CONFERENCE PRE-PRINT

STARTING DTT INFRASTRUCTURES CONSTRUCTION AT ENEA FRASCATI SITE

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Abstract

The Divertor Tokamak Test (DTT) is entering the construction phase of its civil infrastructure at the ENEA Frascati Site. While the main components of the machine are in various stages of manufacturing, a large-scale building programme has been designed to integrate the tokamak and its auxiliary systems. The project combines the reuse of existing FTU (Frascati Tokamak Upgrade) facilities, cleared from previous equipment, with the construction of nine new buildings, including the Tokamak Hall building, the ECRH Additional Heating Building, water-cooling and power supply facilities, and diagnostics areas. The design was carried out through an advanced 3D integration model progressively evolving toward a complete product lifecycle management framework, with special focus on minimizing environmental impact and ensuring full compliance with safety and regulatory requirements. Preparatory activities involve extensive excavations, soil consolidation and refurbishment of FTU infrastructures, while new high-voltage electrical connections and substations are being implemented to meet the increased power demand, reaching up to 198 MVA for pulsed operation. A dedicated Coil Cold Test Facility has been established to qualify superconducting magnets, supported by upgraded cryogenic systems and specialized power supplies. The design of the primary and secondary water-cooling networks, together with auxiliary systems such as nitrogen, compressed air and helium storage, has reached a level of detail that allow optimization of installation in confined spaces. Logistics planning has addressed multimodal transport routes for large components and construction phasing to minimize interference in a densely populated area. Despite delays caused by external factors, the maturity of the infrastructure design now enables realistic and efficient implementation strategy, expected to support the timely of the DTT programme.

1. INTRODUCTION

The Divertor Test Tokamak (DTT) is a strategic facility under construction at the ENEA Frascati site (Fig.1), aimed at addressing one of the key challenges for the development of nuclear fusion: the management of power exhaust in reactor-relevant conditions. The machine is designed to operate with superconducting magnets and

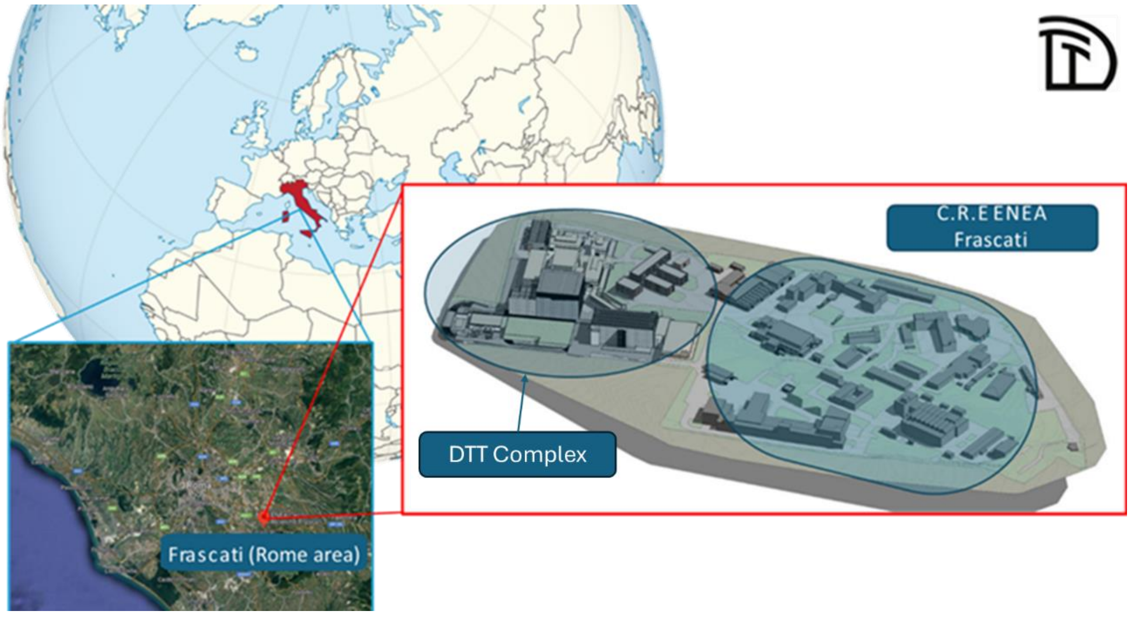

FIG. 1 DTT Complex Geographical Location

high-power additional heating systems, providing a flexible platform to study advanced divertor configurations and plasma-wall interaction processes in regimes relevant for ITER and DEMO.

In parallel with the manufacturing of the mail machine components, the realization of the civil infrastructures has reached the implementation phase. The project involves a complex combination of new buildings, refurbishment of existing facilities, installation of high-capacity utilities and the development of a site-wide integration model. The civil engineering design has been carried out with the objective of ensuring compatibility between the tokamak, auxiliary plants and services, while minimizing impact and guaranteeing compliance with regulatory and safety requirements.

The infrastructure programme includes excavation and soil consolidation activities, construction of nine new buildings and the adaptation of former FTU (Frascati Tokamak Upgrade) areas to host cryogenic, electrical and assembly systems. New high-voltage connections to the national grid and dedicated substations are being introduced to sustain the demanding power requirements of the superconducting magnets and auxiliary systems. Moreover, a comprehensive constructability and logistic plan has ben defined to manage the integration of activities within the confined space oh an anthropized area.

The introduction of these manufacturing represents a fundamental step towards the timely realization of the DTT programme and provides the technical basis for the subsequent assembly activities and operation of the machine.

FIG. 2 Render of DTT Complex

2. CIVIL DESIGN AND BUILDINGS CONSTRUCTION

The civil engineering design of the DTT site has been developed to integrate the new tokamak machine and the associated systems into the ENA Frascati Research Centre, situated in Frascati (Rome), via Enrico Fermi n. 45. The design approach combines the reuse of former FTU facilities with the construction of a nine new buildings complex, supported by advanced three-dimensional plant integration tools (3D Experience). The use of 3D modelling, progressively evolving towards a comprehensive product lifecycle management (PLM) model, has enabled early identification of interfaces and potential conflicts, reducing the risk of modification during construction and assembly The new and existing buildings are identified as in Fig 2 :

2.1. Reuse of existing FTU Complex

The former FTU buildings will be refurbished to accommodate several key infrastructures of the DTT facility, including cryogenic plant (compressor hall, auxiliary cold and recovery boxes), the ICRH power supplies and assembly preparation areas. The refurbishment project has the purpose of defining and executing all necessary civil works to adapt the existing facilities to their new functions.

The scope of the interventions covers both architectural and plant engineering aspects, as well as structural upgrades where required. Architectural modifications are intended to reorganize internal spaces and ensure functional integration with new systems. Plant engineering activities include the installation and adaptation of electrical networks, special technological systems, heating, ventilation and air conditioning (HVAC), and fire protection systems. Structural reinforcement measures are foreseen in specific cases to guarantee compliance with safety and the load-bearing requirements of new equipment.

This comprehensive refurbishment approach ensures that the existing infrastructures within ENEA Frascati Research Centre are adequately modernized and fully integrated into the new DTT area, while minimizing the need for new construction where reuse is feasible.

2.2. New Tokamak Hall and auxiliary buildings

The construction of new buildings within the DTT site, for which tender has been released in May 2025 and the contract expected to be signed in February 2026, represents a fundamental element of the infrastructure programme, with a total volume of approximately 150 000 m^3. The new facilities are designed to host the tokamak, additional heating systems, power supplies, diagnostics, and water-cooling plants, and have been conceived to ensure functional integration with the refurbished FTU structures.

The Tokamak Hall Building constitutes the core of the new complex, providing the space and structural support for the assembly and operation of the machine. In parallel, the ECRH Additional Heating Building will host both the gyrotron systems and their dedicated power supplies. A series of specialized buildings are dedicated to water-cooling, diagnostics, and power supply systems, ensuring redundancy and operational flexibility.

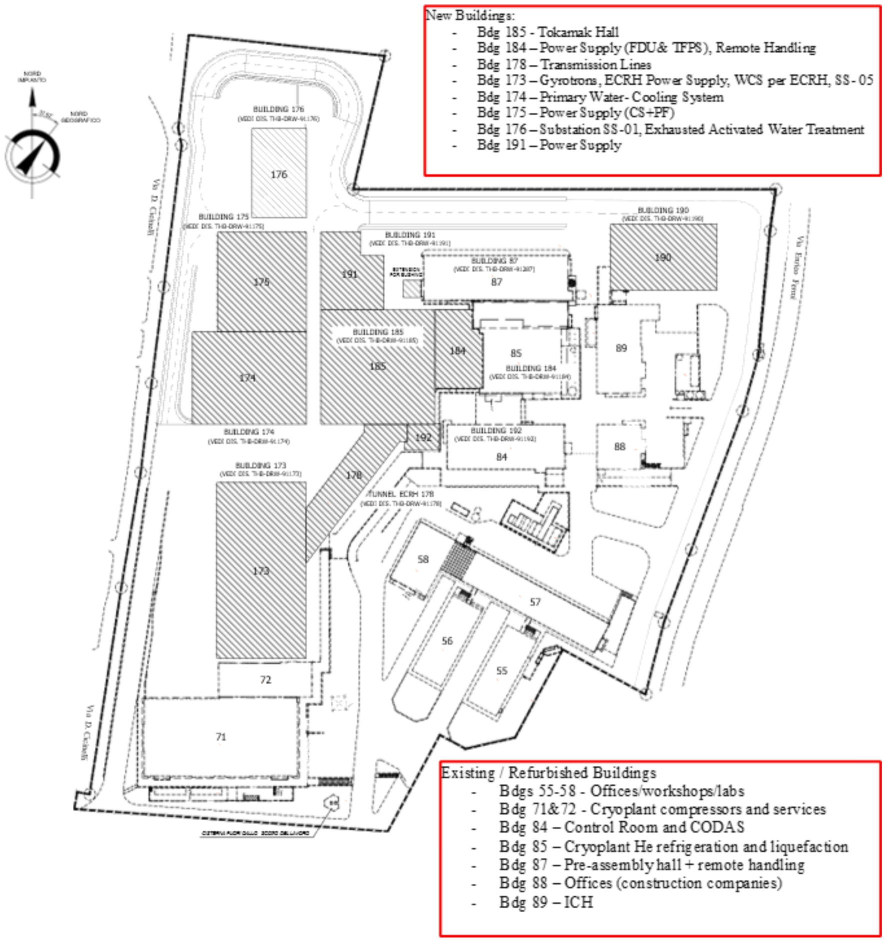

FIG. 3 Key plan of new (hatched) and existing buildings (not hatched)

The construction programme is preceded by extensive preparatory works, including 74 000 m^3 of excavation and soil consolidation activities. To ensure the stability of excavation fronts and allow the subsequent erection of foundation and underground utilities, containments works are foreseen through the construction of retaining walls on a Berliner pile wall system with anchored tie rods. These structures are designed to guarantee safety during excavation activities and to provide permanent support where necessary in compliance with geotechnical and seismic design criteria.

These interventions will substantially modify the existing configuration of the ENEA Frascati Centre, creating the necessary foundations and underground networks for utilities. Site adaptation also foresees the developments of new internal road, ramps, and containment structure, which are essential for ensuring both accessibility during construction and efficient operation of the facility once completed.

The erection of the new buildings has been designed to proceed in parallel with the refurbishment of existing infrastructures, according to a detailed construction phasing plan. This integrated approach minimizes interference between current activities, reduces rework and ensure the progressive availability of critical systems for the assembly of the tokamak machine.

2.3. Schedule and construction phases

A detailed constructability plan has been developed, resulting in a realistic construction phasing, that allows to match the restricted construction space while respecting the constraints of an anthropized area. The plan based on schedule analyses based on widely validated construction times, integrates logistical and accessibility considerations and outlines the site construction organization activities such as excavation, containment structures, new roads and ramps, underground networks and demolition, along with the construction of key buildings. Special focus has been given to the installation of electrical and specialized systems to ensure integration with the infrastructure.

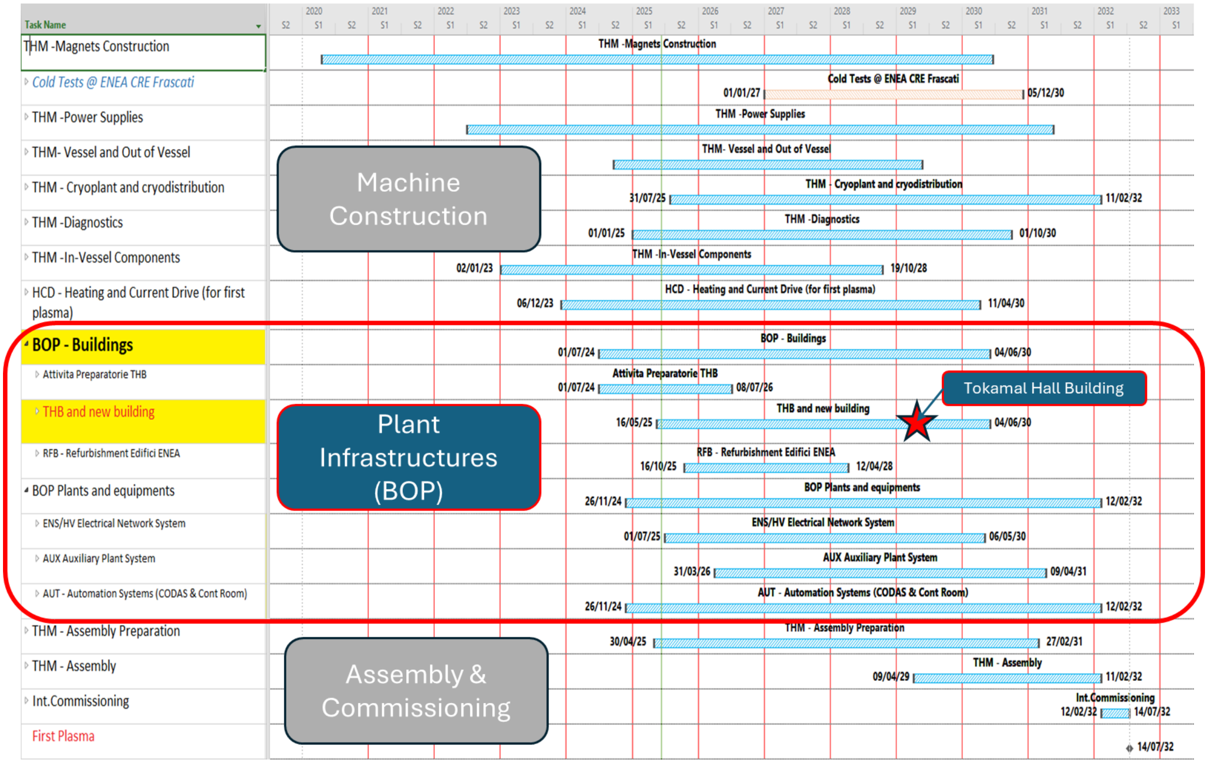

FIG. 4 Overall Schedule with Infrastructures highlighted

3. ELECTRICAL INFRASTRUCTURES

The new machine has required a substantial increase of the electrical power delivered to ENEA Site and for this purpose TERNA, the Italian Transmission System Operator, has started the lay down of two new 15 km high-voltage underground lines connecting the main electrical network node of Roma-Est to a new 150-kV grid switchyard close to ENEA Center. From this new switchyard, an underground cable is going to reach the new DTT substation two step-down transformers for pulsed loads with operating power range from 80 MVA up to 110 MVA and two 20 MVA stepdown transformers for the steady-state loads will supply 20 kV to be distributed to 5 substations strategically located in the DTT site to match power demand of 29 MVA Steady State Power and 198 MVA Pulsed Power. Furthermore, to comply with the National Electricity Grid Code, measures will be implemented to mitigate the power factor and guarantee power quality. A new connection to MV Italian National Grid are arranged to supply the construction site and facilities supporting DTT, while maintaining energized all existing power loads of the ENEA Center. The design is complete and ready for tender.

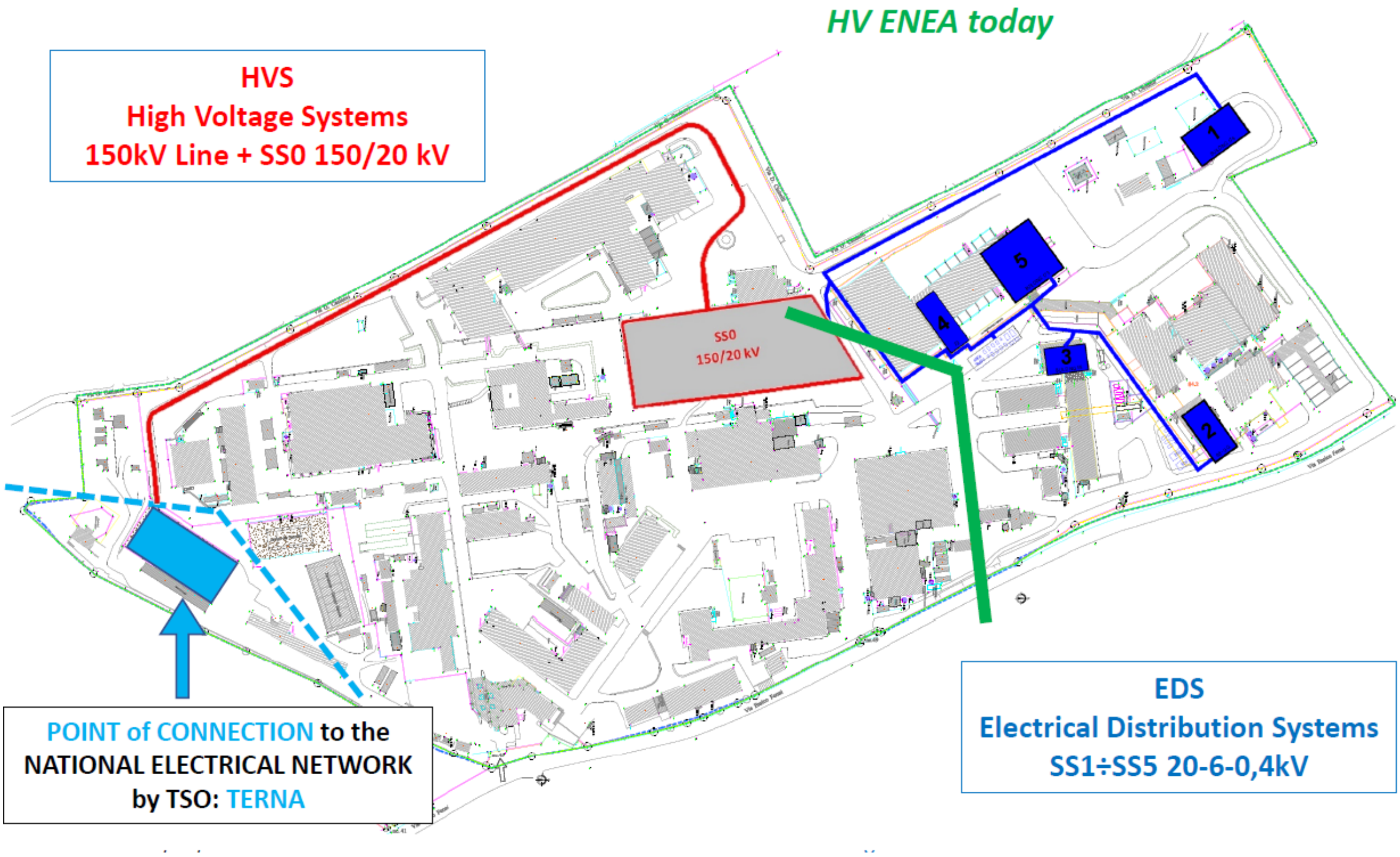

FIG. 5 Overall single line diagram

4. CRYOGENIC PLANT INTEGRATION AND COIL TEST FACILITIES

4.1 Cryogenic plant integration

DTT is equipped with superconducting magnets, that require to be cooled at low temperatures (4.3 K) for proper operation. The DTT magnet system is supported by an actively cooled structure with thermalized gravity supports and is thermally protected in a cryostat with thermal shields (TS) cooled with pressurized helium at 80 K. The superconducting coils are connected to the power supply by means of High Temperature Superconducting (HTS) current leads, which operate between cryogenic (50 K) and ambient temperatures. Further, DTT employs cryopumps behind the divertor targets, which require 4.3 K helium for the cold panel and helium at 80K for its chevron baffles.

The necessary overall cryogenic capacity is currently estimated to be around 10 kW equivalent power at 4.5K. However, the Cryogenic System shall deliver the necessary cooling power at three different operating temperatures: 4.3 K, 50 K, and 80 K.

A preliminary design of the DTT cryogenic system has been developed and its architecture is shown in Figure 1.

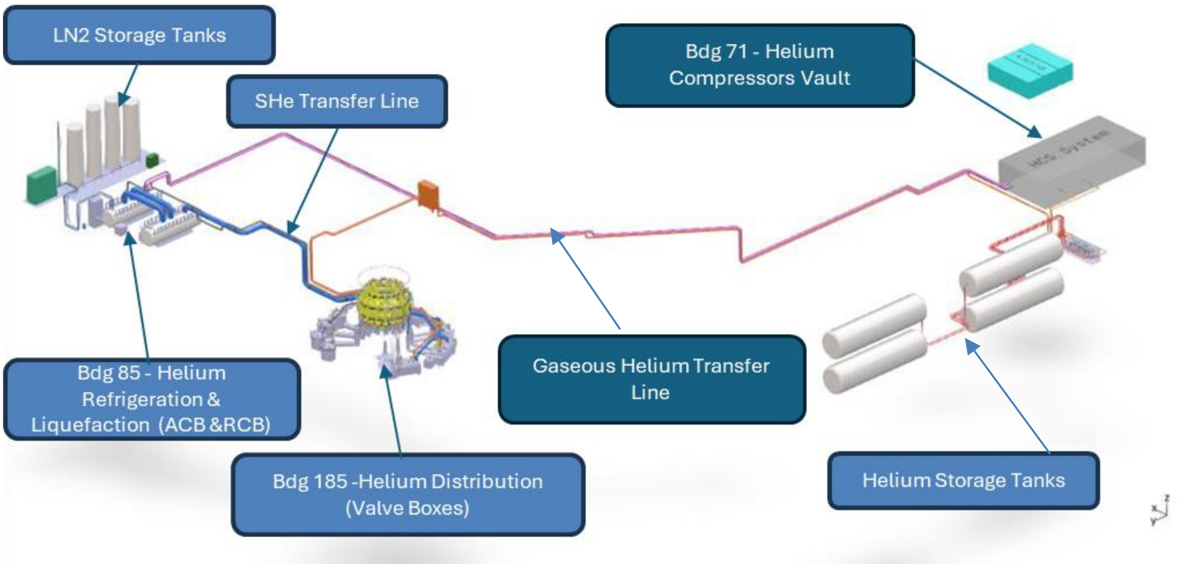

FIG. 6. Cryogenic plant Layout

All the sub-systems span a large area and several buildings of the DTT site, but still must respect the dedicated areas, which are often limited. For instance, a major effort was made by the CRYO-DTT team to develop the layout and the design of the Distribution inside Tokamak Hall respecting space constraints.

4.2 Cold Coil Test Facility

To match the schedule of the DTT superconducting magnets a Frascati Coil Cold Test Facility (FCCTF) has been prepared also by refurbishing existing ENEA infrastructures as the He refrigerator. The FCCTF is equipped with the TF power supplies with an operating current of 44 kA, and a fast discharge unit (FDU) based on silicon-carbide (SiC) varistor in order to perform cold tests on each Nb3SN (TF, PF and CS) superconducting magnet. Now, the TF power supply, have been delivered to the FCCTF and being in the commissioning phase. The new cryostat, able to accommodate all the coils to be tested, is contracted and will be delivered and commissioned in 2026.

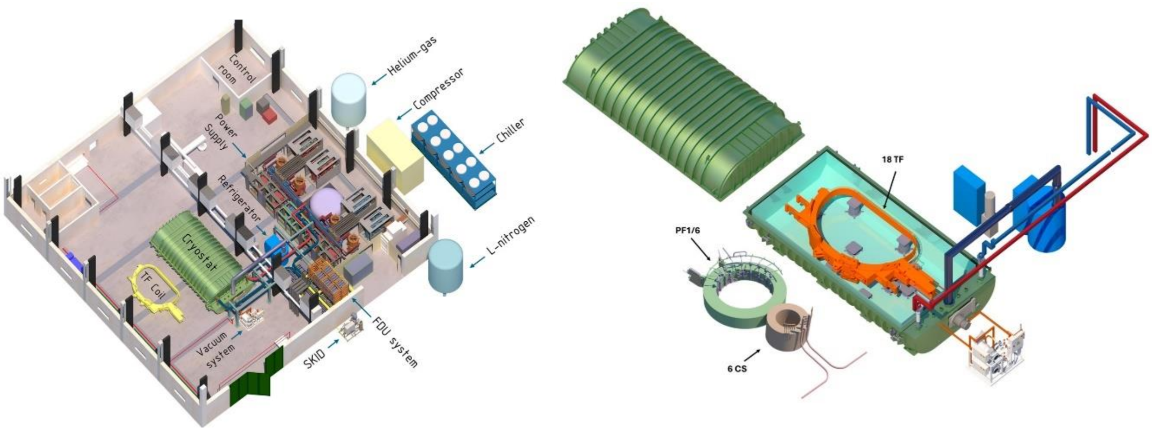

FIG. 7. Frascati Coil Cold Test Facility render

5. WATER COOLING AND AUXILIARY SYSTEMS

The design of the water-cooling and other utilities systems (i.e. nitrogen and instrument air) has been completed and components have been developed to a level allowing, now, a final phase of detailed design, in which optimization of the assembly inside buildings with restricted overhead and side spaces can be performed to reduce installation times and costs. A secondary cooling water system includes circulation and distribution pumps, chillers, storage vessels, piping and activated water treatment packages. A primary cooling circuit, which serves the divertor, first wall, vacuum vessel, ECRH, ICRH, power supplies and diagnostics, is composed by circulation pumps, heat exchanges, electric heaters, piping and mechanical filters. Other auxiliary systems, such as instrument air and nitrogen, are also integrated into the design, along with a comprehensive instrumentation and control system. In addition to these elements, the design included the reutilization and complement of existing LN2 tanks and distribution piping, together with helium storage tanks installation and external cryolines routing.

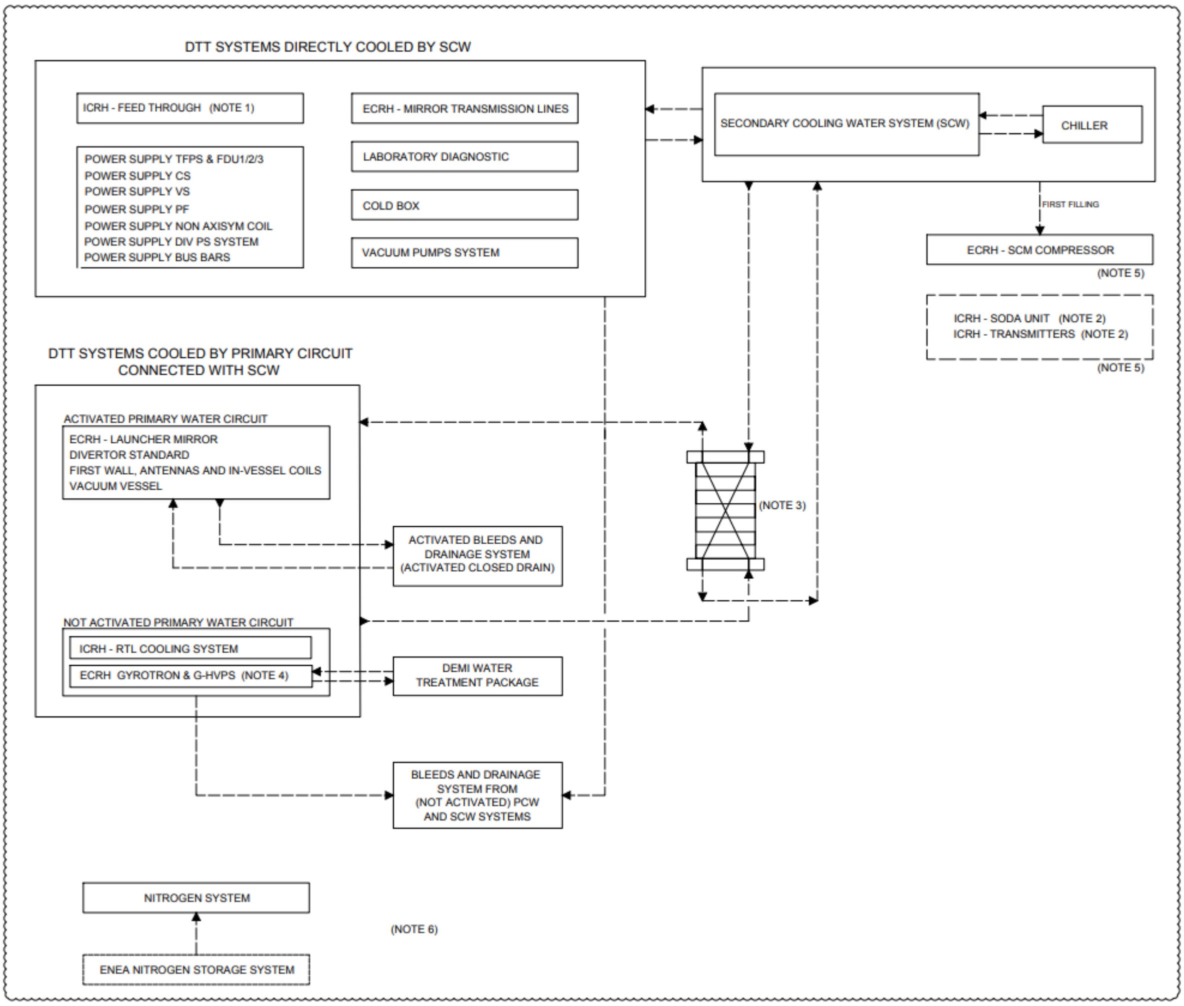

FIG.X. Auxiliary system Water-cooling flow diagram

SYSTEM OVERVIEW
PFD - Bleeds And Drainage From Pcw & Scw
PFD - Non Activated Demi Water Treatment System
PFD - Secondary Cooling Water System
PFD - Activated Bleeds & Drainage System (Activated Closed Drain System)
PFD - Ecrh Mirror Transmission Line Cooling Water System
PFD - Ecrh Gyrotron&Hvps Cooling Water System Train 1
PFD - Ecrh Gyrotron&Hvps Cooling Water System Train 2

PFD - Ecrh Launcher Mirror Cooling Water System
PFD - Smc Compressor System
PFD - Icrh Feed Through Dry/Air/Water Cooling System
PFD - Icrh Rtl Cooling System - Train 1
PFD - Divertor Standard Modules Cooling Water System
PFD - First Wall Antennas And In-Vessel Coils Cooling Water System
PFD - Vacuum Vessel Heating/Cooling System
PFD - Laboratory Diagnostic Package Connected To Secondary Cooling System
PFD - Vacuum Pumps System Package Cooling Water System
PFD - Cold Box Cooling Water System
PFD - Power Supply Cooling Water System
PFD - Nitrogen System

6. LOGISTICS

Logistic studies have been performed for the route allowing main loads, from generic manufacturing sites, either in Italy, Europe or outside Europe, to reach the DTT site, involving multimodal transports (ship, barge, trucks or specialized transport vehicles), roads and bridges reinforcements or temporary block, temporary storage on-route, on-site or ex-site:

- Air freight: through Fiumicino Airport (around 42 km distance)
- Sea freight: through Civitavecchia Port (around 100 km distance)
- Road freight: through Highway A1 exit Rome SUD (less than 3 km distance)
- Road freight: through Highway A1 exit Monteporzio Catone (around 5 km distance)
- Rail freight: through Railway Station Tor Vergata (line Rome-Cassino-Napoli – less than 1 km distance)

The site can be reached by oversize-overweight transportation (dimension over 2.5m x 2.5m x 12m) through the highway A1 exit Rome Sud or exit Monteporzio Catone and no obstacles (bridge, gallery, electric way, etc.) are highlighted along this way.

The biggest components to be delivered are the following:

- PF Coils (2 x 10m x 10m x 1m)
- TFC modules (18 x 7m x 4m x 1.5m)
- Helium Vessel (6 x dia 4m x 20m L),
- Cold Box (diam. 3.2m x 11m L and dia 3.2m x 12m L – 50 tons each)
- Secondary Cooling Circuit Cold Well Vessel (dia 4.5m x 14m L)
- Step-up Transformer (4m x 4m x 6m – 100 tons)

6. CONCLUSIONS

While the start of construction activities has been delayed, due to a combination of external factors (mainly the COVID pandemics and results of the geotechnical and environmental surveys) and reorganization of the DTT management, now the project has taken advantage of this time to produce a mature infrastructures design. which has good changes to proceed according to plans.