development of Collision Risk Maps Between Birds and Power Transmission Lines with an Assessment of Applicable Mitigation Measures

This paper develops GIS-based collision risk maps by overlaying transmission networks with bird habitats and migration routes. A multi-criteria methodology prioritizes high-risk line sections and guides mitigation deployment. The approach supports both retrofitting existing infrastructure and planning new lines. It demonstrates how spatial data integration improves biodiversity-focused decision-making.

12544 – Towards Positive Biodiversity Contribution from Transmission Infrastructure: Safe Osprey Nesting, Fault Reduction and 50+ Year Durable Mitigation Design

The paper presents a nature-inclusive strategy combining nest relocation, deterrence and durable engineering solutions to manage osprey interactions with transmission assets. Results show a significant reduction in faults despite increasing bird populations. Long-term performance is ensured through robust fastening systems and lifecycle design. The approach demonstrates alignment between biodiversity enhancement and network reliability.

12545 – Wildlife-Caused Outages and Mortality in Substations: From Wildlife Mitigation to Durable Biodiversity-Positive Asset Management

This study proposes a structured lifecycle framework for wildlife mitigation in substations, integrating prevention, prioritisation and durable protection measures. It includes exclusion strategies, habitat management and equipment protection to reduce mortality and outages. The approach promotes moving from reactive mitigation to biodiversity-positive asset management. It highlights the importance of durability and long-term monitoring.

PS2 - Building a more sustainable power system for the future

10111 – Enabling Efficient Integration of Renewable Energy Sources into the Grid: A Comprehensive Methodology for Assessing RES Site Suitability in Slovenia Based on Key Performance Indicators.

This study presents a multi-criteria methodology to evaluate and prioritize renewable energy sites (RES) for grid connection in Slovenia. It integrates technical, economic, temporal, and environmental, social, and governance aspects through nine key performance indicators and three assessment levels tailored to project maturity. Supported by geographic information systems and structured data models, the approach enables systematic site selection and early-stage decision-making. It highlights the importance of moving beyond cost-based approaches, offering a practical tool for grid planners managing increasing renewable integration and supporting strategic network development decisions.

10132 – A closed loop business model: a significant contribution for European TSO's to face copper scarcity?

This paper examines the feasibility of closed-loop copper recycling in transmission assets to address future material scarcity. Combining material flow analysis, regulatory assessment, and a pilot project, it shows that recycled copper could cover a limited but valuable share of demand. It highlights challenges such as traceability, supply chain coordination, and regulatory constraints. The contribution provides a realistic perspective on circularity, emphasizing both its potential benefits and structural limitations in the context of growing grid infrastructure needs.

10302 – A Life-Cycle-Based Environmental Passport for High-Voltage Substations

Presents the development of an environmental passport for high-voltage substations as a decision-support tool during the design phase. Based on LCA principles, it aggregates environmental data at component and system levels to identify impact hotspots. A case study demonstrates practical implementation challenges related to data availability and standardization. The approach highlights how sustainability considerations can be integrated into engineering decisions early in the project lifecycle, while emphasizing the need for harmonized methodologies for broader application.

10318 – Climate Adaptation in Dutch Grid Infrastructure: A Guideline Based Framework with Adaptive Feedback.

This paper proposes a pragmatic framework to integrate climate adaptation into distribution network asset management. It addresses the challenge of assessing diverse climate risks under uncertainty by combining qualitative analysis with iterative improvement processes. The approach builds existing asset management practices and promotes cross-functional collaboration. It enables grid operators to prioritize actions without extensive additional analysis and provides a practical pathway to enhance resilience against long-term climate impacts while maintaining operational feasibility.

10474 – Alternate Fuels in Thermal Power Plants: Pathways to Decarbonization and Energy Transition.

This study evaluates alternative decarbonization pathways for thermal power plants, focusing on biomass co-firing and methanol derived from captured CO_2 and green hydrogen. It

presents pilot experiences demonstrating technical feasibility and emission reductions. While primarily generation-focused, it highlights transitional solutions for reducing emissions in fossil-based systems. The contribution provides context for discussions on integrating cleaner fuels into existing infrastructure and the role of circular carbon approaches in the broader energy transition.

10888 – Implementing Eco-Design at EDF HYDRO. Guidelines for Electrical Equipment.
This contribution describes the implementation of eco-design in hydropower projects through a structured, cross-disciplinary approach. It integrates LCA tools with engineering and procurement processes to identify key environmental impact drivers, particularly material use. The study demonstrates how sustainability criteria can be incorporated into project planning while balancing technical and cost constraints. It provides practical insights into embedding eco-design at system level and highlights the importance of organizational alignment in implementing sustainable design strategies.

10893 – Advancing Sustainability and CSR in Procurement: A Collaborative TSO Perspective.
This contribution presents how European TSOs integrate sustainability into procurement through a collaborative approach and harmonized criteria. It introduces tools such as product carbon footprints and raw material passports to improve transparency and supply chain performance. The study highlights implementation challenges related to data availability and supplier engagement. It demonstrates how procurement can act as a lever for sustainability and provides insights into aligning supply chains with environmental and regulatory requirements.

10894 – Leveraging Climate Services to Build Climate Resilient Power Systems
Highlights the importance of integrating climate data into power system planning, introducing the Pan-European Climate Database as a key resource. It combines historical and projected data to support risk-based analysis and long-term planning. The study emphasizes challenges related to data standardization, uncertainty, and usability. It demonstrates how climate-informed planning can improve resilience and system reliability, particularly in scenarios with high renewable energy penetration and increasing weather dependency.

10895 – Material Flow Analysis of Geo-Economic Tensions Affecting the Supply Chains of Low-Carbon Technologies: The Case of the Electric Grid
This paper applies dynamic material flow analysis to assess future demand for materials in transmission networks. It shows that grid expansion and climate adaptation will significantly increase material needs, while recycling alone cannot meet demand. The study highlights supply risks, including dependence on critical and auxiliary materials and industrial constraints. It provides a quantitative basis for understanding resource challenges and supports long-term planning strategies addressing material availability and sustainability in grid development.

10896 – Harnessing Open-Source Standards for Sustainable Digital Design in the Energy Transition

This paper examines sustainability challenges associated with digitalization in energy systems and proposes the use of open-source software standards. These approaches improve transparency, traceability, and efficiency in digital infrastructures. The study highlights the environmental impact of IT systems and the lack of standardized frameworks.

10897 – Tools and methodologies to assess HV products' environmental impacts: state of the art and future trends.
This study analyses the role of Life Cycle Assessment (LCA) for high-voltage equipment, focusing on data quality and methodological consistency. It highlights how data maturity varies across project phases and can significantly influence results. A key contribution is a maturity-based framework aligning LCA methods with development stages from R&D to execution. The paper provides practical guidance for applying LCA as a decision-making tool, while addressing uncertainties and the need for harmonization in environmental assessments of power system components.

10902 – An innovative Eco-design methodology for a sustainable switchgear: the case of the new 245kV GIS.
This study demonstrates the application of eco-design principles in developing SF_6-free gas-insulated switchgear. It integrates LCA into the design process, enabling evaluation of environmental impacts across different development stages. A practical guideline tool is introduced to support engineers in making sustainability decisions without requiring full LCA expertise. The contribution illustrates how eco-design can be embedded into engineering workflows and highlights the importance of addressing lifecycle impacts early in product development to support decarbonization objectives.

10961 – Impact of Evaluation Criteria of Power Loss in LCA
Investigates transformer losses using both energy-based (kWh) and carbon-based (CO_2 equivalent) metrics within a Life Cycle Assessment framework. Using real operational data, it shows that results differ significantly depending on the chosen evaluation criterion. While energy losses depend on load profiles, carbon impacts are also strongly influenced by the electricity mix. The study, too, highlights the risk of relying solely on CO_2 metrics and underscores the importance of selecting appropriate indicators for asset evaluation and sustainability decision-making.

10962 – Life Cycle Impact Assessment and Weighting in Switching Station: Insights from a Case Study.
This paper develops an integrated Life Cycle Impact Assessment approach for switching stations, combining multiple environmental indicators beyond greenhouse gas emissions. Using AIS and GIS case studies, it demonstrates that results vary significantly depending on methodology, geography, and weighting assumptions. The analysis highlights the importance of considering additional areas of protection beyond climate impact. It also identifies methodological challenges such as data gaps and subjectivity, emphasizing the need for improved standardization and transparency in multi-dimensional environmental assessments.

10963 – Effect of the Fluorine Resource Conversion Process of SF6 Gas for a Circular Economy

This paper presents a novel method for decomposing SF_6 gas and recovering fluorine as a reusable resource. The process reduces emissions compared to conventional disposal methods and supports circular economy principles. A pilot-scale demonstration confirms technical feasibility, while highlighting the influence of energy sources on overall environmental performance. The contribution is particularly relevant for managing end-of-life treatment of SF_6 and offers insights into sustainable waste handling and material recovery strategies in power system operations.

11083 – Conventional and Floating Photovoltaic Generation from a Life Cycle Perspective – Carbon and Water Footprint
Compares environmental impacts of ground-mounted and floating photovoltaic systems using Life Cycle Assessment. It shows that manufacturing and construction dominate emissions and water consumption, while operational impacts are relatively small. Floating PV demonstrates lower carbon footprints due to higher efficiency and reduced land-use related impacts. The analysis also highlights sensitivity to manufacturing location. The paper provides useful insights into lifecycle trade-offs when selecting renewable technologies for integration into power systems.

11084 – The Role of SDGs in Shaping Sustainability in the Electric Power Sector
Examines how the electricity sector aligns with the UN Sustainable Development Goals, particularly those related to energy, infrastructure, and climate action. Based on international surveys, it identifies progress trends, drivers, and barriers. The findings indicate that regulatory and financial pressures increasingly shape sustainability efforts. The study provides insight into the strategic integration of sustainability into planning and operations, supporting discussions on how utilities can align infrastructure development with broader policy and reporting frameworks.

11102 – Harmonizing EPD and CBAM methodologies for carbon footprinting of power transformers
Proposes a framework to harmonize Environmental Product Declarations and the EU Carbon Border Adjustment Mechanism for power transformers. It aligns system boundaries, functional units, and reporting methods to improve consistency and efficiency in carbon accounting. A case study demonstrates how LCA-based data can be adapted to regulatory requirements. The contribution highlights challenges in combining voluntary and regulatory approaches and is relevant for stakeholders preparing for evolving carbon reporting and compliance requirements.

11131 – Integrating marine archaeology into HVDC marine cable design and realization
Presents the integration of underwater cultural heritage protection into HVDC cable project planning. Through surveys, geo-information-system-based analysis, and stakeholder engagement, it demonstrates how infrastructure development can incorporate broader sustainability aspects beyond environmental impacts. The approach enables identification and preservation of archaeological sites while supporting engineering decisions. The contribution highlights interdisciplinary collaboration and provides a perspective on extending sustainability frameworks to include cultural and societal considerations in infrastructure projects.

11161 – Environmental Controls and Lifecycle Assessment of Battery Energy Storage Systems (BESS) in South Africa: Lessons from Global Frameworks.
This paper reviews lifecycle environmental and regulatory considerations for battery energy storage systems. It focuses on disposal, recycling, safety, and compliance aspects, particularly in the context of South Africa's energy transition. The study highlights risks related to end-of-life management and emphasizes the importance of planning across the full lifecycle. The contribution provides practical guidance for integrating sustainability considerations into storage deployment and aligns with broader discussions on resource management and system integration.

11187 – A data-driven approach for predicting and monitoring nitrogen oxides emissions of natural gas CCGT in power plants with neural networks
This paper presents the use of machine learning models to predict nitrogen oxide emissions from power plants based on operational data. High prediction accuracy is demonstrated using neural networks. The study illustrates how digital tools can enhance emission monitoring and support operational optimization. While focused on generation assets, it highlights the potential of advanced analytics in improving environmental performance and contributes to discussions on the role of digitalization in sustainable power system operation.

11277 – Modular and regenerative life cycle assessment indicators for sustainable power systems
Proposes an extended LCA framework that includes circularity, modularity, and regenerative aspects. It identifies gaps in conventional LCA approaches, particularly regarding repairability and ecosystem impacts. The framework introduces additional qualitative indicators to support broader sustainability assessment. While primarily conceptual, the study contributes to discussions on expanding environmental methodologies and highlights the need for integrating design-oriented sustainability considerations into lifecycle evaluation.

11611 – Sustainability in HVDC tenders and projects - A pathway to long-term value creation
Explores how sustainability can be embedded into HVDC procurement and project execution. It introduces measurable criteria covering lifecycle emissions, materials, and social impacts, demonstrating how these can influence supplier selection and project outcomes. The study highlights the role of procurement as a driver for sustainability and discusses challenges such as standardization and data requirements. It provides practical insights into operationalizing sustainability in large infrastructure projects and aligning with regulatory and investment frameworks.

11883 – Climate Risk and Vulnerability Assessment for the Croatian Transmission Network
Presents a climate risk assessment methodology applied to a transmission system using spatial analysis and climate projections. It evaluates exposure, sensitivity, and vulnerability of assets across different scenarios. The approach provides a structured overview of potential risks but remains at a high level without detailed mitigation measures. The study is relevant for understanding how climate risks can be incorporated into planning processes and supports discussions on resilience in transmission systems.

12016 – Next Generation Overhead Lines with Carbon Core Conductors: Optimisation of Design Paradigm to meet the Needs of Energy Transition and reduced environmental Footprints.

This study evaluates carbon core conductors for new overhead lines, focusing on environmental benefits. It demonstrates that increased span lengths reduce the number of towers, leading to lower material use and reduced emissions. The study quantifies CO_2 savings and highlights additional benefits such as reduced construction effort. While costs may increase, the analysis supports the consideration of total lifecycle impacts when selecting technologies for grid expansion, particularly in challenging environments.

12084 – Beyond 2050: Decommissioning Frameworks and Environmental Liabilities of the Electricity Sector in the EU and Latin America.

The paper eexamines decommissioning frameworks and environmental liabilities for renewable energy infrastructure, focusing on the EU and Latin America. It highlights emerging challenges related to end-of-life management of assets such as solar panels and wind turbines and identifies gaps in current regulatory approaches. By comparing regional practices, the study raises key questions around international frameworks, the "polluter pays" principle, and value chain responsibilities. The paper is particularly relevant for discussions on lifecycle governance, circularity, and ensuring that the energy transition does not create long-term environmental risks.

12122 – Circular Economy in Power Transformers: Financial Opportunity and Climate Solution in Colombia.

Explore circular economy approaches for refurbishing power transformers in Colombia, focusing on reuse of non-degradable components. It demonstrates significant reductions in emissions, costs, and delivery times compared to new manufacturing. The study also identifies regulatory barriers that limit adoption. It highlights the potential of circular strategies in asset management and emphasizes the importance of aligning regulatory frameworks with sustainability objectives.

12313 – Advancing Circularity in Transformers: Update on recent Solutions and Impacts

Presents an OEM perspective on advancing circularity in transformers through design, refurbishment, and supply chain collaboration. It introduces practical strategies such as material optimization, life extension, and recycling. Case studies illustrate implementation and highlight challenges in material recovery. The contribution provides insights into how circular economy principles can be integrated across the lifecycle and value chain of power system equipment.

12315 – Standardization of LCA for environmental Performance Assessment of High Voltage Switchgear: A critical Evaluation of current Challenges and Needs.

This study compares environmental performance of SF_6-free switchgear technologies using Life Cycle Assessment. It highlights methodological challenges such as inconsistent assumptions, functional units, and system boundaries. The study shows that focusing solely on carbon metrics can be misleading and emphasizes the need for transparency and standardization. It contributes to discussions on technology selection and reliable environmental assessment methods in the transition away from SF6.

12323 – A meta-analysis of Transformer Sustainability evaluations based on Customers Practices, national level policies and voluntary standards in major markets around the world.

Reviews current practices in integrating sustainability criteria into transformer procurement and highlights the lack of standardized assessment frameworks. It discusses regulatory developments and the increasing importance of sustainability in purchasing decisions. The study emphasizes the need for harmonized methodologies to ensure comparability and transparency. It provides useful context for understanding how procurement processes can drive sustainability improvements across the transformer value chain.

12455 – Application of new IEC TS 62271-320 for the Evaluation of Life Cycle Assessment (LCA) Methodologies in High-Voltage Switchgear

Propose a harmonized LCA framework for high-voltage switchgear based on international standards. It identifies key sources of variability such as electricity mix and material sourcing. Sensitivity analyses demonstrate their impact on results. The study recommends standardized approaches, based on either third-party verified declaration or detailed inventory reporting to improve comparability. The contribution is particularly relevant for ensuring consistent environmental evaluations and supporting regulatory compliance in sustainability assessments.

12622 – Life Cycle Assessment (LCA) for assessing the sustainability of high-voltage electrical infrastructure Application to the 150kV double-circuit overhead link of the Canino-Arlena power line to the Tuscania Power Station.

This study presents a detailed Life Cycle Assessment of an overhead transmission line, covering all lifecycle stages. It identifies operational losses as the dominant contributor to environmental impact, influenced by the electricity mix. The study also highlights the importance of material production and recycling. It provides practical insights into key impact drivers and demonstrates how LCA can support infrastructure planning and sustainability evaluation in transmission systems.

PS3 - Disclosing sustainability

10133 – Navigating Scope 3 Emissions in the Context of Increasing Grid Investments Facilitating the Energy Transition

The paper presents approach to improving Scope 3 emissions accounting through a digital "product passport" platform using primary supplier data. It enables progressive data quality, auditability and better identification of decarbonization levers. Different SBTi methodologies are assessed, selecting a physical intensity target aligned with infrastructure growth. The approach balances grid expansion needs with credible climate targets.

10470 – Addressing Greenwashing in Sustainability Reports of Power Transmission Companies: Impacts and Solutions

The paper examines greenwashing in power transmission companies' sustainability reports, and proposes a sector-specific assessment framework, including a Greenwashing Risk Index (GWI), to quantify this gap and improve the credibility, comparability, and auditability of sustainability disclosure.

10480 – Towards Enhancing Sustainability Disclosures – A Comprehensive Analysis of SEBI's BRSR Framework

The paper analyses India's Business Responsibility and Sustainability Reporting (BRSR) framework for power transmission companies. It benchmarks BRSR against GRI, ISSB, and CSRD, highlighting strengths in comparability but limitations in value-chain coverage and assurance showing that while it establishes a standardized and mandatory baseline for ESG disclosures, its effectiveness improves significantly when integrated with global frameworks.

10481 – Scientometric Analysis of Sustainability Disclosure and Stakeholder Perception Research in the Electric Power Sector (2010–2025)

This paper examines research trends in sustainability disclosure using bibliometric methods. It finds a shift from CSR to ESG and climate risk reporting after 2015, driven by global policies. Geographic disparities highlight underrepresentation of developing regions. The study predicts continued growth in policy-aligned research and emphasizes the need for region-specific disclosure frameworks.

10890 – Disclosing Sustainability: Throwback to First Sustainability Reporting – What Next?

The paper examines the first implementation of the Corporate Sustainability Reporting Directive (CSRD) in the power transmission sector and highlights key challenges for using sustainability reporting as a driver of long-term industry transformation. It shows how CSRD acts as a catalyst for integrating sustainability into governance, strategy, and operations. Key challenges include double materiality, Scope 3 emissions, and due diligence across value chains. The study highlights the need for shared methodologies and stronger collaboration across TSOs.

10891 – Unlocking Resilience: Detailed Equipment Data for Future-proof Transmission Grids

This paper presents a multi-TSO initiative to standardize detailed product-level data for grid equipment through Raw Material Passports (RMPs). The approach improves comparability,

Scope 3 accounting, and sustainable procurement decisions. It supports EU regulatory compliance and circular economy objectives. Challenges include data traceability, supplier burden, and harmonization.

11081 – Environmental Impact Assessment and Human Rights Due Diligence: Current State of the Art and Possible Convergences
The paper examines the relationship between Environmental Impact Assessment (EIA) and Human Rights Due Diligence (HRDD) in Brazil's power sector, highlighting that aligning environmental licensing with human rights assessments can strengthen social acceptance of energy projects.

11082 – Effectiveness of Social Monitoring Forums: A Comparative Analysis of Belo Monte HPP, Santo Antônio HPP, and Sítio Grande SHPP
This paper assesses the effectiveness of social monitoring forums in hydropower projects based on stakeholder dialogue and participation indicators. While forums improve transparency and conflict management, they often suffer from power asymmetries and limited representativeness. Comparative analysis identifies strengths, weaknesses, and best practices. Recommendations aim to enhance social license to operate.

11264 – Paradigm Shift in Korean Transmission Grid Construction: Trust-based Governance through Third-party Mediation and Sustainability Disclosure
The study analyses governance failures in Korean transmission projects and proposes a trust-based mediation framework (TCCR TF). A pilot project demonstrates how third-party mediation and transparent disclosure improve stakeholder acceptance and reduce delays. The approach emphasizes procedural legitimacy and participatory decision-making.

12068 – Enhancing the Stakeholders' Trust through a Transparent Sustainability Disclosure: A Case Study of a Power Company in Thailand
This paper presents a case study of ESG disclosure integration in a Thai power utility using double materiality and aligned reporting frameworks. It shows how governance, stakeholder engagement, and data digitalization improve credibility and reduce greenwashing risks. Sixteen material topics are identified and linked to KPIs and strategy. The study proposes a replicable roadmap for transparent disclosure.

12277 – Stakeholder Reporting Requirements – Impact of Disclosure on Social Perception and Acceptance
The paper highlights the importance of early and continuous disclosure in infrastructure projects to ensure stakeholder acceptance. Case studies show that late engagement leads to conflicts, redesigns, and increased costs. Early engagement and effective disclosure enable better understanding of impacts, stakeholder needs, and mitigation measures.

12319 – Improved Stakeholder Engagement Process and Transparency Using Geospatial Cloud Solutions
The paper discusses the benefits of cloud-based geospatial platforms in the project planning process to enable interactive, visual, and accessible stakeholder engagement resulting in reduced opposition through direct participation and decision making