EFDA

EUROPEAN FUSION DEVELOPMENT AGREEMENT

Cadarache
as a
European Site for ITER

Report on the Technical and Socio-economic Aspects

27 September 2001

Photographic credit: CEA, Wallis

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.

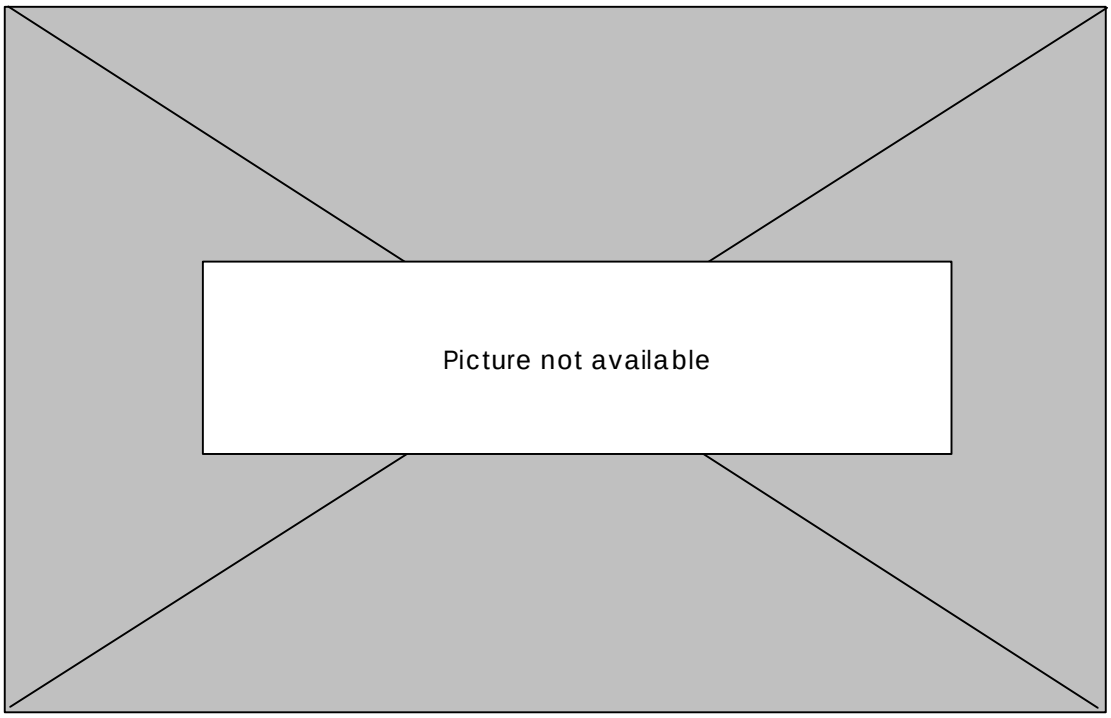


Figure 1.1: ITER location on the Cadarache site

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.

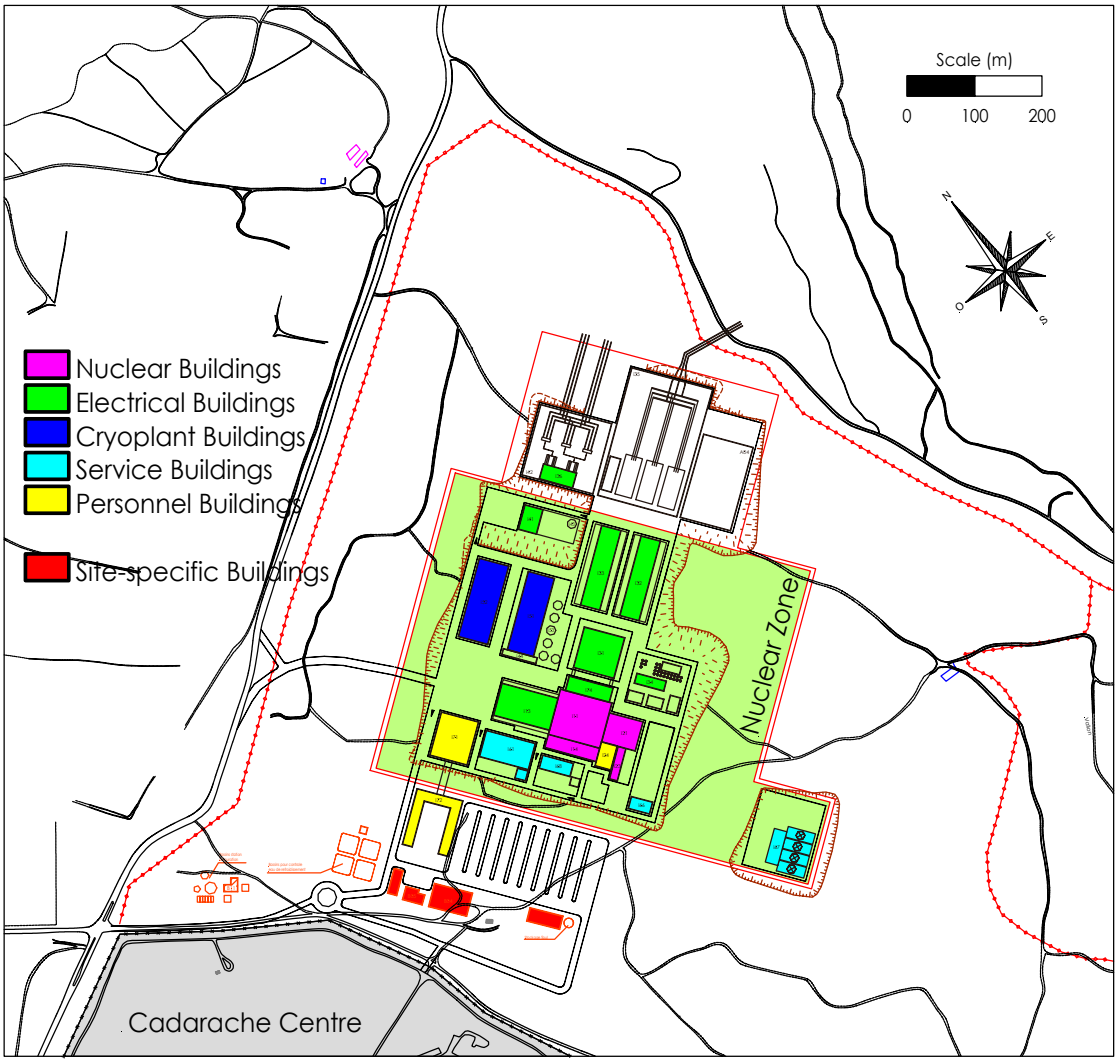


Figure 1.2: Detailed layout of the buildings

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.

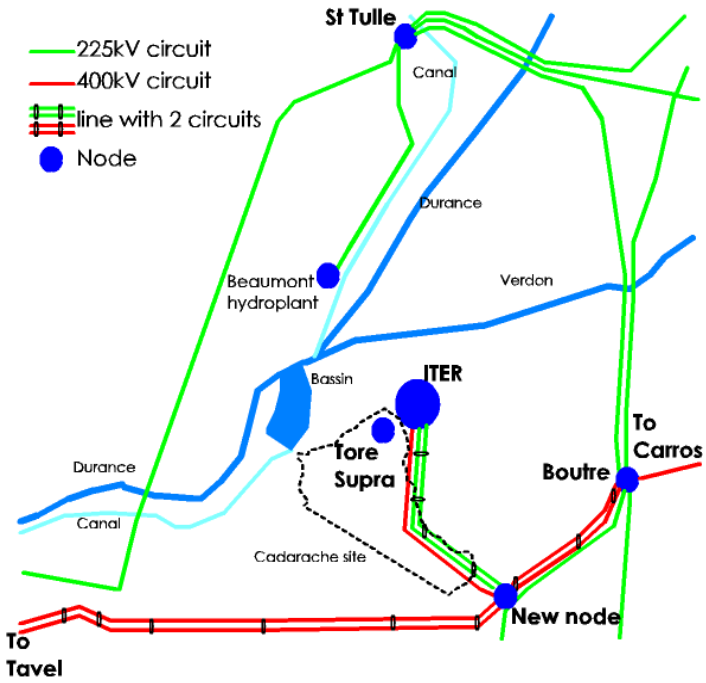


Figure 1.4: Proposed ITER High Voltage Supply Scheme

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 exceptionnnel[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.

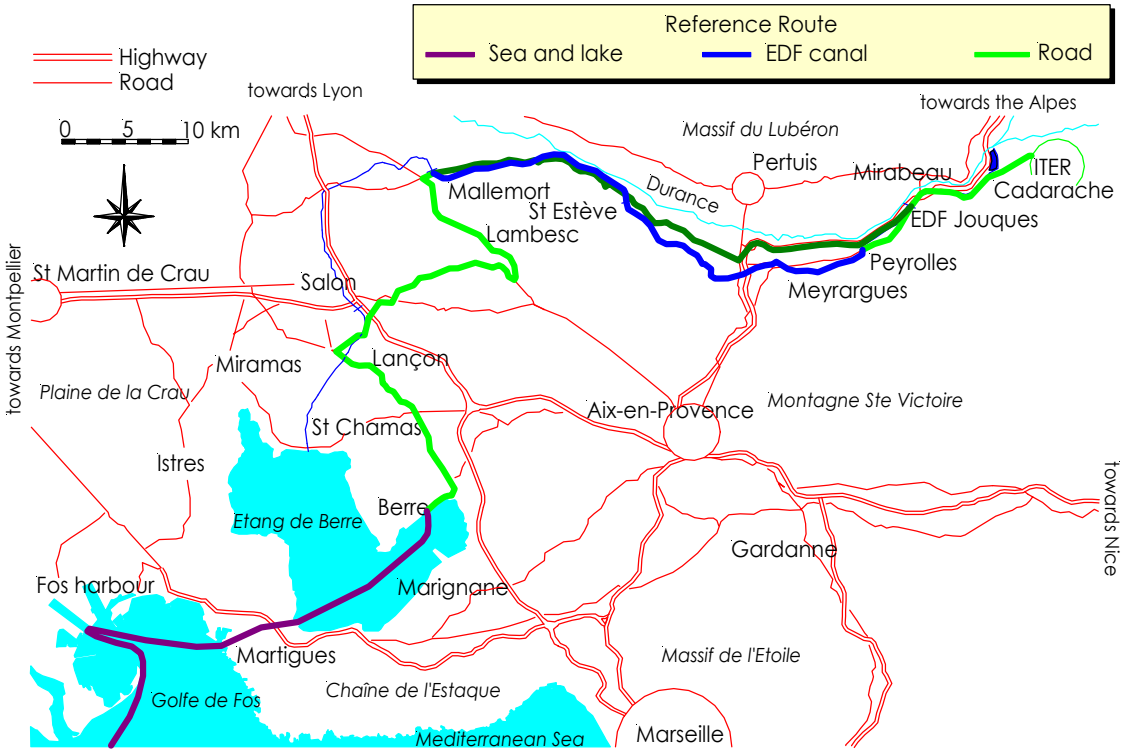


Figure 1.5: Reference routes (by road only, or combination of road and canal), from Fos harbour to Cadarache

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.

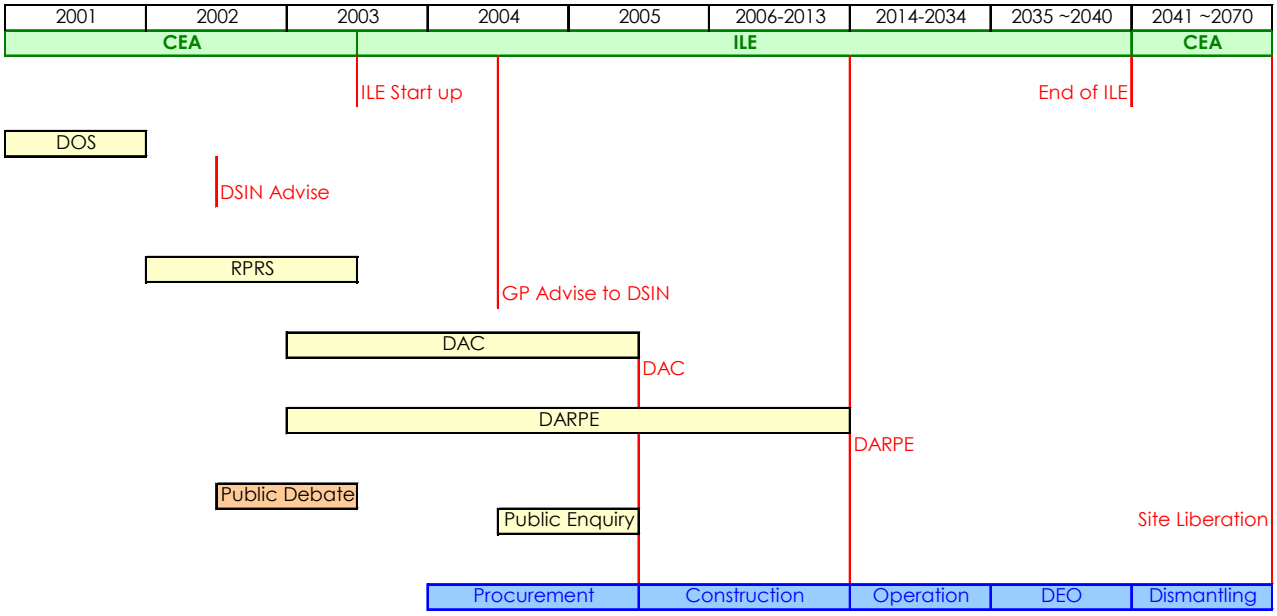
3.1 Licensing procedure

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.

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