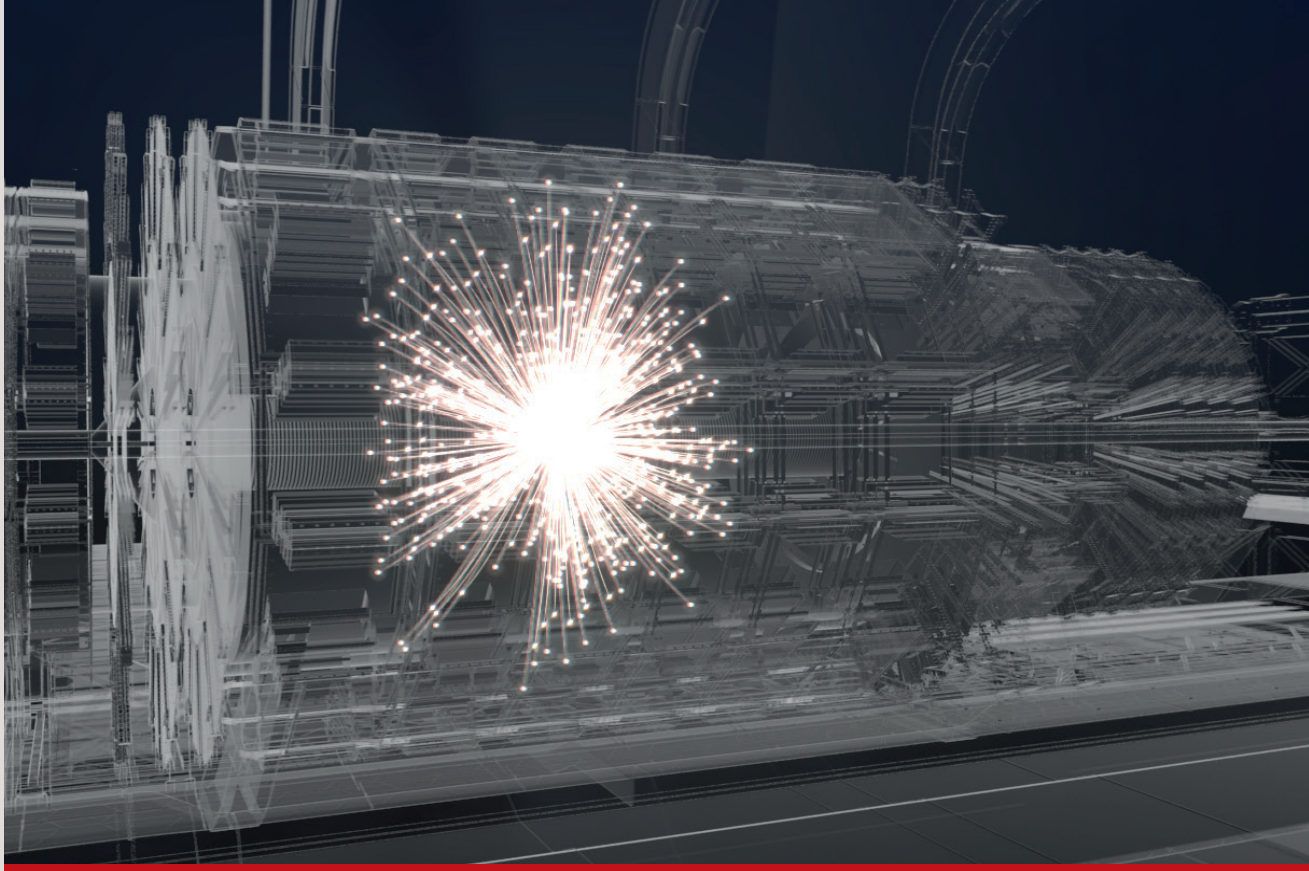

Conclusions of the Comité Suisse pour l'Evaluation du Future Circular Collider (FCC) on the FCC feasibility study by CERN

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Schweizerische Eidgenossenschaft
Confédération suisse
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Swiss Confederation

Federal Department of Economic Affairs,
Education and Research EAER
State Secretariat for Education,
Research and Innovation SERI

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1. The Comité Suisse pour l'Evaluation du FCC (CSEF)

The *Comité Suisse pour l'Evaluation du FCC* (CSEF) is under the aegis of the State Secretariat for Education, Research and Innovation (SERI) and is commissioned by State Secretary Martina Hirayama since 2024. The mandate of the Committee is to evaluate the Future Circular Collider (FCC) feasibility study and its potential realization. The CSEF reports its findings and conclusions in this report to the Swiss Delegation to the CERN Council in an advisory role. The Committee is chaired by the head of the Swiss Delegation to the CERN Council, Ambassador Michael Gerber. The CSEF-members represent the concerned offices and departments of the Swiss Confederation (SERI, FDFA, FFA, FOPH, FOE, FOEN, ARE, SECO)[1], the Canton of Geneva, as well as experts from University of Zurich and the Paul Scherrer Institute (PSI) representing the scientific community.

The FCC feasibility study, published by CERN at the end of March 2025, spans three volumes and over 1,000 pages, with several chapters summarizing more detailed annex documents. To efficiently assess this extensive report, CSEF conducted a structured evaluation between April and October 2025, focusing on identifying critical issues or potential "showstoppers". Topical subgroups, organized according to the study's structure and members' expertise, analysed specific chapters using a standardized evaluation form that categorized findings according to their potential impact on the project. The results were then discussed and refined through a series of online and in-person meetings. This evaluation did not assess the project's financial feasibility; the Committees' considerations regarding cost estimate are limited to the observations noted in section 2.10. This document summarizes the key outcomes and discussions from that collective evaluation process.

[1] FDFA – Federal Department of Foreign Affairs, FFA – Federal Finance Administration, FOPH – Federal Office of Public Health, FOE – Federal Office of Energy, FOEN – Federal Office for the Environment, ARE – Federal Office for Spatial Development, SECO – State Secretariat for Economic Affairs

2. Assessment of the FCC Feasibility Study

This section provides the findings of the CSEF-evaluation listed by subject area and topic. Following the structure of the feasibility study report, this section first notes the Committees' findings on the scientific and accelerator focused topics. More specific topics on the projects' territorial implementation and embedding in the broader societal context are noted as of 2.4. The ordering of the topics does not follow a particular hierarchical order of importance.

2.1 Scientific Relevance

Context and Scientific Motivation

The CSEF acknowledges the profound scientific ambitions that underpin the field of particle physics and, by extension, the FCC. Particle physics seeks to uncover the fundamental laws governing the universe, from the smallest building blocks of matter to the largest cosmic structures. Over the past century, this pursuit has led to extraordinary progress, culminating in the discovery of the Higgs boson at CERN in 2012. Yet, that discovery also underscored the limitations of the Standard Model and the many open questions that remain, such as the nature of dark matter, the matter-antimatter asymmetry, and the underlying principles determining the Higgs boson's properties. The CSEF recognizes that addressing these questions requires experimental facilities capable of reaching unprecedented levels of precision and sensitivity.

The Role of the FCC and Long-Term Vision

The CSEF also acknowledges the central role that particle accelerators have played, and will continue to play, in advancing the frontiers of knowledge. By recreating the extreme conditions of the early universe, accelerators provide unique opportunities to test the Standard Model and search for new physics. In this context, the FCC represents a logical and ambitious next step in CERN's scientific programme. Its design aims to deliver highly precise measurements of key particles such as the Higgs boson, W and Z bosons, and the top quark, potentially revealing new insights into the fundamental structure of nature. Furthermore, the Committee is pleased to note that the FCC's objectives align with CERN's long-standing mission of combining scientific discovery with technological innovation, international collaboration, and societal benefit – elements essential to strengthening Europe's role and competitiveness in global science and innovation.

2.2 Physics, Detectors, and Software

The final report of the FCC Feasibility Study has developed and produced an impressively detailed body of physics potential in Volume 1. The CSEF appreciates the increased attention given to flavor and quantum chromodynamics physics since the midterm version of the report. The studies underscore the richness of intensity frontier physics achievable in the multi-Tera-Z run. Establishing four interaction points as the baseline configuration is a significant advancement. The benefits of this choice are clearly and convincingly presented. It provides greater flexibility in both the experimental programme and the operational model.

A refined list of detector requirements is being developed based on case studies, utilizing benchmark FCC-ee[2] measurements. Dedicated R&D and detailed detector designs will be important in the coming years. The complexity reflects the richness of the physics programme. Achieving the necessary alignment between theoretical and experimental precision and

[2] FCC-ee (electron – positron) is the proposed first-stage, high-luminosity electron – positron collider at CERN dedicated to precise measurements of Higgs, electroweak, and flavor physics. If approved by the CERN Council around 2028, FCC-ee would start its operation in the mid-2040s and run for approximately 15 years.

tailoring detector configurations to the diverse set of physics channels and discovery opportunities remain significant challenges.

For FCC-hh[3] it is essential to ensure that at least two interaction caverns are large enough to host the most demanding detector concepts, including full assembly, services, and maintenance needs. The current plan with two large and two smaller caverns may be sufficient, but this depends on whether FCC-hh will require more than two general-purpose experiments. Before finalizing the design, the dimensions of the large caverns should be validated against FCC-hh detector requirements to avoid costly retrofits later.

The study established a common software framework that enabled key physics studies using fast simulations of benchmark detector designs. Looking ahead, computing needs will grow substantially: FCC-ee Z-pole data volumes will rival those of the LHC, and simulated samples will add further pressure on storage. A system evolving from the Worldwide LHC Computing Grid is expected to be required, with sustainable resource planning starting early. High-Performance Computing will be critical for short-term, high-intensity tasks, and national resources could be integrated into the FCC Virtual Organization, though the practicalities need clarification. Stronger links with the High-Luminosity Large Hadron Collider (HL-LHC) computing and software efforts with institutions outside CERN are essential to ensure knowledge transfer and efficiency. The software framework should be generalized to support detector R&D and future collaborations, while advanced AI/ML methods must be planned for simulation, reconstruction, analysis, and detector optimization.

Furthermore, the CSEF recommends that CERN examines the advantages and drawbacks of maintaining strong independence and competition between experimental collaborations (e.g. ATLAS vs. CMS) versus increasing synergies, such as shared software frameworks or joint infrastructures. The aim is to assess whether the current organizational model best supports scientific excellence and efficiency, or if adjustments could further improve quality and impact.

2.2 CSEF RECOMMENDATIONS TO CERN

a. ***Strengthen detector and software development through focused R&D for the FCC-ee, ensuring alignment between theoretical precision, experimental design, and computational capacity.***
b. ***Validate the planned size of the two large experimental caverns against the range of FCC-hh detector requirements to avoid costly retrofits in the future.***
c. ***Develop a sustainable, scalable computing strategy that considers integration of member states national resources, leverages AI/ML, and builds on synergies with HL-LHC efforts.***
d. ***Review the balance between independent experimental collaborations and shared frameworks to optimize scientific excellence and efficiency.***

[3] FCC-hh (hadron – hadron) is the possible second stage proton – proton collider to be installed in the same tunnel after FCC-ee. Its operating energies of 100 TeV are aimed at directly exploring new physics at the energy frontier. FCC-hh would operate for approximately 25 years from the 2070s onward. A decision by the CERN Council on the FCC-hh programme will be taken at a later stage.

2.3 Accelerator Development

The CSEF notes that the conceptual design of the FCC-ee accelerator is mature and that the remaining challenges are identified, including the required targeted project-oriented R&D in the coming years. Strong collaboration with national laboratories and research universities has been a hallmark of the FCC study so far, and this should be further reinforced by identifying priorities and securing sufficient resources as early as possible.

The Committee commends the high technology readiness level (TRL) of the FCC-ee injector and looks forward to the pre-Technical Design Report (pre-TDR) study defining the civil engineering requirements for the infrastructure by 2028.

R&D for high field magnets and the possible use of High Temperature Superconductivity can pave the way for a higher energy reach in the FCC-hh collider thanks to the higher field margin. Corresponding R&D efforts should be well coordinated and accelerated to reach the necessary TRL by the time the choice of technology in FCC-hh will need to be made.

2.3 CSEF RECOMMENDATIONS TO CERN

a. ***Establish a structured injector project collaboration of contributors with sufficient resources to perform the necessary project-oriented R&D and provide the necessary input for the civil engineering design which should be addressed in the pre-TDR study.***
b. ***Ensure that the R&D on high-field magnet technologies, including High Temperature Superconductors, progresses according to a timeline that secures the required technology readiness level by the FCC-hh technology decision point.***

2.4 Environment

The feasibility study provides a solid initial basis for assessing the project's environmental impacts, addressing both underground and surface aspects. While no major environmental showstopper has been identified at this stage, further work is needed in areas such as groundwater protection, excavation materials management, and nature conservation at the technical site, named PB, located on Swiss grounds. Completing and consolidating the necessary documentation ahead of the pre-TDR phase, in close coordination with the host states, will be key to facilitate timely reviews and minimize the risk of delays in the project's approval process.

The Committee sees progress in the definition of the PB-site and its environmental context since the Mid-term Review of the feasibility study. To fully meet regulatory expectations, the environmental assessment will also need to be aligned with Swiss Environment Impact Assessment (EIA) requirements during the pre-TDR phase, as it relies primarily on French and broader European legal frameworks so far. The CSEF also highlights the importance of including an initial radiological baseline assessment, similar to the one conducted before the LHC, covering air, soil, water, and ambient dose rates, with early clarification of cost responsibilities between CERN and the host states. In addition, the environmental assessment should be expanded to address the eventual dismantling of the facility.

The CSEF considers that Swiss and French environmental laws, in conjunction with the Espoo Convention, are adequate. While Swiss law will apply strictly to Swiss territory and consequently French law to French territory, the Committee sees no need for a formal Tripartite agreement under Article 8 of the Espoo Convention.

The Committee acknowledges the ongoing collaboration with CERN on the project's environmental aspects. It nevertheless emphasizes the need to further strengthen and intensify the

refinement, integration, and coordination with the host state authorities during the pre-TDR phase and subsequent planning stages.

2.4 CSEF RECOMMENDATIONS TO CERN

a. ***Provide finalized and consolidated environmental documentation, well in advance of the completion of the pre-TDR phase, ensuring close coordination with host state authorities to facilitate timely review and minimize potential delays.***
b. ***On Swiss territory, align the environmental assessment with Swiss EIA requirements and expand it to include a dismantling plan for the facility.***
c. ***Conduct an initial radiological baseline assessment.***
d. ***Continue the close collaboration and coordination with the host state authorities on environmental matters throughout the pre-TDR and subsequent planning phases.***
e. ***Rely on existing Swiss and French legal frameworks, which are considered sufficient without pursuing additional formal agreements at this stage.***

2.5 Sustainability

The socio-economic analysis provides a structured overview of the FCC project's potential economic, social, and environmental contributions, using established tools such as cost-benefit and life-cycle analyses. While this offers a useful foundation, the current assessment would benefit from clearer objectives, greater methodological transparency, and a more balanced presentation of qualitative and quantitative evidence. In particular, the counterfactual scenario, in which CERN operates the LHC until its expected end of life and continues to act as a scientific research platform with the existing particle accelerator complex, should be better defined to strengthen credibility. Looking ahead, public and institutional stakeholders are likely to expect a more comprehensive and compelling socio-economic narrative, one that articulates the FCC's broader value to society, aligns with sustainability principles, and reflects the scale and ambition of the project.

The report's current links to the Sustainable Development Goals (SDGs) could be strengthened to enhance its clarity and relevance. A more explicit mapping, such as connecting scientific education to SDG 4, technology transfer to SDG 9, and energy efficiency to SDG 7, would make the socio-economic narrative more compelling and aligned with global priorities. In addition, reflecting more explicitly on how the FCC could engage with and benefit developing countries would provide a valuable opportunity to demonstrate alignment with SDG 17 (Partnerships for the Goals) and other goals related to education, employment, and clean energy.

The avoid-reduce-compensate (ARC) principle is a solid basis and CERN should give assurances that it will be applied consistently. However, while the ARC-approach is well-founded, the Committee considers that stakeholders, including civil society, may reasonably expect the organization to pursue opportunities for environmental and social enhancement that go beyond strict legal compliance, particularly for a project supported by public funding.

Improved estimates of demographic and resource implications such as housing and workforce dynamics should also be provided from the perspective of long-term sustainability.

The CSEF encourages CERN to work towards a more balanced, structured, and transparent socio-economic analysis realistically reflecting benefits, positive and negative impacts as well as costs. The comprehensive socio-economic analysis should align sustainability methodology with impact objectives connecting regional development, industrial spillovers, traditional tourism, and emerging digital value sphere (e.g. online engagement, symbolic and reputational

capital). The FCC project offers the unique opportunity to demonstrate the same level of innovation in the socio-economic domain as it does in fundamental physics, by pioneering new ways to conceptualize, engage with, and generate public value from scientific infrastructures of almost unique world-wide relevance.

2.5 CSEF RECOMMENDATIONS TO CERN

a. ***Strengthen the socio-economic analysis by clarifying objectives, improving methodological transparency, and ensuring a balanced and realistic assessment of benefits, impacts and costs.***
b. ***Align and expand the socio-economic framework with the UN Sustainable Development Goals.***
c. ***Besides the consistent application of the avoid-reduce-compensate principle, seek opportunities for environmental and social improvement beyond legal compliance.***

2.6 Safety

The CSEF commends CERN for the already well-advanced consideration of safety aspects in the FCC feasibility study. Building on the Organization's extensive experience with the LHC, CERN demonstrates a solid understanding of how to address major safety challenges and risks. As the project progresses, however, several areas should be further developed and documented through comprehensive safety files.

For planning purposes, the host states will require indicative estimates of the volume of radioactive waste expected during FCC operation and decommissioning. The proposed use of liquid lead for the beam dumps introduces specific containment and handling risks that should be addressed through a detailed safety concept. Similarly, air filtration and the potential radiological impact of air recycling will need to be integrated more explicitly into the ventilation strategy.

Given the FCC's significantly larger scale compared to the LHC, the Committee notes the introduction of new safety approaches, such as automated patrols and individual tracking for access control. These innovations represent a notable shift from current practices and will require careful validation. Quantitative risk assessments should also cover credible accident scenarios, including fire and radioactive water leakage, and evaluate the implications of extended access tunnels for evacuation and emergency response. These elements will be essential during the next phase of the FCC project to ensure a robust and transparent safety case.

Future safety files should systematically address these topics and be submitted to the competent authorities of the host states for approval, in line with the tripartite agreement on radiation protection and safety of CERN facilities. The Committee recommends that CERN engages with the Swiss and French authorities early in this process to agree on the scope and content of the safety documentation, supported by the dedicated radiation protection and safety studies foreseen in the feasibility study.

2.6 CSEF RECOMMENDATIONS TO CERN

a. ***Prepare and submit comprehensive safety files addressing the identified risks in line with existing agreements.***
b. ***Provide early estimates of radioactive waste volumes expected during FCC operation and decommissioning to support host state planning.***

c. ***Address more specific safety challenges identified by the Committee such as the beam dump containment, air filtration and radiological impact of air recycling.***
d. ***Where new practices are proposed to address the larger scale of the FCC compared to its predecessor, conduct thorough quantitative risk assessments and validation procedures.***

2.7 Civil Engineering

The Committee notes the geological risks associated with tunnelling, in particular the possibility of encountering water under hydraulic pressure or even artesian conditions. CERN is encouraged to review relevant experience from past tunnel projects to define appropriate mitigation strategies. In parallel, legal and planning challenges exist due to the absence of a clear legal framework in Switzerland for reserving underground space ahead of formal project approval. As a result, it is currently not possible to prevent future installations, such as geothermal probes, that could interfere with the FCC safety buffer. A legally sound solution should be identified to manage this risk, including informing future applicants of potential constraints. In the longer term, an analysis of affected geothermal systems will be necessary, along with the definition of terms for compensation or replacement, in coordination with the relevant Swiss authorities.

If train access is to be used for transporting construction materials, equipment, and for material evacuation, a coordinated and detailed design effort must be initiated in collaboration with the French and Swiss national railway authorities. This joint planning process should begin proactively as early as now to ensure feasibility and alignment with national infrastructure requirements.

2.7 CSEF RECOMMENDATIONS TO CERN

a. ***Gather relevant experience from past tunnel projects to define mitigation strategies for the geological risks associated with tunnelling.***
b. ***If train access solutions for material transportation are further pursued, initiate early coordinated planning with the national railway authorities in both host states.***

2.8 Excavated Materials

The CSEF acknowledges that work in this area is ongoing and that updates received since the submission of the feasibility study indicate that several of the previously identified concerns are being progressively addressed.

During the evaluation of the feasibility study report, the CSEF observed that the planning for the management of the excavated material is subject to uncertainties and information gaps. For example, the exploitation of existing data sources from geothermal boreholes should be leveraged. As the subsurface investigations are under way, their results should be integrated promptly and updates shared with the host states.

The Committee notes that, according to the study report, the current plans foresee the extraction of only about 2% of the excavated materials in Switzerland, which does not reflect the proportion of material excavated under Swiss territory. The ongoing work toward a strategy for managing excavated materials should therefore consider options for repatriation or compensation mechanisms, to be developed in close coordination with the host state authorities. The associated transportation and transit of materials through the border area, and potentially beyond the canton of Geneva, should be anticipated within the strategy. Cross-border

transportation will require careful advance planning and coordination between all concerned authorities.

The impact of excavated material management should be duly addressed within the environmental impact assessment. Switzerland looks forward to CERN developing and proposing, in a timely manner, proactive solutions in cooperation with the host states to anticipate the management of transnational material flows and potential compensation mechanisms, ensuring political and diplomatic alignment before the start of excavation.

If temporary storage on Swiss territory is required during excavation activities, the CSEF wishes to recall that such storage cannot take place on *surfaces d'assolement* (SDA, crop rotation areas). CERN should therefore provide appropriate justification and formally plan for the necessary zoning procedures should any change in land use be required for storage purposes.

The civil engineering of the FCC will encounter deeper and more complex geological challenges than the LHC, including karstic zones and tunnelling beneath the lake. The Committee notes that the current assessments may benefit from further refinement and the timely involvement of additional expertise. If approved, the FCC would be a major tunnelling project in Europe likely to mobilize substantial resources and compete with other large infrastructure projects for specialized personnel and equipment. Careful coordination will therefore be required, particularly if shafts and drilling proceed in parallel. Capacities for quarry backfilling sites should be secured early, as they may be claimed by other projects.

2.8 CSEF RECOMMENDATIONS TO CERN

a. ***Timely integration of results from the ongoing subsurface investigations and leverage of available data sources from geothermal boreholes.***
b. ***In close coordination with the host states, CERN should proactively advance the strategy for the management of excavated materials. The proposal should include options for repatriation, address cross-border logistics, and consider alternative compensation mechanisms. The strategy should be updated in a timely manner, as the involvement of multiple authorities is required, and political as well as diplomatic alignment must be ensured before the start of excavation.***
c. ***Anticipate competition for specialized personnel and equipment, given the FCC's scale as a major tunnelling project in Europe.***
d. ***To mitigate risks of unavailability, plan for securing quarry backfilling capacities and disposal options at an early stage.***

2.9 Engagement with the different public stakeholders

2.9.1 Building public interest and understanding of the FCC

This concern's CERN's overall communication strategy on the FCC. Effectively communicating the scientific value, broader significance, and socio-economic impact of the FCC project within a global and local context is essential to building public interest and support. The capacity to engage with the different public stakeholders, to build trust between stakeholders is central to the success of FCC. The quality of future work in the field of sustainability will have to address this aspect of engagement with the relevant public actors.

2.9.2 Public concertation and public debate processes in the Host States

In the host countries the FCC will be subject to public consultation processes, specifically the "débat public" in France and the "concertation publique" in Switzerland. The implementation of the processes will play a key role in preparing the ground for regional acceptance. Insights from these processes can also inform broader communication strategies aimed at other

stakeholders (2.9.1). The public consultation processes are distinct from the general communication strategy as they enable a structured dialogue with local populations and stakeholders directly affected by the project. They ensure the collection of feedback and input from the local population, its documentation and response to concerns as well as expectations. The process informs the project's development through feedback grounded in local contexts. Insights gained can further refine CERN's broader FCC communication strategy, ensuring coherence and responsiveness.

2.9 CSEF RECOMMENDATIONS TO CERN

a. ***Further identify and map out the various stakeholders involved at global, national, and local levels, distinguishing between those addressed primarily through general communication and those engaged through formal public concertation processes.***
b. ***Develop a comprehensive FCC communication strategy tailored to stakeholder groups and addressing the project's scientific, societal, global and local dimensions.***
c. ***Develop specific engagement approaches aligned with the formal public concertation processes in host states and ensure possibilities to feedback learnings to the broader FCC communication strategy.***

2.10 Cost of the FCC

The CSEF takes note of the cost estimate presented in the feasibility study and acknowledges the progress made in refining the underlying assumptions and reducing overall uncertainties. It underscores the importance of continuing efforts to further improve the accuracy and transparency of the cost estimate as the project evolves.

2.11 Tripartite collaboration with the Host States

The CSEF reiterates the importance of intensifying and strengthening an efficient and inclusive collaboration with the host states within the existing *Comité tripartite sur l'implantation territoriale du FCC* involving CERN, France and Switzerland. In this framework, Switzerland looks forward to advancing on several key points, such as the organisational framework and the allocation of the respective responsibilities linked to the various project elements, as well as the establishment of a joint strategy for collaboration with the host states on territorial and planning issues, in order to minimize the risk for potential showstoppers and bottlenecks.

Switzerland remains committed to supporting the preparation of the FCC project and its potential implementation within its competences, under the responsibility of CERN and in collaboration with France.

3. Conclusions

The CSEF acknowledges the significant progress achieved and reflected within the FCC feasibility study and appreciates the continued efforts by CERN to advance the planning of the FCC project such that CERN Council may be able to decide on the FCC in mid-2028. The Committee has not identified any technical showstopper to date. The study demonstrates an impressive level of scientific and technical maturity both in the accelerator and detector concepts and in the overall physics case. The Committee commends the progressive improvement and development on safety concepts and the remarkably detailed study of the circular tunnel's placement, just to name a few.

At the same time, several areas still require further development before the project can advance to subsequent stages with full confidence. These include the completion of all necessary environmental and socio-economic assessments, establishing a coherent and transparent strategy for the management of excavated materials, as well as clear communication strategy and meaningful concertation with the public and local stakeholders. In this report the Committee provides various recommendations to help guide the process in continuing the work on the FCC.

The CSEF encourages CERN to continue strengthening its collaboration with the host states and relevant authorities to ensure coherent planning, political alignment, and timely sharing of information. Continued transparent communication, further refined cost assessment, and sound environmental planning will be key to maintaining trust and facilitating well-informed decisions as the project progresses towards a decision in 2028.