EFDA

EUROPEAN FUSION DEVELOPMENT AGREEMENT

Cadarache

as a

European Site for ITER

Report on the Technical and Socio-economic Aspects

27 September 2001

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Executive Summary

1. Background

The objective of the ITER machine is to demonstrate the scientific feasibility of fusion, with extended burn and marginally controlled ignition for a duration sufficient to achieve stationary conditions on all time-scales characteristics of plasma processes and plasma-wall interactions. To do so the installation will produce 500 MW of fusion power during pulses of at least 400 seconds. The facility will also demonstrate key fusion technologies.

The ITER Engineering Design Activities (EDA) were carried out between July 1992 and July 2001 under the framework of the ITER Agreement and Protocol signed by representatives of the four Parties, the European Atomic Energy Community, Japan, the Russian Federation and the United States of America (the USA withdrew in 1999). During the EDA, the ITER Joint Central Team (JCT) elaborated a reference design, called hereafter "generic design", including in particular a minimum set of requirements to be satisfied by any proposed site and additional assumptions.

Canada, the European Atomic Energy Community, Japan and the Russian Federation are about to start negotiations in order to select a site for the construction of ITER and to establish an ITER Legal Entity. In Europe, on 16 November 2000, the Research Council of Ministers asked the European Commission "to conduct negotiations on the establishment of an international framework allowing the ITER EDA Parties and qualified third countries to prepare jointly for the future establishment of an ITER Legal Entity for ITER construction and operation, if and when so decided."

At the European Consultative Committee on Fusion (CCE-FU) meeting on 11 July 2000, the French Delegation announced that "CEA was proposing the site of Cadarache as a possible site for ITER construction", calling on active contributions from the Euratom-Fusion Associations and on a strong involvement of European industry in the preparation of the proposal. The CCE-FU invited the EFDA Steering Committee to carry out swiftly – in close interaction with CEA and in consultation with the ITER JCT – an in-depth examination of the CEA proposal.

A European ITER Site Technical Study group (EISS group) has been established to examine ITER sites in Europe. For the Cadarache site, the EISS group was asked to:

- establish the compliance of the site with the ITER technical site requirements;
- identify key elements for the licensing procedure;
- examine site specific aspects of the ITER construction and operation costs;
- evaluate the social and infrastructure impacts of the project.

This document summarises the main conclusions of the work undertaken by the EISS group on the Cadarache site.

2. Technical Aspects

Cadarache satisfies all ITER site requirements.

The design assumptions are satisfied, most of them with a comfortable margin, with two minor exceptions:

- the seismic level is slightly higher in Cadarache than on the generic site;
- the capability of the network to supply reactive power is lower than on the generic site.

No technical difficulty is anticipated and the extra cost with respects to these issues is limited.

Two different routes for the transportation of large and heavy components have been fully assessed.

2.1 Overview of CEA Cadarache

Cadarache, established in 1959, covers 1600 hectares and is the largest research centre of the French Atomic Energy Commission (CEA). It is located at the very heart of historical Provence, halfway between Aix-en-Provence and Manosque.

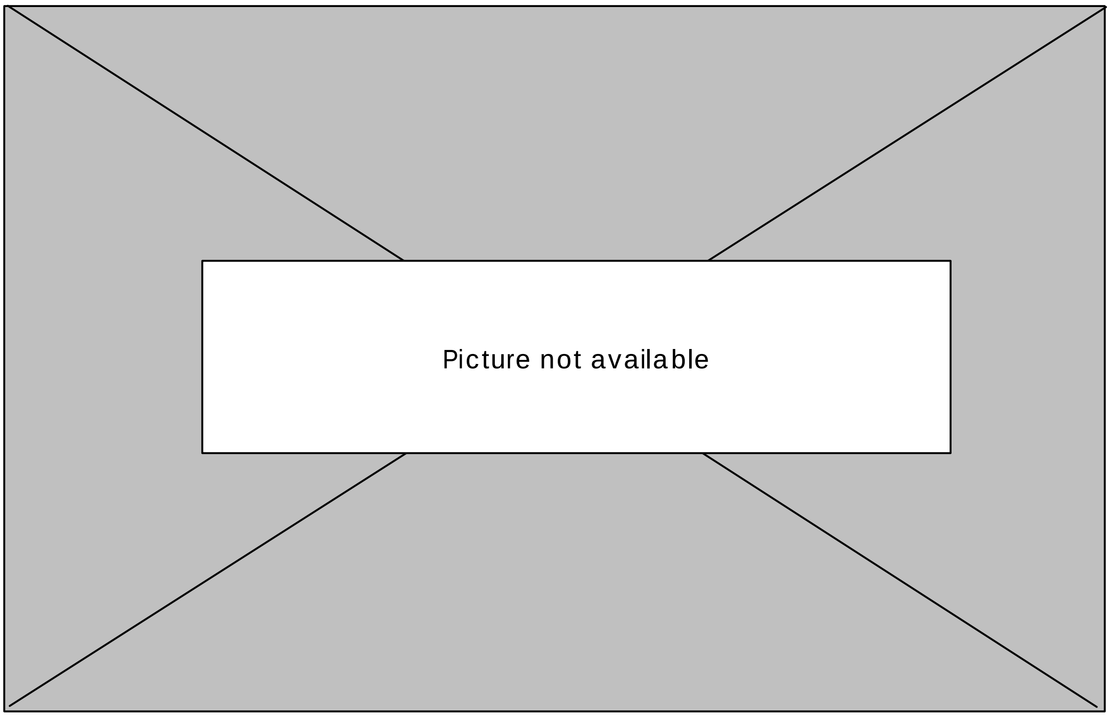


Figure 1.1: ITER location on the Cadarache site

Cadarache is the main CEA centre for power oriented nuclear research, with experimental reactors, specialised laboratories and workshops for a total of 18 nuclear facilities. The centre provides employment for 5 000 people and it has an annual budget of 400 M€. The Euratom-CEA Association, which coordinates the French activity on magnetic thermonuclear fusion, is also based on the Cadarache site and it operates the superconducting tokamak Tore Supra since 1988. In addition to several specialised laboratories and reactors, a number of general services are available on the Cadarache site, e.g. local security and radiation protection.

The Cadarache research centre has all the necessary infrastructure to host a nuclear facility such as ITER.

2.2 ITER site layout

Following the assessment of 3 specific areas, it is proposed to locate ITER at the Northeast boundary of the Cadarache site (Figure 1.1). The layout of the buildings is in accordance with the generic site drawings, except for the cooling towers, which have been repositioned 300 m away according to the dominant winds. The office building has been rotated to improve access (Figure 1.2). Additional buildings and services (restaurant, medical service, etc.) are also indicated.

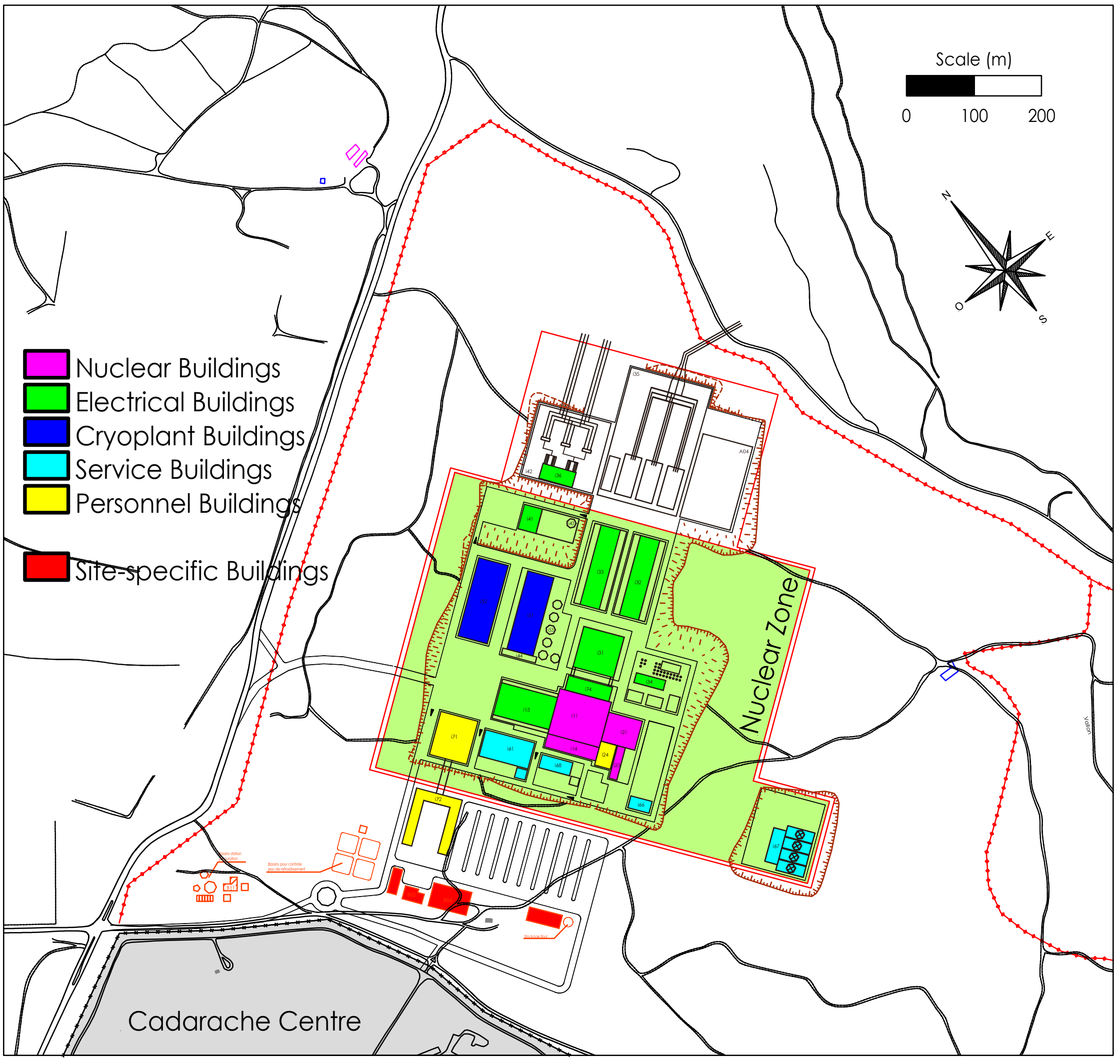


Figure 1.2: Detailed layout of the buildings

Test drillings were carried out to determine the location of the limestone substrate, which was found to be of good quality and at a maximum depth of about 10 m. A more detailed geological investigation is underway to finalise the exact location of all buildings and to determine the soil characteristics necessary for the detailed design of the foundations.

Architectural studies intended to estimate the visual impact were made. Figure 1.3 gives a preliminary outline of the site with the ITER buildings.

Figure 1.3: Insertion of ITER in the Landscape, seen from the Castle of Cadarache

2.3 Seismic aspects

The ITER JCT has designed the safety-classified buildings in accordance with the ASME and the US NRC guidelines. The results should be valid for a wide range of sites with the exclusion of those with unusually soft soils. The primary scaling parameter used is the maximum ground acceleration, assumed to be 0.2 g for the generic ITER site. At Cadarache, the “Règles Fondamentales de Sûreté” require to consider the so-called “Séisme Majoré de Sécurité” (magnitude of 5.8, epicentre at 7.1 km) and the “Paléoséisme” (magnitude of 7, epicentre at 18 km), whose maximum ground acceleration are, respectively, 0.315 g and 0.281 g.

Stress analysis shows that the Tokamak Building, as it is now designed, is able to withstand the Cadarache seismic conditions without any major reinforcement. About 150 eigenmodes have been calculated in each of the three directions and the main modes in the horizontal directions were found in the range 3.6 – 3.7 Hz. A few weak points have been identified at the level where the superstructure is connected to the upper slab. Floor spectra have also been computed in order to assess the design of the safety related equipment inside the tokamak building (this assessment has not yet been done for the generic site).

As an alternative, the use of 400 paraseismic bearings for the ITER tokamak building has been assessed. These bearings, made with elastomer foils interleaved with stainless steel plates, are commonly used for bridge supports and in some nuclear buildings. Their use leads to a decrease in the overall acceleration on the building, and consequently on the equipment, to 0.1 g. This would result in significant savings for the building and all inner equipment but, on the other hand, an *overall* displacement of the building of roughly 75 mm (without bearings, the displacement is a few mm a ground level and 52 mm at the superstructure level) is foreseen at a frequency of 0.56 Hz. The interfaces with nearby buildings will need to be checked carefully because of this motion.

The two options (local reinforcement of the building and the use of paraseismic bearings) are feasible. No major modification with respect to the generic design is foreseen.

2.4 Heat sink and water supply

A consumption of 1.5 million m^3 per year has been estimated for the cooling water circuits. This is equivalent to the present total consumption of the Cadarache centre. It will therefore be necessary to install a new system. The preferred solution is to supply water by means of gravity from the EDF canal of Vinon-sur-Verdon. The investment cost for this solution is slightly higher than for other alternatives, but this is offset by the reduced cost of operation since no pumping station is required. Other new installations are foreseen at Cadarache and will also require modifications of the water supply; synergies might be obtained between the different projects.

The climate in Cadarache, warm but very dry in the summer, allows the overall dimensions of the cooling towers to be reduced, the wet bulb temperature in Cadarache being 24°C instead of 29°C as assumed by ITER. However, the relocation of the cooling towers leads to an increase in the length of pipe work by 300 m (2 pipes of 2 m diameter).

About two thirds of the water evaporates in the cooling towers. The rest will be discharged into the Durance River or the canal, after the necessary controls, making use of the current discharge outlet of the Cadarache site.

2.5 Electrical Power Supply

The electrical network around Cadarache is well equipped with many lines and two powerful nodes, Boutre (5 km east of the ITER site, with an interconnection at the 400 kV/225 kV level through an autotransformer) and Sainte-Tulle (8 km north of the ITER site, with an interconnection at the 225 kV/63 kV level). Moreover, Tore Supra is already supplied by a 400 kV dedicated line and the Cadarache centre by two 63 kV lines.

The generic ITER design is based on a single 400 kV line and a double 225 kV line. Several alternatives have been considered and compared by the public company RTE. In particular, the environmental impact has been considered very carefully taking into account the visual impact of 225 kV and 400 kV pylons. The reference scheme is shown in Figure 1.4. All modifications necessary take place on CEA property.

The design assumptions for the reactive power compensation are not satisfied. The ITER static VAR compensator will have to be increased from 540 Mvar to 660 Mvar and driven as voltage regulator to reduce the voltage drop on the network within acceptable limits. This design modification will have a modest impact because there are margins in the present design. On the other hand, the design assumptions with respect to the active power are widely exceeded and 1000 MW could be delivered for 30 s instead of the assumed 500 MW. Should this point be confirmed, a scheme with only a double 400 kV line could be proposed, leading to cost savings on both site adaptation and generic design. This scheme is fully compatible with the ITER site requirements and design assumptions.

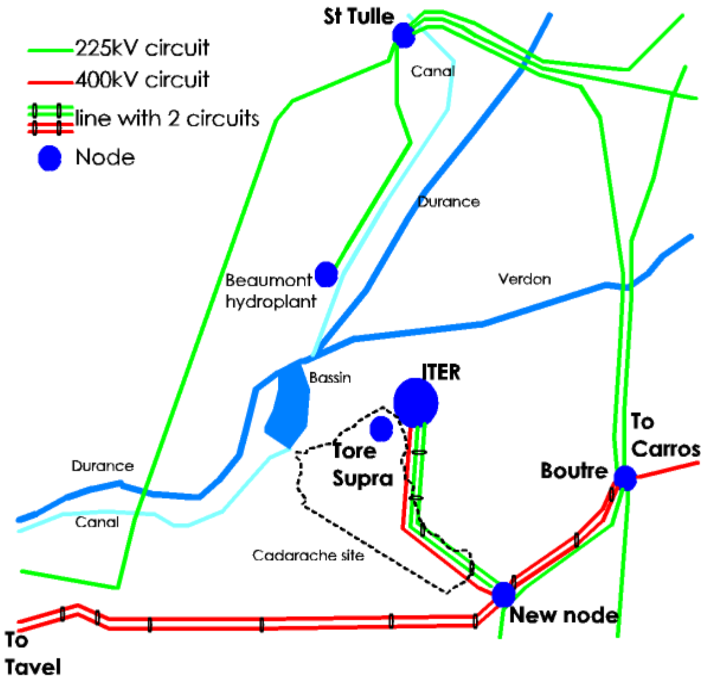


Figure 1.4: Proposed ITER High Voltage Supply Scheme

2.6 Transport of heavy and large components

The transport of large and heavy components to Cadarache, which is located 70 km from the nearest sea harbour, has required specific studies. A careful review of all dimensions and weights of these components has been made in close collaboration with the ITER JCT and the weight and size of the handling and protection equipment have been estimated.

The public agency "Centre d'Études Techniques de l'Équipement" (CETE) has evaluated two routes:

- in a first instance, the use of an already existing itinerary for "convoi exceptionnel[1]" between Fos-sur-Mer (Marseille) and Cadarache. Certain sections would require technical adaptations, in particular roundabouts and bridges, but no administrative difficulty is anticipated. This first scheme requires the use of a section of EDF canal (see below);
- in a second instance, an alternative route, only by road has been assessed. It has the advantage to be faster: 3 days, compared to 10 days (no load transfers to and from the barges), but would require more technical adaptations.

In addition, the "Centre d'Ingénierie Hydraulique d'EDF" analysed the transportation on the Durance EDF canal by means of ad-hoc barges. One hydroelectric power station would be by-passed via a specifically constructed track. The use of about 40 km of the canal requires, besides the manufacture of the barges, the modification of a few bridges and the construction of specific handling equipment for loading and unloading the components on the barges.

[1] Road already qualified for "exceptional" transport

The Figure 1.5 illustrates the two possible routes.

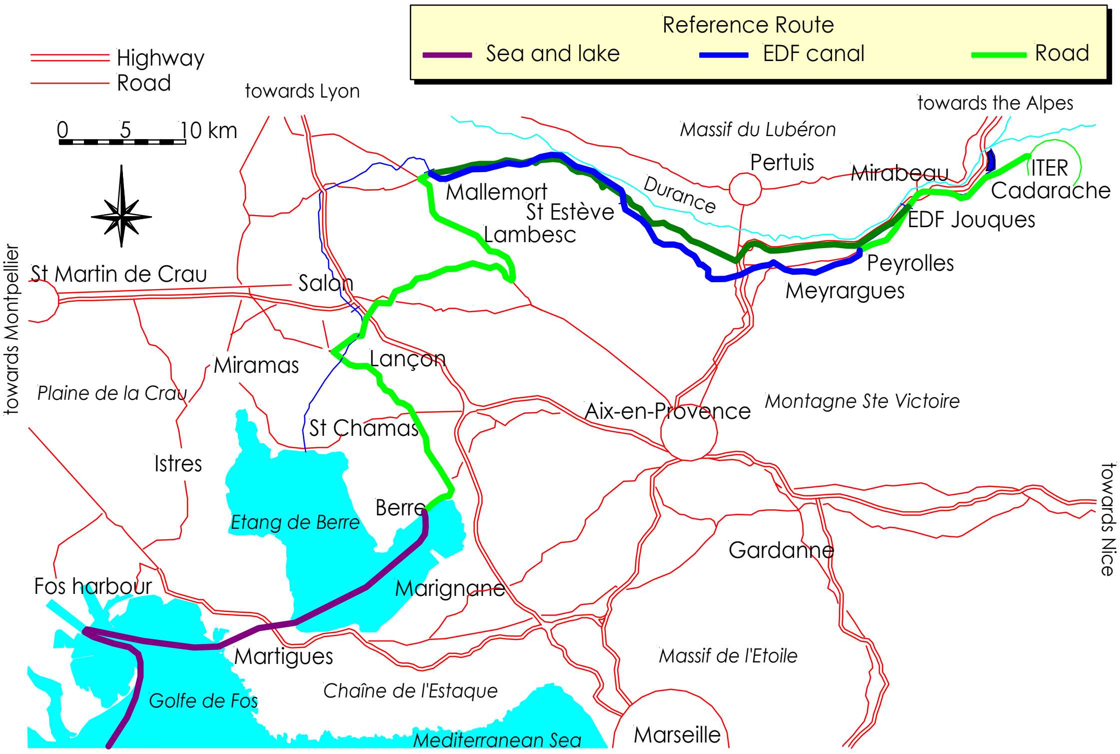


Figure 1.5: Reference routes (by road only, or combination of road and canal), from Fos harbour to Cadarache

3. Safety and licensing

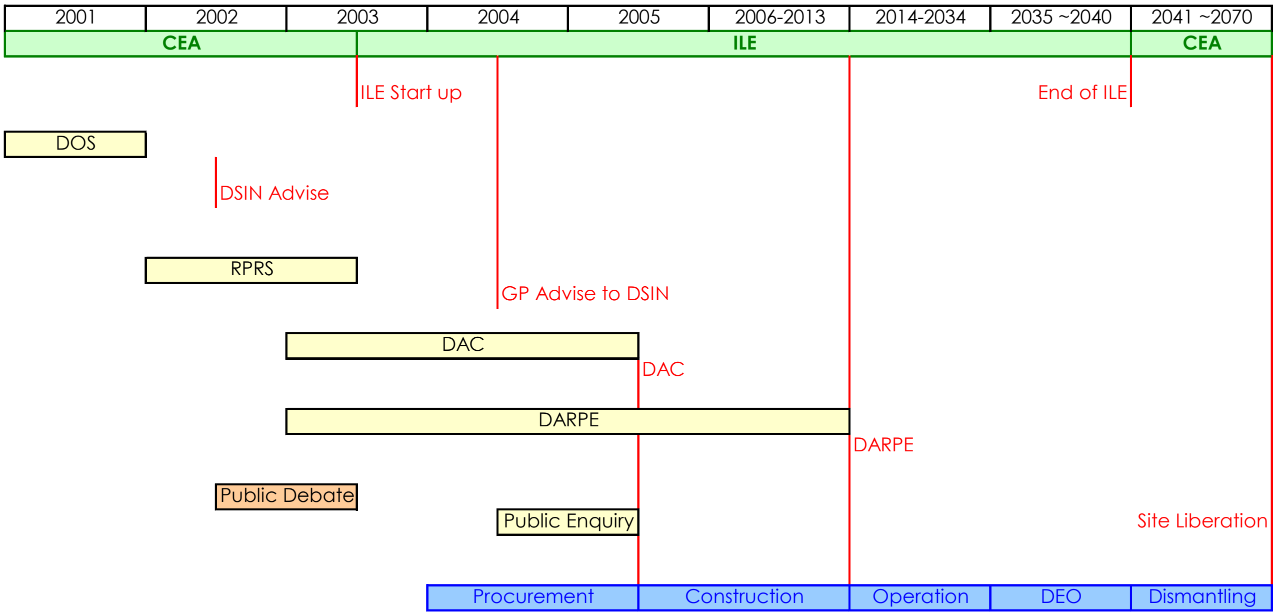
The ITER regulatory and decommissioning requirements are compatible with the French licensing regulations. CEA has started the licensing procedure in order to satisfy the ITER planning assumptions.

3.1 Licensing procedure

A licensing procedure is required in France for all nuclear installations. The definition of a nuclear installation, i.e. an “Installation Nucléaire de Base” (INB), is based on the inventory of radioactivity. The ITER device would be classified as an INB because of the expected tritium inventory.

The operator of the INB is responsible for the safety and for the environmental impact of the installation from the beginning of construction to the final step of decommissioning. The current hypothesis is that the future operator will be the ITER Legal Entity, which will have to undertake the licensing process.

In order not to delay the licensing procedure, CEA and EFDA have started the first step of the licensing procedure, i.e. the preparation of the “Dossier d'Options de Sûreté”, which is planned to be submitted to the French safety authorities at the end of 2001. CEA and EFDA also plan to prepare key elements of the "Rapport Préliminaire de Sûreté" which, to respect the proposed time scale, should be submitted by the ILE to the French safety authorities mid 2003.



Acronym	*French meaning*	*English Translation or Meaning*
ASN	Autorité de Sûreté Nucléaire	French Safety Nuclear Authority
DAC	Demande d'Autorisation de Création	Request of Authorisation of Creation
DAC	Décret d'Autorisation de Création	Decree of Authorisation of Creation
DARPE	Demande d'Autorisation de Rejet et de Prélèvement d'Eau	Request of Authorisation for Water Release and Extraction
DARPE	Décret d'Autorisation de Rejet et de Prélèvement d'Eau	Decree of Authorisation for Water Release and Extraction
DEO	Mise à l'Arrêt Définitif (MAD)	Definitive End of Operation
DIN	Division des Installations Nucléaires	In charge of Nuclear Installation Control
DOS	Dossier d'Options de Sûreté	Description of Safety Objectives (not compulsory)
DSIN	Direction de la Sûreté des Installations Nucléaires	ASN Legal Head
GP	Groupe Permanent	Permanent Group (in charge of Request Examination)
ILE	Entité Juridique ITER	ITER Legal Entity (status to be defined)
IPSN	Institut de Protection et de Sûreté Nucléaire	ASN technical Adviser
RPRS	Rapport Préliminaire de Sûreté	Initial Safety Report (compulsory, to be borne by ILE)

Figure 1.6: Overall Licensing Process, from Today until Site Liberation

According to French law (loi Barnier, 95/101), any new, large project or installation may be submitted to a "public debate" during its design phase. The objective is to promote a countrywide discussion on the project socio-economic and/or environmental advantages and drawbacks. CEA and EFDA are considering how and when it would be more appropriate to initiate the ITER public debate.

The last step of the licensing process would be the authorisation to build and to operate ITER, formalised by two governmental decrees: the "Décret d'Autorisation de Création", required to start the construction, and the "Décret d'Autorisation de Rejets et de Prélèvements d'Eau", required to start operations. A Public Enquiry would also be held at this stage. It is a consultation process among the local communities around the proposed site on the external effects resulting from the construction and operation of the plant.

Licensing of ITER would finally require an agreement with the safety authority clearly stating that CEA would take care of decommissioning and waste management after the ITER Definitive End of Operation (DEO).

The time scale of the complete process is shown in Figure 1.6. Since the preliminary safety report must be submitted to the safety authority by the ITER Legal Entity (ILE), its establishment is on the critical path and should be completed by mid-2003, to allow the construction of the buildings by mid-2005. Assuming 1 year to complete the call for tender for the long-lead items (buildings, superconducting strand and vacuum vessel), their technical specifications should also be ready mid 2003. This time-scale is consistent with groundbreaking mid 2004.

3.2 Effluents and releases

To be granted a license, the design target for the effluents and releases should be defined so as to minimise their effects. The analysis shows that, for all foreseeable accidents, the release level will be about two orders of magnitude below the one for which any countermeasure or food restriction is needed for the population outside the site fence (less than 10 mSv).

The environmental impact related to the gases and airborne particulates effluents and liquid releases is being assessed. Preliminary results indicate that they are well below internationally accepted levels. In fact, the preliminary evaluation of doses to the public from atmospheric release is less than 10 µSv per year **at the end of life of ITER**. Concerning the tritium concentration in water, expectations in terms of doses are also very low (less than 0.1 µSv per year). ITER effluents and release are well below the current legal limits for all effluents (1 mSv). A detailed study will allow checking whether a further reduction of the releases to the Durance can be achieved.

ITER effluents and releases can be accommodated within the present Cadarache site authorisations.

3.3 Waste management and dismantling

The waste inventory expected during the operation phase and during dismantling has been established following the current French classification, which considers four levels for wastes:

- Very low level waste (TFA: "très faible activité"): activity lower than 10^4 or 10^5 Bq/kg, depending on the half-life, but for which trace-ability is mandatory;
- A-type waste: activity lower than 10^6 or 10^9 Bq/kg, depending on the half-life, which can be disposed of in the "Centre de l'Aube" repository;
- B-type waste: all waste that cannot be classified as TFA or A type;
- C-type waste: from fission fuel cycle (ITER does not produce any C-type waste).

It has been foreseen to minimise the B-type wastes volume and weight. Well-known technologies will allow the sorting to be performed.

The analysis of several scenarios shows that the amount of B-type waste does not vary significantly over time, whilst the amount of A-type and TFA-type wastes vary, as shown in Table 1.1. The total amount of waste is currently estimated at 30 000 t. Consequently, after the disassembly of the in–vessel components, the decommissioning process should be mainly driven by considering workers occupational doses and economic aspects.

	Phases	Masses (tons)			
		TFA	A-Type	B-Type	*Total*
Hypothesis 1	All wastes at shutdown	10577	19492	3502	*33570*
	Total of hypothesis 1	**10577**	**19492**	**3502**	***33570***
Hypothesis 2	Part at shutdown	10577	9970	3114	*23660*
	Part after 30 years	4924	1		*4925*
	Part at 50 years or detritiation simulation		387		*387*
	Part at 100 years or CWS decontamination simulation	4598			*4598*
	Total of hypothesis 2	**20099**	**10358**	**3114**	***33570***

Table 1.1: Breakdown of waste at shutdow or after decay

Different methods of disposal are proposed for the different types of waste depending on the disposal foreseen. The reference scenario currently favours the local disposal and the temporary storage on the ITER site before the final deposit in a permanent storage facility.

3.4 Tritium management

After an initial phase of operations with hydrogen and deuterium, ITER will operate during 10 years with a deuterium-tritium mixture. 15 kg of tritium will be supplied from off-site sources so that tritium transport, inventory tracking and accountancy have to be done according to French and international regulations.

A container for the transport of 25 g of tritium is already qualified internationally. Alternatively, a container with a larger capacity could be extrapolated from an existing cask and qualified.

A specific accountability procedure would have to be defined and implemented for non-proliferation reasons. Detailed studies on the uncertainties in the measurement processes are in progress. A periodic check of the tritium inventory might have to be done to minimise the uncertainties due to administrative limits on the total tritium inventory allowed in the torus (ITER has proposed 700 g in the vacuum vessel, and a total of 3 kg on site).

4. Socio-economic aspects

The Provence Alpes Côte d'Azur region has all the necessary resources and infrastructure to respond to the industrial, social and cultural needs of ITER.

Cadarache is located near the city of Aix-en-Provence (distance 35 km, 137,000 inhabitants) and the towns of Manosque (15 km, 20,000) and Pertuis (25 km, 18,000), where the majority of the people currently working on site live. Marseille, the largest harbour of the Mediterranean and second largest city in France, is 70 km away.

Local and regional authorities have expressed their strong support for ITER in Cadarache and they are actively involved in the on-going studies.

European industry would greatly benefit from the ITER construction. This would be particularly true if ITER were to be hosted in Cadarache.

A team of international fusion experts is already working at Cadarache. This presence, together with specific facilities to be set up in the nearest villages, would ease the integration of the ITER international personnel.

Either the expansion of existing, nearby international schools, or the establishment of a new European / international school, as it was done for JET, are being considered for the education of the children of foreign ITER personnel.

Last but not least, the exceptional climate, the great variety in sport and relaxation activities and the quality of Provencal life constitute an "art de vivre" that should be attractive to the best fusion specialists in the world.

5. Cost evaluation

The preliminary cost evaluation of the additional infrastructure required to host ITER, based on the ITER site requirements and assumptions, amounts to about 100 M€. This total includes transport, site preparation (excavation, access, etc.), electrical and water supplies, building adaptation and site services (wastes processing and storage are not included).

6. Conclusion

Cadarache satisfies all ITER site requirements as well as most of the generic design assumptions. The resources required to update the Cadarache infrastructure and all other site specific costs have been estimated at 100 M€.

A license to build ITER in France could be granted mid 2005. This assumes that the ITER Legal Entity, the Preliminary Safety Report and the technical specifications for the long delivery items be finalised mid 2003. In the meanwhile, CEA and EFDA have initiated the licensing process and plan to submit the "Dossier d'Options de Sûreté" to the safety authority before the end of 2001.

Cadarache appears to be remarkably suited to host ITER. The site has a considerable experience in hosting nuclear installations (18 are currently in operation) and hosts the French research activities on magnetic fusion.

Finally, the socio-economic environment of the Provence-Alpes-Côte d'Azur region is particularly attractive.

A table summarising the Cadarache situation with respect to the ITER site requirements and assumptions is given on page 143.

EFDA

EUROPEAN FUSION DEVELOPMENT AGREEMENT

Cadarache
as a
European Site for ITER

Report on the Technical and Socio-economic Aspects

1. Background information

1.1. Introduction

An EFDA Technical Working Group (European ITER Site Study group: EISS group) has been established by the EFDA Steering Committee at its 9th meeting on 23-24 October 2000 to prepare the technical basis for European ITER site proposals. The Terms of Reference and the Work Plan of the EISS group are given in document EFDA (00)-9/5.7.

Following the recommendations of the CCE-FU (11 July 2000), the EISS group activities have been devoted, in the first instance, to the Cadarache site.

The activities of the EISS group have been broken down in three Work Packages. Work Package 2 specifies, as deliverable, "A Possible European Site Proposal for ITER – Report on the Technical and Socio-economic aspects" due in June 2001. The present report corresponds to this deliverable.

1.2. EISS group work organisation

The EISS group activities have been broken down in 4 topical areas, each being supervised by an EISS group member. 13 tasks have been identified to address all issues.

1. Technical Requirements

    Task 1 – Land
    Task 2 – Seismic issues, external hazards and consequences on buildings
    Task 3 – Heat sink and water supply
    Task 4 – Electrical supply
    Task 5 – Transport and shipping

2. Safety and Licensing

    Task 6 – Review of accidental and operation safety analysis
    Task 7 – Definition of a quality assurance procedure
    Task 8 – Effluents and releases
    Task 9 – Waste management and decommissioning
    Task 10 – Tritium transport and control

3. Socio-Economics

    Task 11 – Socio-economic infrastructure

4. General Aspects and Costing

    Task 12 – Cost estimate

A task of generic nature has also been identified.

Task 13 – EISS documentation and Synthesis

Work has been shared between CEA, other Associations, Industry and EFDA Close Support unit, Garching. All Associations have participated under EFDA art. 5.1.b contracts whilst Industry has participated either under EFDA art. 7 contract or under CEA sub-contracts. Commission representatives have taken part in many of the group plenary meetings.

1.3. Content of the report

This report is a synthesis document based on different reports that have been received for the different task fields.

Chapter 2 describes fusion research in Europe and the role of ITER. The ITER schedule is recalled as well as the ITER site requirements and design assumptions.

Chapter 3 focuses on the Cadarache site and the technical issues of ITER construction in Cadarache. Land and implantation, seismic aspects, heat sink and water supply, electrical power and transport of heavy and large components are all dealt with.

Chapter 4 describes the French licensing process for ITER. It details the time schedule for the procedure and the different steps within the procedure. A description and further details of the first step in this procedure is also given.

Chapter 5 details the socio-economic impact of the ITER project and describes the existing socio-economic infrastructure.

Chapter 6 gives a preliminary schedule for ITER construction at Cadarache.

Chapter 7 recapitulates the Cadarache response to the ITER site requirements and design assumptions. For each task a number of deliverables has been identified in the form of reports on specific subtasks.

2. The ITER project

2.1. Thermonuclear fusion

Thermonuclear fusion holds the promise of virtual endless energy supply. It is the energy producing process, which takes place continuously in the sun and the stars. In the core of the sun at temperatures of 10-15 million degrees Celsius and extreme gravitational pressure and density, hydrogen is converted to helium providing enough energy to sustain life on earth. For energy production on earth different less demanding fusion reactions are involved. The most suitable reaction occurs between the nuclei of the two heavy forms (isotopes) of hydrogen, deuterium (D) and tritium (T).

$$D + T \rightarrow He + n + 17.6\ MeV$$

Deuterium is widely available in water; tritium can be bred from lithium using the neutrons generated in the fusion reactions. Lithium, the lightest metal, is plentiful in the earth's crust.

At the high temperatures at which these fusion processes take place, ~100 million °C, the state of matter is that of a plasma, a fully ionised gas, in which the ions and electrons move freely. As charged particles, the ions and electrons are subject to magnetic forces. This provides an opportunity to contain the hot plasma. The most widely used and most successful magnetic configuration to confine the plasma and to obtain nuclear fusion in a controlled way uses a Russian concept, the tokamak.

2.2. Tokamak

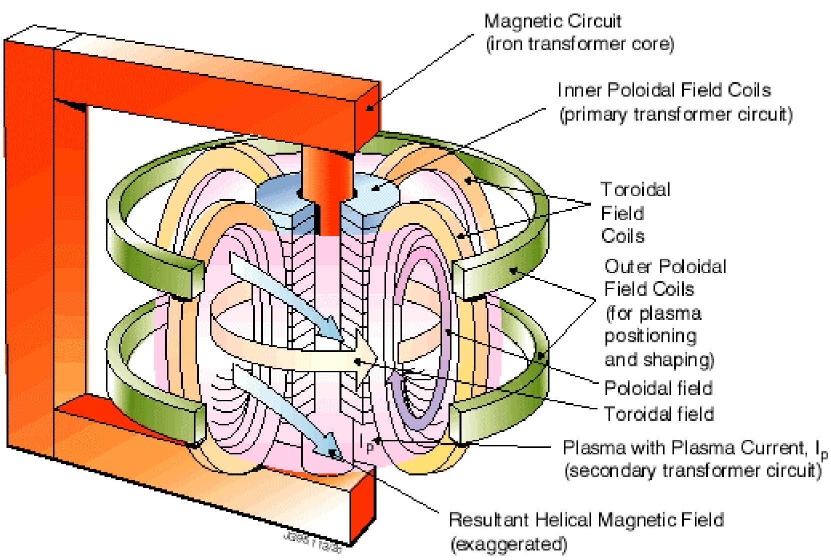


Figure 2.1: Schematic of a Tokamak

A tokamak has a doughnut shaped vacuum vessel (torus), which is surrounded by magnetic coils (see Figure 2.1). These coils generate a toroidal magnetic field. The plasma is formed inside the vacuum vessel when a current is induced in the toroidal direction using a transformer, in which the plasma acts as the secondary winding. The plasma particles move freely along the magnetic field lines in small gyrating orbits. This restricts their radial movement and provides particle confinement. The current is heating the plasma at the same time by ohmic dissipation. The plasma current also produces a poloidal component of the magnetic field, which together with the toroidal field results in a helical field line structure. A number of poloidal field coils are added to provide better control of plasma position and stability.

The Joint European Torus (JET) in Abingdon (UK) is the largest tokamak in the world (Figure 2.2). JET holds the world record in fusion power (16.1 MW) and is currently the only tokamak in the world that can operate with a deuterium – tritium mixture (see www.jet.efda.org/).

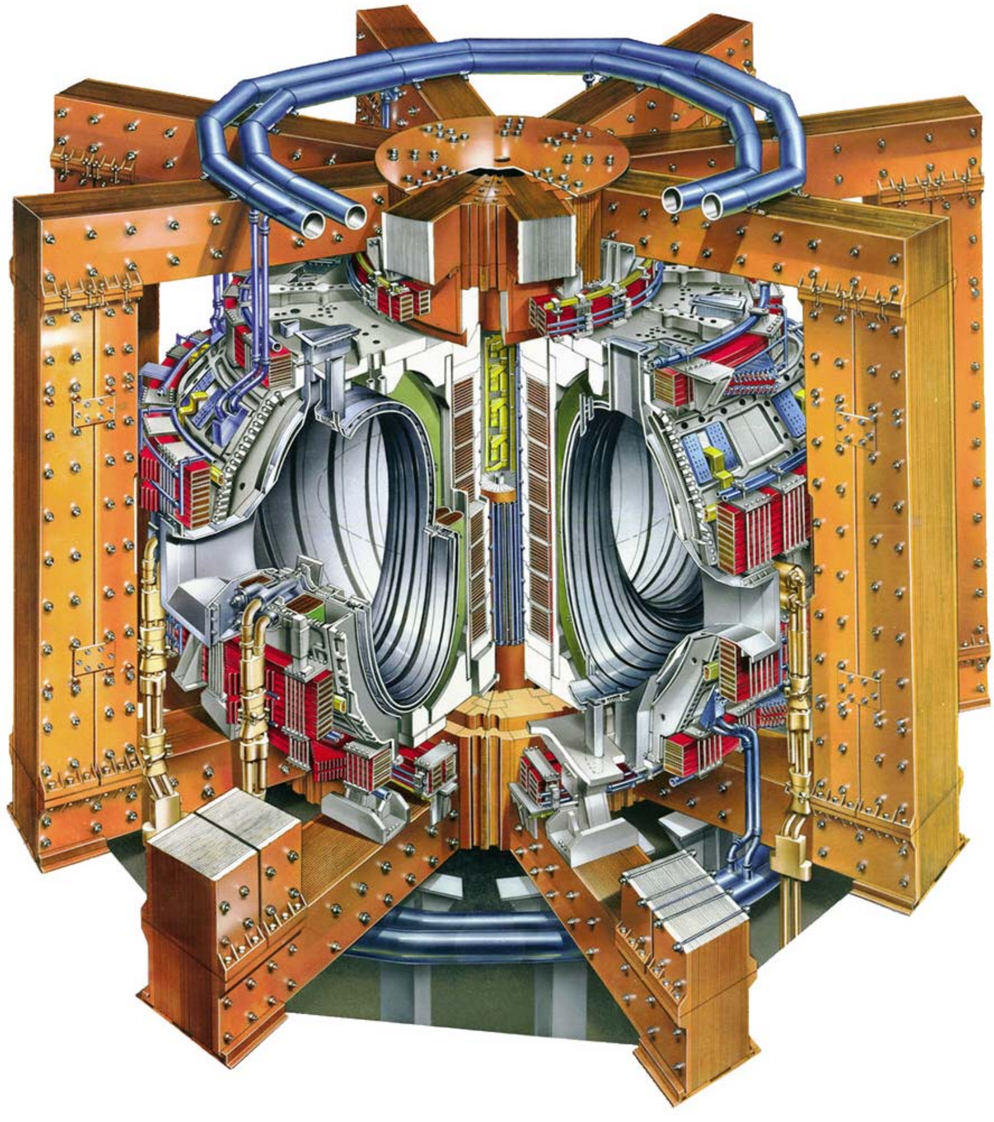


Figure 2.2: Cut through of the JET Tokamak

Tore Supra (Figure 2.3) in Cadarache (France) is a tokamak with a superconducting toroidal field configuration. It has already produced discharges of two minutes and will in the near future be capable to investigate the effects on wall materials under large sustained heat fluxes (see www-fusion-magnetique.cea.fr/).

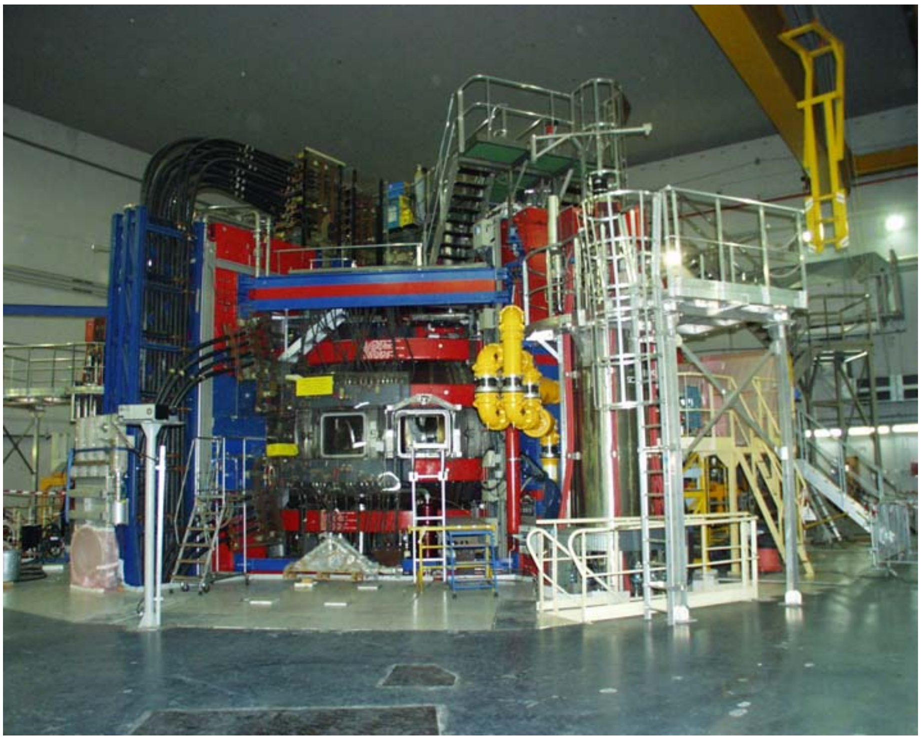


Figure 2.3: Photograph of Tore Supra

Europe has always organised and performed pioneering work in the operation of a number of complementary machines (see DG Research web site, describing the fusion programme at europa.eu.int/comm/research/fusion1). The following European tokamaks can be cited:

- ASDEX, then ASDEX Upgrade in Germany where the first H-mode was observed (www.ipp.mpg.de/de/pr/forschung/asdex/pr_for_asdex);
- TEXTOR in Germany (www.kfa-juelich.de/ipp/), focused in particular on plasma-wall interaction;
- Frascati Tokamak, then FTU, in Italy, tokamak with a high magnetic field and a large current density (www.frascati.enea.it/FTU/);
- DITE, Compass, in the United Kingdom (www.fusion.org.uk/), study of ELMs, control of plasma instabilities;
- START, MAST, in the United Kingdom (www.fusion.org.uk/), tokamak with a "spherical" configuration;
- Tokamak à Configuration Variable, in Switzerland (crppwww.epfl.ch/), enabling many plasma shaping.

Stellerators, which have a different magnetic configuration from tokamaks, are also studied, for example:

- W7-AS (www.ipp.mpg.de/de/for/projekte/w7as/for_proj_w7as), in Germany

- W7-X (www.ipp.mpg.de/de/for/projekte/w7x/for_proj_w7x), machine in construction in Germany
- Flexible Heliac TJII, in Spain (www-fusion.ciemat.es/)

Many other laboratories contribute to the fusion programme in theoretical, experimental or technology (Karlsruhe, where ITER toroidal field model coil is tested…). Figure 2.4 gives a complete overview of the Euratom coordinated fusion research.

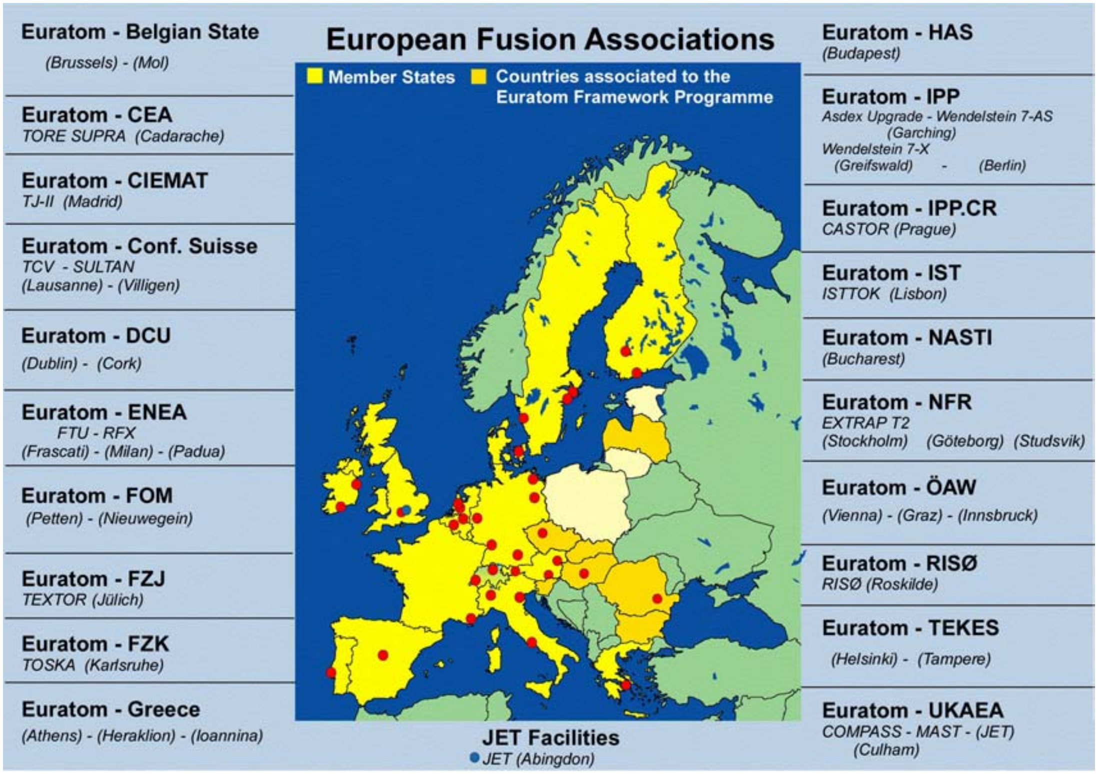


Figure 2.4: European Fusion Associations

The minimum size of a fusion reactor with the Tokamak configuration is set by the requirement that the plasma has to be big enough to confine the energy produced in the fusion reactions sufficiently to ignite – this is the condition when the energy produced by fusion is enough to keep the plasma at a temperature that enables to self sustain fusion reactions. Previous fusion experiments, in particular JET and similar projects in the United States and Japan, have taken fusion very close to this point and their results allow a very reliable extrapolation to the minimum size for a fusion reactor. It would have to be about three times the physical dimensions of JET with a plasma current of about 20 million Ampere (JET can reach about 7 MA). A reactor of this size would produce somewhat between one and two thousand megawatts of electricity – comparable to the biggest power stations that are presently in operation today.

On this basis the parameters of the Tokamak experiment to demonstrate plasma ignition and fusion power production, ITER, were deduced. Figure 2.5, based on worldwide database [1], shows ITER confinement time in comparison with existing machines and illustrates the confidence of the extrapolation.

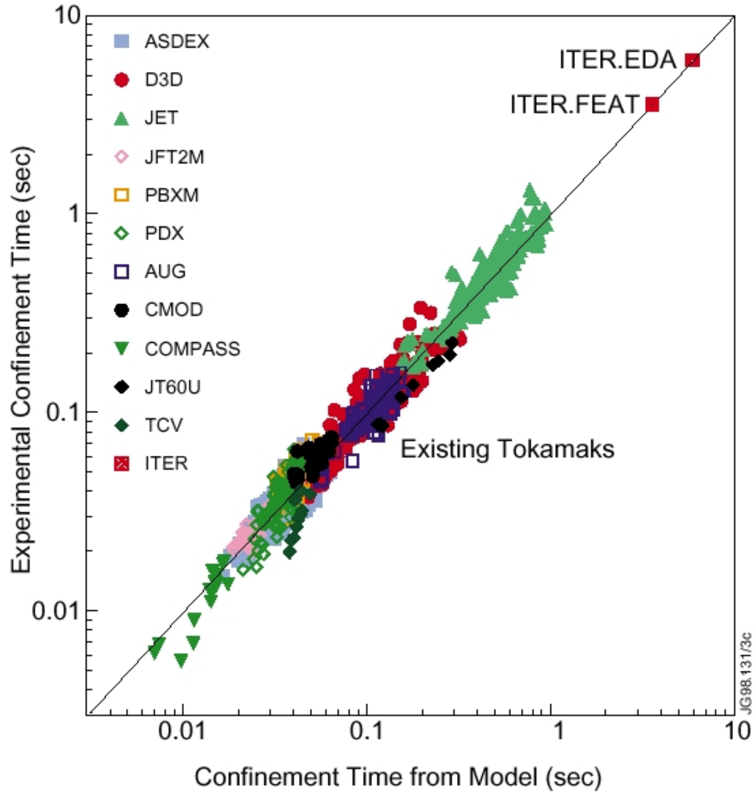


Figure 2.5: Experimental data from all the major tokamaks in the international fusion programme showing predicted confinement time versus measurements

However in order to keep the construction costs as low as possible, the new design for ITER has dimensions about 75 % of those of the previous design with a plasma current of about 15 million amperes. On the basis of present knowledge, this will not be quite big enough to reach ignition – the plasma heating systems will have to be left switched on all the time – but 50 MW of heating will generate about 500 MW of fusion power. In all other respects ITER will be a realistic test bed for a full size fusion reactor. There are also prospects that the reduced size ITER could get even closer to ignition if experiments to improve plasma confinement that are underway on JET and other tokamak experiments prove successful.

2.3. ITER

2.3.1. History

To understand the history of the ITER project, one has to go back to 1958. In Geneva that year, during the second international conference of the United Nations on the use of atomic energy for peaceful purposes, it was decided to declassify research into nuclear fusion by magnetic confinement, and international cooperation in this field was proposed. The European Community of that time, the Six, therefore included nuclear fusion in its research and development programme, with the collaboration of various laboratories. This was the starting point of the Euratom-CEA association for fusion in France.

The first ten years were naturally devoted to determining a suitable magnetic configuration. By 1968, in view of its performances, the tokamak configuration had shown itself to be the most promising. All the large fusion laboratories throughout the world started work in this direction. The beginning of the 70s thus saw the successive development, in France, of two machines based on this principle: TFR at Fontenay-aux-Roses and PETULA at Grenoble. Tokamaks were also built in all the major fusion laboratories in Europe, Japan, Russia and the USA.

A second generation of larger machines was built during the years '80s and many of them are still operational today. Apart from TFTR (USA, closed in 1997), it is worth mentioning JT-60 U (Japan), JET (Europe), the largest and most successful tokamak, and in Europe ASDEX-U, TORE SUPRA, FTU, COMPASS, and TEXTOR.

Current European research activities on fusion, co-ordinated by the Euratom programme are indicated in Figure 2.4.

The results were encouraging. Europe was already thinking ahead to the next generation tokamak aiming at ignition, NET. In November 1985, at the occasion of the Geneva summit conference, President Gorbachev suggested to Presidents Reagan and Mitterand [2] that the next machine be built in an international framework. As a consequence, the four great nations, the Soviet Union, the United States, Japan and the European Community decided to combine their efforts. Thus, under the auspices of the International Atomic Energy Agency (IAEA) the ITER project saw the light.

ITER first study phase, called the Conceptual Design Activities (CDA) started in April 1988 and was completed in December 1990. From its inception the ITER project was envisaged as the decisive step towards the realisation of fusion power. This was expressed in the Protocol of the next study phase – the Engineering design activities (EDA) signed in July 1992 – in which it is stated that: "*the overall programmatic objective of ITER, which shall guide the EDA, is to demonstrate the scientific and technological feasibility of fusion energy for peaceful purposes. ITER would accomplish this objective by demonstrating controlled ignition and burn of deuterium-tritium plasmas, with steady-state as an ultimate goal, by demonstrating technologies essential to a reactor in an integrated system, and by performing integrated testing of the high-heat-flux and nuclear components required to utilize fusion energy for practical purposes.*" Within the EU and generally within the other parties, this objective has been taken to mean that ITER, together with some parallel activities in the field of materials development, would be the only step required to prepare for the construction of a demonstration power plant (DEMO).

In July 1998 the ITER design was completed, and prototypical models of the principal components had been manufactured and have since undergone testing, which is complete in some cases and is successfully ongoing in a few others. However the four parties prolonged the EDA phase and asked the project team to design a smaller machine, which would still fulfil the programmatic objective but would have reduced technical margins yielding a reduction to about half the original cost.

The ITER Council in Vienna in July 2001 accepted the Director's Final Report and concluded:

Upon completion of the ITER Engineering Design Activities, the ITER Council's final conclusions are as follows:

1. *The objectives of the ITER EDA Agreement have been fully met: the Parties have at their disposal a complete, detailed and mature design for ITER, with a supporting body of validating analysis and R&D and other technical information, which meets the detailed technical objectives and cost objectives set for it, including those relating to safety and environmental considerations.*

2. *The ITER co-operation has served to focus the fusion research efforts of the Parties to a common goal and has established a joint capability to undertake successfully tasks that might be beyond the financial or technical capacity of individual Parties.*

3. *ITER would enable, in a single device, full exploration of the physics issues as well as proof of principle and testing of key technological features of possible fusion power stations. It would provide the integration step necessary to establish scientific and technical feasibility of fusion as an energy source.*

In light of these conclusions, the ITER Council, recognising the social importance of the realization of fusion energy:

- *considers ITER as the essential tool to achieve this goal,*
- *affirms a shared single vision of ITER and of the means to realize it,*
- *considers that the fusion programme at the world level is now scientifically and technically ready to take the important ITER step, and*
- *reconfirms a common desire to promote construction of ITER through international co-operation.*

At a time of increasing global pressure on energy resources and global environmental concerns, the time is ripe to undertake the next step in the development of fusion energy. This will establish fusion as an option for large-scale energy supply with intrinsic safety and environmental benefits in the long term.

The ITER Council therefore recommends to the Parties to take the necessary steps to realise a Joint Implementation of ITER as the next step in the development of fusion as a source of energy for peaceful purposes.

2.3.2. ITER machine

ITER is an experimental fusion reactor based on the tokamak concept (Figure 2.6). The overall ITER plant comprises the tokamak, its auxiliaries and supporting plant facilities. In ITER sets of superconducting coils generate the magnetic configuration to confine and control the plasma in the vacuum vessel of the machine. They also induce an electrical current through it. Fusion power is produced by fusion reactions taking place in the plasma. Reaction rate is related to plasma temperature and density. To sustain the burn, the power associated with the helium nuclei generated in the reactions (20 % of the total fusion power) has to be sufficient to maintain plasma temperature at an adequate level.

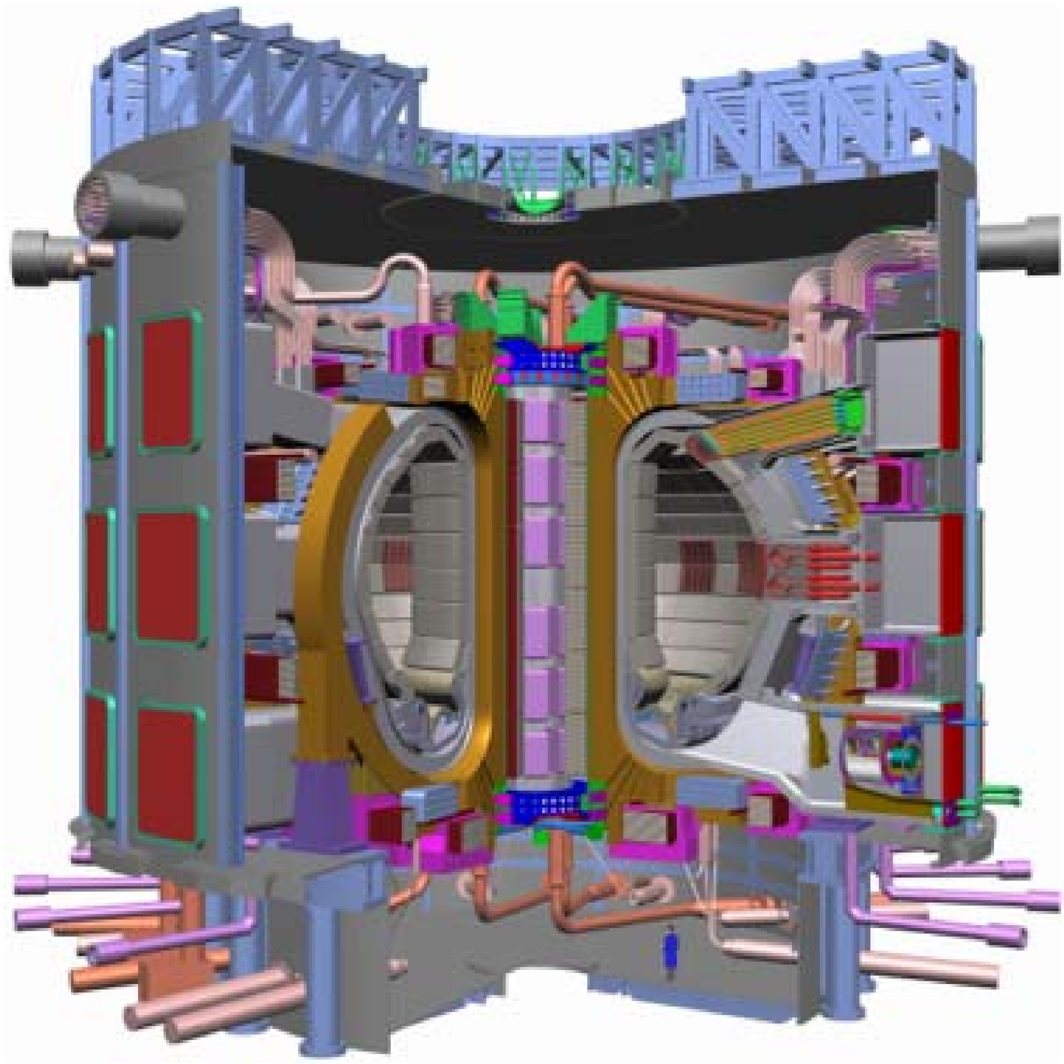


Figure 2.6: Cut of ITER Tokamak

To meet its objectives, ITER will be much bigger (twice linear dimensions) than the largest existing tokamak (JET) and its expected fusion performance will be many times greater, see Table 2.1. These extrapolations in size and physics performance provide the major challenges to the design of ITER. The design of the machine is such that it could be built on the territory of any of the Parties, with options to provide the capability for conducting experiments from remote centres throughout the participating countries.

Plasma Major Radius	R (m)	6.2
Plasma Minor Radius	A (m)	2
Toroidal Field on Axis	B_T (T)	5.3
Plasma Current	I_P (MA)	15
Fusion Power	P_{fusion} (MW)	410
Neutron Flux	$Flux_{Neutrons}$ (MW/m^2)	0.5
Power produced / Heating Power supplied	Q	10

Table 2.1: ITER Main Parameters

2.3.3. ITER organisation

The ITER project is a unique model for effective international collaboration in science and technology. The ITER Parties (European Union, Japan, Russian Federation) share the costs and benefits from the collaboration. Canada and Kazakhstan have also joined the project by associating respectively with Euratom and Russia. By pooling their resources and expertise and having access in common to all the information coming out of the work, the Parties realise much greater returns on their inputs to the project than they could do alone.

The ITER EDA has been conducted within the framework of an international agreement concluded under the auspices of the IAEA. The governments of the Parties are represented each by two members in the ITER Council whose seat is in Moscow. The ITER Council has responsibility for the overall direction of the EDA. It supervises its execution and reports to the Parties. The Council is assisted by Management and Technical Advisory Committees. Each Party delegates 3 members to the MAC, one of whom is the Home Team Leader. The MAC advises the Council on management and administrative matters, including finance, personnel and task assignment. The TAC, which advises the Council on technical matters, consists of up to four representatives per Party, acting in an individual capacity, chosen so that all the necessary areas of technical expertise are represented. The Council had the faculty to establish Special Working Groups or other ad hoc groups to undertake specific tasks.

The Director leads the Joint Central Team, which is located on the working sites at Garching and Naka. Until budget constraints forced the withdrawal of the US party, a third work site was maintained at San Diego. Each of the Parties maintains a Home Team, which performs specific design tasks and carries out validating R & D work. Each Home Team has a Leader who is responsible for the execution of these tasks. The Home Teams consist of a central technical-administrative organisation converting task agreements valued in "ITER credit" into contracts in real currency, and then placing these contracts in institutions and industry, which then also form part of the Home Team. The amount of credit each Party receives for the work is monitored to measure the contribution to the ITER design and R&D.

Following the end of the ITER EDA in July 2001, the project has entered an 18-month period of 'Co-ordinated Technical Activities', CTA, during which the principal role of the International Team will be the provision of information for the preparation of one or more site-specific design adaptations. This will be followed by the Construction, Operation, Exploitation and Decommissioning Activities (COEDA), planned to start in 2003. As these changes occur, a significantly different organisational structure will be required for the project. The central role will be taken by the 'ITER Legal Entity (ILE)', the remit and organisation of which will be formally defined by a new international agreement.

2.4. ITER schedule

The planning schedule for procurement, construction/assembly, commissioning and decommissioning depends on a number of assumptions. As the negotiations toward the joint implementation of ITER progress, decisions reached by the Parties may confirm or alter the assumptions that have led to its present status. The actual plan will therefore depend on the licensing procedure, as well as the organization and arrangements that will be put in place for the procurement/construction commissioning [3].

2.4.1. ITER construction

The ITER joint Implementation Agreement is expected to be signed during 2003 following formal negotiations. The ITER Legal Entity (ILE) will be established after ratification of the agreement within each Party. This organisation will start the formal regulatory procedure and procurement process for the long lead-time items. The regulatory approval process, however, will remain speculative until a site is formally selected. If the site proposals are received before or at a sufficiently early stage of negotiations, it will be possible to assess the time needed for licensing in the various possible host Parties and the effects on the overall schedule. Since the start of the actual construction on the site depends upon when the licence to construct is issued by the regulatory authority, dates in the construction and commissioning plan are, therefore, measured in months from a start date (“T = 0”) defined as the date at which the actual construction work of excavation for the tokamak buildings is started.

Furthermore, the following assumptions pertain at t = 0.

- Informal dialogue with regulatory authorities should be established and should orient the technical preparation toward a licence application with a view to solving the major technical issues prior to the establishment of the ILE. Documents required for the formal regulatory process are assumed to be prepared before the ILE exists, so as to allow the ILE to begin the formal regulatory process immediately after its establishment or to benefit from an already launched process.
- Procurement specification of equipment/material for the longest lead-time items and critical buildings are assumed to be finalised during the co-ordinated technical activities (CTA).
- Procurement sharing is assumed to be agreed among the Parties during the CTA so as to permit the placing of all contracts at the appropriate time.
- The construction site work starts immediately at T = 0. It is assumed that site preparation has been started sufficiently early by the host Party so as not to place constraints on the start of construction.

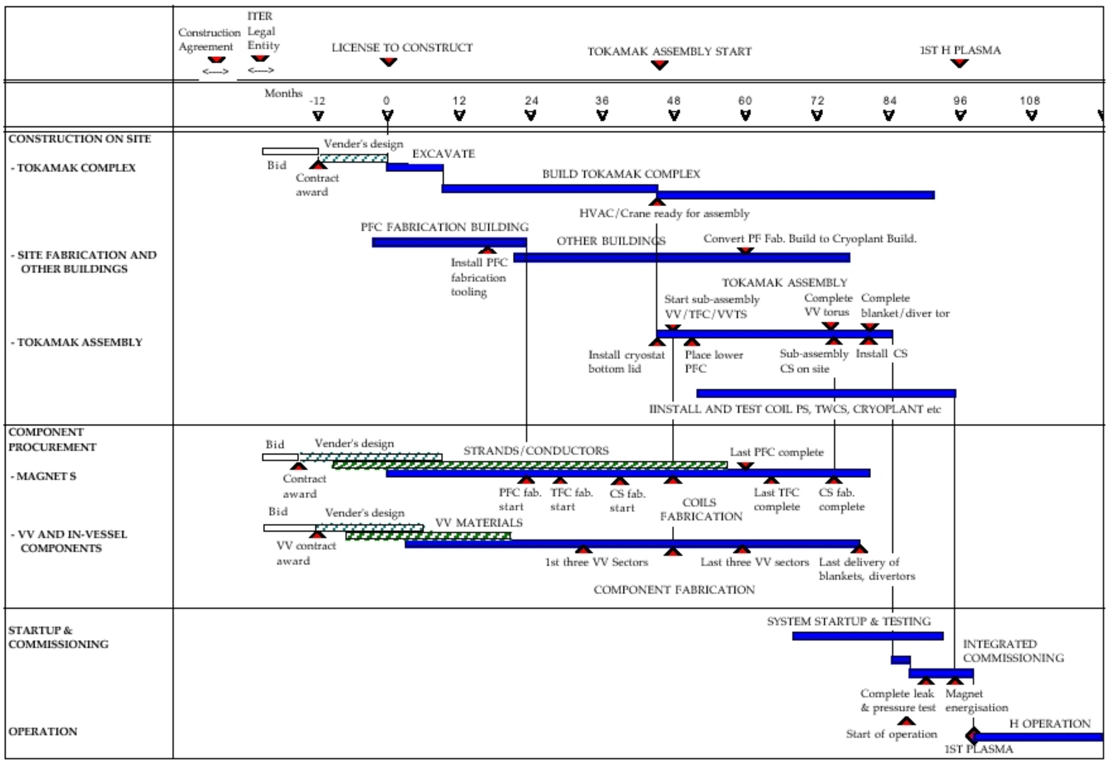


Figure 2.7: Overall Schedule up to First Plasma

See Chapter 6 for the European schedule. The overall schedule that leads up to the first hydrogen plasma operation is shown in Figure 2.7. It represents a reference scenario for the schedule of procurement, construction, assembly and commissioning of ITER. The detailed construction schedule is developed to correspond to each procurement package specified for the cost estimate. The schedule for each package includes procurement specification preparation, bid process, vendor's design (if appropriate), manufacturing (if appropriate), transport to site (if appropriate), installation and commissioning.

2.4.2. ITER operation

As an experimental device, ITER is required to be able to cope with various operation scenarios and configurations. Variants of the nominal scenario are therefore considered for extended duration plasma operation, and/or steady state modes with a lower plasma current operation, with H, D, DT (and He) plasmas, potential operating regimes for different confinement modes, and different fuelling and particle control modes. Flexible plasma control should allow the accommodation of "advanced" plasma operation based on active control of plasma profiles by current drive or other non-inductive means.

Four reference scenarios are identified for design purposes. Three alternative scenarios are specified for assessment purposes to investigate how plasma operations will be possible within the envelope of the machine operational capability assuming a reduction of other concurrent requirements (e.g. pulse length).

2.4.2.1. Scenarios foreseen during operation

Design scenarios

- **Inductive operation I**: P_{fus} = 500 MW, Q = 10, I_p = 15 MA, *with* plasma heating during current ramp-up. Q is the ratio between fusion power produced and heating power applied.
- **Inductive operation II**: P_{fus} = 400 MW, Q = 10, I_p = 15 MA, *without* heating during current ramp-up.
- **Hybrid operation** (i.e. plasma current driven simultaneously by inductive and non-inductive means) to produce longer duration pulsed plasmas.
- **Non-inductive operation type I**: weak negative shear (WNS) operation to explore the so-called advanced regimes.

Assessed scenarios

- Inductive operation III: P_{fus} =700 MW, I_p =17 MA, with heating during current ramp-up
- Non-inductive operation type II: strong negative shear (SNS) operation
- Non-inductive operation type III: weak positive shear (WPS) operation

2.4.2.2. Successive phases of operation

During its lifetime, ITER will be operated in successive phases.

H Phase

This is a non-nuclear phase using only hydrogen or helium plasmas, planned mainly for complete commissioning of the tokamak system in a non-nuclear environment where remote handling maintenance is not mandatory. The discharge scenario of the full DT phase reference operation can be developed or simulated in this phase. The peak heat flux onto the divertor target will be of the same order of magnitude as for the full DT phase. Characteristics of electromagnetic loads due to disruptions or vertical displacement events, and heat loads due to runaway electrons, will be basically the same as those of the DT phase.

Some important technical issues cannot be fully tested in this phase because of smaller plasma thermal energy content and lack of neutrons and energetic alpha particles. The actual length of the hydrogen operation phase will depend on the merit of this phase with regard to its impact on the later full DT operation, in particular on the ability to achieve good H mode confinement with a suitably high plasma density.

D Phase

The characteristics of deuterium plasma are very similar to those of DT plasma except for the amount of alpha heating. Therefore, the reference DT operational scenarios, i.e., high Q, inductive operation and non-inductive steady state operation, can be simulated further. Since some tritium will be generated in the plasma, fusion power production for short periods of time without fully implementing the cooling and tritium-recycle systems could therefore also be demonstrated. By using limited amounts of tritium in a deuterium plasma, the integrated nuclear commissioning of the device will be possible. In particular, the shielding performance will be tested.

DT Phases

During the first phase of DT operation the fusion power and burn pulse length will be gradually increased until the inductive operational goal is reached. Non-inductive, steady state operation will also be developed. DEMO reactor relevant test blanket modules will also be tested whenever significant neutron fluxes will be available, and a reference mode of operation for that testing will be established.

The second phase of full DT operation, beginning after a total of about ten years of previous operation, will emphasise improvement of the overall performance and the testing of components and materials with a higher neutron fluence. This phase will address the issues of higher availability and further improved modes of plasma operation. The implementation and the programme for this phase will be decided following a review of the results from the preceding three operational phases and an assessment of the merits and priorities of programmatic proposals.

A decision on incorporating in the vessel a tritium breeding blanket during the course of the second DT phase will be taken on the basis of the availability of this fuel from external sources, its relative cost, the results of breeder blanket module testing, and acquired experience with plasma and machine performance.

2.4.3. ITER decommissioning

It is assumed that the ITER organization at the end of operation will be responsible for starting the machine decommissioning through a de-activation period after which the facility will be handed over to a new organization inside the ITER host country.

During the first phase, the machine will, immediately after shutdown, be de-activated and cleaned by removing tritium from the in-vessel components and any removable dust. Also, any liquid used in the ITER machine systems will be removed (no component cooling will be further required) and processed to remove activation products prior to their disposal. De-activation will include the removal and safe disposal of all the in-vessel components and, possibly, the ex-vessel components. The main vacuum vessel may be prepared for dismantling by the cutting of the inner vessel wall. The ITER de-activation will also provide corrosion protection, for components that are vulnerable to corrosion during the storage and dismantling period, if such corrosion would lead to a spread of contamination, or present unacceptable hazards to the public or workers. These activities will be carried out by the ITER organization using the remote handling facilities and staff existing at the end of operation. At the end of phase 1, the ITER facility will be handed over to the organization inside the host country that will be responsible for the subsequent phase of decommissioning after a dormant period for radioactive decay.

2.5. ITER site requirements and assumptions

This list of requirements and assumptions was specified by ITER in October 1999 [4]. The version of the Plant Design Specification (PDS) published in July 2001 has the same list of requirements and assumptions [5].

2.5.1. Introduction

A set of site requirements that are compulsory for the ITER site has been defined, supplemented by design assumptions about the ITER site, which are used for design and cost estimates until the actual ITER site is known. Section 1 contains the principles for the development of the site requirements and site design assumptions. Section 2 contains the compulsory requirements, which are derived from the ITER design and the demands it makes on any site. Section 3 contains site design assumptions, which are characteristics of the site assumed to exist so that designers can design buildings, structures and equipment that are site sensitive.

Both the Site Requirements and the Site Design Assumptions are organized in the following categories:

- Land
- Heat Sink
- Energy and Electrical Power
- Transport and Shipping
- External Hazards and Accident Initiators
- Infrastructure
- Regulations and Decommissioning

Each of the categories is subdivided into related elements. Some of the categories are broadly defined. For instance, Infrastructure includes personnel, scientific and engineering resources, manufacturing capacity and materials for construction and operation. Requirements and assumptions for the various elements are justified in the **Bases** statements. These statements explain the rationale for their inclusion and provide a perspective in which they may be used.

2.5.2. Principles for site requirements and site design assumptions

The compulsory site requirements are based on the ITER site layout and plant design. These requirements are firm in the sense that reasonable reconfiguration of the plant design will not result in a less demanding set of requirements. Some of the site requirements are based in part on how the plant and some of its major components, such as the vacuum vessel and the magnet coils, will be fabricated and installed.

The assumptions that have been made to carry out the ITER design until a decision on localisation is reached are also addressed. These site design assumptions form some of the bases for the ITER construction cost estimate and schedule. The assumptions are not compulsory site requirements, but are guidelines for designers to follow until the actual site is known.

The requirements for public safety and environmental considerations are, by their nature, site sensitive. Also, the regulatory requirements for localisation, construction, operating and decommissioning ITER are likely to be somewhat different for each potential host country. Therefore, the Safety Contact Persons, designated by each potential Host Country, will help the Project Team to consider any particular requirements that localisation in their own country would impose. Until that time, the ITER plant will be designed to a set of safety and environmental assumptions contained in the ITER Plant Specifications, which are expected to approximate the actual requirements. Site sensitive considerations during operation such as the shipment of radioactive materials including tritium to the site, the temporary storage of wastes on the site, the shipment of wastes from the site and of the effluents from ITER during normal and off-normal operation, are addressed with the design analysis. Accordingly, a Generic Site Safety Report will be available as a firm basis on which the Site Safety Report will later be established to satisfy the licensing authorities of the Host Country.

The decommissioning phase of the ITER plant deserves special attention. In the absence of firm guidance and without prejudice to future negotiations of the Parties, it is assumed that the organisation in charge of operating ITER will have a final responsibility to "deactivate" the plant. In this context, "deactivation" is the first phase of decommissioning and includes all actions to shut down the ITER plant and place it in a safe, stable condition. The dismantling phase of decommissioning, which might take place decades after the "deactivation" phase, is assumed to become the responsibility of a new organisation within the host country. A technical report on the strategy of deactivation and dismantling will be included inside the design report documentation.

In conclusion the site design assumptions are very important, because without them progress is very limited for the site sensitive design of buildings, power supplies, site layout and safety/environmental studies. These assumptions were selected so that the design would not be significantly invalidated by actual site deviations from the assumptions. Deviations from the site design assumptions by the actual ITER site may require design and/or construction modifications, but these modifications are expected to be feasible. The modifications may determine the need for a revision of the cost estimate and construction schedule.

2.5.3. Site requirements

A. Land

1. Land area **(SR.A1)**

Requirement: The ITER site shall be up to 40 hectares in area enclosed within a perimeter. All structures and improvements within the perimeter are the responsibility of the ITER project. Land within the perimeter must be committed to ITER use for a period of at least 30 years.

Bases: The minimum area for the ITER site is predicted on the basis of providing sufficient area for the buildings, structures and equipment with allowances for expansion of certain buildings if required for an extension of the ITER programme.

The time period is specified to cover the construction (~10 years) and operations (~20 years) phases. Beyond that, the requirements for any decommissioning will be the responsibility of the Host Country.

2. Geotechnical Characteristics **(SR.A2)**

Requirement: The ITER Site shall have foundation soil-bearing capacity adequate for building loads of at least 25 t/m² at locations where buildings are to be built. Nevertheless, it is expected that it will be possible to provide at the specific location of the Tokamak Building means to support the average load of 65 t/m² at a depth of 25 m. The soil (to a depth of 25 m) shall not have unstable surrounding ground features. The building sites shall not be susceptible to significant subsidence and differential settlement.

Bases: The ITER Tokamak is composed of large, massive components that must ultimately be supported by the basemat of the structures that house them. Therefore soil-bearing capacity and stability under loads are critical requirements for an acceptable site. The Tokamak Building is composed of three independent halls on separate basemats, but served by the same set of large, overhead bridge cranes. Crane operation would be adversely affected by significant subsidence and differential settlement.

3. Water Supply **(SR.A3)**

Requirement: The ITER site host shall provide a continuous fresh water supply of 0.2 m^3/minute average and 3 m^3/minute peak consumption rates. The average daily consumption is estimated to be about 200 m^3. This water supply shall require no treatment or processing for uses such as potable water and water makeup to the plant de-mineralised water system and other systems with low losses.

Bases: The ITER plant and its support facilities will require a reliable source of high quality water. The peak rate of 3 m^3/minute is specified to deal with conditions such as leakage or fires. This water supply is not used for the cooling towers or other uses which may be satisfied by lower quality, "raw" water.

4. Sanitary and Industrial Sewage **(SR.A4)**

Requirement: The ITER site host shall provide sanitary waste capacity for a peak ITER site population of 1000. The host shall also provide industrial sewage capacity for an average of 200 m^3/day.

Bases: The ITER project will provide sewer lines to the site perimeter for connection to the sewer service provided by the host. The peak industrial sewage rate is expected to be adequate to deal with conditions such as leaks and drainage of industrial sewage stored in tanks until it can be analysed for release. Rainwater runoff is not included in industrial sewage.

B. Heat Sink **(SR.B)**

Requirement: The ITER Site shall have the capability to dissipate, on average, 450 MW (thermal) energy to the environment.

Bases: ITER and its associated equipment may develop heat loads as high as 1200 MW (thermal) for pulse periods of the order of 500 s. The capability to dissipate 1200 MW should be possible for steady-state operation, which is assumed to be continuous full power for one hour.

Duty Cycle requirements for the heat sink at peak loads will not exceed 30 %. The average heat load would be no more than 450 MW for periods of 3 to 6 days.

***C. Energy and Electrical Power* (SR.C)**

ITER Plant Steady State Electrical Loads

Requirement: The ITER Site shall have the capability to draw from the grid 120 MW of continuous electrical power. Power should not be interrupted because of connection maintenance. At least two connections should be provided from the supply grid to the site.

Bases: The ITER Plant has a number of systems, which require a steady-state supply of electrical power to operate the plant. It is not acceptable to interrupt this power supply for the maintenance of transmission lines, therefore the offsite transmission lines must be arranged such that scheduled line maintenance will not cause interruption of service. This requirement is based on the operational needs of the ITER Plant.

Maintenance loads are considerably lower than the peak value because heavy loads such as the tokamak heat transfer and heat rejection systems will operate only during preparations for and actual pulsed operation of the tokamak.

D. Transport and Shipping

1. Maximum size of Components to be shipped **(SR.D1)**

Requirement: The ITER Site shall be capable of receiving shipments for components having maximum dimensions (not simultaneously) of about:

- Width 9 m
- Height 8 m
- Length 15 m

Bases: In order to fabricate the maximum number of components, such as magnet coils and large transformers, off site, the ITER site must have the capability of receiving large shipments. For the reference case, it is assumed that only the Poloidal Field Coils will be manufactured on site, unless the possibility of transporting and shipping these large coils is proven feasible. For the same reason, it is also assumed that the CS will be assembled on site from six modules, unless it proves feasible that the assembly may be supplied as one large and complete unit. The cryostat will be assembled on site from smaller delivered parts. The width is the most critical maximum dimension and it is set by the Toroidal Field Coils, which are about 9 m wide. The height is the next most critical dimension, which is set by the 40° Vacuum Vessel Sector. A length of 15 m is required for the TF coils. The following table shows the largest (~100 t or more) ITER components to be shipped:

Component	Pkgs	Width (m)	Length (m)	Height (m)	Weight (t)
TF Coils	18	9	14.3	3.8	280
VV 40° sector	9	8	12	8	575
CS Modules	6	4.2	4.2	1.9	100
Large HV transformer	3	4	12	5	250
Crane Trolley Structure[2]	2	(14)	(18)	(6)	(600)

PF1	1	9.5	9.5	2.4	200
PF2	1	18.5	18.5	1.9	200
PF3	1	25.5	25.5	1.2	300
PF4	1	26.0	26.0	1.2	450
PF5	1	18.2	18.2	2.4	350
PF6	1	10.8	10.8	2.4	300
CS Assembly	1	4.2	18.8	4.2	850

Note that transportation and shipping of the PF Coils and of the CS Assembly are not requirements, but could be considered an advantage. Note too, that the PF Coils dimensions are for the coil and connection box envelope, and that for each coil there are vertical protrusions of ~1.5-1.8 m for the terminals.

2. Maximum Weight of shipments **(SR.D2)**

Requirement: The ITER Site shall be capable of receiving about a dozen components (packages) having a maximum weight of 600 t and approximately 100 packages with weight between 100 and 600 t each.

Bases: In order to fabricate the maximum number of components, including magnet coils, off site, the ITER site must have the capability of receiving very heavy shipments. The single heaviest component (Vacuum Vessel Sector) is not expected to exceed 600 t. All other components are expected to weigh less.

E. External Hazards and Accident Initiators

No compulsory requirements

F. Infrastructure

No compulsory requirements

***G. Regulations and Decommissioning* (SR.G)**

[2] Crane dimensions and weight are preliminary estimates

Details of the regulatory framework for ITER will depend on the Host Country. At a minimum, the Host's regulatory system must provide a practicable licensing framework to permit ITER to be built and to operate, taking into account, in particular, the following off-site matters:

1. The transport of kilograms of tritium during the course of ITER operations;

2. The acceptance and safe storage of activated material in the order of thousands of tonnes, arising from operation and decommissioning.

The agreement with the Host should provide for the issue of the liability for matters beyond the capacity of the project that may arise from ITER construction, operation and decommissioning.

2.5.4. Site design assumptions

The following assumptions have been made concerning the ITER site. These site design assumptions are uniformly applied to all design work until the actual ITER site is selected.

A. Land

1. Land Area **(SA.A1)**

Assumption: During the construction it will be necessary to have temporary use of an additional 30 hectares of land adjacent to or reasonably close to the compulsory land area. It is assumed this land is available for construction laydown, field engineering, pre-assembly, concrete batch plant, excavation spoils and other construction activities.

During operating phases, this land should be available for interim waste storage, heavy equipment storage and activities related to the maintenance or improvement of the ITER plant.

Bases: The assumptions made for the cost and schedule estimates are based on construction experience that uses an additional area of 25 hectares. Only a very limited amount of vehicle parking space (5 hectares) is allocated to the compulsory area, whereas a similar amount will be required to satisfy temporary needs during construction.

2. Topography **(SA.A2)**

Assumption: The ITER site is assumed to be a topographically "balanced" site. This means that the volumes of soil cuts and fills are approximately equal over the compulsory land area in Requirement A.1. The maximum elevation change for the "balanced" site is less than 10 m about the mean elevation over the land area in the compulsory requirement.

3. Geotechnical Characteristics **(SA.A3)**

Assumption: The soil surface layer at the ITER Site is thick enough not to require removal of underlying hard rock, if present, for building excavations, except in the area under the Tokamak Building itself, at an excavation of about 25 m.

4. Hydrological Characteristics **(SA.A4)**

Assumption: Ground water is assumed to be present at 10 m below nominal grade, well above the tokamak building embedment of up to 25 m below nominal grade. This assumption will require engineered ground water control during the construction of the tokamak building pit.

5. Seismic Characteristics **(SA.A5)**

Assumption: Using the IAEA seismic classification levels of SL-2, SL-1, and SL-0 and the assumed seismic hazard curves, the following seismic specifications are derived:

IAEA level	Return Period (years)	Peak Ground Acc.[3]
SL-2 50% tile	10^4	0.2
SL-1 50% tile	10^2	0.05
SL-0	short[4]	0.05

Bases: Safety assessments of external accident initiators for facilities, particularly when framed in a probabilistic risk approach, may be dominated by seismic events. Assumed seismic hazard curves are used in a probabilistic approach which is consistent with IAEA recommendations for classification as a function of return period. The selection of the assumed seismic hazard curve is relevant to regions of low to moderate seismic activity. Prior to site selection, specification of the peak horizontal and vertical ground acceleration provide the ITER designers guidelines according to the methodology to be used for seismic analysis, which will rely on a specified Ground Motion Design Response Spectrum and a superposition of modal responses of the structures (according to NRC recommendations). After site selection the actual seismic specifications will be used to adjust the design, in particular by adding seismic isolation, if necessary.

6. Meteorological Characteristics **(SA.A6)**

Assumption: A general set of meteorological conditions are assumed for design of buildings, civil structures and outdoor equipment, as follows:

[3] Peak Ground Acceleration is for both horizontal and vertical components in units of the gravitational acceleration, g

[4] The seismic specifications are not derived probabilistically – local (uniform) building codes are applied to this class. A peak value of 0.05 g is assumed equal to the SL-1 peak value

- Maximum Steady, Horizontal Wind ≤ 140 km/h (at 10 m elevation)
- Maximum Air Temperature ≤ 35 °C (24 hr average ≤ 30 °C)
- Minimum Air Temperature ≥ -25 °C (24 hr average ≥ -15 °C)
- Maximum Rel. Humidity (24 hr average) ≤ 95 % (corresponding vapour pressure ≤ 22 mbar)
- Maximum Rel. Humidity (30 day average) ≤ 90 % (corresponding vapour pressure ≤ 18 mbar)
- Barometric Pressure: Sea Level to 500 m
- Maximum Snow Load: 150 kg/m²
- Maximum Icing: 10 mm
- Maximum 24 hr Rainfall: 20 cm
- Maximum 1 hr Rainfall: 5 cm
- Heavy Air Pollution (Level 3 according to IEC 71-2[5])

Bases: The assumed meteorological data are used as design inputs. These data do not comprise a complete set, but rather the extremes, which are likely to define structural or equipment limits. If intermediate meteorological data are required, the designer estimates these data based on the extremes listed above. Steady winds apply a static load on all buildings and outdoor equipment.

***B. Heat Sink: Water Supply for the Heat Rejection System* (SA.B)**

Assumption: The JCT has selected forced draft (mechanical) cooling towers as a design solution until the ITER site is selected. At 30 % pulse duty cycle (450 MW average heat rejection) the total fresh ("raw") water requirement is about 16 m³/minute. This water makes up evaporative losses and provides replacement for blow down used to reduce the accumulation of dissolved and particulate contaminants in the circulating water system. During periods of no pulsing the water requirement would drop to about 5 m³/minute. Each blow down action will lead to a peak industrial sewage rate of 3000 m³/day.

Bases: The actual ITER Site could use a number of different methods to provide the heat sink for ITER, but for the purposes of the site non-specific design, the induced draft (mechanical) cooling towers have been assumed. These cooling towers require significant quantities of fresh water ("raw") for their operation. For 450 MW average dissipation, approximately 16 m³/minute of the water is lost by evaporation and drift of water droplets entrained in the air plume, and by blow down. This water also supplies make up to the storage tanks for the fire protection system after the initial water inventory is depleted. Cooling towers may not be suitable for an ITER site on a seacoast or near a large, cool body of fresh water. Therefore open cycle cooling will be considered as a design option.

C. Energy and Electrical Power

1. Electrical Power Reliability during Operation **(SA.C1)**

[5] Insulation Co-ordination part 2 Application guide, Provisional Scale of Natural Pollution Levels

Assumption: The grid supply to the Steady State and to the Pulsed switchyards is assumed to have the following characteristics with respect to reliability:

Single Phase Faults	a few tens/year 80%: t < 1 s a few / year 20%: 1 s < t < 5 min where t = duration of fault
Three Phase Faults	a few/year

Bases: ITER power supplies have a direct bearing on equipment availability, which is required for tokamak operation. If operation of support systems such as the cryoplant, TF coil supplies and other key equipment are interrupted by frequent or extended power outages, the time required to recover to normal operating conditions is so lengthy that availability goals for the tokamak may not be achieved. Emergency power supplies are based on these power reliability and operational assumptions.

2. *ITER Plant Pulsed Electrical Supply* **(SA.C2)**

Assumption: A high voltage line supplies the ITER "pulsed loads". The following table shows the "pulsed load" parameters for the ITER Site:

Characteristic	Values
Peak Active Power[6, 7]	500 MW
Peak Reactive Power	400 Mvar
Power Derivative[7]	200 MW/s
Power Steps[7]	60 MW
Fault Level	10–25 GVA
Pulse Repetition time	1800 s
Pulsed Power Duration[8]	1000 s

Bases: The peak active power, the peak reactive power and the power steps quoted above are evaluated from scenarios under study. Occasional power steps are present in the power waveform. The supply line for pulsed operation will demand a very "stiff" node on the grid to meet the assumption.

D. Transport and Shipping

[6] From which up to 400 MW is a quasi-steady-state load during the sustained burn phase, while the remaining 80 to 120 MW has essentially pulse character for plasma shape control with maximum pulse duration of 5 to 10 s and energy content in the range of 250 to 500 MJ.

[7] These power parameters are to be considered both positive and negative. Positive refers to power from the grid, while negative refers to power to the grid. Power variations will remain within the limits given above for the maximum power and for the power derivatives.

[8] The capability to increase the pulse power duration to 3600 s is also assumed, in which case the repetition time would increase accordingly to maintain the same duty factor.

Bases: Several modes of transport and shipping are assumed for ITER because the diversity of these modes provides protection against disruptions for timely delivery of materials and equipment needed by the project. The assumptions for transport and shipping are based on some general considerations, which are common for all modes.

When the assumptions describe the site as having "access" to a mode of transport or shipping, it means that the site is not so far away from the transport that the assumed mode would be impractical. Air transport is a good example, because if the airport is not within reasonable commuting time, the time advantage of this mode would be lost (i.e. it would become impractical).

1. Highway Transport **(SA.D1)**

Assumption: The ITER Site is accessible by a major highway, which connects to major ports of entry and other centres of commerce.

2. Air Transport **(SA.D2)**

Assumption: The ITER Site is located within reasonable commuting time from an airport with connections to international air service.

3. Rail and Waterway Transport **(SA.D3)**

Assumption: It is assumed the ITER site will have rail and waterway access. The railway is assumed to connect to major manufacturing centres and ports of entry.

E. External Hazards and Accident Initiators

1. External Hazards **(SA.E1)**

Assumption: It is assumed the ITER Site is not subject to significant industrial and other man-made hazards.

Bases: External hazards, if present at the ITER site, must be recognised in safety, operational and environmental analyses. If these hazards present a significant risk, mitigating actions must be taken to ensure acceptable levels of public safety and financial risk.

2. External (Natural) Accident Initiators **(SA.E2)**

Assumption: It is assumed the ITER Site is not subject to horizontal winds greater than 140 km/hr (at an elevation of 10 m) or tornadic winds greater than 200 km/hr. The ITER Site is not subject to flooding from streams, rivers, sea water inundation, or sudden runoff from heavy rainfall or snow/ice melting (flash flood). All other external accident initiators except seismic events are assumed below regulatory consideration.

Bases: The wind speeds specified in this requirement are typical of a low to moderate risk site. Tornadic winds apply dynamic loads of short duration to buildings and outdoor equipment by propelling objects at high speeds creating an impact instead of a steady load. The design engineer uses the tornadic wind speed in modelling a design basis projectile, which is assumed to be propelled by the tornado. This design basis is important for buildings and structures that must contain hazardous or radioactive materials or must protect equipment with a critical safety function.

ITER is an electrically intensive plant, which would complicate recovery from flooded conditions. This assumption does not address heavy rainfall or water accumulation that can be diverted by typical storm water mitigation systems. For the purposes of this assumption, accidents involving fire, flooding and other initiators originating within the ITER plant or its support facilities are not considered external accident initiators.

F. Infrastructure

Bases: The ITER Project is sufficiently large and extended in duration that infrastructure will have a significant impact on the outcome. Industrial, workforce and socio-economic infrastructure assumptions are not quantitatively stated because there are a variety of ways these needs can be met. The assumptions are fulfilled if the actual ITER site and its surrounding region already meets the infrastructure needs for a plant with similar technical, material and schedule needs as ITER requires.

1. Industrial **(SA.F1)**

Assumption: It is assumed the ITER Site has access to the industrial infrastructure that would typically be required to build and operate a large, complex industrial plant. Industrial infrastructure includes scientific and engineering resources, manufacturing capacity and materials for construction. It is assumed the ITER Site location does not adversely impact the construction cost and time period nor does it slow down operation. The following are examples of the specific infrastructure items assumed to be available in the region of the site:

- Unskilled and skilled construction labour
- Facilities or space for temporary construction labour
- Fire Protection Station to supplement on-site fire brigade
- Medical facilities for emergency and health care
- Contractors for site engineering and scientific services
- Bulk concrete materials (cement, sand, aggregate)
- Bulk steel (rebar, beams, trusses)
- Materials for concrete forms
- Construction heavy equipment
- Off-site hazardous waste storage and disposal facilities
- Industrial solid waste disposal facilities
- Off-site laboratories for non-radioactive sample analysis

Bases: Efficiency during construction and operation of a large, complex industrial facility varies significantly depending on the relative accessibility of industrial infrastructure. Accessibility to infrastructure can be demonstrated by comparable plants operating in the general region of the site.

2. Workforce **(SA.F2)**

Assumption: It is assumed that a competent operating and scientific workforce for the ITER Plant can be recruited from neighbouring communities or the workforce can be recruited elsewhere and relocated to the neighbouring communities.

It is also assumed that ITER has the capability for conducting experiments from remote locations elsewhere in the world. These remote locations would enable "real-time" interaction in the conduct of the experiments, while retaining machine control and safety responsibilities at the ITER Site Control Facility.

Bases: The workforce to operate, maintain and support ITER will require several hundred workers. The scientific workforce to conduct the ITER experimental program will also require several hundred scientists and engineers. The assumption that these workers and scientist/engineers come from neighbouring communities is consistent with the site layout plans, which have no provisions for on-site dormitories or other housing for plant personnel.

A significant scientific workforce must be located at the ITER Site as indicated in the Assumptions. However, this staff can be greatly augmented and the experimental value of ITER can be significantly enhanced if remote experimental capability is provided. The result of the remote experiment is that scientific staffs around the world could participate in the scientific exploitation of ITER without the necessity of relocation to the ITER Site. Remote experimental capability is judged to be feasible by the time of ITER operation because of advances in the speed and volume of electronic data transfers that are foreseen in the near future.

3. Socio-economic Infrastructure **(SA.F3)**

Assumption: The ITER Site is assumed to have neighbouring communities, which provide socio-economic infrastructure. Neighbouring communities are assumed to be not greater than 50 km from the site, or one hour travel. Examples of socio-economic infrastructure are described in the following list:

- Dwellings (Homes, Apartments, Dormitories)
- International Schools from Kindergarten to Secondary School
- Hospitals and Clinics
- Job Opportunities for Spouses and other Relatives of ITER workers
- Cultural life in a cosmopolitan environment

Bases: Over the life of the ITER plant, thousands of workers, scientists, engineers and their families will relocate temporarily or permanently to the communities surrounding the ITER site. These people could comprise all the nationalities represented by the Parties. This "world" community will present special challenges and opportunities to the host site communities.

To attract a competent international workforce, international schools should be provided. Teaching should be partially in the mother tongue following programmes, which are compatible with schools in each student's country of origin. All parties should assist with the international schools serving these students.

The list of examples is not intended to be complete but it does illustrate the features considered most important. The assumed 50 km distance should maintain reasonable commuting times less than one hour for workers and their relatives.

G. Regulations and Decommissioning

1. General Decommissioning **(SA.G1)**

Assumption: During the first phase of decommissioning, the ITER operations organization places the plant in a safe, stable condition. Dismantling may take place decades after the "deactivation" phase. Dismantling of ITER is assumed to be the responsibility of a new organization within the host country. The ITER operations organization will provide the new organization all records, "as-built prints", information and equipment pertinent to decommissioning. Plant characterization will also be provided for dismantling purposes after "deactivation".

Bases: Experience and international guidelines (IAEA Safety Series No. 74, 1986, "Safety in Decommissioning of Research Reactors") stress the importance of good record keeping by the operations organization as a key to decommissioning success.

2. ITER Plant "Deactivation" Scope of Work **(SA.G2)**

Assumption: The ITER operations organization will develop a plan to put the plant in a safe, stable condition while it awaits dismantling.

Residual tritium present at the end of ITER operations will be stabilised or recovered to secure storage and/or shipping containers. Residual mobile activation products and hazardous materials present at the end of ITER operations will be stabilised or recovered to secure storage and/or shipping containers such that they can be shipped to a repository as soon as practical.

ITER deactivation will include the removal of in-vessel components and their packaging in view of long-term storage. This removal from the vacuum vessel will be done by personnel and remote handling tools, trained for maintenance during the previous normal operation.

Liquids used in ITER systems may contain activation products, which must be removed before they can be released to the environment or solidified as waste. It is assumed that all liquids will be rendered to a safe, stable form during the "deactivation" phase, and afterwards no more cooling will be necessary.

ITER "deactivation" will provide corrosion protection for components, which are vulnerable to corrosion during the storage and dismantling period, if such corrosion would lead to spread of contamination or present unacceptable hazards to the public or workers.

Bases: It is recommended (IAEA Safety Series No. 74, 1986) that all radioactive materials be rendered into a safe and stable condition as soon as practical after the cessation of operations.

***H. Construction Phase* (SA.H)**

General requirements for the construction phase (except land) are very dependent on local practice. However, water, sewage and power supplies need to be provided at the site for a construction workforce of up to 3000 people.

References

[1] "ITER Physics Basis", Nuclear fusion, vol. 39, n°12 (1999), pp. 2137-2638

[2] IAEA Bulletin 374, T J Dolan, D P Jackson, B A Kouvshinnikov, D L Banner, "Global co-operation in nuclear fusion: Record of steady progress"

[3] Extracts from "Summary of the ITER Final Design Report", May 2001, section 8

[4] ITER Site Requirements and ITER Site Design Assumptions, N CL RI 3 99-10-19 W 0.2

[5] Plant Design Specification, chapter 4, G A0 SP 2 01-06-01 R 2.0

3. The Cadarache site

Cadarache satisfies all the ITER site requirements.

From the point of view of the layout and geotechnical characteristics, the site requirements are more than satisfied thanks to a large available surface and to the presence of a good quality limestone substrate.

The design assumptions are satisfied, widely exceeded for most of them. Two exceptions with minor impact are:

- The seismic level is slightly higher in Cadarache than on the generic site.
- Concerning the electrical supply, an additional voltage drop compensator will be necessary.

These two aspects require an adaptation of the ITER generic design. The evaluation of the consequences of such an adaptation is almost completed for the first and is finished for the second. No major technical difficulty is anticipated. The extra cost will be reasonable for aspects related to the seismic issue and small for the electrical issue.

A reference route for the transport of large and heavy loads has been technically and financially evaluated. An alternative solution that could be cheaper is under investigation.

3.1. Overview of CEA Cadarache

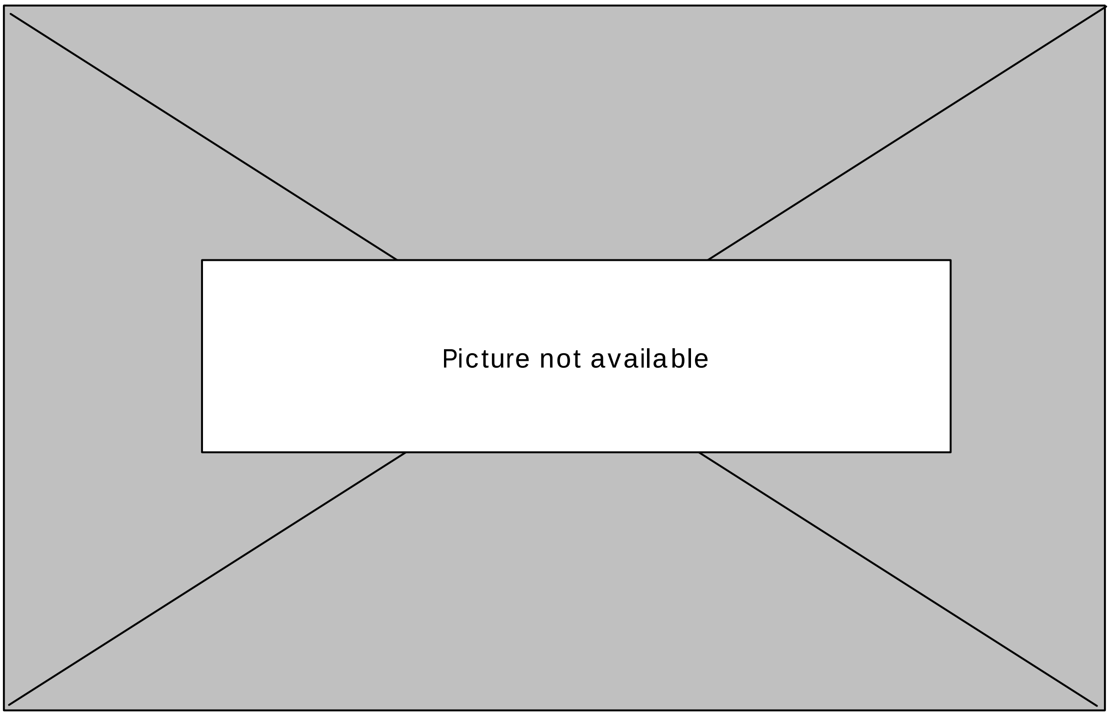


Figure 3.1: Aerial View of Cadarache Centre

Cadarache, established in 1959, is with its 1600 hectares the largest research centre of the French Atomic Energy Commission (CEA). Due to the number of staff (2500) and annual budget (400 M€) the centre has a large impact on the region. It is located at the very heart of historical Provence, halfway between Aix-en-Provence and Manosque.

Cadarache is the main CEA centre for power-oriented research (see Figure 3.1 and Figure 3.2), with experimental reactors, specialised laboratories, workshops and test facilities. Work is also carried out on plant safety and on the protection of the environment. The Euratom-CEA Association coordinates the French activity on magnetic thermonuclear fusion and has operated the superconducting tokamak Tore Supra since 1988. As well as the different specialised laboratories and reactors a number of general services are also available on the Cadarache site.

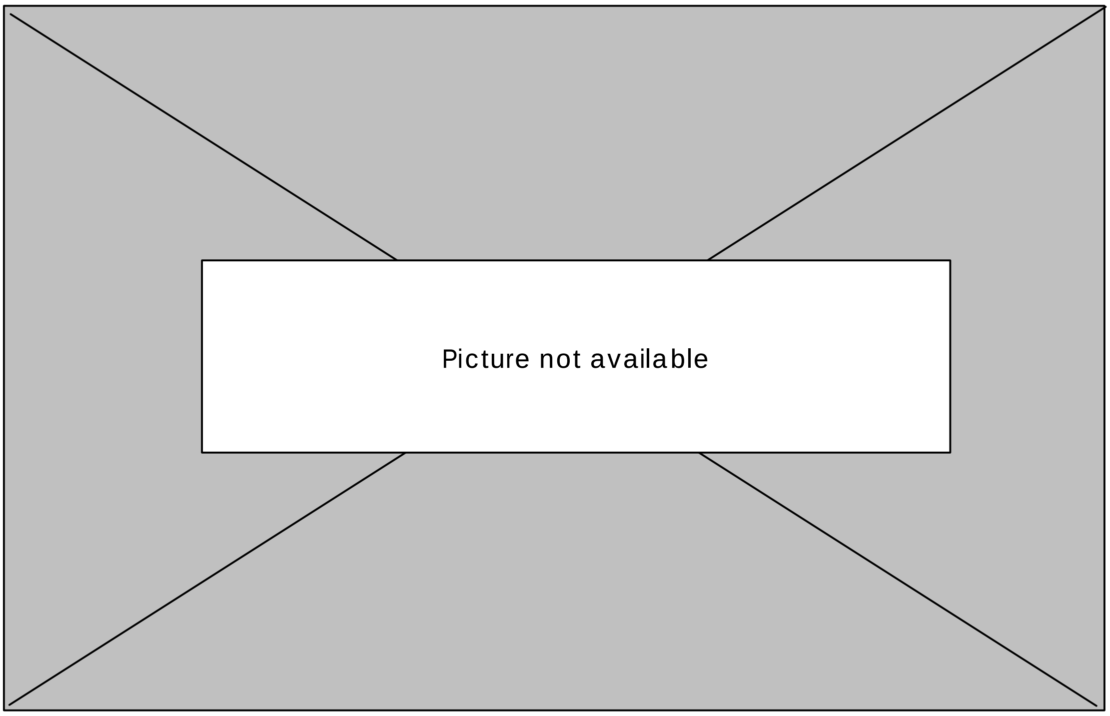


Figure 3.2: Aerial View of some of the Test Reactors on Site

- **Local Security Service**: The FLS (Formation Locale de Sécurité) is responsible for the protection of installations and other property with respect to classical risks, both internal and external. It has the latest and most modern equipment at its disposal to intervene in case of (nuclear) incident or accident. The FLS is responsible for the execution of the site emergency plan. All alarm systems from the different installations are connected through a fibre network to the FLS central command unit.

- **Radiation Protection Service**: The SPR (Service de Protection contre les Rayonnements) has as mission to make sure that the national radiation protection regulations are implemented. All the SPR staff have been trained by the INSTN (Institut National des Sciences et Techniques Nucléaires), who themselves have a representation in Cadarache. In addition to the control task the SPR also has an assistance task.
- **Medical Service**: A medical team is permanently present on site. Just as the security services they have modern equipment available to deal with accidents. The medical service also monitors the general health of the staff in Cadarache, with a special emphasis on radiological matters.
- **Technical Services**: The “Services Techniques” are responsible for the overall infrastructure and communication on site and specifically for the installation of general alarm systems, overall infrastructure and communication on site. They have a large experience with respect to the particular needs of nuclear installations.
- **Waste and Combustibles Service**: The “Service de Gestion des Déchets et des Combustibles” takes care of all the problems with the treatment, containment and elimination of nuclear waste and effluents within the framework of the French regulations. A treatment station is equipped with, amongst others, incinerators, presses and temporary storage facilities for all classical nuclear waste. A large experience on tritiated waste products has been built-up in cooperation with CEA Valduc, another CEA nuclear centre, with particular experience with tritium.

The Cadarache research centre has the necessary infrastructure. Taking into account the presence on site of French and European experts on magnetic fusion and the wide expertise on nuclear installations, the site is well capable to host an installation like ITER.

It is nevertheless foreseen to implement specific services on ITER site, as:

- a welcome building, with conference room, exhibition hall for public and scientists…
- a restaurant, more dedicated to ITER employees and visitors;
- local safety antennas (firemen, medical service for immediate intervention).

3.2. Land and implantation

The location at the Northeast of the current boundary of the Cadarache site is confirmed (see Figure 3.3). This zone is one of three zones, which had been considered in previous studies for ITER localisation. It was preferred to the two others after comparison on the basis of various criteria (quality of the substrate, hydrogeology, access, impact on the environment, topography, etc.). The selected zone is close to Tore Supra, allowing ITER to benefit from the existing equipments and laboratories, notably during the construction phase. The available surface on the selected site is well over 180 ha, easily fulfilling the site requirements and design assumption (SR.A1 & SA.A1, chapter 2.5).

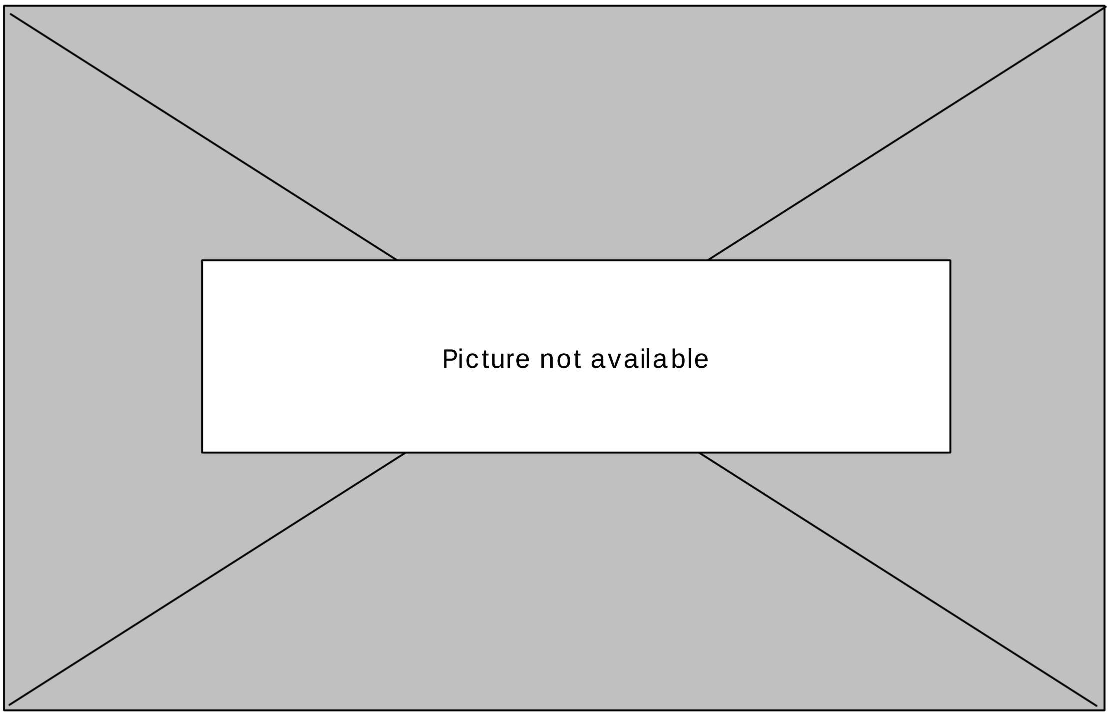


Figure 3.3: ITER Location on the Cadarache Site

3.2.1. Meteorology

Site design assumptions on meteorology have been detailed (SA.A6, see chapter 2.5), because these figures may have a significant impact on the design. The data for Cadarache is well documented due to the presence of nuclear facilities for more than 40 years. Two meteorological stations are in operation at the centre and the following data are permanently recorded:

- Maximum air temperature
- Minimum air temperature
- Average air temperature over 24 hours
- Rainfall over 24 hours
- Rainfall over 1 hour
- Wind speed at 110m elevation
- Relative humidity

All data are within the design assumptions except:

- The maximum air temperature, which has been 40.1 °C once over a period of 40 years (35 °C in the ITER design assumptions). This figure could have an impact on the cooling system (see chapter 3.4).
- The maximum relative humidity, which is 100 % (95 % in ITER design). This figure has no significant impact because it occurs only during limited periods when the temperature is low.

The climate at Cadarache is a mix between continental and Mediterranean, relatively dry and warm. One of the major characteristics is the large daily variation of the air temperature as shown in Figure 3.4.

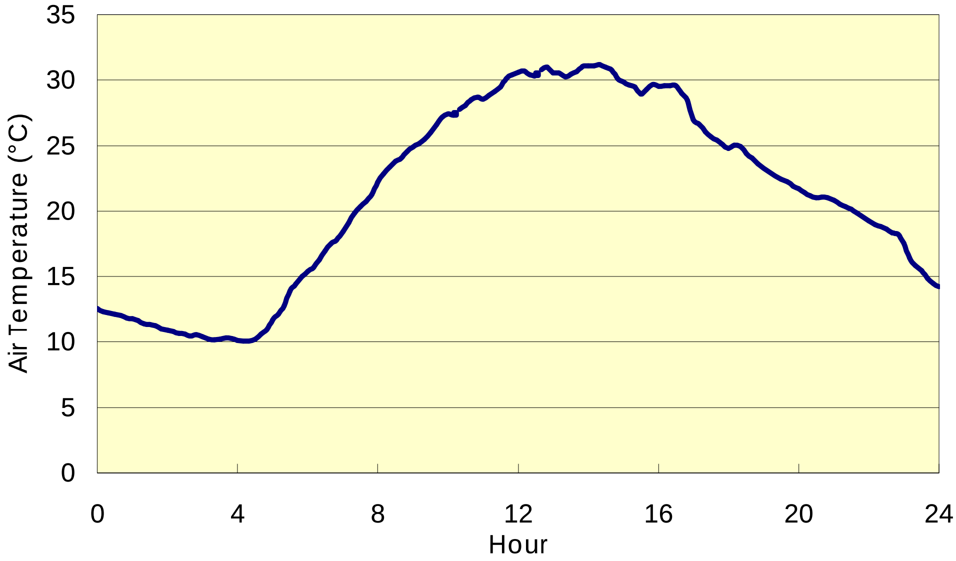


Figure 3.4: Temperature Variation on 18 June 1999

3.2.2. Geotechnical and hydrological aspects

While the topsoil is partially alluvia (see Figure 3.5), a first campaign of drillings, conducted during autumn 2000, has localised a limestone substrate of good quality at around ten metres depth at most. These results have been used to establish the final levels of the different platforms, taking into account soil support strength requirements (SR.A2) and hydrological assumptions (SA.A4).

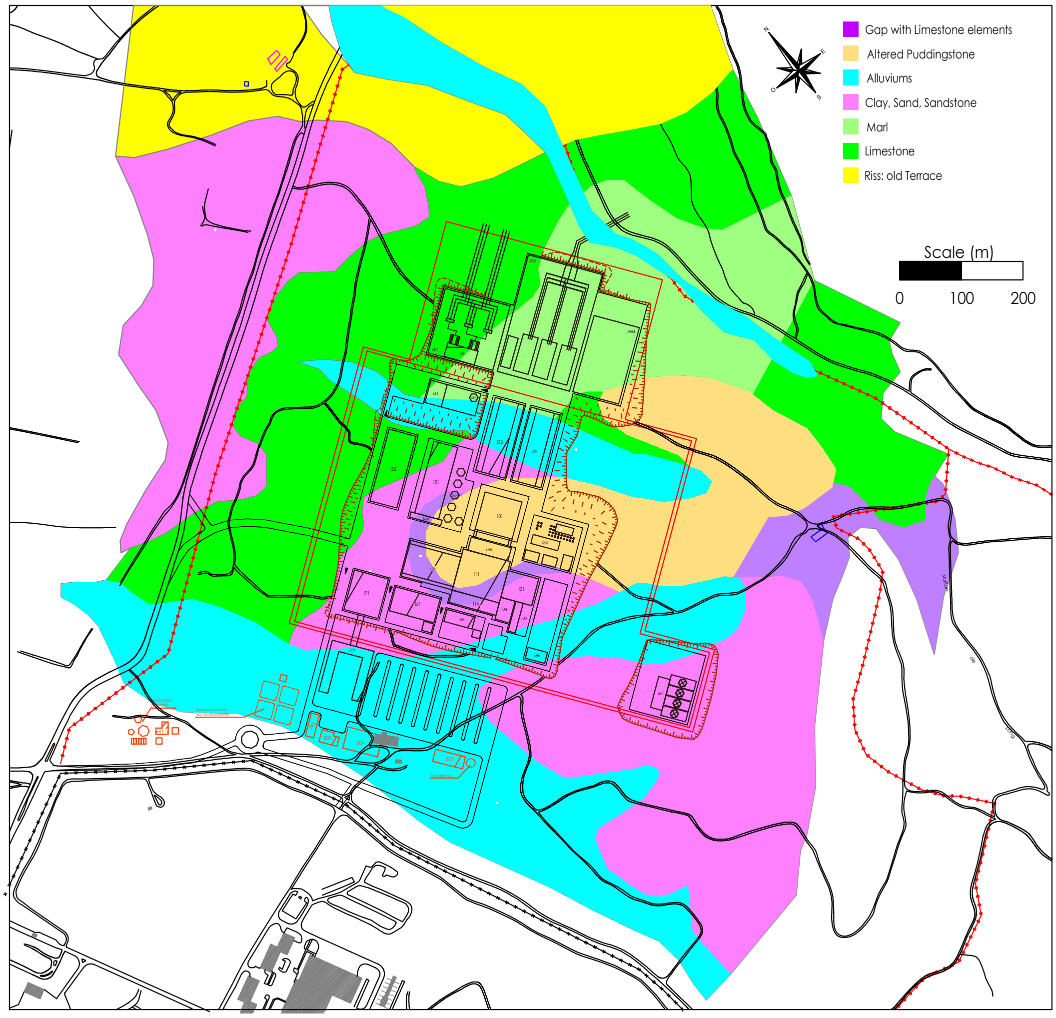


Figure 3.5: Soil at Natural Ground Level

During a ground surface review, no major singularity, which could have shown underground problems, was found.

Nevertheless, a very detailed geological investigation has been launched. This investigation includes (see Figure 3.6):

- **Geological measurements using seismic refraction**: the objective is to identify faults. This programme will cover most of the ITER area.
- **Drillings, destructive drillings and core samples**: the objective is to determine the soil composition and characteristics, necessary for the design of the building foundations. Some of these drillings will be equipped with water level probes and recorded. The depth of these drillings will be 60 m and will concentrate mainly on the area where the nuclear buildings are foreseen.
- **Geotechnical tests, dilatometry and cross-hole tests**: the objective is to measure the dynamic characteristics of the soil, which will be used for the foundation design and the seismic modelling.

The site could be moved by some tens of metres to optimise the location in view of the results of this campaign. The soil characteristics will be known and used for further design of the building foundations.

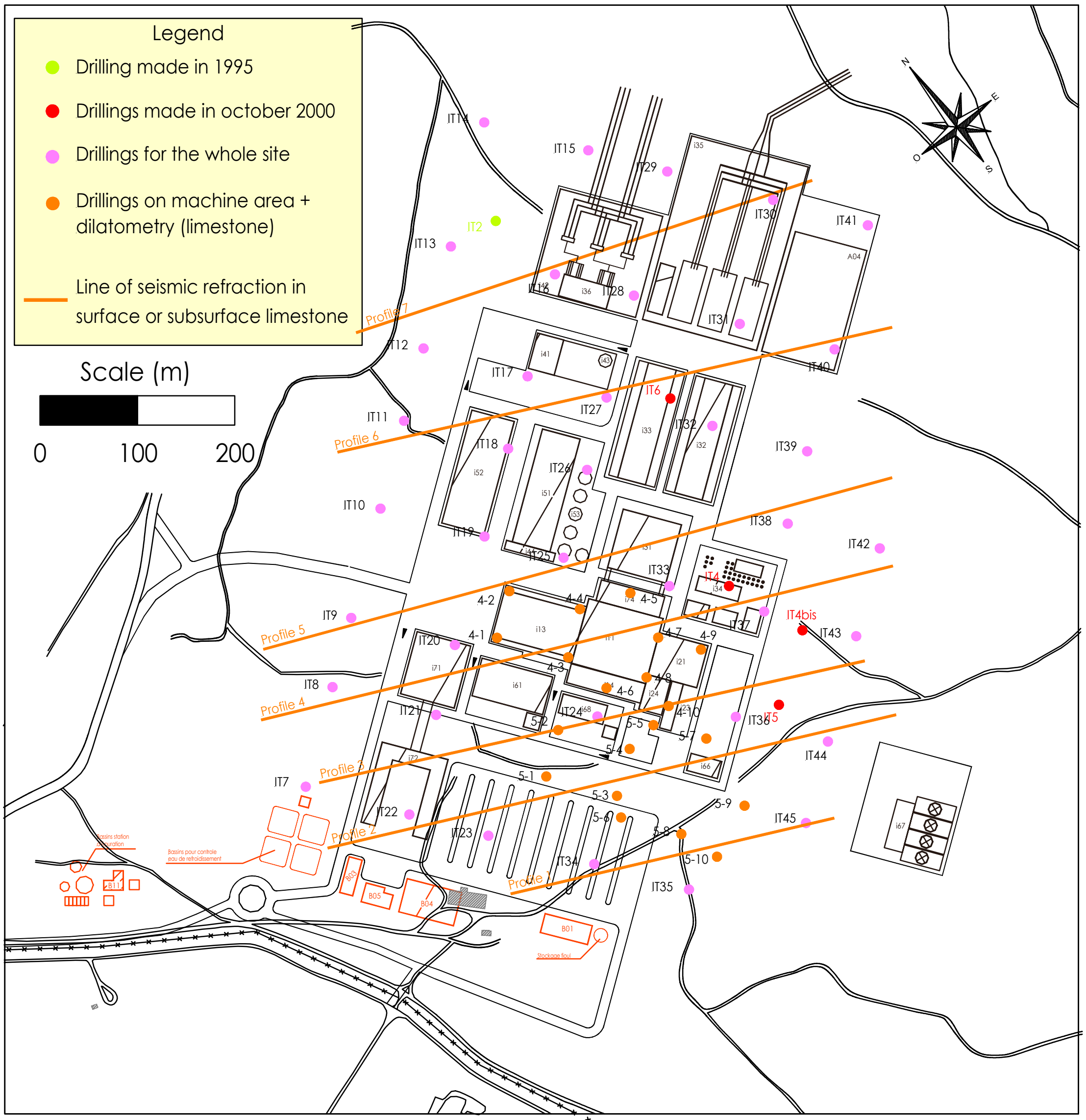


Figure 3.6: Detailed Geological Programme

3.2.3. Site layout

The arrangement of the buildings is in accordance with the generic site layout except for the cooling towers, which are positioned according to the dominant winds about 300 m away. The office building is rotated to improve its access (see Figure 3.7). Additional buildings and services (restaurant, medical service, access control, fire station, sanitary sewage station, pluvial water basins, etc.) have also been sketched. A special area for temporary workshops and storage during the construction phase has also been selected.

Since the natural ground is hilly, buildings are implemented on three different platforms to reduce the overall excavation. Nevertheless, all the nuclear buildings have their foundations on limestone:

- **Platform 1, 306 m above sea level**: control room, pumping station, site service buildings and emergency power supply;
- **Platform 2, 320 m**: cooling towers;
- **Platform 3, 310 m**: all other buildings.

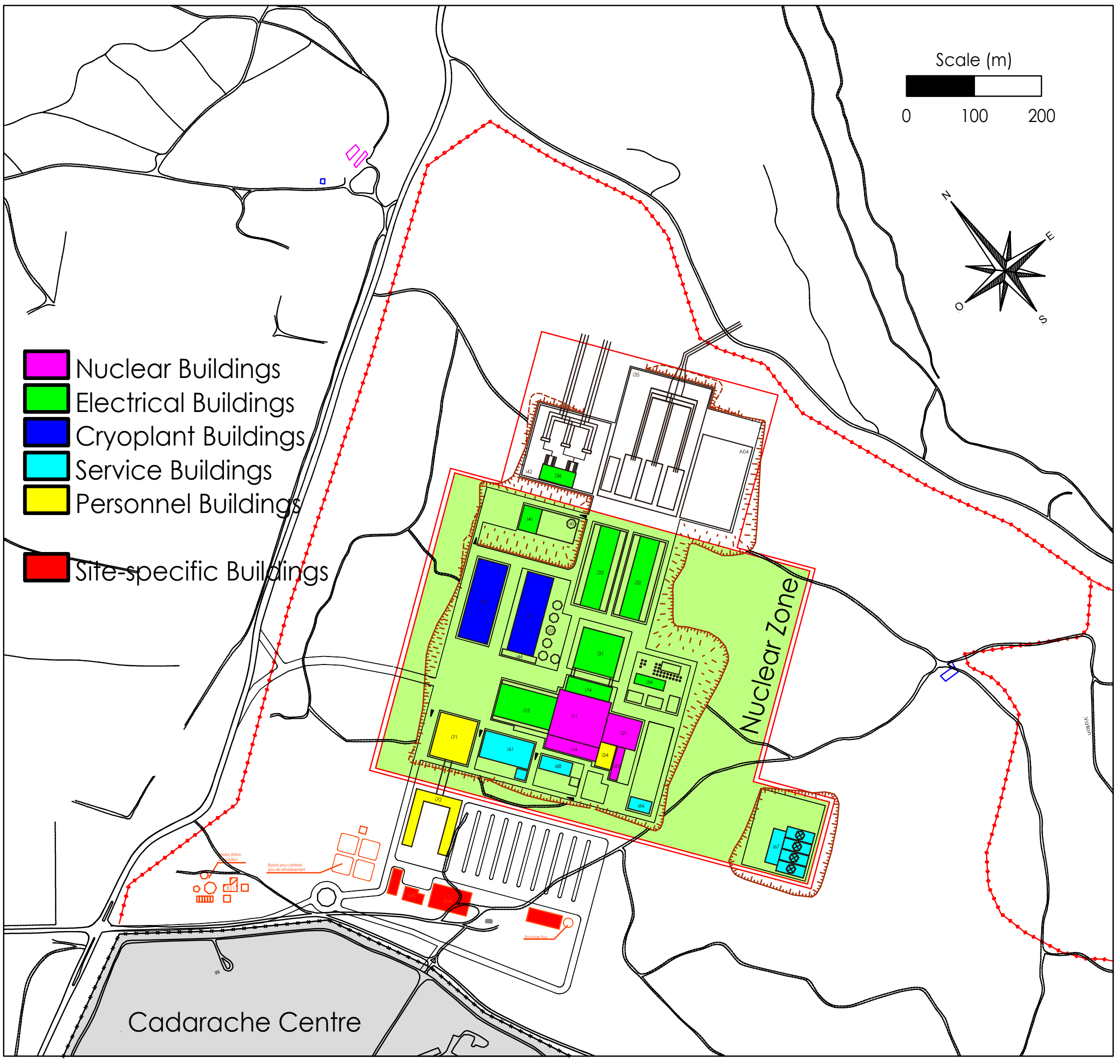


Figure 3.7: Detailed Layout of the Buildings

Excavated materials will be stored in a nearby small valley in order to reduce the overall environmental impact and transportation costs. The establishment of the platforms meets the design assumptions on topology (SA.A2) and geotechnical characteristics (SA.A3).

Architectural studies intended to estimate the visual impact were made. Figure 3.8 gives a preliminary outline.

Figure 3.8: Insertion of ITER in the Landscape, seen from the Castle of Cadarache

Figure 3.9: Artist Views of ITER Plant

3.2.4. Sanitary and industrial sewage

A new sanitary sewage treatment station will be built on the ITER site with a total capacity of 1500 people (SR.A4). This facility will also be used during the construction phase, but since the total number of people on site is estimated to be about 3000 at this time (assumption SA.H), a temporary connection with the existing Cadarache station will be made (see green lines on Figure 3.10).

For industrial sewage, ITER will be connected to the existing network, which already has the corresponding additional capability (SR.A4) (see red lines on Figure 3.10).

Potable water will be supplied by the existing pumping station, which feeds basins (SR.A3). This water is used for both drinking and fire security purposes. A new basin will be built to improve the storage capacity, especially in case of fire (see blue lines on Figure 3.10). Water from these basins is supplied by gravity.

Supply and sewage scheme for the cooling water system (doted red lines on Figure 3.10) is detailed in chapter 3.4.

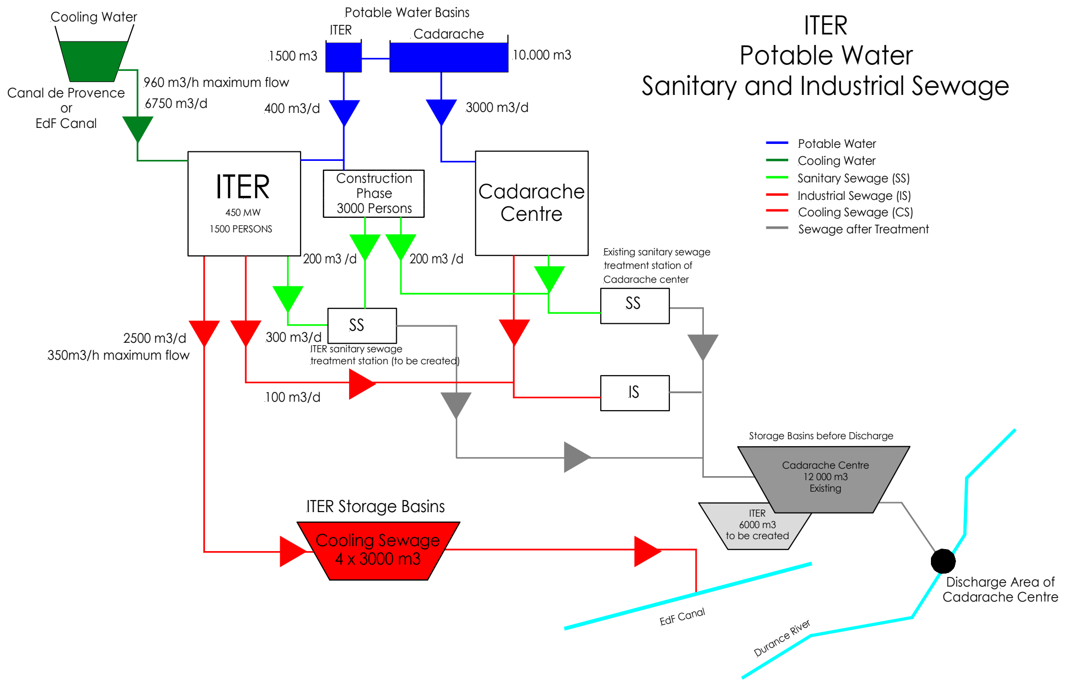


Figure 3.10: Overall Scheme for Water Supply and Sewage

3.3. Seismic aspects

The design of the safety classified buildings has been made by the ITER team on the generic site in accordance with the guidelines of ASME[9] and the U.S. NRC[10], with the objective to be applicable to a wide range of sites, with the exclusion of those with unusually soft soils. The primary scaling parameter used in the construction of the acceleration versus frequency spectrum is the design maximum ground acceleration, which has been assumed to be 0.2 g for the generic ITER site (SA.A5). At Cadarache, the "Règles Fondamentales de Sûreté" (RFS) require the use of two excitation spectra:

- the so-called "Séisme Majoré de Sécurité" (SMS): magnitude 5.8, distance to the epicentre 7.1 km, design maximum ground acceleration 0.315 g;
- the "Paléoséism": magnitude 7, distance 18 km, design maximum ground acceleration 0.281 g.

The comparison between the generic site (ASME 0.2 g) and Cadarache site specific Design Response Spectra is shown in Figure 3.11.

[9] ASME III Appendix N- Dynamic Analysis Methods
[10] NRC: U.S. Nuclear Regulatory Commission

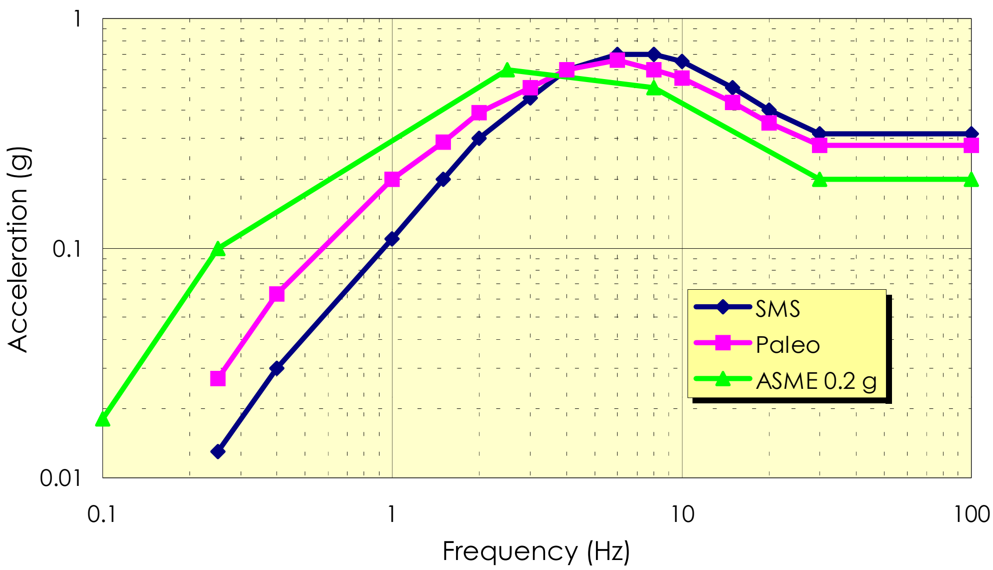


Figure 3.11: Comparison between the generic site "ASME" and Cadarache site specific Design Response Spectra (SMS and Paleo, both being applied)

Studies were launched to estimate the capacity of the Tokamak Building, as designed by the ITER team, to cope with Cadarache seismic conditions and to determine the necessary adaptations and reinforcement if any. Two studies were made in parallel and the first results are:

- **Response of the ITER generic tokamak building to the Cadarache spectrum**: a 3D mesh of the building was made (see Figure 3.12) and then a spectral analysis. About 150 eigenmodes have been identified in each of the three directions, covering a frequency range between 0 and about 20 Hz. Main modes, for which the effective mass is the largest, are shown in Table 3.1. Main modes in the horizontal directions, x and y, are in the range 3.6 – 3.7 Hz. Within this frequency range, the Cadarache spectrum and the ITER generic spectrum are rather similar (see Figure 3.11). **Stress computations show that the building, as it is now designed is able to withstand the Cadarache seismic conditions without any major reinforcement.** However, a few weak points have been identified at the level where the superstructure is connected to the upper slab (see Figure 3.12). This problem is **not site-specific** and the attachment would have to be redesigned in any case. The studies have been made in close collaboration with the ITER Joint Central Team and have shown a possible interaction between the tokamak and the building: further studies will be performed to complete the sensitivity analysis of the Tokamak Building and tokamak versus uncertainties such as stiffness (soil, mechanical supports, concrete, etc.) and distribution of masses (in building levels, in vacuum vessel ports, etc.). For the Cadarache site, considering that the soil is extremely stiff, the cross coupling of the Tokamak and Building modes is foreseen to be insignificant. The work has already been initiated in the ITER team yielding a preliminary report. Floor spectra are also computed; they will be used to assess the design of the safety related equipment inside the tokamak building. It has to be noted that this assessment has not yet been done for the generic site.

Direction	Frequency (Hz)	Effective mass	Comments
Horizontal X	1.74	7.1 %	Superstructure mode
	3.63-3.66	38.3 %	Building + tokamak translation and bending
	3.91 & 4.34	12.4 %	Building + tokamak / superstructure in opposition
Horizontal Y	2.22	0.1 %	Bending mode of the north front wall
	3.63-3.95	52.6 %	Building + tokamak translation and bending
	4.70 & 5.22	9.3 %	Building + tokamak / superstructure in opposition
Vertical Z	2.54	0.7 %	Bending mode of the roof support
	6.73-6.97	85.1 %	Overall vertical motion of the building

Table 3.1: Main Eigenmodes of the Building

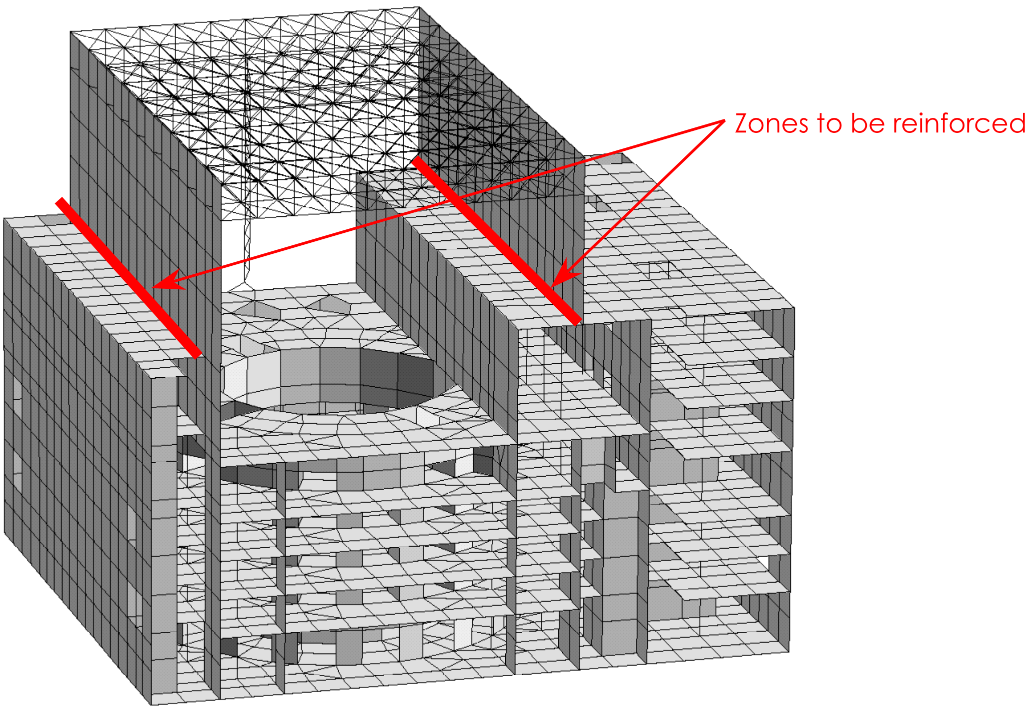


Figure 3.12: 3D Tokamak Building Mesh and necessary Reinforcements (see arrows)

- **Study of the use of paraseismic bearings for the ITER tokamak building**: These bearings are made with elastomer foils interleaved with stainless steel plates, implanted on specific concrete supports (see Figure 3.13). They are commonly used as supports for bridges and more specifically for nuclear buildings. Due to the excellent quality and homogeneity of the limestone in Cadarache, it would be possible to use such bearings for ITER. A preliminary design and layout (see Figure 3.14) have been proposed, leading to a decrease in the overall acceleration on the building and then on the equipments to 0.1 g, i.e. two times less than for the generic design. Significant savings are expected in the design of the building and all inner equipment thanks to the reduced acceleration. On the other hand, an overall motion of the building of roughly 75 mm is foreseen, with a frequency around 0.56 Hz. The interfaces with nearby buildings will need to be checked carefully because of this motion (see Figure 3.15).

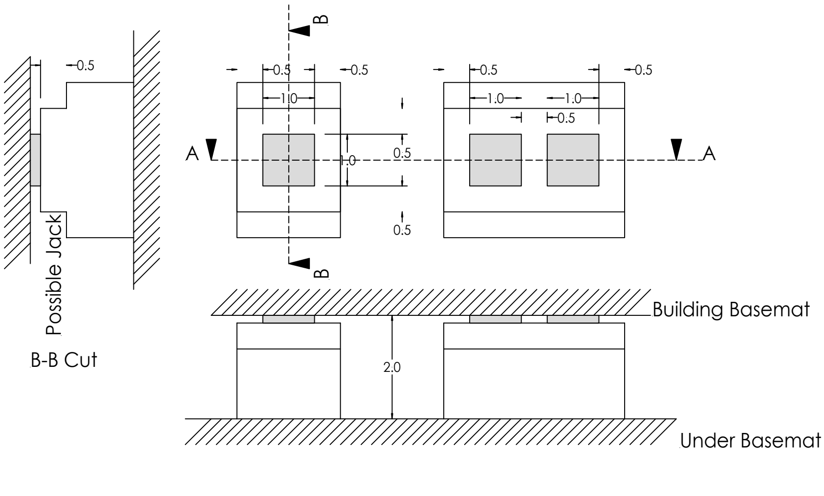


Figure 3.13: Schematic of 1 m² Paraseismic Bearings

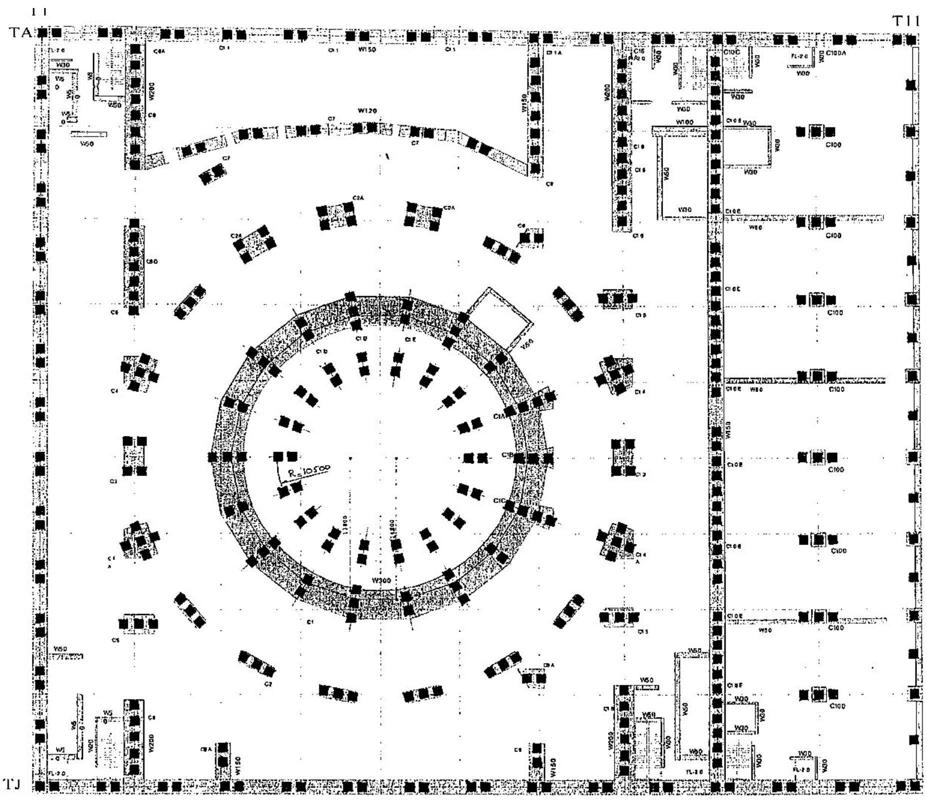


Figure 3.14: Position of the 400 Paraseismic Bearings under ITER Tokamak Building

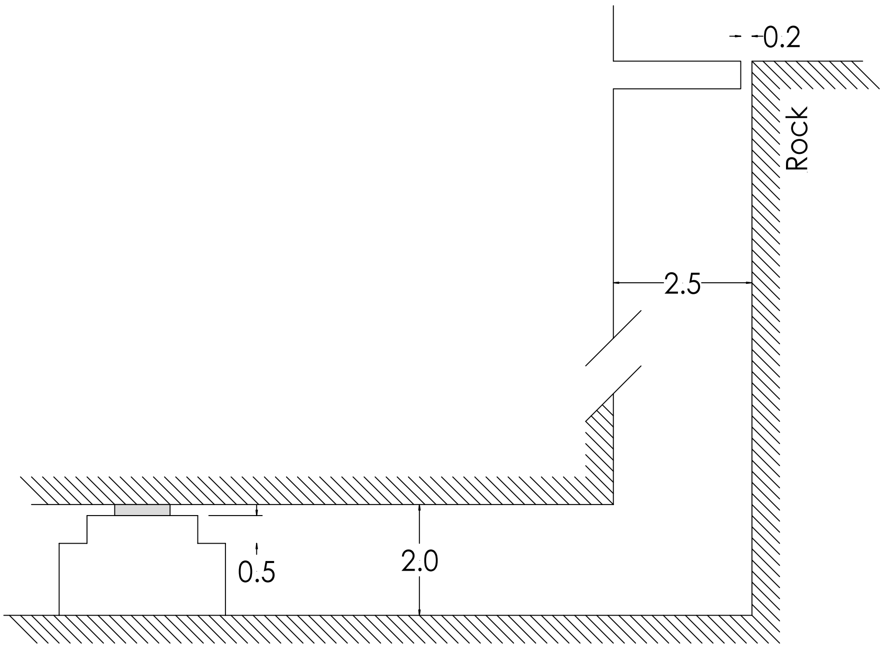


Figure 3.15: Principle for External Walls

Both options (local reinforcement of tokamak building and the use of paraseismic bearings) are feasible and show that the location of ITER is possible in Cadarache, with respect to the seismic level, without major modifications as compared with the generic design.

In the hypothesis of paraseismic bearings, the interface between the building and outer equipment must be carefully looked at.

3.4. Heat sink and water supply

A consumption of 1.5 million m³ per year has been estimated for the cooling water circuits (SR.B and SA.B). This is roughly equivalent to the actual total consumption of the Cadarache research centre. It will, therefore, be necessary to install a new supply system. Amongst several solutions, one possibility is preferred: supply by means of gravity from the EDF canal of Vinon-sur-Verdon. The investment cost for this solution are slightly higher than for the other possibilities, but this is offset by the reduced cost during exploitation since no pumping station will be necessary (see Figure 3.16) The climate in Cadarache, warm but very dry in the summer, allows the overall dimensions of the cooling towers to be reduced, the wet bulb temperature in Cadarache being 24 °C (against 29 °C in the hypothesis taken by ITER). However, the displacement of the cooling towers leads to an increase in the length of pipe work necessary by 300 m (2 x dia 2 m) with respect to the calculated length.

About two thirds of the water evaporates in the cooling towers. The rest will most likely be discharged into the Durance, after the necessary controls, making use of the current discharge outlet of Cadarache.

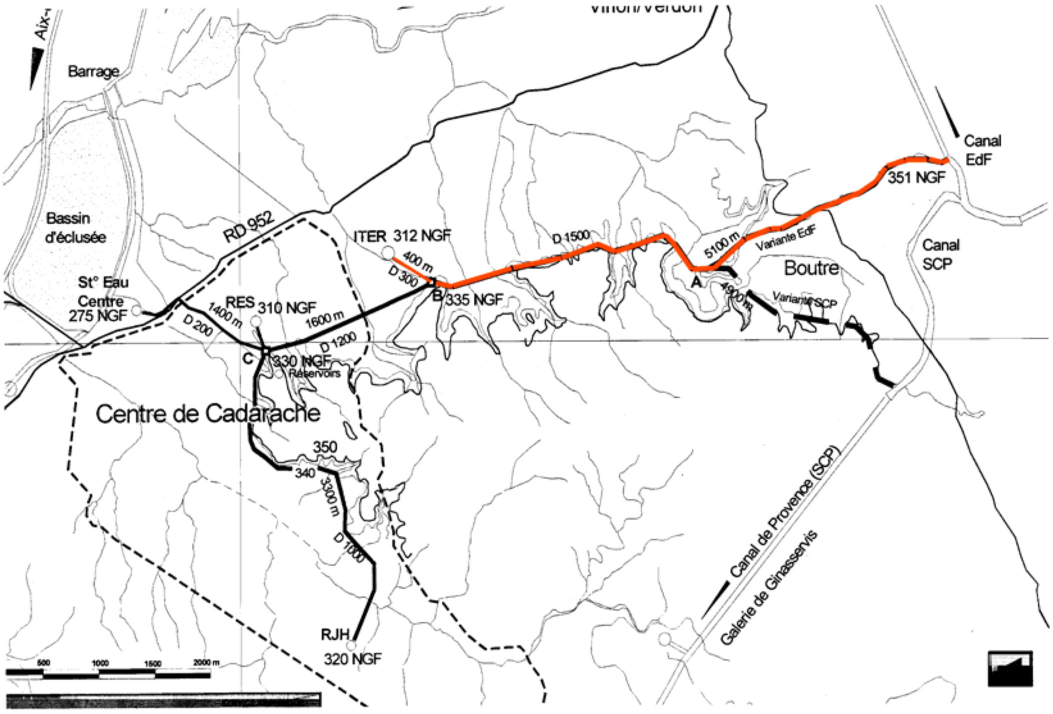


Figure 3.16: Possible Water Supply Route

3.5. Electrical power

The Network capability to supply the ITER Electrical Power at Cadarache has been tested with reference to the ITER site requirements and assumptions reported in chapter 2.5. The ITER electrical loads are divided in Steady State Electrical Power Network (SSEPN) and Pulsed Power Systems (PPS). The first one is mainly related to the power required by the ITER auxiliaries, while the Pulsed Power is to supply ITER poloidal and toroidal coils and additional heating systems. The active power required for SSEPN is P = 120 MW and the reactive power is Q = 60 Mvar. The active and reactive power assumed for PPS are, respectively P = 500 MW, Q = 400 Mvar during 1000 s every 1800 s.

The electrical network around Cadarache is well equipped with many lines and two powerful nodes:

- **Boutre**: 5 km east of the ITER site, with an interconnection at the 400 kV / 225 kV level and one autotransformer;
- **Sainte-Tulle**: 8 km north of the ITER site, with an interconnection at the 225 kV / 63 kV level.

Moreover, Tore Supra is already supplied by a 400 kV dedicated line and the Cadarache centre by two 63 kV lines, one being supplied independently by a nearby hydroplant as backup in case of emergency. The current high voltage supply situation is shown in Figure 3.17.

The public company RTE[11] has been asked to provide a supply scheme for ITER. Many options have been studied and compared with respect to technical, financial and environmental aspects. This last aspect has been decisive since the visual impact of 225 kV and 400 kV pylons is significant. The presently foreseen upgrades due in 2010 to the current high voltage supply scheme are shown in Figure 3.18.

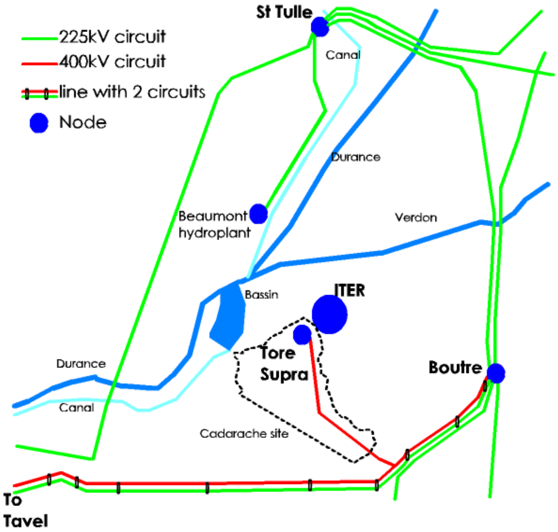


Figure 3.17: Current High Voltage Supply Situation

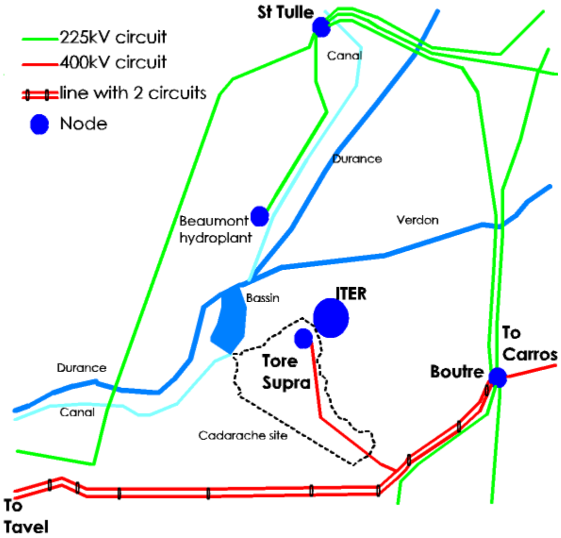


Figure 3.18: Foreseen High Voltage Supply Scheme (2010)

All the modifications are on CEA property:

- Creation of a new 400 kV / 225 kV node on the east boundary of Cadarache centre;
- Modification of the 400 kV existing T connection with the addition of 3 breakers to improve the reliability;
- Extension of the 400 kV line from Tore Supra to ITER;
- Construction of a double 225 kV line from the new node to ITER in parallel with the 400 kV line.

The proposed ITER high voltage supply scheme is presented in Figure 3.19.

The scheme fulfils all ITER site requirements (SR.C).

The design assumptions with respect to the reactive power are not satisfied because the assumed 400 Mvar would cause too high a voltage drop on the network ($\Delta V > 6$ %). For this reason, the power of the fast ($\Delta t \sim 10$ ms) ITER static VAR compensator will have to be increased from 540 Mvar to 750 Mvar and driven as voltage regulator (SA.C1 and SA.C2). In this way the maximum voltage drop can be maintained within an

[11] Réseau de Transport de l'Électricité, part of Électricité de France

acceptable value (< 4 %). This design modification will have a modest impact because there are margins in the present design with respect to the thyristor design.

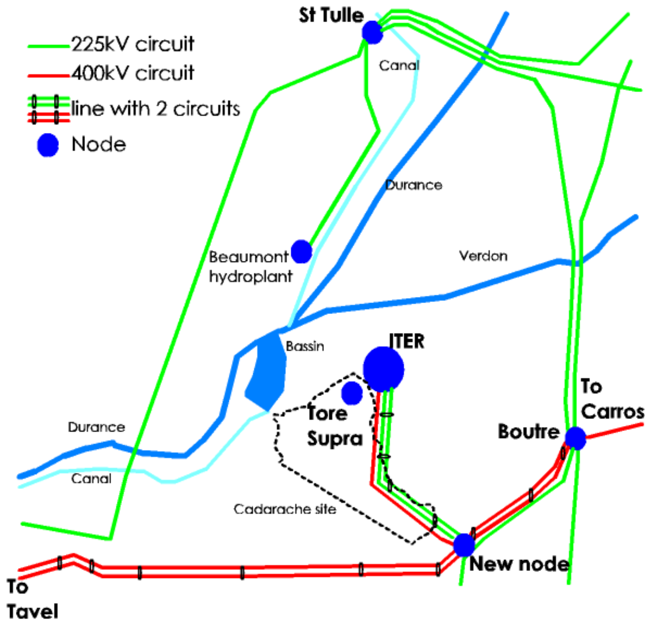


Figure 3.19: Proposed ITER High Voltage Supply Scheme

On the other hand, the design assumptions with respect to the active power (500 MW) can be met with a well acceptable voltage frequency variation (< 50 mHz). In addition, an active power up to ± 1000 MW seems to be deliverable from the grid for a short time ($\Delta t \sim 5$ s) instead of the assumed ± 60 MW. On this basis, a scheme with only a double 400 kV line should be studied in detail, leading to significant cost savings on both site adaptation and generic design. Such a large active power step that can be supplied and/or received by the grid and the high value of reactive power locally compensated can also lead to other possible system simplifications and cost savings (poloidal coils switching network, main step down transformers rating, reactive power requirements by poloidal and toroidal converters…). A detailed study will optimise the whole system.

3.6. Transport of heavy and large components

The transport of large and heavy components to Cadarache, which is located at some tens of kilometres from the sea, requires specific studies.

A review of all dimensions and weights of these components has been made in close collaboration with the ITER Joint Central Team. The results, a basis for all further studies, are shown in Table 3.2 (SR.D1 and SR.D2). Since no transport and handling study has yet been undertaken in the frame of the ITER reference design, an estimation of the weight and the size of the handling and packaging devices has been done. In order to remain within the width dimension of the vacuum chamber (8.50 m) the possibility to transport the toroidal field coils (TF coils) in an angled position has been envisaged.

Component	Number	Width (m)		Length (m)		Height (m)		Weight (t)	
Equipment		Bare	Packed	Bare	Packed	Bare	Packed	Bare	Packed
Vacuum vessel 40° sector	9	8.23	**8.50**	12.02	12.50	6.42	**6.90**	600	**700**
TF coils flat	18	9.13	9.30	16.80	17.00	2.80	3.00	280	320
TF coils at 33°2		8.30	**8.50**	16.80	**17.00**	5.96	6.27	280	**350**

Table 3.2: Dimensions and Weight of ITER Components

A preliminary study has indicated that a specific articulated convoy would be necessary for the transport of the packages.

The height constraint hinders passage under most viaducts and bridges along a classic itinerary. The width constraint imposes problems, often insurmountable, with respect to the passage of towns and other built-up areas. The weight constraints give problems for each bridge or viaduct to be crossed and also in a more general way on the distribution of weight along the axles of the transporting unit.

Two study contracts for the transport by road have been given to the public agency "Centre d'Études Techniques de l'Équipement" (CETE):

- in a first instance, the use of an already existing itinerary for "convoi exceptionnnel[12]" between Fos-sur-Mer (Marseille) and Cadarache. Certain sections would require technical adaptations, in particular roundabouts and bridges, but no administrative difficulty is anticipated. This first scheme requires the use of a section of EDF canal (see below);
- in a second instance, a second route, only by road has been evaluated, both technically and administratively. It has the advantage to be faster (no load transfers to and from the barges), but would require more technical adaptations.

Complementarily, the "Centre d'Ingénierie Hydraulique d'EDF" analysed the transportation on the Durance EDF canal by means of ad-hoc barges. One hydroelectric power station would be by-passed via a specifically constructed track. The use of about 40 km of the canal requires, besides the manufacture of the barges, the modification of a few bridges and the construction of specific handling equipment for loading and unloading the components on the barges.

The combination of these three studies on large and heavy components has allowed the definition of two itineraries:

- **The first route follows a mixed itinerary**, road and fluvial, starting from the Marseille-Fos harbour (see Figure 3.20):
    - The Caronte canal and the Étang de Berre on fluvial barge, until Berre l'Étang town;
    - Part of the "abnormal load route" until Mallemort;

[12] Road already qualified for "exceptional" transport

- The EDF-Durance canal up to Peyrolles, including by-pass of the hydroelectric station at Saint-Estève;
- Road and motorway A51 up to Cadarache, implying an enlargement of the D952 road near Mirabeau bridge.

This itinerary is technically feasible and realistic from the point of view of administrative authorisation since the impact on the general public is low.

- **The second route, totally by road between Berre l'Étang and Cadarache**, has the advantage to avoid the load transfers, necessary on the reference itinerary. It will reduce the time necessary for the transports (3 days, compared to 10 days), as well as the risks and cost. However this itinerary requires more technical adaptation of existing roads.

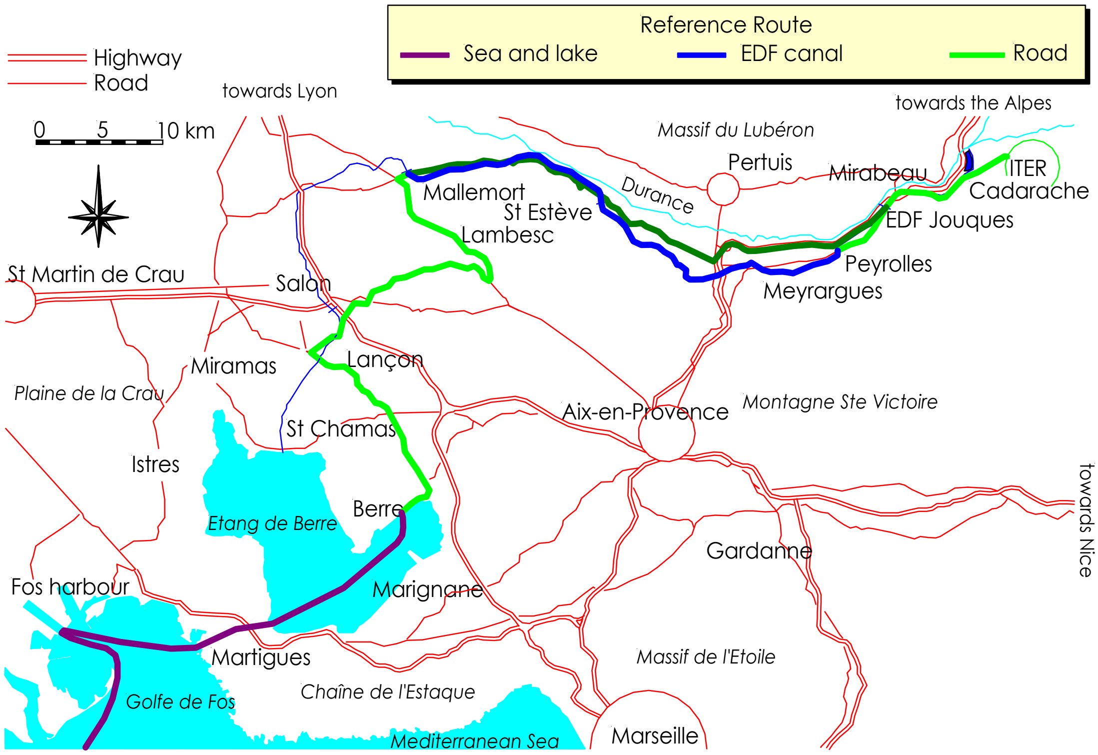


Figure 3.20: Reference routes (by road only, or combination of road and canal), from Fos harbour to Cadarache

4. Licensing ITER in France

4.1. Licensing procedure

4.1.1. ITER safety approach

The ITER safety approach adopted by the project draws upon experience in nuclear and non-nuclear industries. Objectives are established for protection of the public, the worker, and the environment. Quantitative criteria are set against which to judge the success in achieving the safety objectives. Hazards are identified that may challenge the objectives. Preventive and mitigative measures are implemented as needed to ensure that facility operation meets the objectives. Techniques of deterministic safety analysis supplemented by those of probabilistic assessment are used to determine and demonstrate the safety of the facility.

Following site selection, the host country regulations will apply which may lead to modification of the requirements or their detailed implementation.

The ITER project safety objectives, principles and criteria are documented in the Plant Design Specification [PDS01] and are summarised below.

- **Safety objectives**

  ITER safety objectives [PDS01] address the potential hazards in ITER from normal operation, accidents and waste:

  - ensure in normal operation that exposure to hazards within the premises is controlled, kept below prescribed limits, and minimised;
  - ensure in normal operation that exposure to hazards due to any discharge of hazardous material from the premises is controlled, kept below prescribed limits, and minimised;
  - prevent accidents with high confidence;
  - ensure that the consequences, if any, of more frequent events are minor and that the likelihood of accidents with higher consequences is low;
  - demonstrate that the consequences from internal accidents are bounded as a result of the favourable safety characteristics of fusion together with appropriate safety approaches so that there may be, according to IAEA guidelines [IAEA96], technical justification for not needing evacuation of the public (external hazards are site dependent, but are considered for a generic site);
  - reduce radioactive waste hazards and volumes.

  In addition, ITER is to be developed in such a way that it can be sited by any participant in the ITER EDA Agreement with minor design modifications.

- **Safety principles**

The following safety principles are considered in the safety approach. These principles not only provide direction to guide the design, but also include on-going, independent review and assessment to ensure the design will meet the safety objectives.

  - *'As Low As Reasonably Achievable' (ALARA)*

    As a basic principle, exposures to hazards shall be kept as low as reasonably achievable, economic and social factors taken into account.

  - *Defence-in-Depth*

    All activities are subject to overlapping levels of safety provisions so that a failure at one level would be compensated by other provisions. Priority shall be given to preventing accidents. Protection measures shall be implemented in sub-systems as needed to prevent damage to confinement barriers. In addition, measures to mitigate the consequences of postulated accidents shall be provided, including successive or nested barriers for confinement of hazardous materials.

  - *Passive Safety*

    Passive safety shall be given special attention. It is based on natural laws, properties of materials, and internally stored energy. Passive features, in particular minimisation of hazardous inventories, help assure ultimate safety margins.

  - *Consideration of ITER Safety Characteristics*

    The safety approach shall be driven by a deployment of fusion's favourable safety characteristics to the maximum extent feasible. However, the experimental nature of the facility shall also be addressed. A robust, fault-tolerant safety envelope shall be provided to enable flexible experimental usage. In view of the limited operational experience with DT plasmas and hence some plasma physics uncertainties, experimental components will be conservatively designed considering the expected loads from plasma transients so as to reduce the demands on systems which are required for safety. A safety function will not be assigned to experimental components, but faults in these will be considered as expected events in the safety assessments. The experimental programs and related machine modifications and operations shall be developed to take advantage from preceding operations.

  - *Review and Assessment*

    Safety assessments shall be an integral part of the design process and results will be available to assist in the preparation of safety documentation for regulatory applications. These analyses shall comprise normal operation, all categories of accidents, and waste.

- **Safety and environmental criteria**

  Regulatory approval will be required before the construction of ITER, but before site selection, the design will follow international recommendations, in particular technology-independent ones. Guidelines for doses to the staff from radioactivity and releases to the environment are set for the design, construction, operation and decommissioning. These project guidelines follow the recommendations by the ICRP and the IAEA. Following site selection, host country regulations will apply.

  ITER complies with the ICRP recommendations regarding occupational exposure. The radiation protection practices are consistent with the IAEA and ICRP recommendations and make use of best practices. In particular, efforts are made such that exposures during operation, maintenance, modification and decommissioning are as low as reasonably achievable (ALARA).

  The favourable characteristics of ITER can be further demonstrated if, even for hypothetical events that can be postulated, the calculated doses to the local population are below 50 mSv (early dose). This would be below the generic optimised intervention level for temporary evacuation developed by the IAEA [IAEA96] which is 50 mSv avertable dose within a period no more than 1 week.

  ITER safety is described in the Generic Site Safety Report, GSSR. The scope of GSSR is primarily radiological safety of ITER; however, some additional information on conventional hazardous materials and possible environmental issues are included to provide a more complete indication of hazards such as may be required to support localisation efforts.

The following chapters give an overview of the main safety issues that will be addressed in the framework of licensing ITER in France and are based:

- on the one hand, on the information contained in the ITER Generic Site Safety Report (GSSR), which reports the extensive safety studies carried out during the ITER Engineering Design Activities,
- on the other hand, French safety documentation referred at the end of each chapter.

Details of the safety studies made by the ITER team are normally referred to and explicitly recovered when helping for comprehension.

4.1.2. Licensing process in France

The main objective of the licensing process is to obtain authorisation to build and operate a nuclear installation, which is formalised by two decisions at government level: the “Décret d’Autorisation de Création – DAC” (required to start construction) and the “Décret d’Autorisation de Rejets et de Prélèvements d’Eau – DARPE” (required to start operation).

Within French regulations, the licensing procedure is clearly defined for any nuclear installation. The definition of a nuclear installation, called an “Installation Nucléaire de Base (INB)”, is based on the inventory of radioactivity. ITER will be classified as INB due to, at least, the expected tritium inventory.

The licensing procedure is based on a continuous technical dialogue between the plant owner, the ITER Legal Entity (ILE) and the Safety Authority, the "Direction de Sûreté des Installations Nucléaires (DSIN)", assisted by technical experts.

The ILE has not yet been defined as formal ITER owner, but it will have to be established before the beginning of the public enquiry, i.e. the last step of the licensing process as described in the following chapter. Practically the ILE will exist from the first steps of ITER construction until the end of the operation. Consequently, CEA will initiate the licensing process prior to the establishment of the ILE.

Concerning waste management and decommissioning an agreement may be signed between CEA and ILE which will have to state clearly that CEA would take care of decommissioning and waste management provided that financial provision will be made by the parties during ITER operation.

There are three sequential steps prior to the signature of the "Décret d'Autorisation de Création" which are briefly described in the following chapter:

- The "Dossier d'Options de Sûreté" (DOS)
- The "Rapport Préliminaire de Sûreté" (RPRS)
- The "Enquête publique"

4.1.3. Roadmap for licensing

1. **The "Dossier d'Options de Sûreté" (DOS)**

   Duration: approximately 1 year.

   This document will be issued by the CEA and it will be assessed by the Safety Authority.

   The DOS is a document, prepared by the plant owner, which defines the major risks and the proposed means to avoid or to mitigate them. It describes the installation briefly, proposes general safety objectives and explains how they have planned to be implemented in the installation.

   The document is being prepared by the CEA, it will be checked by the International Team in order to assure the coherence with reference design and will be sent to the Safety Authority for assessment.

   The DOS is a concise technical document that may refer to more detailed supporting documents, which do not formally belong to the DOS itself. Although certain points are not mentioned explicitly in the DOS, in particular the supply, transport and control of tritium, some of their implications will nevertheless be addressed (e.g. accidental tritium releases).

   An advice on this report by the Safety Authority is expected in the middle of 2002.

2. **The "Rapport Préliminaire de Sûreté" (RPRS)**

   Duration: approximately 2 years.

The second step of the licensing procedure is the preparation and the assessment of the "Rapport Préliminaire de Sûreté, RPRS". The RPRS, or preliminary safety report, consists of a detailed description and a comprehensive safety analysis of the plant. The RPRS is examined by the technical services of the Safety Authority (the "Institut de Protection et de Sûreté Nucléaire" – IPSN). During this phase the Safety Authority usually asks advice to a "Groupe Permanent", i.e. an advisory board at national level.

The RPRS will be prepared under EFDA auspices but will have to be submitted by the owner, the ILE.

In parallel, ITER project may be submitted to a "Débat Public" (**Public Debate**), as it is stated in a recent French law (loi Barnier, 95/101). Any new large project or installation may be submitted to a public debate during its elaboration phase. The objective of the debate is to launch an overall country discussion on the project socio-economic or environmental advantages and drawback. It should focus on the **objectives and main characteristics of the projects** and must be organised **during their elaboration phase**. An independent commission is in charge of surveying this process, which cannot last more than six months. CEA is exploring how and when it may be initiated.

In parallel to the preparation of the RPRS, the various administrative procedures required to obtain the licenses (DAC and DARPE) should be started. The documents required to do so will refer extensively to documents prepared in support of the RPRS (design justification study, accident analysis study, environmental impact study, etc.). It will be necessary to clarify which parts of these documents only require the re-writing of existing reference documents and which parts require substantial new work (e.g. the Seismic, Fire and Waste studies).

3. The "Enquête Publique"

Duration: approximately 2 years.

After the first positive advice on the RPRS by the Safety Authority, the Public Enquiry Procedure can be launched. It is a consultation process limited to the local communities (located within a radius of 10-15 km from the proposed plant site) on the external effects resulting from the construction and operation of the plant.

The construction can only start after a positive opinion from the Public Enquiry Commissioner. It is, nevertheless, possible to anticipate a positive decision and to start site preparation work and the procurement of components that do not have any safety function. In the case of ITER, it should be possible to order the magnet superconducting cable, which is on the construction schedule critical path.

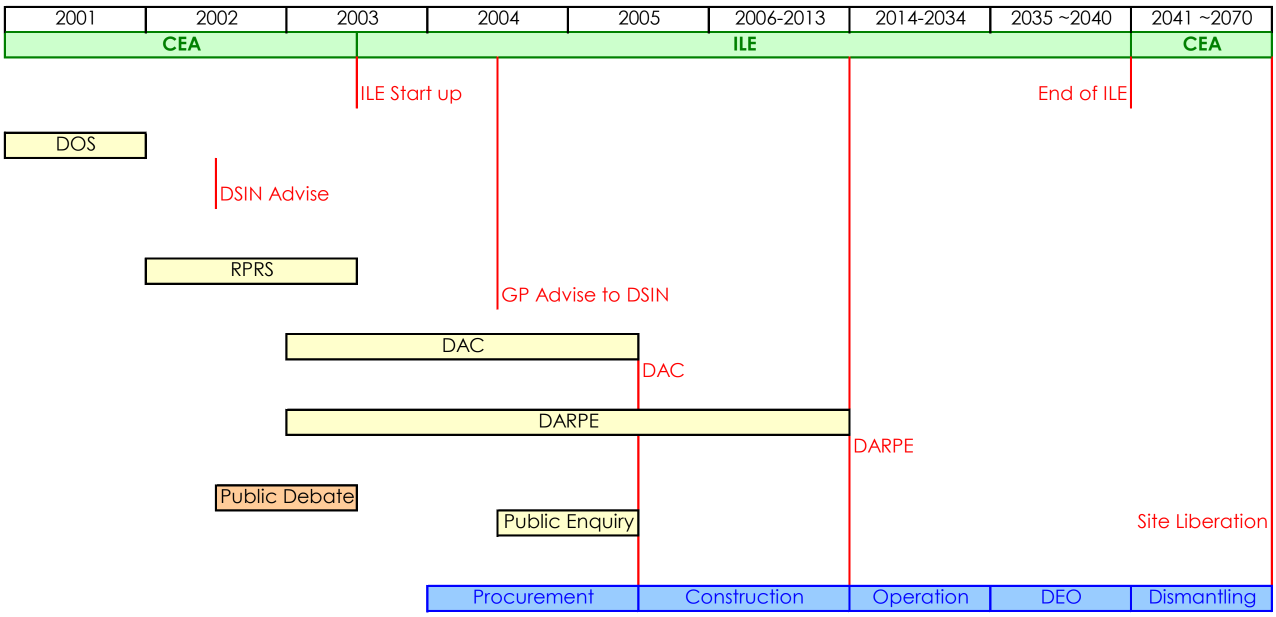
Time Schedule

The overall time schedule for ITER preparation and construction could be as follows:

- The legal implementation, which has started officially mid of November 2000 in Europe, with the decision taken by the European Council of research Ministers to delegate the European Commission to negotiate the "ITER Legal Entity" with the partners.

- In the meantime, administrative procedures will start to prepare all legal documentation, in view of the official approval, which should allow the beginning of the construction phase.
- From the technical point of view, some anticipation can be envisaged, in particular for the construction of the components, which are on the initial path, as the superconducting coils.
- The excavation can also be anticipated to the official "décret".

The regulatory process is described in the Table 4.1.



Acronym	*French meaning*	*English Translation or Meaning*
ASN	Autorité de Sûreté Nucléaire	French Safety Nuclear Authority
DAC	Demande d'Autorisation de Création	Request of Authorisation of Creation
DAC	Décret d'Autorisation de Création	Decree of Authorisation of Creation
DARPE	Demande d'Autorisation de Rejet et de Prélèvement d'Eau	Request of Authorisation for Water Release and Extraction
DARPE	Décret d'Autorisation de Rejet et de Prélèvement d'Eau	Decree of Authorisation for Water Release and Extraction
DEO	Mise à l'Arrêt Définitif (MAD)	Definitive End of Operation
DIN	Division des Installations Nucléaires	In charge of Nuclear Installation Control
DOS	Dossier d'Options de Sûreté	Description of Safety Objectives (not compulsory)
DSIN	Direction de la Sûreté des Installations Nucléaires	ASN Legal Head
GP	Groupe Permanent	Permanent Group (in charge of Request Examination)
ILE	Entité Juridique ITER	ITER Legal Entity (status to be defined)
IPSN	Institut de Protection et de Sûreté Nucléaire	ASN technical Adviser
RPRS	Rapport Préliminaire de Sûreté	Initial Safety Report (compulsory, to be borne by ILE)

Table 4.1: Overall Licensing Process, from Today until Site Liberation

4.2. Key elements for the "Dossier d'Options de Sûreté"

4.2.1. DOS main elements

The main objective of the "Dossier d'Options de Sûreté", DOS, is to present the terms of reference of safety approach when applied to ITER in the site of Cadarache.

The ITER Generic Site Safety Rapport, GSSR, has been taken as the base document in order to specify the safety functions and the envisaged way to implement them. This approach will give the assurance of controlling hazards related to Cadarache site conditions in accordance with French regulations.

The safety approach in the DOS is the following:

- Definition of the safety objectives,
- Identification of consequent safety functions,
- Definition of the technical safety options which will maintain the safety functions.

In particular, objectives on effluents and liquid releases are defined for normal, incidental and accidental cases. In addition a preliminary evaluation of the impact of these releases on the populations has been made and it will be verified that they are under the project limits. Besides, it must be shown that no cliff effect will evolve from an off-dimension situation.

This report will also present a preliminary strategy for tritium transport, waste management and effluent releases produced during machine operation as well as the foreseen steps for decommissioning and dismantling of the installation at the end of life, and the issues regarding different waste generated during dismantling.

The following chapters give an overview of the main safety issues that will be addressed in the DOS.

4.2.2. Preliminary safety analysis

The radiological source terms that could potentially present an occupational or public hazard, and the energy sources that might be available to drive an accident sequence are largely independent of site characteristics. These are reviewed first (section 4.2.2.1). Then the occupational safety analysis in GSSR is assessed against the likely requirements for French licensing (section 4.2.2.2), followed by a review of analyses of potential accident hazards (section 4.2.2.3). These are all based on internally initiated events, whereas external events are more site-specific, so the particular characteristics of Cadarache are outlined in reference to regulatory requirements (section 4.2.2.4).

4.2.2.1. Radiological and energy source terms

Radioactive sources, chemically toxic or reactive substances, and stored energy sources to be used or handled in ITER are given in Volume III of the GSSR. They include:

- Radioactive materials (tritium, neutron activated products in structure and in-vessel dust, and neutron activated corrosion products in coolant water);
- Non-nuclear hazardous materials – chemically toxic (e.g. beryllium) or reactive (e.g. hydrogen);
- Stored energy sources (plasma, magnets, activation decay heat, coolant thermal energy, chemical energy).

Each of these has been quantified in the ITER design and are summarised bellow:

- **Tritium**

After a phase of H-H and D-D operation, ITER will be operated with D-T fuelling. Tritium will be supplied from off-site sources. Tritium transport, inventory tracking and accountancy have to be done following French regulation. A container to transport 25 g of tritium has been internationally qualified. Alternatively a container with a larger capacity could be designed and qualified on the basis of an existing cask. A specific accountability has to be done in France for non-proliferation means. The total site inventory is less than 3 kg. A particular French regulation concerning the storage of tritium does not exist. A periodic inventory assessment will be done, in order to minimise machine uncertainties and to respect administrative limits of tritium inventory in the torus. For the tritium processing, detailed studies of the uncertainties in the measurement are underway. Tritium is located inside the vacuum vessel, in the fuel cycle processes, in the long storage zone inside the tritium building and in the hot cell and waste controlled buildings.

- **Dust**

Dust will be generated during plasma pulses inside the vacuum vessel by erosion of plasma facing components. Consequently those materials, beryllium, carbon and tungsten will accumulate inside the vacuum vessel. Analyses and extrapolation from experiments suggest that between 100 and 200 kg of dust are expected after 500 plasma pulses. The dust inventory must be limited with regard to chemical reactivity (Be, C, W) and activation hazards (W). Methods for extracting them have been developed for previous devices (JET) and will be investigated for ITER. The potential of dust mobility and radioactive inventory have been detailed in GSSR vol. III and have been taken into account for impact calculations in normal and abnormal operations following ITER guidelines.

- **Activated Corrosion Products (ACP)**

ACPs are located in the different coolant loops. As they impact on safety, an assessment methodology has been set-up, which is based on code development and associated experiments. As for dust radioactive resulting inventory is given in GSSR vol. III and has been used for calculation of impact on the public.

- **Conventional (non-nuclear) Hazardous Materials**

The most important chemical sources of energy described in GSSR and of concern from the French regulation point of view are:

- Hydrogen present in the different systems connected with the tritium plant.
- Exothermic reactions between beryllium or tungsten with air or steam inside the vacuum chamber at high temperature.

  These reactions can also drive to hydrogen production, from which a potential risk of explosion in case of infringement of the conditions of flammability / explosion in the air during the incident can follow. Concerning the explosions of dusts, the maximal mass of dust admitted inside the vacuum chamber (free volume of 1350 m^3) has been defined to protect itself.

- Ozone production inside the cryostat in case of an air leak with a potential of release of chemical energy from a concentration 4 % molar.

- **Stored Energy Sources**

  The stored energy source terms are related to the installation activity: fusion power, plasma, magnetic, decay heat, chemical and thermal coolant energy.

In conclusion, it should be pointed that main radiological and energy sources are well described in GSSR taking into account some uncertainties, due to the design conception phase of the project and the fact that ITER is an experimental device that will itself answer to a lot of today estimations and extrapolation. Nevertheless the solid basis of the project allows making a clear assessment of the needs required for licensing ITER in Cadarache.

4.2.2.2. Occupational safety

This chapter is focused on a regulatory perspective. Consequently the French Regulatory Regime, and more specifically the CEA regulatory regime at Cadarache have been taken into consideration in the following and are commented and compared with ITER safety approach. Then an ITER radiation protection assessment is presented. Finally conclusions are presented.

Cadarache Regulatory Regime

State regulations and CEA guidelines regulate French nuclear installations.

State regulations specify that in France worker radiation protection is based on three fundamental principles:

- **Dose justification**: requires that each nuclear facility or device has sufficient benefit to society to justify the radiation exposure that will arise from its use.
- **Dose optimisation**: requires that the radiation exposure resulting from the use of a nuclear facility or device be optimised such that the number of persons exposed and the level of exposure will be maintained As Low As Reasonably Achievable (ALARA), social and economic factors taken into consideration.
- **Dose limitation**: requires that regulatory limits for worker doses be established to ensure a consistent level of protection and to eliminate the risk of overexposure.

The requirement for worker radiation protection is enshrined in the French Regulations and applies to all French nuclear facilities [1], [2]. These are the existing regulations based on the recommendations of ICRP-26 [3] and conforming to Euratom Directive 80/836 [4]. The Regulations contain the dose limits and the fundamental requirements to maintain doses as low as reasonably achievable (ALARA), social and economic factors taken into consideration. The current regulations are being updated [5] to comply with ICRP-60 [6] and Euratom Directive 96/29 [7]. They will be issued in the near future.

The radiation zoning that is applied in nuclear facilities is given in the Table 4.2[13]:

[13] Where SPR stands for "Service de Protection contre les Rayonnements", or the "Radiation Protection Division".
DAC: Derived Air concentration

	BLUE	GREEN	YELLOW	ORANGE	RED
Time Spent		Permanent (8 h/day)	Controlled/ monitored	Controlled/ monitored	Controlled/ monitored
Dose rate threshold (μSv/h)	2.5	7.5	25	2,000	100,000
Max allowable Air Concentration (DAC)	0.3	1	80	4,000	
Dose Limit (effective dose)	15 mSv/a	50 mSv/a & 30 mSv/q	50 mSv/a & 30 mSv/q	50 mSv/a & 30 mSv/q	50 mSv/a & 30 mSv/q
Access Requirement			Written authorization from SPR	Written authorization from SPR	Written authorization from Centre Director

Table 4.2: CEA Radiation Protection Zoning

CEA Guidelines

CEA Direction Centrale de la Sécurité (DCS) issues guidelines that are more restrictive, to ensure that the Regulations will always be satisfied. The CEA guideline for maximum exposure of a radiation worker is 15 mSv per year and that for the average dose for all exposed workers is 2.5 mSv per year [8]. Such guidelines are issued periodically in the form of three-year plans for worker safety improvement. DCS-34 is the most recent three-year improvement plan issued by CEA. Besides, an ALARA optimisation has to be done at any time.

ITER Radiation Protection Approach

The ITER radiation protection framework is described in the ITER Generic Site Safety Report (GSSR), Volume VI. Project guideline for annual individual worker doses is 5 mSv.

The ITER project has proposed to satisfy the dose optimisation requirement, during the design stage, by a prioritised ALARA process. In the GSSR ALARA is a three-step process:

- The starting point of the ALARA process considers the ITER facility as a whole. At this stage of the design, the emphasis is on identifying the hazards and the systems posing the greatest risks.
- The second step is to identify ALARA assessment guidelines to help determine where effort and resources should be focused. Three so-called “ALARA guidelines” are defined:
    - if a system or activity is anticipated to require an individual to exceed 0.5 mSv/shift, then the system/activity is modified;
    - if an activity is performed in a dose rate > 100 μSv/h, then more detailed assessment is required;
    - if the collective dose for a system operation or maintenance activities is estimated to exceed 30 person·mSv, more detailed assessment is needed.

- In the third step, the guidelines are applied to the individual systems. Those exceeding the guidelines are designated as requiring analysis to find areas for improvement to reduce risk and exposure.

During design and operation phase, this iterative process will continue in reviewing the systems, and optimising them, reducing the ALARA thresholds.

The ITER project proposal for radiation zoning is presented in Table 4.3, partially reproduced from the ITER Safety Report (Vol. VI) and the Plant Design Specifications; it includes a system of radiation access control that has a direct correspondence with the system of radiation zoning.

Access Zone (Area Classification)	Access Limitations	Airborne Total Dose Rate Area Contamination Characteristics
Zone A	Unlimited Access	No airborne contamination Dose rate < 0.5 µSv/h WHITE
Zone B	Limited for NRW[14]	Unlimited for RW[15] Total dose rate (internal + external) < 10 µSv/h GREEN
Zone C	Limited Access for all workers	< 100 DAC < 1 mSv/h AMBER
Zone D	Restricted access areas	Airborne > 100 DAC or external dose rate > 1 mSv/h RED

Table 4.3: Area Classifications and Radiation Access Zones

Assessment of the occupational doses in many parts of the ITER plant and in different types of maintenance operations are being developed and continued work on this is still necessary. The list of systems, structures and components described in the GSSR Vol. II is proposed as a tool to be applied for the worker dose exposure calculation and a dose assessment report preparation.

In conclusion, for occupational safety in routine operation and maintenance, the ITER project has adopted dose guidelines that are in line with international practice. These are also generally in accordance with French regulatory requirements. The principle of maintaining doses below these guidelines and as low as reasonably achievable (ALARA) is a project approach that is also a regulatory requirement. At the present stage in the project the implementation of the ALARA process should continue and extend to all the systems. A radiation zoning and access control approach is adopted in ITER that is compatible with French regulations.

[14] NRW: Non Radiation Workers
[15] RW: Radiation Workers

4.2.2.3. Hazards analysis

The following chapters review the approach used in the ITER project to the identification of hazards and protection against them, the identification of postulated accidents and the analysis of selected reference events, and the assurance that radiological guidelines are complied with. This is based on the material presented in the Generic Site Safety Report (GSSR), in particular volumes VII, VIII, X and XI.

Identification and Control of Hazards

ITER processes and plant areas have been systematically reviewed to identify potential hazards (see section 4.2.3.1). From this analysis, protective measures or safety functions have been identified and assigned to implementing systems and components.

The inventories are restricted to the minimum in order to control hazards. The most fundamental safety function is the confinement of hazardous materials.

Identification of Reference Events

Techniques of deterministic safety analysis, used to determine a fully representative set of reference events, were supplemented by techniques of probabilistic assessment used to check its comprehensiveness. The selection of the reference events covers release of the main energy sources (plasma, coolant, magnet); decay heat removal, chemical reactions (hydrogen, ozone) and potential failures in the confinement (in-vessel and ex-vessel coolant leaks) are investigated. All plausible initiating events were systematically identified to provide a justification that the selected sequences are indeed the most severe ones of their category and the Postulated Initiating Events (PIE) family.

To help ensure that all aspects of plant operation have been considered, two complementary and fundamentally different approaches have been applied to identify potential initiators: these are the component-level (bottom-up) and the global (top-down) approaches. The concluding part of both the bottom-up and top-down studies is to show that identified accident sequences have been addressed by analyses that show that potential consequences are within acceptable guidelines.

Analysis of Reference Events

Reference events have been demonstrated in GSSR vol. X to cover all major systems; the radioactive inventories distributed amongst these systems and initiator types that have the potential to cause releases.

The postulated initiating events (PIE) and sequences of subsequent failures are categorised as Incidents or Accidents, and their consequences are evaluated and compared with safety objectives and release guidelines. Each reference event starts with a postulated initiating event, adds all consequential failures, and assesses the complete sequence up to environmental release. In most events, the loss of off site and others aggravating failures are postulated. The main safety functions and associated safeguard systems are identified. The whole sequence of events is described including the actuation (time + logic) of safeguard systems.

Parametric studies of hypothetical sequences are used to investigate the ultimate safety margins of ITER and to demonstrate its robustness in terms of safety with regard to the project's objectives and radiological guidelines. Key notions in the context of hypothetical sequences are:

- Avoidance of "cliff edge effects"
- "No-evacuation" to demonstrate the safety and environmental potential of fusion power
- Robustness of defence-in-depth.

Two accidents are discussed hereafter:

- *Within the reference events, the large divertor ex-vessel coolant leak which leads to the highest amount of tritium release*.

  The large divertor ex-vessel coolant leak investigated is initiated by a hypothetical double-ended pipe break in a divertor primary cooling loop inside Tokamak Cooling Water System (TCWS) vault at fusion nominal power (500 MW). This is also assumed to lead to an induced in-vessel break. The main safety concerns are the bypass of first safety barrier (vacuum vessel) and the pressurisation of the TCWS vault and the vacuum vessel that is likely to challenge the containment integrity. The sequence includes aggravating event (loss of off-site power).

  The main safety functions and associated safety systems involved allow limiting the consequences of the accidents. The total environmental releases, taking into account uncertainty on vacuum vessel tritium inventory, are 1.5 g-T, 0.07 g-dust and 0.6 g-ACP.

- *The tritium event illustrates the method to investigate the ultimate safety margins of ITER: a reference event is considered postulating an additional failure of the safety function*.

  The reference event is a failure of the tritium fuelling line, postulating coincident failures of both primary and secondary tubing. DT gas (the amount over the atmospheric pressure (> 100 kPa)) is released.

  Due to safety systems the tritium release is relatively limited compared to the sequence mentioned above: 0.17 g. Thus the mitigation of the consequences of this accident strongly relies on the efficiency of the confinement.

  In case of a postulated failure of the safety system elements (confinement), leading to a hypothetical event, the mobilised tritium inventory (13.4 g) is released.

Radiological Releases

The consequences of each reference event have been calculated in terms of environmental releases for the three main hazards (tritium, dust and activated corrosion product), for several exhaust heights and different meteorological conditions, with or without ingestion. The results can be compared to the French guidelines to check the acceptability of the scenarios. In comparison to the release guidelines adopted by the ITER project itself, all calculated consequences fall well within the allowable range.

Safety Models and Codes

The analyses of transients and consequences arising from the reference events use a number of computer codes as well as analytical techniques. Information is given for each code:

- About its applicability, limitations, availability and physical modelling approaches and simplifications,
- Its verification and validation status.

Some verification and validation work is still underway aimed at validating the codes on fusion-specific analytical tests.

A main goal of ITER is to demonstrate from the viewpoint of safety the attractiveness of fusion. To accomplish this goal, ITER safety needs to address the full range of hazards and minimise exposure to these. The safety approach draws upon experience in nuclear and non-nuclear industries.

In conclusion, the analysis of ITER implements general and recognised safety principles. Reference events have been identified and analysed. The whole set of results obtained, although some of them may need to be deepened, leads to a robust safety demonstration. Verification and validation work is still in progress on the numerical tools that are used for the assessment of the accidental sequences.

4.2.2.4. External hazards

To assess the possible construction and operation of ITER in Cadarache, it is necessary to consider the totality of external hazards for which it would have to be designed. This section considers the different hazards, taking account the site characteristics, in relation to the requirements of the French safety rules.

The documents which have been used in following are prescriptions relative to the site [9], main safety rules "Règles Fondamentales de Sûreté" [10-14], calculation rules and unified technical documents "Règles de Calcul et Documents Techniques Unifiés" [15-17], ITER Technical Basis for the final Design Report and GSSR vol. IX.

The external hazards that must be taken into account in the building design have been considered and compared with ITER design assumptions where they have been specified. They are reviewed in the following:

Wind Actions

The study of wind actions on a construction has to consider prescriptions defined in the calculation rule [16]. Wind actions on a building depend on:

- The speed of the wind or base dynamic pressure;
- The category of the construction and its total dimensions;
- The position of the element considered in the construction and its orientation towards the wind (height effect, site effect, mask effect);
- Dimensions of the element considered.

The speed parameter or base dynamic pressure is defined according to the geographical implantation of the project. The speed of the wind is 35 m/s, **but to be compared with ITER design assumption of 38.9 m/s**, then the base dynamic pressure is 750 Pa. Furthermore, the verification of resistance and stability conditions of a construction under wind actions has also to envisage in calculations an extreme dynamic pressure; the ratio of that here to the basis dynamic pressure is taken equal to 1.75 increasing thus the pressure to 1310 Pa. Concerning the other parameters listed above that can amplify or decrease the base dynamic pressure; they can be defined only in a precise analysis of the project regarding the exact building geometry and their implantation with respect to each other.

Snow Actions

Snow actions studied on a construction have to follow prescriptions defined in rules NV65 and N84 referred in [16] and [17]. Actions of snow on a building depend on:

- The base normal overload;
- The altitude;
- Characteristics of the roof;
- The concomitance of effects of snow and wind.

The parameter base normal overload is defined according to the geographical project implantation. The basis normal overload is 350 Pa. Considering the altitude of the implantation site (310 m), the normal overload is then 460 Pa. Furthermore, the verification of resistance and stability conditions of a construction towards the actions of snow has to envisage in calculations an extreme overload that increases, in regard to the altitude of the site, to 780 Pa. The design assumption value given for ITER is about 1500 Pa. Concerning the other parameters listed above that can amplify or decrease the basis overload; they can be defined only by carrying out a detailed analysis of the project regarding the exact building geometry.

Aircraft Crash Risks

Risks linked to aircraft crash have to be studied with prescriptions of the RFS I.2.a referenced [10]. The RFS defines three aircraft families:

- General aviation;
- Commercial aviation;
- Military aviation.

For each site, an evaluation of the probability of crash on each target is undertaken for each of the three aircraft families above. For this evaluation, formulations introduce crash statistics according to the aircraft family, the nature of the aerial space, the phase of flight and the virtual surface notion of the buildings housing each safety function. Furthermore, the RFS fixes a limiting probability of occurrence of the event of 10^{-7} per year.

Concerning the Cadarache site, the "Présentation Générale de la Sûreté de l'établissement", PGSE, referenced [9], gives information in impact probability of the aircraft on buildings on this site that are the following:

- general aviation $1.6 \cdot 10^{-10}$ per year / m²
- commercial aviation $1.3 \cdot 10^{-12}$ per year / m²
- military aviation $1.2 \cdot 10^{-11}$ per year / m²

Regarding comments in the RFS applied to nuclear plants, whose geometrical characteristics are comparable to those of installations in the ITER project, it appears that only probabilities of aircraft crash of the general aviation reach values higher than 10^{-7} per year.

Installations must be then calculated to resist to their impact. It is admitted to consider two aircraft types considered representative of the different categories of aircraft of general aviation:

- CESSNA 210 single-motor;
- LEAR JET 23 twin-motor.

Buildings to be justified are defined by an analysis of safety undertaken in accordance with the RFS [10]. Walls protected by another wall designed to withstand the aircraft crash are not subject to this action. Regarding the RCC-G section 1.3.2.3-3 [15], characteristics of reference aircraft are as given in Table 4.4. Justifications can be led by using an equivalent static effort such as specified in the section 1.3.2.3-3 of the RCC-G [15]. This has been pointed out in GSSR vol. IX and detailed assessment will be needed.

	LEAR JET	CESSNA
Speed of impact	100 m/s	100 m/s
Aircraft mass	5.7 t	1.5 t
Impact surface of the aircraft	12 m² (1.2 x 10)	4 m² (0.5 x 8)
Motor mass	./.	200 kg
Impact surface of the motor	./.	0.5 m²

Table 4.4: Characteristics of Reference Aircrafts

Seismic Risks

Seismic studies in the framework of the ITER project have to consider prescriptions and methodologies defined in the RFS I.2.c [11] and V.2.g [14]. The reference spectra can be found in Chapter 3.3. Two studies have been done showing that the design assumption of 0.2 g can be complied with without major building modifications.

Industrial Risks

The principles are to take account of those risks specified in the RFS I.2.d [12]. The RFS presents three family sources of the potential hazards:

- Permanent industrial installations such as storage and units of production;
- Piping of transportation such as pipelines;
- Road, railway, fluvial and maritime.

Considering the geographical implantation of the ITER project, only the road is considered as a potential hazard source. Furthermore, the RFS states that risks to be studied are those linked to the following hazards categories:

- The wave of aerial pressure due to an explosion;
- The increase of temperature due to an external fire;
- The seismic wave associated with an explosion;
- Toxic or corrosive gas clouds, gases and consequent smoke of a fire.

For external explosions Accordingly to the RFS, the convention is to assume as the minimal plausible hazard a wave of aerial overpressure incident with triangular form and with a stiff front that comes from any horizontal direction. It presents the following characteristics:

- Maximum overpressure 0.05 bar
- Duration of overpressure 300 ms

The load to take into account on buildings considers phenomena of reflection and focalisation according to section 1.3.2.3-2 of the RCC-G [15].

For external fires, regarding the prescriptions of the RFS, there is no conventional load to consider. This external hazard has then to be studied in a particular safety study.

For seismic wave associated with an explosion, it is noted that dispositions of construction taken against seismic consequences in application of the RFS 1.2.c and V.2.g referenced [11] and [14] are in general estimated sufficient for the protection against the seismic wave effects due to explosions.

For gas emissions, there is no conventional load to consider. This external hazard has then to be studied in a particular safety study.

Flood Risks

The principles to take into account are specified in the RFS I.2.e referenced [12]. Regarding the expected geographical implantation of the project, this risk is not envisaged.

References

[1] Decree n° 86-1103

[2] Decree n° 88-662

[3] ICRP-26

[4] Directive 80/836

[5] Decree 98-1185

[6] ICRP-60

[7] Euratom Directive 96/29

[8] DCS-34

[9] Centre d'études de Cadarache – Présentation générale de la sûreté de l'établissement – 12/1994

[10] RFS I.2.a Prise en compte des risques liés aux chutes d'avions (Aircraft Crash Risks)

[11] RFS I.2.c Détermination des mouvements sismiques à prendre en compte pour la sûreté des installations (Seismic Inputs)

[12] RFS I.2.d Prise en compte des risques liés à l'environnement industriel et aux voies de communication (Industrial Environment and Roads Risks)

[13] RFS I.2.e Prise en compte d'un risque d'inondation d'origine externe (External Flood Risks)

[14] RFS V.2.g Calculs sismiques des ouvrages du génie civil (Seismic Calculations of Structures)

[15] RCC-G Ed. 1988 Règles de conception et de construction du génie civil des îlots nucléaires REP – Tome I – Conception (Conception of Nuclear Plant)

[16] DTU P 06-002 Règles NV 65 modifiées 1999 et annexes définissant les effets de la neige et du vent sur les constructions (Snow and Wind)

[17] DTU P 06-006 Règles N 84 modifiées 2000 – Actions de la neige sur les constructions (Snow)

In conclusion, the bases of climatic actions (snow and wind) considered in the ITER design studies are conservative towards the rules and applicable conditions of the Cadarache site. Concerning aircraft crash and industrial risks, in the framework of a safety analysis, targets to be protected must be identified and, if necessary, actions characterised that are not evaluated in RFS. The building will be constructed to avoid any radioactive release in case of Cessna or Lear Jet crash. The low inventory of mobilisable radioactive material is a key factor to reduce radioactive release in any accidental event. Finally, the seismic studies carried out in the framework of the design of the tokamak and tritium buildings have highlighted the need for an analysis of the seismic behaviour according to prescriptions and regulations in force in France for this type of building.

4.2.3. Effluents and Releases

The purpose of this chapter is to assess ITER effluents and releases of and look for an optimisation with the hypothesis of a construction at Cadarache on the basis of a comprehensive ALARA process. After reviewing general aspects on the implementation of the ALARA principle for optimising the effluent management systems of ITER, the strategy in the ITER design for effluents is described. Then the impact on the public exposures of effluents for Cadarache site conditions is detailed. Finally an assessment on optimisation of effluent management systems is given.

This chapter will refer to the individual dose limit for the members of the public. Following ICPR-60 [1] and Euratom Directive 96/29 [2], the following principles apply:

- in the context of optimisation, all exposures shall be kept As Low As Reasonably Achievable (ALARA), economic and social factors taken into account;
- the sum of the doses from all relevant practices shall not exceed the dose limits laid down separately for exposed workers and members of the public.

The application of the optimisation principle is defined in the French regulation [3]. As concerns the individual dose limit for the members of the public, the common practice for nuclear power plants in France employs a dose limit of the order of 10 µSv per year for normal operation. In the consideration of licensing ITER under French conditions, the design target for the effluent management is that consequences should be minimised for normal operation, maintenance and accidents. The studies show in particular that, for all foreseeable accidents, the release level will be far below the one for which any countermeasures or food restrictions are needed for the population at the site boundary.

4.2.3.1. General aspects on the implementation of the ALARA principle for optimising the effluent management systems of ITER

For the releases brought about by normal operation and planned maintenance activities, the ITER design process applies Project Release Guidelines (see Plant Design Specification, PDS). In the evaluations presented in the Generic Site Safety Report (GSSR, vol. IV) it has been shown that these guidelines have been met for the different types of effluents.

The application of the optimisation principle implies continuous efforts to be made to reduce the releases and the impact they may cause. The design of ITER has gradually evolved building on the experience at similar existing research facilities, such as JET. The adopted design process is in principle fully compatible with the general requirement of optimisation. The material contained in the present GSSR emphasises the most recent design features rather than providing a comparable description of the previous design variations.

4.2.3.2. Strategy and options for the effluents and releases management in the ITER design (GSSR vol. IV)

The effluents and releases from ITER dealt with here are gases, airborne particulates and liquids that are released during normal operation and maintenance from the ITER facility (see section 4.2.3.1) and which contain substances that could have a detrimental environmental impact. The objective is to keep these releases to at least below the permitted levels and in general to levels considerably less than these.

Gases and Airborne Particulates

The plan for ITER is to have a single discharge point for all gases arising from the operational areas of ITER. At present this discharge point is at the level of the highest point of the ITER buildings, i.e. the roof of the main tokamak building. The exact position and height is site dependent and will be optimised taking into account the local dispersion conditions and the wake effect of ITER buildings and possible other nearby facilities. The gases will be entrained in the exhausts from all the Heating, Ventilation and Air Conditioning systems (HVAC), which are routed to this single discharge point.

This discharge point will be monitored both for control purposes and compliance monitoring, that is both to indicate to operators what is being discharged (control monitoring) and to measure what has been discharged for reporting to the relevant environmental agency (compliance monitoring). Gases that are expected to be discharged are tritium in various chemical forms and activated air products. It is possible for airborne radioactive and chemically toxic particulates to be released from this discharge point.

Methods to minimise Releases

Particulates: These will be minimised by filtering of all air streams of the HVAC systems before discharge using standard filtering techniques. These filters have a high efficiency only allowing some fine particulates to pass through, which will be monitored at the discharge point. Good housekeeping techniques in the relevant areas (i.e. Hot Cell) will assist in reducing the source of particulates.

Tritium: ITER is to be equipped with an extensive set of Atmosphere Detritiation Systems (ADS) to remove as much tritium as possible from gaseous streams that arise from normal operations, maintenance procedures and accident situations. The design of these systems is closely linked to the design of the confinement arrangements and HVAC systems. The concept of all these systems is well proven in tritium handling facilities such as JET or the Tritium Laboratory Karlsruhe TLK and basically consists of converting elemental tritium (HT) or hydrocarbons such as tritiated methane (CH2T2) into tritiated water vapour (HTO) and carbon dioxide by catalysts and then collecting the HTO on molecular sieve beds. Any pre-existing HTO will also be collected this way. These molecular sieve beds will be regenerated either routinely or as required and the resulting water will be collected and handled according to the level of tritium. The way tritiated water is handled will be described later. Each ADS has a high detritiation factor to reduce the tritium releases to the environment to very low levels.

Design of the ADS

The number of ADS systems and the parameters of each individual ADS have been calculated according to the estimated amount of tritium it will have to deal with, atmosphere flow rates, duty (normal, standby or emergency) and other relevant factors, such a the physical location of the system (i.e. Hot Cell, Tritium Building). The design produced for the complete system has been assessed and found to be satisfactory. Certain refinements are suggested, such as standardisation of major components and cross-linking of systems to add greater flexibility and to expand the possibilities for dealing with abnormal situations. These should be assessed and incorporated during the detailed design stages.

Liquid Effluents

Liquid effluents from ITER will primarily be contaminated water. The type and level of contaminants will determine how they are managed. Tritium contaminated water arises from various sources:

Regeneration of the Molecular Sieve Beds of the ADS Systems

Water arising from the regeneration of molecular sieve beds in ADS systems will be measured for tritium content and then transferred to one of four water collection tanks depending on the level of tritium. The water detritiation system WDS will process water from these tanks on a campaign basis. There is no liquid waste product from the WDS system. The WDS produces hydrogen and oxygen gas. The tritium-depleted hydrogen fraction is passed through a flame arrester and then discharged to stack. The oxygen is discharged through an ADS after processing in a drier bed. The tritium-enriched hydrogen is fed into the Isotope Separation System (ISS) of the Tritium Plant.

Releases from the Tokamak Water-Cooling Systems due to Leakage, Maintenance, Accidents

Any releases from the tokamak cooling water system (TCWS) will be collected in a drain system installed in the tokamak building. This water will be tested and either sent to site waste or reused back into the TCWS after processing.

In addition, potentially tritium contaminated water could arise from:

Condensation within the different HVAC Systems

Water condensed by local atmosphere coolers and by the HVAC systems will only be tritium contaminated under abnormal conditions. This water is collected in tanks containing the lowest category of tritium concentration and is considered for direct discharge after assaying. Experience at tritium processing facilities such as JET or TLK has proven the validity of the above statements.

Showers/Laundry

It is expected that the water arising from these activities will have very low levels of contamination and will be discharged to the site waste system. However, this water will be collected and assayed before any discharge is initiated.

Trade Waste including Sewage

It is possible for the trade wastes to contain trace levels of tritium and it is expected that this will be dealt with according to site requirements and practices.

4.2.3.3. Evaluation of the public exposures caused by the normal operational effluents

In the GSSR, estimates of the gaseous and liquid releases into the environment have been presented and compared to the ITER project guideline releases. However, the licensing process of the ITER facility in France requires site-specific evaluation of the arising radiation exposures via different pathways, including the ingestion doses from the consumption of locally grown foodstuffs.

Gaseous Releases

In the safety and licensing considerations for the Cadarache site no specific estimation of the gaseous releases was carried out. Consequently **a conservative case of 1 g of tritium as HT and 0.1 g as HTO and 1 g of activation products AP (SS316), and 5 g of activated corrosion products (ACP)** was taken as the source-term for a global radiation dose evaluation in normal conditions. The different isotopes activities have been deduced from GSSR data in vol. III and vol. IV and the total annual releases for different radio nuclides corresponding to the chosen source term have been taken as input for the site-specific dose calculations. Population distribution around Cadarache, weather conditions, food habits and others parameters defined for Cadarache site have been used.

The annual effective doses for an adult in the closest habitation (Château) near Cadarache have been estimated to be less than 2.5 µSv per year after 10 years of continuous D-T operation. In all the calculated cases, for the releases in normal operation the individual dose for the adults, the children and the babies for all the studied groups is lower than10 µSv per year. For tritium the ingestion pathway is dominant, whereas for activation products (AP) and activated corrosion products (ACP) the dose is dominated by external exposure from deposited activity as it is shown in the Figure 4.1.

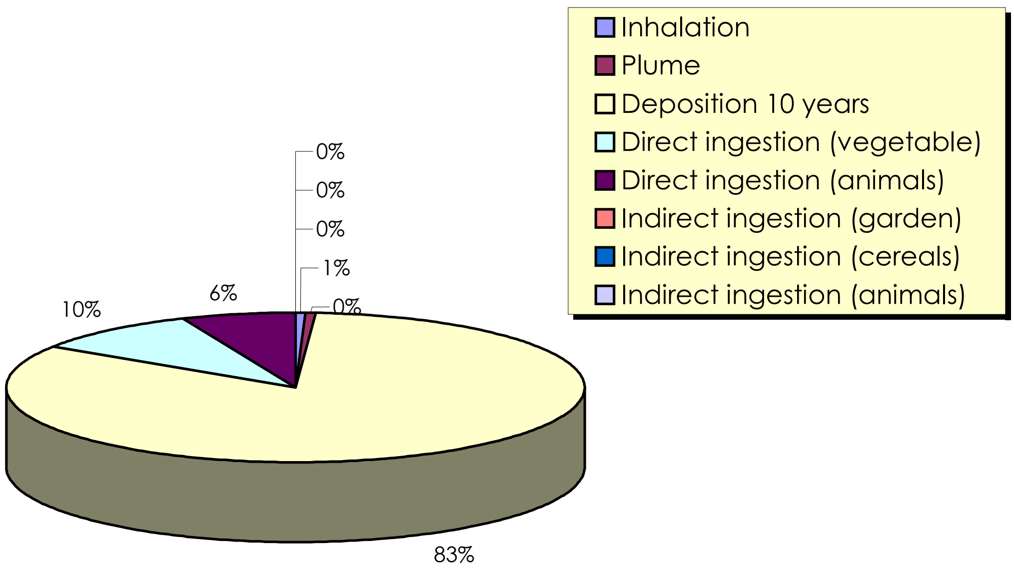


Figure 4.1: Contribution to dose due to gaseous release pathways, at the Cadarache Château after 10 years of exposure due to ITER normal operational effluents

Liquid Releases

The source term for the annual liquid releases are taken from table IV.3.1-1 of GSSR IV. This corresponds to the total estimated values of liquid releases: 0.14 TBq per year tritium and 0.77 g per year of ACP. Based on this source term the total annual releases for different radionuclides corresponding to the estimated liquid releases are taken from GSSR vol. III for the dose impact calculation. For the Cadarache site the maximum annual effective dose after 50 years was calculated to be about 0.1 µSv per year in the nearest village (Saint-Paul lez Durance).

4.2.3.4. Assessment of optimisation of effluent management systems

Evaluation of the current status of the design

In the current ITER design, the process followed has taken into account the current international radiation protection requirements. For the optimisation of effluents from ITER operations the ALARA process has involved the following steps (GSSR Vol. IV):

- Design approaches were surveyed at other fusion devices as TFTR and JET and tritium plants, with wide operating experience in control of releases. Analysis of these good practices and equipment used for effluent control in these facilities has benefited the design of the proposed effluent management of ITER.
- In addition, for normal operations, CANDU reactors have extensive experience in control of tritium releases, and the ITER design utilises this experience in establishing design specifications for many components.
- Establishment of stringent project effluent guidelines that are sufficiently conservative to be acceptable by most national regulations.
- Estimation of possible effluents. A systematic review of systems, activities and pathways has been undertaken to estimate releases and to ensure that all release pathways are accounted for and the obtained estimates for releases are lower than the project guidelines.
- In the design these release pathways are analysed to identify the main contributions and possibilities of design improvements for further reduction of the releases. The release reduction process is carried out in parallel with the general design evolution.

The last mentioned step is a key element in the application of the ALARA principle. Two main targets of current application of ALARA to reduce releases from normal operations are:

- Design improvement or changes to reduce process effluents;
- Design improvement for maintenance releases.

The ALARA process allows a reasonable guarantee that, at the current design status of ITER, the radiological and environmental impacts of the effluents will comply with the requirements established for the Cadarache site, and that they will be ALARA.

In addition, the process of reviewing the design is continuing, with the goal to incorporate or improve new equipment, which may lead to a greater optimisation of the effluent management.

The following conclusions can be drawn concerning the optimisation of gaseous and liquid effluent management:

- The different ADS systems as designed and planned for ITER will accomplish their objective of ensuring that tritium releases to the environment are within design guidelines for normal operations, maintenance and design basis accident scenarios. This is accomplished by the application of established techniques derived from experience from existing plants.
- The liquid effluents arising from ITER operations will be handled according to the concentration of tritium. The objectives will be to recover as much tritium as possible from these liquids for reuse in the ITER fuel cycle and simultaneously reduce the tritium concentrations in the other product streams to very low levels. These other product streams, either gaseous or liquid, will only be discharged to the environment if they comply with the site requirements for both concentration and total discharge.

Evaluation of the Detailed Design

In a detailed engineering study of the ITER project, a thorough review of the design using ALARA criteria should be carried out. Following the usual procedures in this field, a manual for the entire facility, which should include a checklist of ALARA criteria to comply within specific areas, should be prepared.

Even though a wide operating experience of most systems and equipment have been used for the treatment and discharge of the effluents (including a high degree of standardisation), this detailed ALARA review would allow to guarantee that all ALARA aspects have been taken into consideration. This review is of special interest given the unique nature of the facility.

Evaluation of Machine Operation

Operation of the ITER device comprises different phases (H-H, D-D and D-T) with a gradual increase of the effluents to be discharged. The treatment systems have been designed to handle all the effluents produced during all of these phases of operation being base on expected conditions at the end of nominal life.

This progressive increase in the production of effluents will permit an assessment of their impact on the environment and of the corresponding adaptation of the facility, should it be required, for the incorporation of new equipment or improvement of existing ones.

References

[1] ICRP-60

[2] Euratom Directive 96/29

[3] Decree 98-1185

The values of effluents and releases, which are expected according to the GSSR evaluation, are well below internationally accepted levels and are compatible with the current authorisation of the Cadarache centre.

The assessment has shown that the best available means have been used in the design for minimising the effluents. However, the installation of future nuclear facilities in the Cadarache Centre has to be taken into account.

Preliminary evaluation of doses to the public from atmospheric release is low, less than 10 µSv per year at the end of life of ITER.

Concerning the tritium concentration in water, limits are driven by the fact that water from the Durance and the EDF Canal are used as drinking water.

4.2.4. Waste management and decommissioning

The purpose of this chapter is to give an overview of the radioactive waste from ITER, regarding the management, streams and characteristics. The waste is both from operational activities as well as the decommissioning phase. ITER is a completely new machine regarding construction and performance; therefore the base of experience is very limited for the estimation of amount of waste and level of activity in the waste. In the development of design, analyses of materials and preparatory assessments have been performed with a focus to minimise the radioactive waste. This work was already started from the previous concept of the 1998 ITER design. The material selected for different components are with present knowledge and technology the best, from technical performance during operation and radiological waste points of view. In the following the waste classification is presented (4.2.3.1), then the possible repositories (4.2.3.2), and finally the dismantling operations foreseen (4.2.3.3). References are given at the end of this chapter.

4.2.4.1. Waste classification: methods and assessments

French waste classification criteria

In GSSR vol. V, it is said that "*work and results reported in this volume largely address the concept of clearance, a process recommended by the IAEA for releasing solid materials with very low level radioactivity from regulatory control and assuring that the consequences to the public would be trivial. Natural background radioactivity provides a reference level for man-made radioactivity. Relative to this reference, doses around 10 µSv per year are considered insignificant and have been used by IAEA for quantifying the concept of unconditional clearance*."

Since the concept of "clearance" cannot be applied in France, it is necessary to review all the wastes and to define which repository has to be adopted in each case according to French regulation criteria.

In France, the radioactive waste is classified in four categories, depending on their activity and the half live of nuclides:

- **TFA waste**: "Très Faiblement Actifs", very low activation waste,
- **A-Type waste**: Low and Intermediate Waste;
- **B-Type waste**;
- **C-Type waste** (no type C waste in ITER case).

Each of these categories has its own acceptation criteria.

- **TFA Waste**

  Data are taken as working values from official documents under preparation, and have to be used as preliminary guidelines waiting to final approbation.

  - The "Indice Radiologique d'Acceptabilité en Stockage", IRAS (radiological acceptance index in storage) must be less than 1:

$$IRAS < 1, \text{ where } \quad IRAS = \Sigma A_i / 10^{C_i}$$

A_i is the radionuclide activity and Ci its class (from 0 to 3)

- Maximum limits for acceptance related to water transfer (LMAE, Limites Maximales d'Admissibilité liées aux transferts par Eau) must be complied.

- **A-Type Waste**

  The CSA (Centre de Stockage de l'Aube) criteria are used as reference since all shallow land disposals will have the same type of criteria as CSA.

  - Maximum limits for acceptance (LMA, Limites Maximales d'Acceptabilité) must be complied.

- **B-Type Waste**

  All the waste that cannot be stored in A-type waste disposal.

The demonstration that a beryllium threshold is respected during decommissioning processes is required for the acceptability in shallow land disposal of wastes suspected to be polluted by beryllium.

As a first hypothesis, three zones can be defined to identify nuclear and non-nuclear parts of the installation:

- **Zone 1**: zone without radioactivity such as office building.
- **Zone 2**: non-contaminated zone such as bioshield. None contamination is foreseen in this zone in normal operation. In case of contamination in incidental situation, the zone can be decontaminated.
- **Zone 3**: radioactive zone.

An added radioactivity on natural radioactivity in the range of 1 Bq/g is considered as the limit between zone 2 and zone 3.

Review of Waste Streams and Classification

The overall dominating amount of radioactive waste, both regarding masses as well as activity is the decommissioning waste. The operational waste will only be a minor part. Some components are exchanged during lifetime of the installation; the major masses are from the blanket system and the divertor. The activity in the construction material of the machine has been calculated with a 1-D activation model. With these data and the physical data of the components, the activity in each component has then been estimated [1]. This allows having for the different zones used in 1-D calculation and then for each component, the material, the mass and the activity characteristics. The management of wastes containing beryllium is foreseen in a French law (13/07/92) concerning special industrial wastes. The amount of non-active beryllium, produced during ITER construction and during component replacement, has to be assessed.

Operational Waste

The radioactive operational waste will come from activated waste material from normal operation, and will be maintained within controlled areas. The major part of the waste consist of:

- Exchanged components;
- Vacuum pump oils;
- Process residues (waste by-products such as resins, slurries, dusts, etc.);
- Ion exchange resins and filter masses;
- Used or defective tools and equipment;
- Protective clothing;
- Materials from decontamination operations;
- Process (hot) area office trash such as paper, towels, laboratory samples, etc.

The total amount of operational waste from the hot cell and waste treatment facility is estimated to 1,400 ton with a total activity of 60 TBq.

In a first hypothesis, the process waste can be finally disposed as TFA (20 %), type A (75 %) and type B (5 %). A finer estimation of these wastes must be performed.

All the exchanged components (about 750 tons) must be classified as B-type even if their decay time is longer than 30 years. If detritiation processes are performed on only tritiated wastes (tritium plant equipment, fuelling system equipment…), this mass of B-type could be slightly reduced.

Decommissioning Waste

During operation, the tokamak and surrounding equipment will be activated and contaminated, and the activity will remain after final shutdown. The activity decays by time and the total activity in the waste will then be reduced.

Decommissioning will produce about 30000 tons of wastes.

Comments on Tritium Contamination due to Permeation

The steel of in vessel components and vacuum vessel will contain tritium not only from transmutation reaction (activation) but also from permeation from the plasma side (contamination). Blankets and divertor have to be considered as B-type because of transmutation reaction products, so tritium contamination has no major impact on their classification. The tritium from permeation alone increases tritium inventory but would not change the basic judgement that detritiation is not necessary. Concerning vacuum vessel, the tritium contamination does not change classification into A-type.

Tritium plant equipment, fuelling system equipment and remote handling equipment, which are assumed to be only tritiated, will be B-type due to the tritium content and will need to be detritiated if another storage will be foreseen.

The presence of tritium, from activation and permeation, will require specific performances of the packaging to allow a controlled tritium degassing.

Waste management strategy

In order to reduce A- and B-type wastes, processes such as decontamination and detritiation are foreseen. Furthermore an interim storage is considered to allow radioactive decay. If these measures are not applicable or they provide no advantages an evacuation of waste to a repository directly after plasma shutdown is planned.

The Table 4.5 shows the total mass of waste distributed by type at shutdown for operation and decommissioning materials (Hypothesis 1). Hypothesis 2 shows their distribution after decay or specific handling. After 30 years 4924 tons of type A waste can be declassified to TFA and 1 ton of type B to type A. After 50 years 387 tons of type B can be considered type A. After 100 years 4598 type A tons are acceptable as TFA.

Optimisation studies will confirm if further reduction from type A to TFA are beneficial.

	Phases	Masses (tons)			
		TFA	A-Type	B-Type	*Total*
Hypothesis 1	All wastes at shutdown	10577	19492	3502	*33570*
Hypothesis 2	Part at shutdown	10577	9970	3114	*23660*
	Part after 30 years	4924	1		*4925*
	Part at 50 years or detritiation simulation		387		*387*
	Part at 100 years or CWS decontamination simulation	4598			*4598*
	Total	**20099**	**10358**	**3114**	***33570***

Table 4.5: Breakdown of waste at shutdow or after decay

4.2.4.2. Waste management options

Hypotheses on repositories

Hypotheses are made on waste repositories and packaging. Different repositories can be considered for the storage of waste packages:

- Specific industrial waste disposal;
- On-site buffer interim storage waiting for a definitive repository (the date of the interim storage end must be determined at the beginning of storage);
- Industrial dump;
- TFA dedicated repository;
- Shallow land final disposal for type A wastes;
- Cells dedicated to tritiated wastes in shallow land disposal.

Long-term interim storage: the duration is not determined for the moment but should be lower than 100 years. The possible functions of interim storage are B-type declassification to A-type. From the costing point of view, B-type waste management is the most expensive but for this waste there is no change expected in its classification since the plasma shutdown until the 100 years interim storage availability except for only tritiated wastes.

Deep final disposal: only for wastes that cannot be stored in A-type shallow land disposal and can not be declassified.

Waste Management Strategy

For each type of waste, the following strategy is proposed:

Conventional Waste

These wastes come from civil engineering structure dismantling. Depending on their nature (concrete, steel…), management systems are defined for these types of wastes.

TFA Waste

The wastes are classified in this category after final shutdown or after a decay time at maximum of 30 years, which allow type A waste declassification to TFA. They can be treated using management modes currently developed for this type of waste as buffer interim storage in on-site cells for 30 years at maximum to allow declassification to TFA. Waste waiting for packaging or transport could also use this storage.

The interest of direct storage of large massive part of components must be investigated. The current reference solution for transport to a TFA storage centre is to use ISO containers.

A-Type Waste

Compacting could be used to reduce waste volume. For this type of waste, the waste matrix generally used is a hydraulic binder. The use of large dimension container allows reducing operations on metallic pieces. The reference solution, which is selected for calculation, is a concrete package with 3 m^3 waste volume, external volume of 5 m^3.

B-Type Waste

No declassification of type B waste will be possible after 100 years decay except for only tritiated wastes.

- *Activated and Tritiated Waste (stainless steels, Cu and Ag)*

  The management modes of these wastes must take into account the large dimensions and the weights of the components and the presence of tritium. The principal stake of the packaging is the control of tritium degassing: the external waste casing must warrant a tritium gas confinement level satisfying the repository requirements. This has to be investigated

The waste packaging must also satisfy:

- Durability,
- Mechanical stability,
- Handling properties.

A concrete packaging with concrete waste matrix can be used. A square base fibre concrete package will be proposed for calculation with 3 m^3 waste volume, external volume of 5 m^3.

For this waste, the envisaged repository is deep disposal, as they cannot be accepted in A-type repository even after long-term interim storage for radioactive decay. Nevertheless, a long-term interim storage could be used before deep disposal to allow tritium decay for the highly tritiated wastes. The facility may need an atmosphere detritiation.

- *Waste with Beryllium and Highly Tritiated*

ITER will use 13 tons of Be in blankets first wall (10 mm thickness). Due to its chemical toxicity, it is necessary to reinforce protection lines. The maximum allowance performance, related to safety constraints, will be put on the packaging. Different points have to be investigated:

- **Specific treatments before packaging**: the possibility of Be recycling have to be studied;
- **Packaging**: specifications for a waste matrix with resistance in particular to lixiviation and a packaging with double confinement barrier (stainless steel internal container and concrete external container for example);
- **Repository**: deep final disposal.

A double barrier package with 3 m^3 waste volume and external volume of 5 m^3 is proposed.

There are also components with tungsten and Carbon-Carbon fibre composite (CFC) in divertor first wall. They will collect tokamak activated dust and will be polluted by Be. They can be pulverulent and for CFC they can contain an important quantity of tritium.

The management of such waste will need:

- **Specific treatments before packaging**: detritiation or Be decontamination for example,
- **Packaging**: the Be container could be used. This allows reducing the typology of the containers. This is the reference solution for calculation,
- **Repository**: deep final disposal.

- *Only Tritiated Waste*

This waste comes essentially from operation and dismantling of the tritium plant, fuelling system and remote handling equipment. The interest of detritiation will be investigated. Nevertheless, a long-term interim storage of about 100 years (8 half live of tritium) can be envisaged if after this period, due to tritium decay, the repository of the waste can be optimised. It is necessary to take into account the management of potential gaseous outlets.

For information, the maximum tritium-degassing rate for packages stored in CSA is currently 2 Bq/g/day.

For this type of waste, storage in specific cells in shallow land disposal (with or without preliminary radioactive decay storage) could be envisaged as definitive repository. Studies are currently performed to determine the acceptability of solid tritiated wastes coming from CEA.

A package with 3 m^3 waste volume and external volume of 5 m^3 is proposed for calculation.

In conclusion, after a first analysis, all the radioactive materials of the ITER machine appear to be manageable.

Nevertheless, two points are sensitive:

- **Mixed wastes (chemical and radiological wastes such as beryllium irradiated wastes) are a key issue. For these wastes, the maximum allowance requirements, related to safety constraints, will be put on the packaging that has to be carefully designed and qualified.**
- **The technical processes used during the operation and deactivation periods, are a second key issue since the classification of waste packages will depend on guarantees (mainly demonstrations on contamination, beryllium level…) provided by the process.**

The following should be investigated:

- Definition of dismantling and cutting processes which guarantee a contamination below threshold for beryllium;
- Interest of detritiation, Be decontamination, compacting…
- Definition of the packaging (controlled tritium effluents and beryllium handling must be guaranteed);
- Study of an in-situ long-term interim storage if a final repository is not available.

4.2.4.3. Decommissioning

Decommissioning deals with the operations from first dismantling to the packaging of produced waste in order to evacuate them to the appropriate repository. This is a preliminary approach to a possible solution.

Several parameters must be considered:

- Dates when wastes reach the allowed levels in the different repositories (particularly mass activity);
- Dose rates at the same key dates, and also at other important dates corresponding to levels to define (sorting by zone: green, yellow… for example);
- Physical access;
- Radiological access (dose rate of the surrounding areas);
- Mechanical availability of parts to be dismantled.

Removed parts must be drummed. In order to perform this packaging, it is necessary to cut to fit to the drums characteristics (size and weight first) and to fit to the repository conditions (dose rate, chemical limitations…). This packaging is performed on the production site. This operation is among the heaviest regarding the needed human works and materials, taking into account the dose rates which can be high and taking into account the characteristics of this kind of packaging (repository and transport regulations are severe). The buildings concerned with the additional activity are tokamak hall, hot cell, radwaste and tritium building.

It is assumed that all other buildings are free of additional activity after phase 1 decommissioning.

The reference solution containers are those described in the previous chapter.

Dismantling Operations

The purpose of the studied dismantling is to reach the third level of the IAEA classification. The three level characteristics are indicated in Table 4.6.

	Level 1	Level 2	Level 3
	Closing and survey	Conditional and partial liberation	Full dismantling
Status of the plant and of the equipment	All barriers in operation Limited access Monitored confinement	Reinforcement of the containment Only one barrier Free access around the containment	Everything is removed[16]
Survey	Heavy	Light	No
Inspections	Often	Scheduled	No
Identified stage	DSD (definitive shutdown)	New INB (basic nuclear installation)	Absence of additional activity

Table 4.6: Levels of Dismantling

[16] Everything with any additional activity is removed. This classification does not deal with the non-additional activity materials. Sorting between elements with additional activity or not is under the responsibility of the site owner.

The main phases established on the basis of the IAEA recommendations and on the basis of the French regulation are:

Phase 1

Phase 1 is under the responsibility of the plant operator. And therefore it is not studied here. Works to be performed during this phase are described in GSSR vol V and Decommissioning Plan.

This phase concerns removal of tritium and removal of in-vessel components (blanket and divertor).

The duration of this phase is about 5 years in the generic ITER decommissioning planning.

Phase 2

According to the general regulation the following items are dismantled:

- What can be dismantled for physical and radiological reasons (man access);
- What can be evacuated to an identified repository (conventional, TFA, type A and type B);
- If possible, dismantling begins with the lowest levels of activity and ends with the highest level.

Gauging should be done immediately to avoid dispersion. It may not be possible to gauge some parts for several reasons and these will be dismantled on a specific area to be created. This area may be the assembly hall with some adaptations (means and tools). Use of the hot cell is not excluded.

The necessary sorting (materials, radiological, destination) must be performed as soon as possible in order to limit pollution, interim storage, and handling. The packaging is performed on another area to be defined. Particularly, it is necessary to allow the needed radiological measures on the closed parcels. The ambient dose rate in the gauging zone may be important. The hypothesis that it is not necessary to perform decontamination is made:

- The main contamination is due to tritium into the vessel, this tritium is removed as good as possible during phase 1;
- The contamination part of the dose rate is low compared to the activation level;
- Repository acceptance criteria for contamination would be respected without decontamination operations;
- Hand cleaning is possible also in order to limit the dispersion.

The creation of a new INB, "Installation Nucléaire de Base", could be necessary. This stage is not absolutely imposed by the regulations. It could be used to wait for the decay. In the case of ITER in France, waiting does not seem to be useful. Nevertheless packages could have to be removed away. Duration of this phase will depend on the building flow on the site and on the evacuation flow. Works on the non-nuclear part of the site may be performed in parallel.

Phase 3

The purpose of this phase is to liberate the site, every additional activity materials being removed. The main part of the work is performed during phase 2. At least the dismantling of the parcels interim storage building must be considered during this third phase.

Other Radioactive Data (Equipment outside the Pit)

The systems outside the pit (Water Cooling System and vacuum system) are supposed to be decontaminated during phase 1. As the detritiation performed during phase 1 is supposed to have removed all the tritium, these circuits can be sorted, as TFA or type A. Beryllium pollution is not considered in this document.

A potential problem of the hot cells is the beryllium pollution. The hypothesis is that all this pollution is removed during phase 1. These rooms that are not highly contaminated are sorted as TFA or conventional waste. Their dismantling schedule is independent of the tokamak one.

The radwaste building contamination would only be due to incidents during the operation. The necessary cleaning is assumed to have been done so that the rooms are not sorted as TFA. Phase 1 includes a detritiation of this building, and thus these zones are considered as highly decontaminated. Dismantling of the tritium building is independent of the others buildings.

Dismantling of In-Pit Equipment

The purpose of this study is to develop a feasible scheme for dismantling and sorting equipment located in the pit. Further study and optimisation are needed to complete the actual plans.

The equipment will be cut in some large parts, using remote tools if necessary. Then they will be removed from the pit using the existing heavy crane and placed in a special pool. The special pool is built in the assembly hall. This allows reducing the dose to the personnel, and reducing the contamination dispersion. In this pool, the large parts are cut to fit the chosen drums, using simple remote tools. Regarding the results of the sorting analysis, the dismantling of the large parts is performed following mechanical criteria only. The general schedule of dismantling is to follow the reverse schedule of the assembly. The initial sorting cannot be performed in the pit because of the difficult mechanical access (interlocked structures) and the weight of the components, which exceeds the crane capacity. The pool will be equipped with a circuit that allows filtering and purifying the water. The water is not replaced during the complete dismantling phase. Small parts are handled from the pool in air, to the sewage or drying zone. After sewage or drying, the parts are handled in the packaging zone.

The assembly hall will be adapted to the dismantling operations requirements.

Packaging is done as soon as possible. There will be a buffer zone for drums waiting for the transport. An interim storage of all the drums has not been considered. The packaging will be done regarding the foreseen criteria of acceptance and transport (limits on size and weight for road and rail transport). If an interim storage will be decided, for any reason, the packaging could be delayed but has been done. Packaging should be done as soon as possible. The packaging zone is foreseen to fill the drums, and to perform all post-packaging operations (measurements, identifications, documents…). The packaging zone is installed in the assembly hall, near the pool, but with a physical separation. After packaging, the drums are sealed and handled to the interim storage zone. This zone will also be established on the assembly hall.

Other scenarios

Other solutions have been studied:

- The previous study was based on main guidelines given by the Decommissioning plan (annex DP to the PDD) [5]
- Another solution has been considered which consists, in removing the internal parts of vacuum vessel after a radioactive decay of about 25 years, using a robot and in evacuating waste to the hot cells. The other components are dismantled, cut in the pit and progressively evacuated to the assembling hall by the cryostat access points. Cryostat, vacuum vessel and coils are cut directly at the right size from top to bottom by moving a specific working platform built inside the pit. With this scenario, the duration of decommissioning will be about 12 years.

The best strategy will be chosen after complementary studies.

References

[1] ITER Generic Site Safety Report (GSSR), Volume V, Radioactive materials, decommissioning and wastes, 30/03/2001

[2] CD-ROM ITER task D451, subtask 1, 1 D activation calculation of ITER, D.G. Cepraga, G. Cambi, M. Frisoni, ENEA, July 2000

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[5] Decommissioning Plan, Annex DP to the PDD, N 23 FDR 1 01-05-17 W0.1

The main goal of the dismantling is to minimise the type B wastes volumes and weights. Known technology allows performing the sorting.

Depending on the scenario, dismantling could start immediately after phase 1 and could last 16 years or could start 25 years after phase 1 and could last 12 years . Feasible schemes for dismantling of ITER in line with French regulations and practices have been developed.

5. Socio-economy

5.1. Introduction

One of the aims of the ITER project is to demonstrate the feasibility of magnetically confined nuclear fusion as an energy source for future generations. To evaluate the impact of fusion on the future energy system the SERF study (Socio-Economic Research of Fusion) was conducted jointly by the fusion associations with the financial support of the European Commission [1]. The results of these studies support the idea that fusion might become one of the corner stones of the future energy system. Especially the rather advantageous safety and environmental characteristics of fusion compare well with those of renewables.

Beside these rather general arguments to promote fusion in general and ITER in particular, the ITER project will lead to significant benefits for the region around Cadarache, for France and for the whole of Europe. These benefits are expected in a number of areas: political, economic, industrial, scientific, employment and skills, cultural and environmental [2]. Early communication with the local population is considered to be essential for the success of a project like ITER, and to obtain public acceptance of this new form of nuclear energy.

This chapter focuses mainly on the economic benefits expected for the region Provence-Alpes-Côte d'Azur (PACA), for France and for Europe and describes the social environment in Cadarache. A short review about work done in the past on public participation is presented.

The studies on economic benefits were elaborated by two French institutions:

- **IDEFI**, Institut de Droit et d'Économie de la Firme et de l'Industrie, CNRS laboratory at Nice-Sofia Antipolis,
- **IDEP**, Institut d'Économie Publique, CNRS laboratory of GREQAM, Groupement de Recherche en Économie Quantitative d'Aix-Marseille.

The characterisation of the socio-economic environment of the site was done by the CEA, with the strong involvement of French official institutions (sous-préfecture d'Aix-en-Provence, rectorat, statistic institute INSEE…).

5.2. Economic and industrial benefits of siting ITER in Cadarache

Economic development does not only lead to the production of greater quantities of the same goods and services but to the creation of completely new entities. In the described investigations both aspects of economic development triggered by the construction of ITER are investigated.

Former fusion projects have well demonstrated that the benefits of fusion are distributed all over Europe. This can be shown by JET and even the orders for the Wendelstein-7X experiment, which is still a national project – of course with strong European support – has distributed the major procurement packages all over Europe [3]. The same holds for the procurements done in the course of the ITER EDA. A number of large prototypes of key ITER components were produced by the European industry, with the coordination of EFDA, the European partner team of ITER.

More detailed information on the economic tasks can be found in [4] and [5].

5.2.1. Qualitative improvements of the economy

Since ITER is not constructed yet, investigations have to focus on past experience. As an example the industry involved in constructing Tore Supra (TS) was researched. Obviously a one to one comparison of the two projects is not possible since size and organisation of the projects will be different. Nevertheless, a comparison is still very valuable so far, as key technologies like cryogenics, advanced magnetics, sophisticated electronics and so on are crucial for both projects.

Using a methodology that has been set up for evaluating economic effects of CERN and ESA (European Space Agency) activities [6], indirect effects are identified with the net value added that the firms working under contracts with CEA for the TS project would have not realised if these contracts had not been signed. A distinction is drawn between four different kinds of benefits – new, better and more diversified products; more advanced processes and improved management; positive commercial effects; increase in the efficiency of the labour force – and their respective time profiles will be traced, so as to get a hint of the dynamic process of innovation viewed as a distributed phenomenon. This study is a first step toward a better understanding of the way the economy reacts to a technical advance of the ITER kind.

The empirical base of the study was laid by interviews with thirty key industrial participants of the Tore Supra experiment. The core interview data have been enlarged with an opinion poll concerning the indirect impacts. The following types of spin-offs have been investigated:

- advances in scientific and technological knowledge;
- advances in expertise among core industries and related firms;
- creation and improvement of products and services that found a wider market;
- transformation in management and the organisation of labour resources;
- changes in the industrial and commercial networks linking suppliers, partners and customers.

Members of university and research institute teams (primarily the CNRS) have also been interviewed to determine the indirect effects of controlled fusion research on the relationships between industrial R&D on the one hand and fundamental research on the other hand.

This case study has provided very significant results. The most important one concerns advances in technological know-how. 14 % of the firms sampled consider those results to be either important or very important. The improvement of technological skills was particularly significant for small and medium sized firms because only 22 % import R&D from outside sources.

These positive impacts are concentrated in those sectors that are specific to controlled fusion technology. For example, in the realm of magnets and cryogenics, the indirect impacts were remarkable: 67 % of the companies enjoyed spin-off benefits from advances in technological know-how ranging from important to very important. Still, the most significant spin-offs occurred in the creation of new products and services. Over half of all the companies surveyed, 52 %, saw either important or very important benefits flow from Tore Supra contracts in the form of new products and services put on the market (see Figure 5.1). The significance of these figures can be seen when they are placed in a national context: in France, 25.8 % of small and medium sized firms innovate in creating products new to the market and 35 % in creating products new to the company. These figures pale in comparison to the performances of companies, which participated in the Tore Supra project, as shown in Figure 5.1.

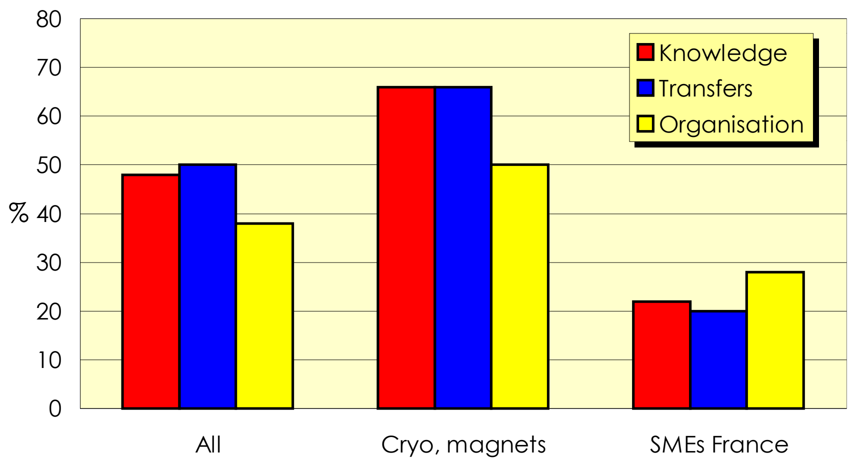


Figure 5.1: Results from opinion poll amongst firms involved in Tore Supra. The results proof that companies involved in Tore Supra could realise spin-offs and innovations far better than the French average. The result is especially pronounced for the cryo-systems and the magnets.

The spin-offs flowed from a constant interaction between Tore Supra engineers and the contracting firms. Participants needed to communicate specifications and to resolve the problems, which inevitably cropped up when completing orders. At the same time it has been demonstrated that innovation arose from the uniqueness of the contract specifications: the firms took advantage of this to create original products and services for a wider market. The markets created varied according to the technologies involved. In general, controlled fusion has created industries for the design and construction of superconducting magnets and their cryogenic systems, whose wider markets are in the fields of medical and biological equipment. This is a lucrative but narrow opening. For other sectors the markets are wider, for example, in scientific instrumentation, and information technologies, the latter of which profited from the processing and communication of the vast quantities of data such as Tore Supra produces.

As was proven by the Tore Supra experience Fusion is very well capable of triggering various innovations in the involved industries. The rate of these innovations is considerably higher than those produced by usual industry procurements. It is fair to expect that this finding will be even truer for ITER. The steady interference between project and industry representatives is one of the necessary prerequisites to assure the spill over effects. Siting ITER in Europe produces a short cut between European industry and ITER, which makes it for the European economy possible to realise numerous spin-offs and innovations. European industry can learn from these studies how to organise themselves in respect to ITER to harvest a maximum of benefits.

5.2.2. Quantitative impact of the construction of ITER

The quantitative activation of the economy in total and the labour market in special has been analysed. Purchasing components for ITER, like the magnets or the buildings, will lead to numerous activities in the economy on various geographical levels. The construction company – just as an example – will order concrete, it will need fuel for the trucks and so on and in the end it will pay their worker who in turn will spend their salary to buy food and pay their rents. All these activities need to be accounted for. A way to do this is to describe the economy of the region, a nation or Europe in a highly aggregate way by defining sectors of the economy and households. The interchange between these sectors is then evaluated from empirical data, which is supplied by the various offices collecting national and international statistics (like INSEE in France).

The flows between each sector can be mathematically described by an Input-Output matrix. The rows and columns of the matrix represent the purchasing and the supplying sectors respectively. The purchases of ITER can be modelled with a vector that addresses an exogenous demand of the economy. Each entry of the vector corresponds again to the sector where the purchase is placed. The combination of this vector with the input-output matrix gives the demands that the sectors will address to the economy in order to satisfy the exogenous demand. This new endogenous demand, the direct effect, will create another impacts that will leads to successive demands. The limit of this process is the total impacts in the economic system.

To evaluate the employment effect, the employment productivity of each sector – again derived form empirical data – must be known. By multiplying the productivity by the activation and by summing over all sectors, the total employment effect is found. A general problem in economical studies is to value benefits that can only be realised in the future. The standard approach is to discount the future benefits. Central problem is to find the proper discount rate. In the described investigations a discount rate of 8 % was assumed. The results have been expressed in constant Euro of 1998, which take into account an estimated inflation rate of 3 %. These hypotheses can be considered as upper bound estimates. A 1-point decrease in the discount and the inflation rates gives a 9 % increase in the impacts.

The input data were derived from the ITER costing exercises, which were evaluated in the extension of the ITER-EDA. The data were made available through EFDA. Costing of the buildings, assembly, remote handling, cryoplant, power supply, heating and current drive, magnets, vacuum vessel, blanket and divertor were available. These orders will be in various economic sectors. Figure 5.2 shows a distribution of the sectors for roughly 80 % of the procurements. As the distribution proves, various parts of the industry will be directly involved (the distribution of salaries will involve many other sectors).

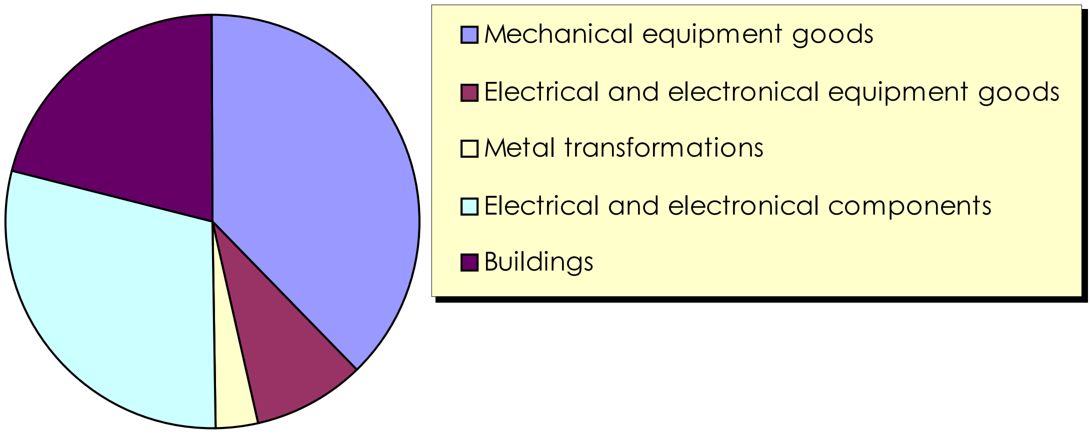


Figure 5.2: Distribution of the ITER procurements on the various industrial sectors (basis are 80 % of the procurements, where it is likely that they could be placed in Europe)

For the following investigations, the input-output matrix describing the French economy will be taken as a rough estimation to describe the European industry. Since it is at this stage not possible to give a clear indication on how the procurements will be distributed between the ITER partners only the relative effects are discussed.

The multiplication factors for the various industries are given in Table 5.1. The factor gives the total activity produced in the economic system by the spending of one Euro in the sector.

Sector	**Multiplication Factor (MF)**
Mechanical equipment goods	2.88
Electrical and electronic equipment goods	2.73
Metal transformers	3.01
Electrical and electronic components	2.64
Buildings	3.73

Table 5.1: The multiplication factors derived form the French input-output table. If 1 € is spent in one of the sectors, the whole economy is activated by MF €.

For Europe, an overall multiplication factor of roughly 2.9 should be expected. For an actual value of 10 M€ spent during the 11 years of the construction phase the discounted impacts on the production will be around 29 M€, and a yearly average of 23 jobs will be created. With some assumptions on the repartition of the sectors between France and the region PACA the multiplication factors for the region can be estimated around 2.8. The multiplication factor for the region is smaller than for the European level because of the specific economic structure of the region. For an actual value of 10 M€ spent during the construction phase, the yearly employment created is about 29 jobs. The higher jobs creation in the PACA region can be explained by the fact that the region will, in the construction phase, supply a lot of the low-tech parts like buildings that activate labour intensive sectors. The PACA region will benefit also from an extra revenue spending that comes from the mobility of workers involved at the

European level in the construction of ITER, and will stay in the region during installation of the components and on-site acceptance tests,

ITER construction will lead to a considerable activation of industry and employment and not only of those industrial sectors, which are directly involved.

5.2.3. A few remarks on public participation

Social scientists investigate possible mechanisms to include representative parts of the population from an early stage in the decision of the construction of large technical and infrastructure devices. Some of the procedures have found their way into the licensing procedures like the French "Enquête Publique".

No specific work in this direction was yet done for the site in Cadarache. It is one of the focuses of work in the second phase of EISS.

In SERF I and II some work in this direction was pursued by Italian and English groups. Main result of the Italian group was that they were able to install a successful participation process for an Italian city that could have been picked as site for ITER. The results of these studies are well documented in [7]

5.3. Social environment

This chapter verifies the compliance of the Cadarache site with the ITER site requirements and design assumptions, related to the socio-economic environment.

The following points are treated:

- Accessibility;
- Scientific and industrial environment;
- Social environment;
- Education;
- Housing;
- Health;
- Leisure, sport and tourism.

Numerous contacts with local authorities (prefectures, chambers of commerce and industry, regional councils, Rectorat) have shown that the region has a big interest in the project and will support the construction of ITER; some studies and propositions still have to be completed, notably the study concerning the reception of foreign staff and their families.

Figures quoted in this chapter have been obtained from the "National Institute of Statistics and Economic Studies" (INSEE). Detailed information is available in [8].

5.3.1. Access to Cadarache

The site proposed to host ITER is very well equipped in the way of communication and transport. Access to the site is very easy; the international reputation of the Cadarache centre having contributed to the development of its accessibility.

The European site proposed for the construction of ITER is located in the southeast of France; it is next to the "Centre d'études de Cadarache" of the "Commissariat à l'Énergie Atomique" (CEA).

Such a choice is motivated by the fact that plenty space is available around the centre, which already possesses the infrastructure necessary for the reception of a project of this scale. The surrounding region has a strong industrial and scientific presence.

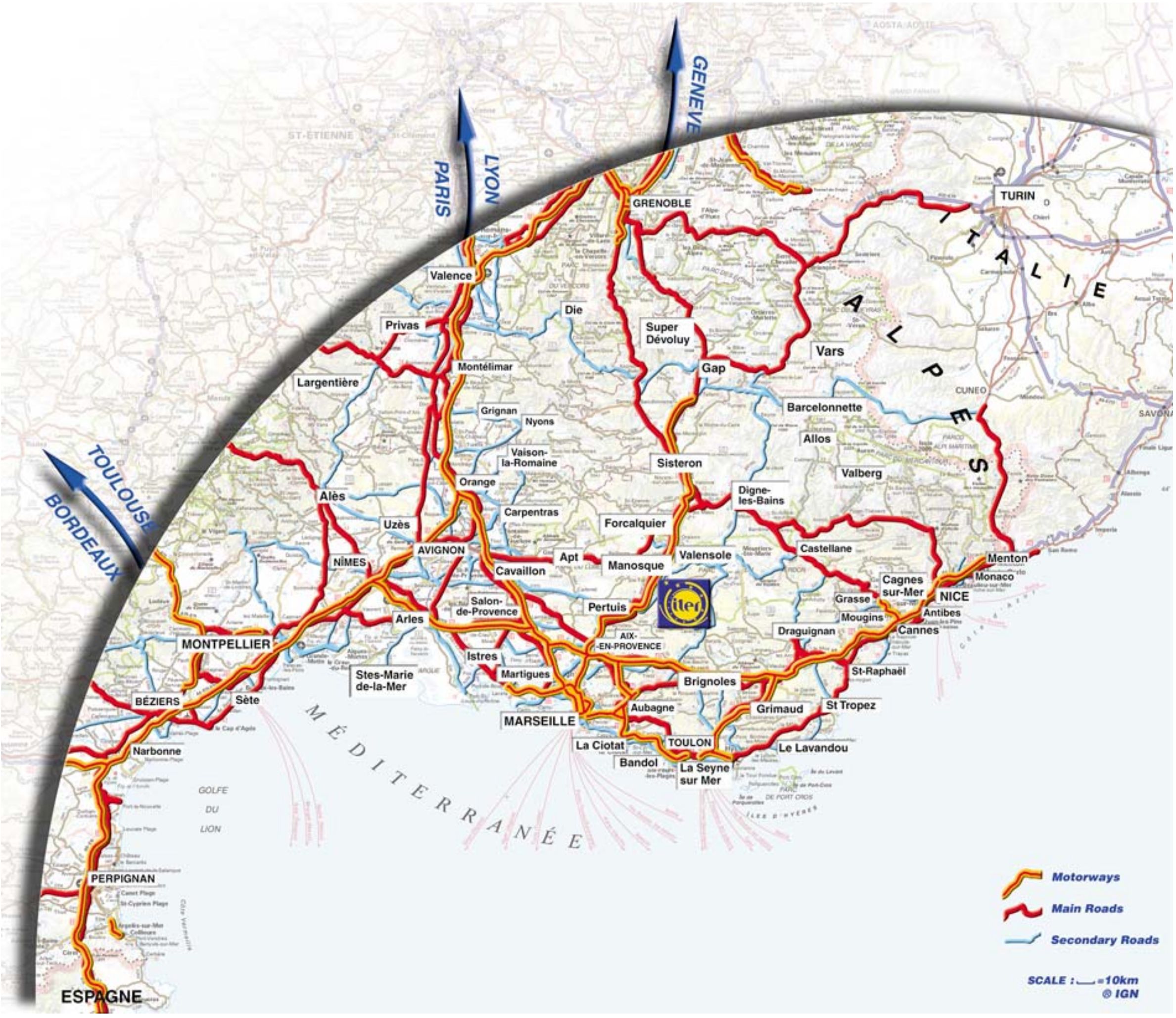


Figure 5.3: Main Roads and Motorways in the Region

The Cadarache site is located just south of the confluence of the Durance and Verdon valleys, near two major cities (Marseille and Nice).

Figure 5.4: Main Railways, Harbours and Airports in the Region

The site is well served by a network of roads and motorways (SA.D1), as well as by two railroads (SA.D3). The very recent construction of a French high-speed train line (TGV Sud-Est Méditerranée, June 2001) reduces the journey to French and European large cities (for example Marseille – Paris: 3 hours).

The region has four airports (SA.D2): two international (Marseille Provence and Nice Côte d'Azur) and two national (Toulon / Hyères and Avignon). Marseille and Nice are the two largest French airports outside Paris and assure an excellent connection towards the European big "hubs" such as Amsterdam, London, Paris, Brussels and Zurich.

Figure 5.3 and Figure 5.4 show access network in the region: main motorways, railways (including TGV), airports and harbours are illustrated.

5.3.2. Scientific and industrial background

Although the region (Provence Alpes Côte d'Azur) is strongly geared towards tourism, it possesses nevertheless a broad spectrum of industrial activities, ranging from heavy industry to high technologies. Some key figures:

- 40 % of the national microelectronics production;
- 1/3 of the French oil refining;
- 1/4 of the steel production in France;
- 10 % of the national chemical production;
- World's foremost producer of helicopters;
- World leader of the smart card.

Apart from the large groups that have set-up around Aix / Marseille and Nice / Sophia-Antipolis, the region has a dense fabric of small and medium-sized enterprises and is very much oriented towards the service industry. The rate of new business creations illustrates its dynamism. The region has a strong research potential, classed second French region in public research, with well-known universities and the presence of the main French research organisations. Private research is also strong, in particular in the field of high-tech microelectronics and telecommunications.

Finally, various structures take on the task of ensuring an interface between industry and research, to achieve a true synergy between innovative manufacturers and advanced research.

5.3.2.1. Industry in the region

One finds, in this region strongly dominated by tourism, a large palette of industrial activities, with mixed zones of heavy industry and numerous poles of excellence in high technologies.

Although the region around Cadarache is dominated by the service industry, it has nevertheless a large industrial activity, and also other sectors such as construction and agriculture are present (see Table 5.2). The partition between the different sectors is in constant evolution.

Sector	Domains	Number of employees	Percentage
Primary	Agriculture, forestry, fishing, agricultural and food Industries	45,000	3 %
Secondary	Consumer goods, Car industry, Equipment Industry, Energy Construction	180,000 105,000	12 % 7 %
Tertiary	Transport, finance, property, services to companies, services to private individuals, education, health, administration, social services	1,170,000	78 %

Source INSEE 2000

Table 5.2: Distribution of Industrial Sectors in the Region

With a Gross Domestic Product (GDP) of 73,000 million euros in 1999, the region produces 7 % of the national wealth, and is classified in third place behind Ile-de-France (Paris) (29 %) and Rhône-Alpes (9 %).

In 1997, one counted 24,000 industrial establishments (not included building and civil engineering companies, see below), 60 % of which are found near the coast (Marseille and Nice). In the rest of the region (Vaucluse, Alpes-de-Haute Provence, Hautes Alpes) more scattered industrial centres are found (SA.F1).

The industrial fabric is changing rapidly, and all the fields are, in different degrees, represented in the region (see Table 5.3).

	Mechanics Metal Industry	Agro Food	Chemistry Pharmacy	Electronics Data-processing	Energy	Others[17]	Totals Industry	Total Employees
Establishments	3,387	6,679	1,104	2,107	623	10,295	24,195	
Jobs	25,506	26,019	23,450	15,888	17,083	61,008	168,953	1,327,200

Source INSEE 1996

Table 5.3: Distribution of main Industrial Activities in the Region

The building and civil engineering sector, very strongly present in the region, is very dynamic as a consequence of the important tourist industry. It is a rapidly growing activity in Provence: the region had in January 2000, 30,000 companies in the construction sector, which accounts for 10 % of the French companies. Most establishments employ between 1 and 9 people (15,000 small and medium sized enterprises) and almost as many craft companies (12,000) can be found. Large construction projects are divided between roughly a hundred companies.

For a period of a few years, the French economy caused a slump in building and civil engineering. The upswing in the economy experienced since 1997 has encouraged

[17] Naval, aeronautical, railway, wood, paper, minerals, Publishing, textile, equipment

investment, particularly by local government bodies, resulting in a significant increase in demand.

For example the construction site for the TGV Méditerranée (3,800 M€) strongly contributed to a return of growth. Local governments (departments, region, communes) have since 1998 increased their investment in construction. In years to come it will stay at an important level, because of current projects and because of those still to be finished.

The region has an important proportion of establishments of small size, which translates to its large capacity to start-up new businesses.

The region has a large number of innovative companies: it is the second region of France, after Ile-de-France, for the start-up of new businesses by researchers (about 30 per year). The activities of engineering service and technical studies are well developed in the region, presenting a strong potential in this domain.

Finally, it should be noted that the region, which has several exceptional natural sites among its assets, strives to apply a development policy that allows highly protected zones and zones for industrial use to coexist.

Figure 5.5: Sollac refinery by night – "Pont du Gard", close to Nîmes

5.3.2.2. Scientific resources

The region has in total 11,000 researchers. It appears in second place after Ile-de-France in public research (6,500 researchers) and in third place for private research (4,500 researchers or engineers) behind Ile-de-France and Rhône-Alpes(SA.F1).

- ***Public research***

  With about 700 M€, civil public spending on research and development (R&D) in the region represent 8.5 % of national expenditure. This is divided up between university research (28 %), the "Centre National de Recherches Scientifiques" (CNRS, 18 %) and applied public research organisations (54 %). Around a thousand public research laboratories insure about 7.5 % of the national production (theses and publications).

- ***University research***

University research is well developed in the region. Distributed over 6 universities, and covering very different domains, it concerns 3,100 lecturers-researchers who dedicate half their time, as well as technical and administration staff (about 500 persons).

The CNRS is present through two regional delegations in Marseille and in Sophia-Antipolis, near Nice, with in total 1,750 researchers, as well as technical and administrative staff (about 650 persons) and student researchers. The CNRS is present in all major disciplines, such as physical and mathematical sciences, nuclear physics and sciences of the universe, engineering sciences, chemistry, life sciences, sciences of man and society, etc.

- ***Applied research***

Applied research is particularly well represented in the region (about 1,700 researchers and about 2,500 technical and administration staff). Indeed, practically all the large organisations for applied research are present in the region.

- ***Construction of large scientific instruments***

ITER is not the first large research installation to be build in the region. For more than 40 years scientific instruments have been constructed, mainly in Cadarache. The CEA research centre is one of the important economic players in the region.

- ***Private research***

With about 1,000 M€, the regional internal spending on R&D by private companies represent 5.8 % of national expenditure. Around 4,500 researchers and research engineers as well as about 4,000 support staff (technical and administration staff) are involved in the private research sector. The region accounts for 4.5 % of patents deposited in France.

- ***Technology transfer***

Various structures encourage technology transfer between industry and research establishments in the region.

Several regional technology centres exist, administered by manufacturing associations, covering a large variety of domains: automation, industrial production and data processing, electric engineering and electronics, electromagnetism and microwaves, electromagnetic compatibility, mass metrology and dynamic weighing, quality, metrology and non destructive testing, characterisation of materials, advanced material, etc.

Cadarache has its own network of technological distribution: the Technical Centre of the Mediterranean Sea (CETREM) makes the know-how of the CEA available to small and medium size firms and small industrial firms in the region.

5.3.2.3. Professional resources, jobs

The region proposed to host ITER has a strong labour potential, in very varied disciplines. It is defined by the relative importance of trade activities (transport, business), reception and residence activities (hotel business, restoration, property) and industry. The region has a large public works industry, but the service sector remains dominant (SA.F2).

- ***Emergence of new economic activities***

The economic recovery of the last few years has brought more prosperity to the region. It is clear that the evolution has brought changes at a structural level, both in the nature of the economy and the long-term prospects.

Connected to the evolution of the national and international economy, the regional economy has undergone profound changes. There is also a geographic effect on the economy. The coastal region, with a strongly urbanised and rapidly expanding economy compensates for the rest of the region with a more traditional rural and slower evolving economy. However, in all parts of the region the service sector is rapidly expanding, particularly related to the tourist industry.

- ***New business creations: symbol of economic growth***

The region saw in 1999 a large number of new businesses (19,956 new companies, 11 % of them French). The region also has seen an increase over the years in the number of new companies. In 1999, with 10.4 companies created for every 100 existing, the region had the strongest rate of growth in France.

5.3.3. Social aspect

The French social system is one of the most developed in the world. For the ITER project, local authorities suggest creating a coordinating structure for the reception of foreign staff, facilitating their social integration.

5.3.3.1. Society and daily life

- ***French administrative breakdown***

France is split in 100 departments, divided into districts (arrondissements), every district in cantons and every canton in communes (36,679 in total, administered locally by “mairies”).

For example Cadarache falls in the commune of St Paul-lez-Durance, part of the canton of Peyrolles, in the district of Aix-en-Provence of the department of the Bouches-du-Rhône.

Each department has a Prefecture (example Marseille for the Bouches-du-Rhône) and a variable number of sub-prefectures, situated generally in the other large cities within the department. Every department has a chamber of commerce and industry and an agricultural chamber, which are public establishments and help with economic planning.

The French departments are regrouped in 22 metropolitan regions and 4 overseas regions. The president of the regional council exercises executive power. The region has extensive jurisdiction in economic, social and cultural development.

Cadarache is situated at the crossroads of 4 departments in the region "Provence-Alpes-Côte-d'Azur", which has 6 departments and a total of 4.500.000 inhabitants (see Table 5.4).

- ***Population***

The Region has a strong attractive power. Population growth is the largest France. Immigration into the region remains above the national average.

Departments	Num	Population (Thousands)	Surface km²	City (Prefecture)
Alpes-de-Haute Provence	04	139.6	6925	Digne
Hautes-Alpes	05	121.4	5549	Gap
Alpes-Maritimes	06	1011.3	4299	Nice
Bouches-du-Rhône	13	1835.7	5088	Marseille
Var	83	898.4	5973	Toulon
Vaucluse	84	499.7	3567	Avignon
Region	**PACA**	**4506**	**31400**	**Marseille**
France		*56600*	*544000*	*Paris*

Table 5.4: Size and Population of the Departments of the Region

- ***Main living areas***

Large cities in the region are Marseille (800,000 inhabitants), Nice (342,000), Avignon (86,000) and Toulon (168,000).

Near Cadarache, one finds the city of Aix-en-Provence (photo, 35 km, 137,000 inhabitants) and two medium sized towns: Manosque (15 km, 20,000) and Pertuis (25 km, 18,000). These are the main places of residence for the staff employed at Cadarache. These cities have a well-developed commercial infrastructure (trading estates, supermarkets, etc.)

and are important employment centres.

For those that prefer a more rural lifestyle many villages, 500 to 5,000 inhabitants, are located around Cadarache. Also these villages have all necessary commodities, mainly due to the importance of tourism.

- ***A multi-cultural region***

  As it is open to the sea, the south east of France has since long been a region of trade and commerce. Being at the crossroads of trade routes puts the region in a privileged position. Being a cosmopolitan region, it welcomes numerous foreign communities, many of which originate from southern Europe.

- ***A welfare system of high quality***

  The French welfare security system is one of the most developed in the world. Part of the salary is automatically transferred every month to a health insurance system. This allows a reimbursement of most medical expenses: doctors, medicines and hospital.

  A large number of mutual organisations exist allowing additional refunds in special cases.

  Welfare aid exists for the elderly (meals at home, medical help, etc.). The state also provides help to families, calculated according to the family income and the number of children. It is also possible to obtain help from the Social Security Office: for example for isolated relatives, rent allowances, etc.

5.3.3.2. Welcome of international ITER staff

The sub-prefecture of Aix-en-Provence will organise the reception of international ITER staff. Help with administrative issues and practical matters will be provided (SA.F3). Multilingual personnel, specialised in reception and information, will staff the reception centre. They will be in direct contact with the main governmental organisations and agencies. Four specialised groups will be created:

- *Residence Group*

  Housing demands will be centralised and the best possible solutions will be found if required. This group will also have a planning function: taking into account he ITER staff planning the group will study and propose the necessary real estate investments.

- *Partner Employment Group*

  This group will study the possibilities of jobs for partner of ITER employees; it will coordinate the search for positions and will perform an individual analysis of personal circumstances.

- *Education Group*

This group will help families with registration at a school, university, or other educational establishment. It will ensure centralisation of demands and will take care of registrations. It will assure, according to the ITER planning, the necessary adaptation of the educational establishments.

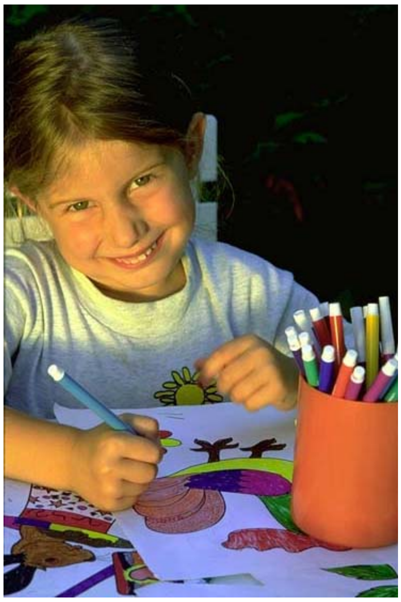
- *Administration Group*

  The prefecture of the Bouches-du-Rhône will constitute a group of civil servants specialised in administrative matters. It will manage statutory procedures concerning ITER employees. In particular, this group will ensure residence permits and work permits for foreign staff. Its mission will be, with respect to French legislation, to facilitate and to accelerate the acquisition of any license necessary for employees and their families.

5.3.4. Education

A study is currently underway by the Rectorat of the Academy of Aix-Marseille (Ministry of Education) to propose evolution or adaptation of the existing educational infrastructure, with possibly the construction of a new international establishment. The aim is to assure the continued education for the children of foreign ITER staff (SA.F3).

5.3.4.1. French school system



In France, schooling is compulsory from the age of 6, with a minimum duration of 10 years. Public and private structures are both available. In the public establishments, which are the most numerous, education is non-religious and free of charge, until a secondary school diploma has been obtained.

There are also numerous private establishments, for which a financial contribution is often asked from the families. Some follow a foreign educational programme (American, Japanese, English for example).

International secondary schools, or international sections in secondary schools also exist and nothing opposes the establishment of new international schools or sections.

- ***0 to 3 years: nurseries and pre-school playgroups***

  One of the objectives of French social and family policy has always been to provide day care for children of pre-school age. In all cities and often even in villages, there are establishments to look after young children all day, from morning to early evening, including a meal. This service is aimed at children from 3 months to 3 years whose relatives work. Staff at these establishments is required to have a special qualification.

- ***3 to 6 years: nursery school (maternelle)***

Education in the French system can start in nursery school. These public schools are aimed at children from 3, sometimes even starting at the age of 2, to 6 years. Education at this age is optional and free of charge.

- ***Primary school (école primaire)***

Compulsory schooling starts with a period of 5 years of education given in elementary schools. The day-to-day running and investment (including non-teaching staff) are guaranteed by the communes, the educational programmes and the teaching staff fall under the responsibilities of the state.

- ***Secondary school (collège)***

Pupils who have finished elementary education pursue their education for a period of 4 years at the first part of secondary school (collège). At the end of these 4 years a diploma ("brevet") is obtained.

- ***Secondary school (lycée and professional lycée)***

Secondary schools (lycée) prepare the pupils in 3 to 4 years for the baccalaureate. The general and technological lycée offers three general courses (Literature, Economy and social, Scientific) and several technological courses. The professional lycée offers education corresponding to different jobs in the economic sectors. The baccalaureate allows entrance to French higher education.

- ***Apprentice schools***

After the collège pupils can join apprentice school oriented towards trades and crafts, providing them with a professional qualification in 2 or 3 years.

- ***Higher education***

To enter French University it is necessary to have a baccalaureate or an equivalent foreign diploma. The student can obtain a DEUG ("Diplôme d'Etudes Universitaires Générales") in two years, followed by a "licence" in the third year, and a "maîtrise" in the fourth year. After that a student can envisage a DEA ("Diplôme d'Etudes Approfrondies") followed by a doctorate or a DESS ("Diplôme d'Etudes Supérieures Specialisées").

To be admitted to an engineering school or a business school (3 year course), it is necessary to pass a very selective entrance examination, prepared for in 2 years in the CPGE ("classes préparatoires aux grandes écoles").

Students wishing to enter the medical profession must complete 7 years of education after obtaining their baccalaureate.

5.3.4.2. Educational establishments in the region

- ***Nurseries***

For those younger than three years, the zones of Aix, Pertuis and Manosque have 1,128 crèche places and 397 day-nursery places available. In the region, a total of 24,339 places are available. The extent of the facilities is well above the national average.

- ***Kindergarten***

A satisfactory network of public nursery schools is present around Cadarache. It is possible to open supplementary classes in the concerned communes if the current accommodation facilities turn out to be insufficient.

- ***Primary and secondary schools***

Cadarache is a part of the academy of Aix-Marseille, which covers 4 departments: Bouches-du-Rhône, Alpes-de-Haute Provence, Hautes-Alpes and Vaucluse. Most of the communes have a primary school. Collective transportation is organised for those living in more rural areas.

A considerable number of establishments for secondary pupils exists in the Cadarache zone: as example 8 in Aix-en-Provence, 2 in Manosque, 2 in Pertuis, 1 in Peyrolles, 1 in Tour d'Aigues, and 1 in Riez. New schools are planned in Vinon and Sainte-Tulle.

Manosque has one general and technological secondary school and one professional school (a third general secondary school will open in 2004). Pertuis has also one general and technological school. Aix-en-Provence has a total of 5 secondary schools, professional and general and technological, including the international school in Luynes.

- ***Universities and engineer schools***

The Academy of Aix-Marseille is a great university place, with around 100,000 students, French and foreign. Higher education and high quality research with an international reputation are well established.

Six universities are located in the region; they are situated in Aix-en-Provence, Marseille, Avignon, Toulon and Nice.

Offered subjects cover all domains: sciences, law, literature and social sciences, languages, medicine, art education.

The region has highly rated engineering schools; in the nearby regions, the cities of Grenoble and Montpellier, also provide a wide selection of establishments of higher education.

5.3.4.3. Integration of pupils and foreign students

The children of families arriving from abroad must find a schooling possibility that is suited to their needs and their ages.

- ***International Secondary Schools and International Sections***

They may receive schooling either free of charge in public establishments that already exist in the national education system, or in fee-paying private establishments. All children, regardless of their nationality, can benefit from the pre-school structures, i.e. nurseries and playgroups, as well as kindergartens.

The international sections in France have been established to host foreign pupils (25 to 50 % of the total number of pupils in the section) and to facilitate their integration in the French educational system and their return to the educational system of origin. The international section give at the same time the opportunity to French pupils to learn a foreign language at a high level.

For this purpose, French and foreign teachers, often provided by the state of origin, work together. The foreign teachers provide education in their language in history, geography and literature of the country concerned, following educational programmes established in co-operation between the French and foreign educational authorities. For this reason, international sections are a good example of international educational programmes. The international sections are open to those pupils that have proven to the school that they have the proper linguistic ability as well as the required level of education.

The education given can be characterised as follows:

- *Primary education*: 3 to 6 hours of education in the language of origin;
- *Secondary education*: 4 hours per week on history-geography of which 2 in the mother language. Minimum 4 hours per week on foreign languages in the mother tongue on top of the normal hours in the mother tongue given in the section.

The sections prepare the pupils for the "collège brevet", international option and for the baccalaureate with international option.

French legislation allows the establishment of private, fee-paying school. Under certain circumstances, such establishments can enter into contract with the state, which then undertakes to pay the salaries of the teaching staff. The state inspects the classrooms and the educational programme provided to the pupils.

- ***European Schools***

The European schools are educational establishments controlled collectively by the member states of the European Union. In the countries where they have been established they enjoy the same legal status as public schools.

In the different member countries the duration of the primary and secondary education varies between 12 and 13 years. Pupils at European schools have a pre-school education for 2 years, a primary education for 5 years and secondary education for 7 years. At the end of the secondary cycle the pupils obtain a European Baccalaureate, which is recognised in all countries of the European Union as well as in a certain number of other countries. This diploma provides them with access to universities and other establishments of higher education.

Education is provided in the official languages of the parties allowing education to continue in the mother tongue. As a consequence each school has several linguistic sections. With the exception of the tuition in the native language, the programme of education is identical in every section. Next to the education in the mother tongue, general subjects are thought in one of the working languages of the community (English, French and German), promoting the integration of pupils into a European society.

It might be possible to add non-European language sections such as Japanese or Russian.

- ***Complementary Courses***

French schools can set up courses on Wednesday and/or Saturday in foreign languages for the children educated in the establishment. These classes are called "additional courses". At the request of a non-French-speaking community, the children have courses in their mother tongue. These courses concern the language and general education in the mother tongue.

The university of Provence offers, in Aix-en-Provence French as foreign language courses. The courses are aimed at foreign students who follow studies in other departments of the university. The courses are also available to foreign adults who do not follow other courses at the university. At request courses can also be provided outside the university, for instance on-site in Cadarache. The courses can be used for the foreign ITER researchers and their partners and can also be used by their children to follow their studies at Aix-Marseille in excellent conditions.

Numerous associations of volunteers, private organisations as well as public structures in secondary schools organise "French as a foreign language" classes for adults. Many possibilities for "education at distance" exist as well in France.

5.3.5. Accommodation

The region proposed to host ITER has a large and very varied housing pool, with a high level of availability due to the large number of secondary residences and the regular influx of tourists on long stays (SA.F3).

5.3.5.1. The housing market in France

The property sector in France has undergone a strong expansion since the 1990's, consolidated by economic recovery. This tendency has become more marked, with a highlight in 2000, and continues in 2001, notably thanks to favourable conditions for loans due to governmental measures.

The market for older property is most dynamic. The craze of the French for rural life in the country has allowed the property sector to grow. Encouraged by the national measures of help for the improvement of the environment, many French dash into the renovation. This allows a development of property holdings. Furthermore, economic recovery has reinstated a strong purchasing power. Therefore French build, move, and rent in a very fast way.

The market for new houses is also growing. A total of 30,000 construction sites was started in 1999.

The increase of tourism, notably from abroad, has maintained the increase in the property market. Many wish to buy in France, either a holiday home or a more permanent house.

5.3.5.2. Housing in the Cadarache region

The region has more than 2,5 million homes (1999 data). This total can be divided between main homes (75 %) and secondary homes (25 %). Most of the permanent housing is in the form of apartments (43 %) and detached houses (32 %).

In a synthetic way, the region is divided into 5 residential zones. These zones correspond to the main regional agglomerations.

Prices vary from 220 to 2,200 € per one constructed square meter.

The prices for old houses fluctuate between 230 and 600 k€), depending on size, location and maintenance state. The well-balanced market for rental accommodation offers dwellings from one-room apartments to 3 and 4 bedroom houses. Demand for luxury and large apartments remains steady.

In Aix-en-Provence for example, with a constant population growth since 1990 and with the arrival of the TGV, the property market is particularly very buoyant. The demand for new houses is steady, but is met by a sufficient number of new housing projects. With regard to smaller dwellings the market is increasing as well. The market for smaller new houses is almost non-existent, but the market for older houses has seen numerous sales. Average prices are around 180 k€.

The levels of rent in the suburbs of the large agglomerations are representative for average prices in other communes, notably those around Cadarache. However, prices vary with demand.

5.3.6. Health care

As stated by the World Health Organisation in 2000, the French health care system is one of the best in the world. In Provence, the available equipment and health care staffing levels in the region are even above the French average. The system will have no problem coping with the arrival of ITER personnel and their families (SA.F3).

5.3.6.1. The French health care system

The quality of the health system is very good in France. This capacity has just been underlined by the World Health Organization, which has just classified France as the most successful health system in the world (WHO report 2000).

The French health system is based on the "Sécurité Sociale", a government organisation, which has as objective to insure and respect solidarity amongst the insured without distinction of age, income or health.

The Social Security is financed for three quarters on the basis of employers and employees' contributions.

The current health insurance, covers more than 80 % of the working population for risks connected to disease, industrial accidents, professional diseases, incapacity, death and assures coverage of maternity expenses.

The insured benefit from an almost complete refund for health care without limitation on the number of consultations or prescriptions. However, certain care (aesthetics for example) is partially or totally charged to the insured, who can take-out additional insurances from private companies (mutual insurance).

People suffering from severe and/or long-term afflictions can be completely exempt. The refund by the Social Security is then 100 % throughout the disease or for life, according to the severity of the situation.

In France, the insured can choose his doctor and his pharmacist and is free to search for a second opinion. He can also chose freely to consult specialists as often as he wishes and he can, under certain conditions, seek hospitalisation himself.

5.3.6.2. Health care in Provence-Alpes-Côte d'Azur

The region has more than 43,000 hospital beds and places for adults in health establishments, for care of short, average and long duration. There are 2 regional hospital establishments, each including a medical research centre, and 38 classic hospital complexes. The presence of medical research centres allows the patients to benefit from the latest techniques and equipment, increasing the chances of recovery.

The region is ranked third in France in terms of medical equipment. It distinguishes itself notably in surgery, medicine, obstetrics, follow-up care and rehabilitation.

In 1999, the region had a total of 23,153 beds in medicine, surgery and obstetrics, that is 5 beds per 1,000 inhabitants. These beds are divided between 55 public and 119 private establishments, i.e. a total of 174 establishments for short-term care.

There is no shortage medical staff. The region counts 8,227 general practitioners and 8,627 specialists, i.e. a total density of 267 doctors per 100,000 inhabitants. This is higher than the national average (198 per 100,000 inhabitants).

The region has 32 public and 25 private maternities. 21 maternities have units for premature babies offering a total of 228 beds. Specialised children's hospitals are found in Marseille in Nice (269 beds).

Large medical equipment is available in the region in accordance with French national guidelines and provides all the needs for the population.

Because of the quality of care in the region, patients from outside the area (6 % of the patients in the bordering regions) come here for their health care.

5.3.6.3. Around Cadarache

The sector around Cadarache can be divided into two large "health" zones: in the south, the zone of Aix and Pertuis, covering 56 communes, and in the north, the zone of Manosque and Forcalquier (65 communes).

The zone in the south includes two public establishments (hospital complex in Aix and local hospital in Pertuis), a private establishment providing services to the public system, and six private clinics, three of which with a capacity of more than 100 beds.

In Aix, there are 348 beds in medicine, 190 in surgery and 51 in obstetrics. In Pertuis, there are 37 beds in medicine, 19 in surgery and 24 in obstetrics.

The zone in the north offers two public establishments (hospital in Manosque and local hospital in Forcalquier) and four private establishments. A total of 61 beds in medicine, 45 in surgery and 20 in obstetrics are available.

The Medical Service, present in Cadarache, also provides emergency care. On account of the good motorway network installed around the research centre, access times to the casualty wards are even shorter. The ones furthest away are in Marseille, Toulon and Nice, in which case helicopter transport is used. However, for the zone under consideration, the services of these sites are only called on to deal with extreme cases involving acute drug intoxication or requiring immediate neurosurgery for babies, children or adults. The establishments in Aix, Pertuis and Manosque deal with all other emergency cases. The community hospitals (or local hospitals) located in Valensole, Oraison and Forcalquier also deal with first-degree emergencies.

5.3.7. Art of living

Art of living in the Region Provence-Alpes-Côte d'Azur is characterised by the exceptional climate, the extraordinary variety of landscapes, the wealth of culture, the cheerfulness of its inhabitants and their love of the outdoor life. This region offers a very high quality of life, known all around the world.

Its traditions and history make the region a very welcoming area where everybody finds one or several reasons to settle down for a little while or for life (SA.F3).

5.3.7.1. The country

Provence and the Mediterranean coast (the famous "Côte d'Azur") are always perceived as the country of sun and blue sky. The exceptional period of sunshine (on average 2,500 hours a year) shines from the Mediterranean in the south to the mountain climates in the north.

The climate is one of the foundations of the quality of life in the region because it allows the practice of many different activities, every season offering its palette of opportunities.

The region Provence-Alpes-Côte d'Azur offers very varied and contrasting landscapes from the sea to the mountain through hilly landscapes with large forests and lavender. Going through the region, one discovers a variety of sites such as Montagne Sainte-Victoire, the massif of the Luberon, the Porquerolles islands, Embiez and Port Cros.

The exceptional light in the region brings out the colours inspiring artists and painters in particular.

Natural species, whether animals or plants, in many cases unique, have found favourable conditions for their development. The natural zones of ecological interest for their fauna and flora cover more than a million hectares. They form the habitat for more than 230 protected species and more than 400 animal species.

National and regional parks allow the protection of landscapes, sites and species in the region. The region contains three national parks and four regional parks.



This region has learned how to provide, in harmonious way coexistence between traditional, tourist human activities and environmental protection.

The animal parks offer visitors the chance to have surprising encounters with caimans at a crocodile farm, marine animals, seals and dolphins at Marineland, land tortoises in the village of turtles and animals from all over the planet in the region's many zoos.

The gardens in the region offer innumerable possibilities of beautiful walks and discoveries: French and Italian formal gardens in castle grounds, exotic and Mediterranean gardens by the seaside, aromatic gardens, oriental gardens and bamboo plantations, as well as arboretums and orange groves.

Numerous amusement parks and theme parks offer joy to young and old alike.

5.3.7.2. Tradition and culture

History has left its mark on the region, dating back to pre-historic times. Numerous Greek and Roman archaeological sites can be found. A multitude of monuments, abbeys and castles give evidence of the varied and rich history of the region.

The historic hearts of cities like Aix-en-Provence and Manosque as well as most of the villages remind people of the wealth of Provencal history. The "Palais des Papes" in Avignon still bears witness to the stay of the Popes in the 14th century. The history of the Port of Marseille always been connected to discoveries, trade, and large projects such as the opening of the Suez Canal.

Culture and traditions are today the evidence of this rich history.

Provencal tradition and its language, still practiced today, show the deep love the inhabitants have for their roots.

The harbour of Marseille, nicknamed "Gateway to the East", has seen the arrival of many different cultures. This has fed a melting pot of populations providing a unique integrated culture today.

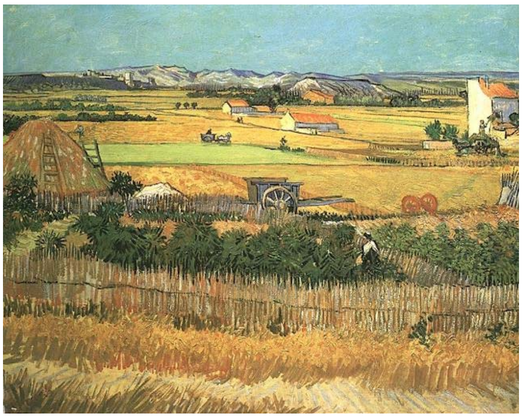
From the Rhone, where Spanish customs took root, to the borders in the east influenced by Italian customs, the region is fed from the sea with African, Asiatic and Arabic influences.

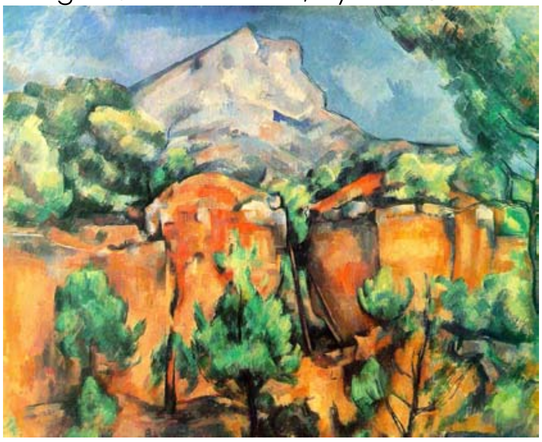
The wealth of history, cultures and traditions also expressed itself through artists of all the times.

The region Provence-Alpes-Côte d'Azur has numerous museums that show its traditions, its culture and its history. There is also an exceptional cultural, musical and choreographic development with many festivals organised throughout the year (let us list the three most prestigious of them: "festival de Cannes", "festival d'art lyrique" at Aix-en-Provence, and "theatre festival" in Avignon).

Literature is present in the libraries and media libraries of the region. Aix-en-Provence has a special "town of the book" distinction. One can find works from all countries, all authors and in foreign languages. International bookshops are also available.

The landscapes have seduced numerous painters who have tried to capture the unique light and colours of the region.


Moisson, by Vincent Van Gogh

Montagne Sainte-Victoire, by Paul Cézanne


Finally, the region is known worldwide for its high quality festivals. Numerous cities and villages from the smallest to the largest show their taste for art in this way.

5.3.7.3. The people

Leisure activities of the people in the region are organised by many associations: sport, entertainment, creative, cultural, humanitarian and social activities. One finds musical associations with choirs and amateur musician groups, as well as artistic associations that offer drawing, painting pottery and classes. Environment, preservation of the countryside, heritage and international exchanges are also represented in the associative life, as well as associations that help the most deprived. In the numerous associations present in the region's cities and villages one can pursue photography, riding, cycling, touring and dozens of other activities.

Variety, cultures, traditions, all senses of identity are reflected in the Provencal kitchen, in its colours, smells and flavours of the territory. It makes abundant use of the natural resources of the region.

Wine is obviously very present in the Provencal cuisine with 9 "appellations contrôlées".

The numerous restaurants in the region do not offer only the traditional Provencal cuisine. The Mediterranean delicacies, as well as other French regional ones, are represented, without forgetting flavours from around the world. All five continents are represented.

5.3.7.4. Sport and leisure activities

The sports opportunities on offer in the region are important and varied.

From the high mountains to the sea, in the air and in the water, all possibilities are offered to all people. Recently, one has seen a multiplication of the sites of mountain climbing and paragliding.

New activities have also been established over the last years: rafting on the alpine torrents and "canyoning" in the calcareous rock formations.

Training in sports professions is very developed. More and more qualified personnel offer therefore proper guidance in all sports.

Many of the rivers and lakes, as well as the sea offer numerous sporting opportunities and nautical activities during most of the year.

Ports, islands and creeks are destinations that can be rediscovered over and over again.

Numerous mountain stations offer during the summer gliding, paragliding, hang gliding and other mountain related activities. During the winter there is a large choice of ski stations both for cross-country and downhill.

Cities and villages alike offer to their inhabitants sports facilities such as swimming pools and stadiums.

It is therefore understandable that the region is one of the most popular tourist destinations in the world, however it is still possible to find a quiet spot as well.

The region around Cadarache opens great perspectives in the development of the most different activities: cultural, tourist, sports of all kinds.

Accommodation facilities are plentiful and available in the form of hotels, hostels, campsites, bed & breakfast rooms and rural shelters, where the traveller can get acquainted with the wealth of the region along many varied routes.

5.3.8. Conclusions

This chapter has shown that the socio-economic environment of Cadarache, the European site proposed for ITER, is particularly rich. Scientific and industrial resources are widely available, and the region provides also a rich variety of schools, medical care, housing, leisure and cultural activities. The infrastructure, with existing roads, motorways, trains and airports, fulfils all possible needs. There is a constant investment in the region to improve the already high quality of life for its inhabitants.

Local and governmental authorities, as well as local organisations and associations, by their constant implication in this project have shown a great interest for the implementation of ITER at Cadarache. In particular, the region will organise at Saint-Paul-lez-Durance a specific welcome office for ITER employees, in order to facilitate their life and integration.

Furthermore, and this is not to be forgotten, it is a region where it is good to live, with a particularly pleasant and renowned climate. The famous “Côte d’Azur” and the Provencal country behind it, attract many tourists every year.

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6. Schedule for ITER construction at Cadarache

A detailed evaluation of the Cadarache features, compared to the ITER generic site and ITER JCT recommendations is ongoing.

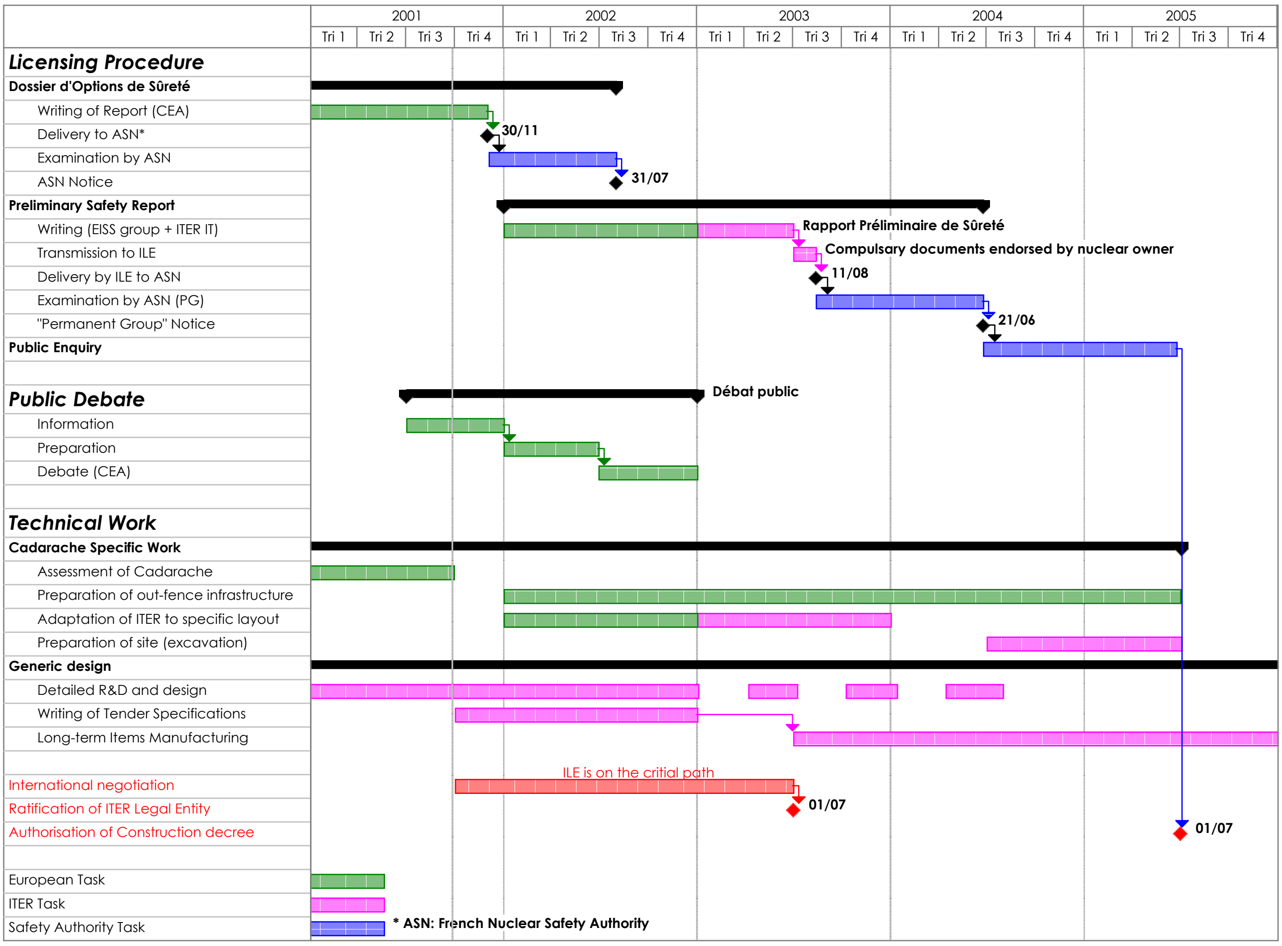

Figure 6.1: Short Term Schedule

Assuming that the ILE will be established in the first half of 2003, the construction planning will be determined by the sequence of the **licensing process**. Provided work is actively progressing in all aspects (detailed design, licensing process, tender actions for time critical components) the official authorisation to start construction could be given in 2005. The site preparation and the procurement of long lead-time items could start in 2004. The planning given in Figure 6.1 summarizes the necessary steps to obtain all authorisations.

A **public debate** should be presumably organised in the second half of next year (2002) and it is necessary to start an information and preparation phase in 2001.

7. Conclusions

The two tables below summarise ITER site requirements and assumptions (see their detailed description in chapter 2.5), with the situation of Cadarache. The corresponding chapter of the present document where information is detailed is indicated for each item.

7.1. ITER site requirements and design assumptions

7.1.1. Requirements

	ITER Generic site	Cadarache
A. Land		
[SR.A1]	Land area: 40 hectares available for at least 30 years	180 ha are available on the selected site Chapter 3.2
[SR.A2]	Geotechnical: 25 t/m² for buildings, 65 t/m² to 25 m for Tokamak building	Requirements satisfied Chapter 3.2 Note 1
[SR.A3]	Water supply: 0.2 m^3/minute average, 3 m^3/minute peak, daily average 200 m^3	Requirements will be satisfied Chapter 3.4 Note 2
[SR.A4]	Sanitary waste 1000 people, industrial waste 200 m^3/day	Requirements will be satisfied Chapter 3.2 & 3.4 Note 2
B Heat Sink		
[SR.B]	Average 450 MW (thermal) energy to environment	Requirements satisfied Chapter 3.4
C Energy & Electrical Power		
[SR.C]	120 MW continuous electrical power, 2 connections to be provided to site, no interruptions due to maintenance	Requirements will be satisfied Chapter 3.5
D Transport & Shipping		
[SR.D1]	Maximum size of components: width 9 m, height 8 m, length 15 m	Requirements satisfied Chapter 3.6
[SR.D2]	Maximum weight: 12 packages of maximum 600 t, 100 packages over 100 t	Requirements satisfied Chapter 3.6
G Regulatory & Decommissioning		
[SR.G]	Depending on host country, practicable licensing frame work has to exist to permit ITER to be build and operated, off-site matters: tritium transport, storage activated	Requirements satisfied Chapter 4.14.2

	material	

7.1.2. Assumptions

	ITER Generic site	Cadarache
A Land		
[SA.A1]	Land area: additional 30 ha, close to site	140 ha (SR.A1: 180-40) available Chapter 3.2
[SA.A2]	Topography: maximum elevation change less than ±10 m	Assumption met Chapter 3.2 Note 3
[SA.A3]	Geotechnical: No hard rock removal (possible exception tokamak building 25 m)	Assumption met Chapter 3.2 Note 4
[SA.A4]	Hydrological: groundwater 10 m below nominal, since tokamak embedment is 25 m, engineered ground water control necessary	Assumption met Chapter 3.2
[SA.A5]	Seismic characteristics: see chapter 2.5.4 for details	Cadarache site very similar to generic site assumptions Chapter 3.3 Note 5
[SA.A6]	Meteorological characteristics: see chapter 2.5.4 for details	Assumption met Chapter 3.2.1 Notes 6 & 7
B Water supply and industrial sewage for heat rejection system		
[SA.B]	Total fresh water requirement: 16 m^3/minute (average) No pulsing: 5 m^3/minute Industrial sewage: 3000 m^3/day	Assumption will be met Chapter 3.4 Note 2
C Energy and Electrical power		
[SA.C1]	Electrical power reliability during operation Single phase faults: a few tens/year 80% t<1 s a few/year 20% 1 s<t<5 min Three phase faults: a few/year	Assumption met Chapter 3.5
[SA.C2]	ITER Plant pulsed electrical supply: see chapter 2.5.4 for details	Assumption met Chapter 3.5 Note 8

D Transport and shipping		
[SA.D1]	Highway transport: ITER site accessible by major highway connecting to major ports of entry and centres of commerce	Motorways and national roads Chapter 5.3.1
[SA.D2]	Air transport: ITER site located within reasonable commuting time from airport with connections to international air service	Less than 1 hour to international airport (2 hrs to 2nd int. airport) Chapter 5.3.1
[SA.D3]	Rail and waterway transport: ITER site will have rail and waterway access. Railway is assumed to connect to major manufacturing centres and ports of entry.	Available Chapter 3.6 & 5.3.1
E External hazards and accident initiators		
[SA.E1]	External hazards: ITER site not subject to significant industrial and other man-made hazards	Assumption met Chapter 4.2.2
[SA.E2]	External (natural) accident initiators: see chapter 2.5.4 for details	Assumption met Chapter 4.2.2
F Infrastructure		
[SA.F1]	Industrial: access to industrial infrastructure, manufacturing resources and materials, see chapter 2.5.4 for details	Assumption met Chapter 5.3
[SA.F2]	Workforce: competent operating and scientific workforce can be recruited or can be relocated to neighbouring communities	Assumption met Chapter 5.3
[SA.F3]	Socio-economic infrastructure: communities not further than 50 km from site with socio-economic infrastructure, see chapter 2.5.4 for details	Assumption met Chapter 5.3
G Regulatory and decommissioning		
[SA.G1]	General decommissioning: Dismantling of ITER responsibility of new organisation within host country	Wide experience available Chapter 0
[SA.G2]	ITER plant deactivation work: see chapter 2.5.4 for details	Existing capabilities adequate Chapter 0
H Construction Phase		
[SA.H]	Water, sewage and power supplies for construction force of up to 3000 people	Assumption will be met Chapter 3.2 Note 2

Notes and comments:

1. A geotechnical study is currently underway for the selected site. The site could be moved by some tens of meters to optimise the location in view of the results of these studies. The soil characteristics will be known and used for further design of the building foundations.

2. Although these site requirements and design assumptions are not satisfied at the moment since they serve no purpose, the solutions will be easy to implement once needed.

3. Since the natural ground is hilly buildings are implemented on three different platforms to reduce the overall excavation. Nevertheless, the nuclear buildings will have their foundations on limestone. Platform 1 (306 m) control room, pumping station, site services building and emergency power supply; platform 2 (320 m) cooling towers; platform 3 (310 m) all other buildings.

4. The topsoil is partially alluvia. The site will be prepared with the creation of three platforms (see note 3).

5. The French Safety Regulations require taking into account the actual seismic conditions at Cadarache, which are slightly higher than those taken for the generic site. The impact is rather minimal and the induced extra cost will be reasonable.

6. The maximum air temperature has been 40.1°C over 40 years. This has a minor impact on the design of the cooling towers.

7. The maximum relative humidity is 100% in Cadarache. This has no significant impact since this humidity only occurs during limited periods when the temperature is low.

8. Due to the fact that the Cadarache site is located far from the electrical power stations, an additional voltage drop will need to be installed. The associated extra costs will be small.

7.2. Conclusion of the first phase of studies

In conclusion, Cadarache fulfils all ITER site requirements.

Most of ITER generic design assumptions are already fulfilled, and when differences exist, an evaluation of the additional work has been made. The resulting site-specific cost for the construction phase, inside and outside the fence, is low (less than 3 % of ITER investment cost).

Cadarache appears to be remarkably suited to host ITER: the site has considerable experience in dealing with nuclear installations and hosts broad expertise on magnetic fusion research.