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FUTURE CIRCULAR COLLIDER
PRE-TDR DESCRIPTION

TECHNICAL INFRASTRUCTURE
WP4
ELECTRICITY & ENERGY MANAGEMENT

Abstract

This document describes the proposal for the Work Package Electricity and Energy management needed for pre-TDR phase (2025-2028).

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History of Changes

Rev. No.	*Date*	*Pages*	*Description of Changes*
	9 September, 2024	First draft	

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1. INTRODUCTION AND CONTEXT

The FCC feasibility study will be terminated in 2025 and presented at different scientific bodies. The next step is the approbation of FCC by the CERN council in 2028 after the completion of the European Particles Physics Strategy foreseen in 2027. A pre-TDR phase is proposed to cover this period with the goal to be ready to launch Civil Engineering procurements right after the CERN council approval. The civil engineering procurement phase is divided in two main phases. Phase 1, different contracts to design the civil engineering infrastructures (2028-2029), phase 2, different contracts for the civil engineering construction (2029-2031). The plan is to start the civil engineering construction in 2031 for a completion foreseen in 2038. The first installation works of the technical infrastructure will start in 2037. The first installation works of the accelerators will start in 2040. The first installation works of the experiments will start in 2040. This gives the main milestones of the project if approved.

2. PRE-TDR OBJECTIVES

The period before the approval is defined as a pre-TDR phase and its main objective is to be able to launch the civil engineering procurement right after the approval. Many studies have to be completed to be able to launch this procurement, this concerns the technical infrastructures design, the accelerators design, the experiments design and all the studies for the authorisation process. The objective of this document is to define all the work to be performed during this period for the work package 4.

3. WP ELECTRICITY AND ENERGY MANAGEMENT

The FCC machines will require a strong electricity supply for power demand in the order of 400 to 600MW. A Detail study was performed for the Feasibility Study with 3 sub-stations at 400kV as delivery points. FCC-hh and FCC-ee were considered and a strong baseline was achieved including the delivery points and sub-station voltage, the transmission between points and the failure scenarios to secure the electricity supply, the integration of energy production and storage, the immunity against transient disturbances, and the power quality.

The objectives for the Pre-TDR are to complete the technical design of the grid and to validate the space required underground for electrical sub-stations, all cables, distribution boards...

This includes:

Update of the power demand and optimization between FCC-ee and FCC-hh

Define the grid connection and the architecture of the HV network

Design of the underground distribution including secured and uninterruptible networks

Some studies will continue in parallel with

The develop of the optimization tool Capex+opex

The study of alternative DC transmission systems

The study Energy Storage Systems

4. WP4 STRATEGIC SCHEDULE

The main milestones of the WP4 are listed in the Table 1:

Table 1: WP4 strategic schedule

2028	Completion of engineering design of underground sub-stations and distribution Completion of power demand Completion of grid connection requirements Completion of engineering design of surface sub-stations
2031	Delivery of local grid connection for civil engineering construction sites
2037	Start of the installation of electrical infrastructures (in shaft)
2038	Delivery of HV grid connection (RTE)
2042	Start of the commissioning of the FCC electrical network
2043	Completion of the electrical infrastructures Electrical network operational

5. WP4 PROCUREMENT PLAN

The main milestones of the WP4 procurement plan are listed in the table 2:

Table 2: WP4 strategic procurement plan

2028	Placement of contract for Local grid connection
2030	Placement of contracts HV grid connection
2031	Start of the procurement process, MS
2033	Start of call for tenders, IT
2035	Placement of contract for installation Works Placement of contacts for transformers, cables, switchgears….

6. WP4 INTERFACES

The work package is interconnected to most of the others work packages as electricity power everything, see Figure 1, the interconnections map.

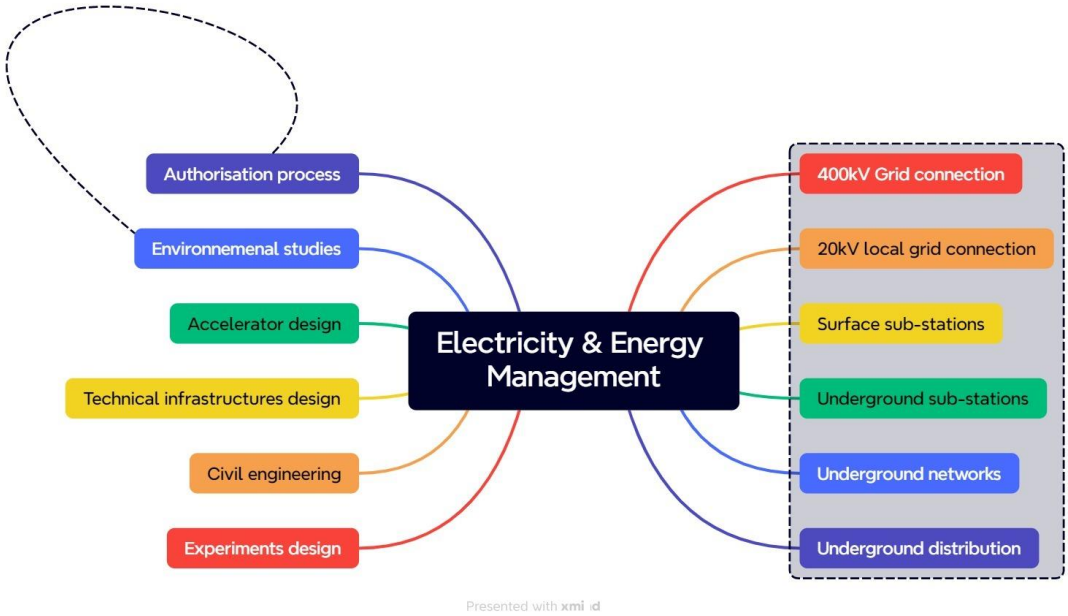

Figure 1: WP4 interconnections map

Dependency Impact analysis on electricity and energy management from other stakeholders is detailed in Table 3.

Table 3: WP4 dependency impact analysis table

	Low	Moderate	High	Description
Civil engineering	☐	☒	☐	Size of alcoves
Experiments	☐	☒	☐	Sie of service cavern
Accelerators	☐	☐	☒	Power demand, cabling
Technical infrastructures	☒	☐	☒	Power demand, cabling
Environmental impact	☒	☐	☐	Technology selection
Authorisation process	☐	☐	☒	Grid connections

7. WP4 IMPACT ON CIVIL ENGINEERING DEFINITION

The WP4 impacts on the civil engineering requirements is detailed in table 4 with the level on integration works performed for the Feasibility study.

Table 4: Level of integration

Integration	Basic estimation	Draft integration	Detailed integration	description
Underground alcoves	☐	☐	☒	However, depends on the power demand evolution
HV sub-station in service caverns	☐	☒	☐	However, depends on the power demand evolution
Distribution for Experiments	☒	☐	☐	No study performed
Surface sub-stations	☒	☐	☐	No study performed
Energy storage	☒	☐	☐	No study performed

8. WP4 RESEARCH & DEVELOPMENT

The work package is largely based on classical industrial products on the market. Some innovations are introduced to respond to specific needs of the project. The main R&D topics are:

- Energy storage
- Smart grid control
- Availability and robustness with FACTS
- DC grids

9. WP4 MATURITY AT THE COMPLETION OF THE FEASIBILITY STUDY

The works performed during the feasibility study are the main inputs for the Pre-TDR phase. Some parts of the work package are more advanced than others, see table 5.

Table 5: Maturity of the design

Design	Conceptual phase	Research phase	Preliminary engineering	description
Grid connection	☐	☐	☒	Study performed by RTE and ENEDIS
HV sub-station	☒	☐	☐	Proposal for Gas Insulated Switchgear
MV network	☒	☐	☐	Study and selection of voltage levels

Energy storage	☒	☐	☐	Evaluation of different solutions
Smart grid control	☐	☒	☐	RF2.0 project

The advancement of the WP in relation to the overall project schedule is detailed in table 6.

Table 6: WP4 advancement

Global schedule	behind	In phase	In advance	
Grid connection	☐	☒	☐	Study performed by RTE and ENEDIS
HV sub-station	☐	☒	☐	Proposal for Gas Insulated Switchgear
MV network	☐	☒	☐	Study and selection of voltage levels
Energy storage	☐	☒	☐	Evaluation of different solutions
Smart grid control	☐	☒	☐	RF2.0 project

10. DESCRIPTION OF THE PRE-TDR WORKS

Task 1: Update of the power demand and optimization between FCC-ee and FCC-hh (EN-EL, SY-EPC)

- Update power demand from the different loads
- Update for FCC-ee and FCC-hh
- Participate in the accelerator designs to minimize infrastructure needs
- Try to define a common electrical infrastructure compatible with the two machines
- In view of minimizing costs of the first FCC-ee stage, and to minimize the upgrade costs toward the next FCC-ee stages and FCC-hh, provide solutions aiming at reusing specific components (e.g. distribution transformers). The optimal powering distribution solution shall integrate a staged approach.

Table 7: Task 1 deliverables

Deliverables	**Time**	**Comments**
Task 1.1: Power demand	**June 2027**	
….		

Task 2: Define the grid connection and the architecture of the FCC High-voltage network (EN-EL)

- Review the connection to the French and Swiss electrical grids
- Define the number of connection points and the voltage level of the sub-station

- Define the architecture of the internal high-voltage network to supply all loads and experiments
- Build a software model of the HV network
- Define failure scenario and study back-up solution
- Define the preliminary requirements for integration (surface and underground)

Table 8: Task 2 deliverables

Deliverables	Time	Comments
Task 2.1: Grid connection	**June 2027**	
….		

Task 3: Development of a global optimisation tool for FCC powering (SY-EPC)

- Develop a global optimisation tool to help with the technical choices taking into account investment and operational cost. Starting with basic cost (investment and operational) and volume models, develop an optimization environment able to provide rapid answers to the project in terms of general performances (cost, volume in primis). This environment will be flexible enough to adapt to specifications changes and to different powering topologies. In view of gradually improving this environment, a constant effort will be provided to refine models.

Table 9: Task 3 deliverables

Deliverables	Time	Comments
Task 3.1: Optimisation tool	**June 2026**	
….		

Task 4: DC transmission systems (SY-EPC)

- Study DC transmission solutions (e.g. topologies, controls, protection strategies) and provide advanced models to be integrated into a global optimization environment (performances, cost, volumes, etc.).
- Compare solutions with and without DC transmission systems in terms of investment and operational costs. This includes the impact cost on civil engineering and services (collaboration with other WPs and WUs).

Table 10: Task 4 deliverables

Deliverables	Time	Comments
Task 4.1: DC tranmission	**June 2027**	
….		

Task 5: Energy Storage Systems and power quality (SY-EPC)

- Evaluate existing and evolving technological solutions for Energy Storage Systems (ESS). Develop ESS models (performances and cost) and use them in the global optimization environment to determine the best ESS and location in the distribution network (HV, MV, LV, AC side or DC side). Explore ESS solutions considering the FCC integration environment.

Table 11: Task 5 deliverables

Deliverables	Time	Comments

Task 5.1: Energy storage	**June 2028**	
….		

Task 6: Investment and operational costs (EN-EL, SY-EPC)

- Other than investment cost models, special attention shall be given to operational costs. Losses models need to be developed to estimate the energetic cost of operation. Reliability models are essential to estimate failure rates and provide hints on topological solution (e.g. with redundancies). Availability (downtime) shall be addressed and solutions for fast repairing need to be studied.

Table 12: Task 6 deliverables

Deliverables	Time	Comments
Task 1.1: Cost model	**June 2027**	
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Task 7: Minimize energy consumption and introduce sustainability (EN-EL, SY-EPC)

- Analyse how to minimize energy consumption
- Analyse how to introduce energy production or new concept of energy storage in the FCC infrastructure

Table 13: Task 7 deliverables

Deliverables	Time	Comments
Task 7.1: Energy consumption	**June 2027**	
….		

Task 8: study of the underground distribution system

- Definition of principles for underground distribution
- Definition and modelling of typical LV distribution schemes
- Definition of principles for secured and uninterruptible networks

Table 14: Task 8 deliverables

Deliverables	Time	Comments
Task 8.1: LV Distribution	**June 2028**	
….		

11. PRELIMINARY SCHEDULE FROM EN-EL

	2021		2022				2023				2024				2025			
Task	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Retrieve/update preliminary users' requirements																		
Provide/update preliminary baseline to integration																		
Assess HV grid connection scenarios (with RTE)																		
Software model of HV high level network																		
Analysis of available scenarios and possible backup/recovery options																		
Definition of baseline for HV single line diagram																		
Definition of key-parameters for the required network(s) (availability, reliability, etc..)																		
Definition of HV network model																		
Development of underground distribution principles																		
Development of LV distribution principles (including auxiliaries)																		
Development of secured network principle																		
Define typical electrical architecture for each point																		
Preliminary cost update for mid-term review																		
Define requirements to integration																		
Define requirements to other services (CV, transport, safety, etc.)																		
Review of updated users' requirements																		
Contribution to power quality, energy management and sustainability principles																		
Contribution to TDR, including description of the solution, cost and feasibility analysis																		
TDR ready																		

To be developped

12. PRELIMINARY SCHEDULE FROM SY-EPC

13. MANPOWER & BUDGET

13.1 SUMMARY TABLE EN-EL

EN-EL		**2025**	**2026**	**2027**	**2028**	**2029**
Manpower [FTE]						
	Engineer (ENG)					
	Technician (TEC)					
	Fell/PJAS (FEL)					
	PhD					
	FSU (FSU)					
Material Budget [kCHF]						
	Total					
	Used					
	Carry over					

13.2 EN-EL POST DESCRIPTIONS

Engineer 1, staff name: Senior electrical engineer, WP manager and grid study leader.
Engineer 2, staff to be hired: Junior electrical engineer, design of LV dristribution
Engineer 3, fellow electrical engineer: young graduate, study of energy storage
…

13.3 SUMMARY TABLE SY-EPC

SY-EPC		**2025**	**2026**	**2027**	**2028**	**2029**
Manpower [FTE]						
	Engineer (ENG)					
	Technician (TEC)					
	Fell/PJAS (FEL)					
	PhD					
	FSU (FSU)					
Material Budget [kCHF]						
	Total					

	Used					
	Carry over					

13.1 SY-EPC POST DESCRIPTIONS

Engineer 1, staff name: Senior electrical engineer, WP manager and power design leader.

Engineer 2, staff to be hired: Junior electrical engineer, Power electronic engineer, design of high-efficiency converters

Engineer 3, fellow electrical engineer: young graduate, study of medium voltage converters for RF HVPS.

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