

7 Resources

7.1	Resources Required for ITER Construction	2
7.1.1	Cost Estimating Approach for ITER Construction	2
7.1.2	Basic Data — Procurement Packages for Cost Estimation	2
7.1.3	Evaluation of Cost Estimates	3
7.1.4	Conclusions on the Approach to the ITER Construction Cost	8
7.1.5	Cost Estimates Summary	8
7.1.5.1	Component/system “Evaluated Cost Estimate”	8
7.1.5.2	Siting and Construction Costs	9
7.1.5.3	Procurement Scheme	9
7.1.5.3.1	Heating and Current Drive Systems	10
7.1.5.3.2	Diagnostic System	11
7.1.5.4	ITER Direct Capital Cost	12
7.1.6	Construction Management and Engineering Support	12
7.1.6.1	Assumptions	13
7.1.6.2	Estimated Personnel Cost during Construction	13
7.1.6.3	Possible R&D Cost during Construction	14
7.1.7	Cash Flow for the Direct Capital Cost	14
7.1.7.1	Payment Schemes for each Procurement	15
7.1.7.2	Cash Flow	15
7.2	Resources for ITER Operation	17
7.2.1	Project Manpower Costs	17
7.2.2	Energy Costs	17
7.2.3	Fuel Costs	18
7.2.4	Capital Improvement, Spare Parts, Maintenance Costs	18
7.2.5	Conclusion: Average Annual Operation Costs	19
7.3	ITER Decommissioning Costs	19
7.4	Summary	19

Article 2 of the ITER EDA Agreement states, inter alia, that the Parties shall conduct jointly the following EDA:

- "(a) to establish the engineering design of ITER including
 - (iii) a planning schedule for various stages of supply, construction assembly, tests, and commissioning of ITER together with a corresponding plan for human and financial resources requirements;
- (c) to establish both the proposed program and the cost, manpower and schedule estimates for the operation, exploitation and decommissioning of ITER."

This report addresses the estimated human and financial resources requirements for the construction of ITER (Part I) and for its subsequent operations including integrated commissioning and exploitation (Part 2) and decommissioning (Part 3). The estimates follow from and are consistent with the plans for construction, operation and decommissioning as set out in "ITER Construction and Commissioning Plan" (Chapter 6).

7.1 Resources Required for ITER Construction

7.1.1 Cost Estimating Approach for ITER Construction

The approach to cost estimating for the construction of ITER is based on the presumption that ITER will be constructed as an international joint project in which the participants' (Parties') contributions will mainly be specific systems or components contributed directly to the project ("in kind").

The main objective of ITER cost estimates is to provide a realistic and sufficient basis for ITER Parties to make their decisions on the scope of their involvement and to select the desirable systems for them to manufacture. The estimates have been developed from the engineering designs following a "bottom-up" approach which emphasises physical estimates (such as labour hours, material quantities, physical processes, etc.) so as to ensure that the data are comprehensive and coherent and provide a basis for evaluating results from different Parties.

In considering the ITER cost estimate, it is important to recognize that:

- economic conditions in the Parties vary widely over time and these changes are not necessarily or adequately reflected in relative monetary exchange rates;
- domestic industrial practices, contracting policies and labour costs for manufacturing prototypes depend on Parties and are not reflected in relative currency exchanges (only valid for goods for which a worldwide market exists);
- the overall ITER management approach and specific procurement and contracting practices have not been determined and the host party has not been selected;
- the aggregate costs that will be incurred in constructing ITER will depend greatly on how the responsibilities for specific components are distributed between the different participants, and on the procurement policies pursued by each.

Given these uncertainties, the approach adopted focuses on establishing an "evaluated cost estimate" which normalizes the industry estimates from the Parties. The full scope of ITER is cost using itemized material and component pricing. This approach provides for consistent comparison of estimates. Manufacturing/installation costs are arrived at from estimated industry productivity and typical labour costs within the Parties' industries.

This approach allows the Parties, jointly, to appreciate the full cost of ITER and the relative contributions that each might make to building ITER and, individually, to estimate from underlying physical data the absolute costs (in their own currency) that each might expect to incur in providing a given overall percentage contribution.

7.1.2 Basic Data — Procurement Packages for Cost Estimation

In order to elicit the basic data for ITER cost estimates, about 85 "procurement packages" have been developed for the elements of the project work break down structure (WBS), each defined at a level consistent with a plausible procurement contract. Each package comprises comprehensive information, including the functional requirements, detailed designs, specifications, interfaces and other relevant data that would be needed by potential suppliers

in order to prepare for contract quotations, e.g. the proposed split of responsibilities between supplier and customer and the necessary QA arrangements.

In some areas the packages provide for the possibility of splitting contracts between several suppliers in case more than one Party might wish to participate in a specific area. In some others, this splitting between suppliers in more than one Party is necessary in order to produce the volume required because of the limited capacity of each supplier (e.g. superconductor strand, shield/blanket modules, divertor targets).

The main categories of procurement type referred to in the procurement packages are defined below. The distribution of responsibility between supplier and customer (and hence the engineering resources required) vary significantly by procurement type; this is reflected in the cost estimates.

- A. "Build-to-print": The design is fully specified and the performance responsibility lies with ITER. Suppliers use the design exactly as it is provided to develop fabrication/shop drawings. Suppliers can request changes to the design, if necessary during fabrication, but those changes have to be analysed, and approved by ITER.
- B. "Detailed design": ITER specifies a design that a supplier must follow. ITER is responsible for the analyses leading to the main design. From this design, the supplier develops a detailed design to be approved by ITER prior to manufacture. Shop drawings are then generated from that detailed design. Analysis to verify adequacy of the detailed design are performed by the supplier. The supplier is responsible for those analyses, and therefore shares performance responsibility with ITER.
- C. "Functional specifications": ITER provides functional specifications and accompanying explanatory drawings. The design and performance responsibility lie with the supplier.

Industrial companies or large laboratories with relevant experience were invited, through the Home Teams, to generate, from the procurement packages, their best estimates of the likely current costs of supply, assuming that all data necessary to support procurement would be available on schedule. To allow review and comparative evaluation of the estimates, the participants were requested to provide detailed supporting data and detailed descriptions of the potential deliverables and processes, in the format of standard ITER Cost Estimation Workbooks.

The information thus generated offers a comprehensive database for cost analysis, comparison and evaluation.

However, the cost estimates provided by each Party are not intended to be the lowest values which could be obtained in this Party, keeping the same technical specifications, since they were not the result of competitive estimation and tendering.

7.1.3 Evaluation of Cost Estimates

The JCT has analysed the results of the procurement package studies in consultation with Home Teams concerned, with the objective of deriving "evaluated estimates" which distill

the database to a consistent set of project cost estimates. The main steps in this process for each package are:

- (1) expression of input data in common terms;
- (2) comparison and reconciliation of estimates from different Parties;
- (3) “evaluated cost estimate” by JCT;

The final result is a complete set of “evaluated cost estimates” for building ITER, expressed in IUA, which is robust to currency fluctuations and domestic escalation rates and which can be used by the Parties jointly and individually in reviewing their options and the possible budgetary effects of participating in ITER construction [1 IUA = \$ 1000 (Jan 1989 value)].

(1) Expression in common terms

Data expressed in terms of physical quantities can be readily compared directly, after confirming the definition of the terms. Data expressed in money values needs to be converted into common terms for the purposes of comparison and analysis.

Financial data have first been converted from current costs to the established reference date for ITER cost estimates of Jan 1989, using standard inflation factors for each Party. Where basic data for estimates from the EU were expressed in one of the European national currencies, the figures were first converted to Euro using the established fixed exchange rates and then converted through the Euro (ECU) inflation factors to Jan 1989 values. Because of the shortage of reliable price indices for the RF, basic data in 2000 roubles were converted to US dollars at current exchange rates and then converted to Jan 1989 dollars using, arbitrarily, the inflation factors for the US. The deflated figures were then converted to IUA using the prevailing exchange rates at Jan 1989. Table 7.1 shows the exchange rates and deflation factors used.

This methodology has already been applied for the ITER 1998 design cost estimates.

It is not assumed that the 1989 exchange rates between currencies is better than those at any other date. Even, exchange rates between two currencies and inflation rates in their two countries do not sometimes vary in a coherent way (examples are Canadian and US Dollars, British Pound and Euro).

Nevertheless, looking backwards in time, using this approach the Parties have their own appreciation of these old rates and can apply at once the correction factor they feel appropriate (because of labour cost, industrial practices or any other reason) to quantify directly their potential contribution in their current money.

Moreover, a constant reference unit is the most appropriate tool to cost a project which extends in time over many decades in an international framework.

Table 7.1.3-1 Conversion Rates from National Currencies and IUA

Currency	Conv. Rates to US\$ 2000 (for comparison only)	Conversion Rates to Euro (Fixed)	Conversion Rates to US\$, (January 1989)	Escalation Factors for Reference Years					Conversion Factor 2000 to IUA (x 10 ⁻³)
				1989	1997	1998	1999*	2000*	
US \$	1.000		1.000	1.00	1.32	1.35	1.37	1.39	1.392
Can \$	1.507		1.207	1.00	1.21	1.22	1.24	1.25	1.509
Euro	1.036	1.0000	0.876	1.00	1.37	1.41	1.44	1.46	1.279
DM		1.9558							
FF		6.5596							
Lira		1936.3							
UK Pound	0.634		0.585	1.00	1.42	1.47	1.51	1.55	0.906
Yen	107		128	1.00	1.13	1.14	1.15	1.16	0.148
Rouble	28.34		39.45	1.00	1.00	1.00	1.00	1.00	39.45

Note: * Extrapolated data

References [1] : International Financial Statistics Yearbook, International Monetary Fund, 1999, [2] : Eurostat Yearbook, Edition 98/99.

(2) Comparison and reconciliation of estimates

In consultation with the Home Teams concerned, the data were subjected to detailed analysis and comparison to check for consistency and completeness and, as far as possible, to identify and eliminate anomalies.

A distinct advantage of the ITER Project is the ability to obtain multiple estimates from industries in the different Parties. These multiple estimates were evaluated in detail and compared to identify missing items, possible misunderstandings, and opportunities from design or process improvements to achieve cost reductions. When possible, the estimates were discussed with industrial staff concerned to gain a thorough understanding of cost considerations. In some cases, industries suggested changes to reduce costs; these were considered and, where feasible, the cost saving changes were made.

(3) Evaluated cost estimate by the JCT

In order to emphasise the relative costs of the different systems/components, the following method has been used to derive from the basic data a JCT cost estimate, consistent across the whole ITER plant:

- world market prices have been used where they exist, for instance for standard materials or items of equipment;
- unified standard labour costs have been established which reflect (see Table 7.2):
 - rates in IUA/khour established for the main categories of labour, averaged across skill levels and Parties;
 - the different levels of manufacturing support costs, including facility, equipment, overhead and profit, for different types of industrial works and

working conditions (e.g. staff in their existing home facilities, on site, or in a facility charged as an itemised cost).

After analysis of the proposals from the different Parties for amounts of tooling, material quantities and labour hours to manufacture each identified item, the JCT has established its own assessed numbers for these cost driving elements and, using the above-mentioned lists of standard materials prices and labour costs, has derived an “evaluated cost estimate” for each identified item.

Summing all items per procurement package, the JCT provides through this methodology a normalised cost for each package, the most credible given the present uncertainties on ITER construction management and procurement. For reasons described above, when applying to each package the conversion factor from IUA to the present value of currency in one Party, the result should not be expected to match the cost incurred by this Party to provide the given component.

Table 7.1.3-2 ITER Labour Rates

The cost estimates prepared for the EDA Final Design Report include a number of parameters which need to be normalised. A large table was established to provide a set of labour rates for both field construction and shop manufacturing operations. These rates were used for all estimates for both home and field manufacturing operations as well as site installations. Established in IUA /khours, these rates are assumed constant in time (which means that, converted in any Party's currency, they will follow the inflation rate of that Party).

Labour costs are composed of labour wage rates and support costs:

- *The Labour Wage rates are the Hourly Wages each worker earns plus fringe benefit packages including employer's contribution to taxes, health benefits, vacation benefits if any, and related employer-paid labour cost items.*
- *Support costs, also presented as an hourly rate, include the cost of use of the manufacturing facility and equipments, ship supervision, management, consumables, other overheads, and profit.*

For some commodities, such as for the TF or PF coils, in which Facilities, Special Tooling and Equipment are estimated separately, the support costs have been decreased accordingly. For those items to be fabricated on site (in the same Country as Home), it is assumed that the support costs will be the same as at Home, but that a premium (0.005 IUA) is added to the hourly wage.

The Wage Rates were determined by using an average of wage rate cost data from the U.S. ("R.S. Means, 30 City Average, January 1997"), Japan ("Chingin Jijyo", Factory labour direct cost and "Seskisan Shiryo", construction labour rate), and EU (Eurostat). All rates include 5% casual overtime. Manufacturing labour cost is based on a composite of Highly Skilled, Skilled, and Semi-Skilled Labour. Site Installation Labour is based on a composite of Craft Labour.

From these values of 1997 using conversion factors to IUA (according to inflation rate in each Party), one can note that in average:

- *the normalised labour wages are 20% above the European values and 20% below the Japanese ones;*
- *the normalised support cost per hour is equal to the European value and 10% below the Japanese one; it amounts to a value between about 2 (for welding) and 3 (for machining) times the normalised labour wage, and only about 1.25 (for welding) and 1.80 (for machining) if the special equipment is estimated separately.*

A few global values for Labour rates are mostly used in the ITER "estimated cost" (in IUA/khour):

- *for Engineering, a mix of professional designers (90), professional engineers (67), CAD and procurement technicians (38), in average 67-73,*
- *for machining including full support (67) or limited support (48),*
- *for welding including full support (55) or limited support (40),*
- *for QA and testing, (45),*
- *for assembly/installation, (35 to 45, depending on the amount of professional support).*
-

For civil work, the costing is done through the use of a table of commodity rates for all activities referred to the "unit measurement" of the quantity of the commodity used (m³, m², t, etc.). They include material and labour amounts as well as specific support per unit.

7.1.4 Conclusions on the Approach to the ITER Construction Cost

The approach to develop a JCT evaluated cost estimate for ITER construction, expressed in IUA tries, to the extent possible, to remove variations in costs that are due to differences in estimating practices by the different Parties, and to exchange rate fluctuations. This means that although ITER costs for each item reflect the same “value” in two Parties, they will not, when expressed in these Parties’ currencies, necessarily correspond to each other through exchange rates at any date.

The approach provides fair and consistent relative costs for the different ITER systems and components. The Parties can, jointly, appreciate in advance the relative contributions (in percentage) that each might make to building ITER and, individually, estimate from the underlying physical data the absolute costs (in their own currency) that each might expect to incur in providing specific components, inside their contribution “in kind”, by applying their own appropriate conversion factor to IUA.

This detailed “evaluated cost estimate” aids the “design to cost” and, later, the “manufacture to cost” approaches by which design/process changes are made to maintain costs within the budgeted amount because itemized quantities and manufacturing man-hours are clearly defined.

7.1.5 Cost Estimates Summary

7.1.5.1 Component/system “Evaluated Cost Estimate”

The evaluated cost estimates for ITER construction in kIUA, summarised by procurement packages, are presented in the Table "ITER Cost Estimate Summary". A much larger "Business Confidential" document provides for each procurement package the JCT detailed evaluation. The table also indicates, for each package, which of the Parties provided data, what is its direct capital cost, its percentage of the total capital investment, the cost of spares and of deferred items to be supported by operation funds, and their comparison with the relevant numbers for the ITER 1998 design.

For a few items (and a small total cost \simeq 30 kIUA) no detailed cost estimate is yet possible following the described method, because their design has not yet reached the level of detail needed to make a cost estimate “bottom up”. They are included in a cost element defined as “allowance for indeterminates (AFI)” and part of the deferred investment. The costs of transportation, being unknowable, are also excluded from the estimates, but each procurement package includes the cost of packaging for transoceanic crossing and transport to the closest port of embarkation (Free On Board - FOB).

As recognised by Experts from the four Parties, who have reviewed the details of the component/systems costing which support these estimates, they are not intended to be the lowest values which could be obtained, keeping the same technical specifications, since they were not the result of competitive estimation and tendering within each Party.

Globally for ITER construction they represent the most credible cost estimates, given the present uncertainties on ITER Construction Management, Siting and Cost sharing: a global value inside which one can be confident to be able to build ITER.

In addition, there is room to achieve substantial savings in some areas already identified, and more might be found through the needed and expected industry feedback on design to optimise manufacturing processes.

7.1.5.2 Siting and Construction Costs

The present ITER design, and its “evaluated cost estimate”, follows the “ITER Site Requirements and Site Design Assumptions”, which have been approved by the ITER Council¹. Site specific adaptations of the design may induce changes in the cost of some systems; they will be analysed during the Coordinated Technical Activities (CTA), when potential sites are characterised.

Similarly, the present design is consistent with codes, and standards which have been defined *-inside the project. These rules are coherent but are not identical to those of any specific Party, even if they do not contradict them. Regulatory bodies from potential host country may request application of different and specific design rules or quality assurance measures. This can induce cost variations to be analysed again during the CTA.

The “ITER Site Requirements and Site Design Assumptions” describe a list of Host responsibilities, for which the project bears no cost, and which include in summary:

- infrastructure for industrial support of ITER and socio-economic provisions,
- land for the ITER site,
- high quality (potable), and raw water, treatment for sanitary and industrial sewage,
- supply to steady state electrical power network and a tie line capable of large pulse power for magnet and plasma heating,
- off site fire protection equipment and personnel,
- receipt of waste of all types, generated from ITER operation and decommissioning

7.1.5.3 Procurement Scheme

Each procurement package relies on a single dominant technology, and therefore mainly leads to a single industrial contract and avoids the need for a large amount of subcontracts. On the other hand, the possibility of sharing the work to be done for a package between more than one industry was always considered, even if this splitting leads to an increase in cost. This method provides for the ITER Parties the possibility, if they wish, to contribute in all fusion specific technologies. For example, the following list offers a possible splitting of procurement orders:

- the Nb₃Sn and NbTi conductors (355 kIUA in total) should be provided by contributions from all Parties; even more, industries in the Parties should be encouraged to prepare for a larger production capability, in particular in Russia for niobium of the required quality;
- two suppliers are proposed to share equally the manufacturing of the TF coils windings (117 kIUA in total);

¹ PDS Chapter 4

- one or two equal suppliers for the procurement of TF coil mechanical structures (168 kIUA in total).

In these cases, it is thought appropriate that one contractor will have the responsibility to develop the design for the special toolings, which will be duplicated for use by the second contractor. The two sets of tools are anyway necessary to meet an acceptable manufacturing schedule. Therefore, this sharing possibility between two Parties' industries leads to only a small increase of cost due to a small loss of labour efficiency.

- one manufacturer for the central solenoid (31 kIUA),
- one manufacturer for the PF coils, (50 kIUA), assumed to work on the ITER site and thus from the Host,
- one manufacturer for coil Feeders (41 kIUA): a complex area of superconductor and cryogenic technologies and instrumentation,
- at most, three equal industrial partners for the vacuum vessel manufacture (155 kIUA in total), and one or two more to produce the port structures (75 kIUA in total), if they agree on cooperation in the engineering of the specific process toolings,
- no difficulty should be met to share between different industries the delivery of more than 420 blanket modules (143 kIUA in total),
- the high flux components for the divertor are assumed to be provided by three, or more industries (65 kIUA in total),
- a few of the packages require only one responsible supplier per package (joined by industrial subcontractors): assembly of the machine, (50 kIUA), reinforced concrete buildings (312 kIUA), the steel frame buildings (69 kIUA) – all activities on ITER site and thus for the Host industries – the cryostat manufacturing (76 kIUA), the cooling water piping (60 kIUA), and the steady state electrical power network (40 kIUA) which all require also a large amount of work on site,
- all other packages should be procured through more than one supplier; particular ones provide for heating and current drive systems and diagnostics, and are discussed below.

In summary, the procurement of the machine core (1465 kIUA) could be possibly split into about 40 different contracts of 40 kIUA in average. The procurement of Auxiliaries and Heating and CD systems, except the Concrete Building (800 kIUA) could be split into 40 different contracts of 20 kIUA on average.

7.1.5.3.1 Heating and Current Drive Systems

The ITER requirements for plasma heating and current drive cannot be satisfied by a single method. Four have been envisaged (NB, IC, EC and LH), which could provide ITER with flexibility of operation. The machine design makes possible the installation of three NB lines, each assumed to provide 16.5 MW of neutral deuterium atoms at 1 MeV. All RF heating systems have been designed to provide 20 MW to the plasma per port. All these systems costs have been estimated per port of injection.

Provisions in the layout of equipments are such that heating and current drive systems procurement can be staged, to reach a maximum of 50 MW of NB (three lines), and 40 MW for any of the three RF methods: in all possible scenario, installed power cannot provide more than \simeq 130 MW and more than 110 MW available at the same time.

The present status of R&D results in any of those heating methods has not achieved the level required to be confident in their assumed performance and therefore in their availability at the start up of ITER operation. An R&D effort in all Parties, more extended and more efficient, is absolutely needed with the highest priority.

For the time being, it is assumed that the start up scenario will use two NB lines (33 MW, 96 kIUA), one equatorial port equipped with an IC launcher (20 MW, 32 kIUA) and 20 MW of EC power (77.5 kIUA) which can be delivered either through one equatorial port or through 3 upper ports (for NTM stabilisation).

7.1.5.3.2 *Diagnostic System*

ITER requires a comprehensive diagnostic system for monitoring in real time the conditions of the different machine components and for measuring the value of the key plasma parameters, in order either to control ITER operations or to increase the understanding in physical phenomena.

The diagnostic system comprises about forty individual measurement systems. The responsibility for design and procurement of these specific systems should be shared by the Laboratories of the Parties which aim at participating in ITER operations through their physicists. The Central ITER Team cannot bear alone this responsibility, even if it should specify all interfaces with the machine and in particular the responsibility of all “generic” packages.

The cost of the diagnostic system has been estimated through:

- seven diagnostic specific procurement packages: A: Magnetic diagnostics – B: Neutron systems – C: Optical systems – D: Bolometry – E: Spectroscopic systems – F: Microwave systems – G: Operational systems.
- and six “generic” packages: N01: In vessel services - N03: Diagnostic port plugs and first closure flanges - N04: Port inter-space structures and second closure flanges - N05: Divertor diagnostic components - N06: Ex vessel services - N07: Windows assemblies.

In addition, the cost of the Diagnostic Neutral Beam has been obtained together with the Heating Neutral Beam cost. Other related costs are for Blanket Shield Modules for Diagnostics Ports and the Test Stand in the Hot Cell, which are included in other packages.

Costs of providing the diagnostic system are divided into several components (see Table 7.3.). The cost of diagnostics required for initial operation (startup) is determined separately from the cost of those that are not required until the DT operation (deferred). Included in the startup costs is the cost of the in-vessel and inter-space equipment, and interfaces, for the deferred systems which would otherwise be expensive and time consuming to install later. Further, the diagnostic costing identifies items which would have to be provided during construction under control of the central ITER Team (in-machine items) and those which could be provided by the ITER Parties directly (ex-machine items). Examples of the former

could be in-vessel services and wiring, while examples of the latter could be specialised lasers and spectrometers. As in previous costing exercises, the cost of the specialist diagnostic effort to support the design, procurement and implementation of the diagnostic systems is costed separately in PPY: part of this effort will be required early to prepare for consistent plans and interfaces with the central ITER Team.

Table 7.1.5-1 Diagnostic System – Procurement Scheme and Cost

Diagnostic category	Start up			Deferred	
	Total	KIUA	Laboratories PPY	KIUA	Laboratories PPY
		In-machine			
A	3.25	3.25	5.6	0	0
B	3.9	1.4	6.0	6.2	14.0
C	16.9	0.6	33.0	8.8	17.3
D	6.7	0	8.5	0	0
E	8.9	0.3	26.6	13.6	43.2
F	8.3	2.2	23.8	9.4	31.5
G	11.0	5.4	17.7	0	0
N01	8.0	8.0	0	0	0
N03	13.4	13.4	0	0	0
N04	5.7	5.7	0	0	0
N05	0.8	0.8	0	0	0
N06	4.4	4.4	0	1.8	0
N07	4.0	4.0	0	2.4	0
DNB	22.7	22.7	0	0	0
TOTAL	118.0	72.2	121	42.3	106

7.1.5.4 ITER Direct Capital Cost

Taking account of the previous assumptions, the total “JCT estimated capital investment” for ITER amounts to 2,755 kIUA; in addition the cost of spares and items needed only a few years after start of operation (full DT operation) amounts to 258 kIUA and is deferred to be supported by operating funds. The present investment cost is only 49.2 % of the previous estimate for the ITER 1998 design, which amounted to 5603 kIUA and 302 kIUA deferred.

7.1.6 **Construction Management and Engineering Support**

An estimate of the cost of construction management and support cannot be done without assumptions on the future organisation to execute the construction and the manner of contracting and managing contracts for procurement.

7.1.6.1 Assumptions

For this purpose, it is assumed that the ITER Legal Entity (ILE), which will be responsible for the management of ITER during its whole life time, will provide a direct and effective line of accountability by incorporating all actors in a single management entity, including:

- an International Team at the ITER site which will have the overall responsibility to meet the project objectives and to ensure the design continuity and coherence.

For this goal, it will :

- define the technical specifications for procurement packages, the general QA rules and contracting rules,
- control, analyse and decide upon design changes or deviations,
- maintain databases on R&D and manufacturing results,
- integrate all aspects of ITER: technology and physics - safety and licensing - assembly - CODAC and diagnostics - cost and schedule.

- a National Team, as part of the ILE in each Party, which will manage and follow up the technical content of the procurement contributed by the Party, when the financial and legal contents of the relevant contracts are being taken care of by a Domestic Agency

For this goal, each National Team will:

- adapt technical specifications to its national usages and ensure engineering at detailed level,
- implement QA,
- assure technical control of each domestic supplier contract by a permanent presence in suppliers' premises, and a schedule control by accepting contractual payments according only to work progress.

With these assumptions it is clear that the size of the International Team can be deduced approximately from its functions, but the size of each Party National Team will depend on the level of the Party's contribution to ITER construction, on these specific packages in its contribution, and on the specific national practices in contract management.

Presently, when the respective choices of the ITER Partners in matters of procurement packages are unknown, a global approximation can only be given of the manpower necessary to follow up all the procurement packages, expressed in professional and technical manyears, integrating all National Teams, and taking no account of the possible splitting of procurement contracts between Parties and its relevant increase in manpower for their follow-up.

7.1.6.2 Estimated Personnel Cost during Construction

To exercise its responsibilities, the International Team will probably include a core management group and a few technical groups, in charge of physics, safety, engineering, assembly, etc.. These groups should be able to ensure technical continuity with the EDA and CTA, and, as construction approaches its end, these groups, suitably increased by personnel from the National Teams who have followed procurements, will eventually be involved in the integrated commissioning and start up of operation of the facilities. The number of professionals of this International Team can thus range from about 80 at the beginning of construction, to about 200 towards the end.

The support personnel for the core management (mostly administrative) and for the technical groups (mostly CAD) is expected to be in number equal to the number of professionals.

Following the assumed schedule (seven years of construction beginning two years after establishment of the ILE – the one year of integrated commissioning is assumed to be the first year of operation) the global manyears for the International Team during construction amounts to 840 PPY and a similar number for support personnel.

The global estimate of professionals and support personnel (clerical, technicians and CAD) for the different National Teams to follow up all procurement contracts in all Parties amounts to about 960 PPY and twice this number for support personnel. The number of professionals is assumed to be about 120-140 in average for six years and decreasing during the last three years of construction, for probably being transferred to the site to participate in the components installation and commissioning.

Assuming the annual cost of one professional and one support staff to be 150 IUA and 75 IUA respectively, the cost estimate for the International Team during construction until the start of ITER operation (integrated commissioning of the whole machine) amounts to 189 kIUA and the global estimate for all the National Teams during the same period amounts about 288 kIUA. Again, these costs are normalised and global, including all Parties; they might not be representative for the specific conditions of each Party. Excluded from the previous numbers are those relevant to diagnostic procurement referred in 7.1.5.3.2. above.

7.1.6.3 Possible R&D Cost during Construction

In addition to personnel costs, a certain amount of R&D during construction should always be considered. As already mentioned, R&D for all heating and current drive methods is required with high priority.

The EDA has provided the principle qualification of design solutions to be implemented in ITER. Nevertheless, during the manufacturing of components, proposed process improvements and design changes or unexpected difficulties could require new tests.

Moreover, to achieve in industrial production reliable results and good efficiency in the manufacturing of a large amount of high technology components (e.g. superconductor strands, high heat flux components, etc...), it is probably more efficient to launch, at the chosen industrial firm, a manufacturing R&D before contracting the global procurement. Along a similar line, it is conceivable that some Nb₃Sn coils (TF and CS) should be tested at their operational cryogenic temperature to confirm quality, even if presently the cost/ benefit ratio of technical results to be expected from these tests does not appear high enough.

It is therefore prudent to expect a spending in R&D of 60-80 kIUA during ITER construction.

7.1.7 **Cash Flow for the Direct Capital Cost**

The ITER construction plan discussed in section 6 requires a specific schedule for the procurement of each system and therefore appropriate profiles of commitments and payments, the total of which will amount to the JCT estimated capital investment. The most important to consider is the profile of payments, which when combined with the construction schedule, establishes the necessary cash flow over time for the project as a whole.

7.1.7.1 Payment Schemes for each Procurement

For each Procurement Package, the following simplified scheme is assumed for payment according to the planning of manufacturing until delivery after the ordering contract is signed:

- 10% of the whole contract value is paid when the contract is awarded;
- 80% of cost of professionals is distributed evenly, and paid accordingly, from the vendor's design phase to delivery of the components or acceptance of the system (as appropriate);
- 80% of labour cost is distributed evenly, and paid accordingly, during fabrication, installation and test if appropriate;
- 80% of tooling cost is paid when the tools become operational;
- 80% of materials or subcontracted equipment costs is paid when the materials or equipment are accepted by the main contractor and checked by the ILE QA representative if appropriate;
- the last 10% of their contractual value is paid when a component or a modular part is accepted by the ILE after the results of contractual acceptance tests, or when a system delivered on site, has satisfied the contractual performance test.

7.1.7.2 Cash Flow

Table 7.4 and Figure 7.1.7-1 show a yearly distribution of payments of the direct capital cost (including spares and deferred items) based on the above assumptions. Before the grant of license and the defined start of construction on site ($T=0$), contracts for the conductor, TF coil fabrication, buildings and the water cooling pipes should be awarded and 10% of these contracts paid, i.e. about 180 kIUA in total. Annual payment reaches about 350 kIUA in the second year after $T=0$ and continues at this level until the seventh year so that most of the direct capital cost is paid in nine years. The integrated commissioning activities are then started in the eighth year when the whole operation staff is fully on site, and this is the start of the operation phase of ITER.

This example offers an illustrative first approximation and is capable of further refinement and modification, in particular by splitting the procurement of large packages into smaller ones in content or in successive time steps and by adjusting the assumptions on payments profiles.

Table 7.1.7-1 Cash Flow of Direct Capital Cost including Some Spares and Deferred Items

WBS/Year	-2	-1	1	2	3	4	5	6	7	8	9	10	11	Total
10: Magnets, VV and In-vessel Components	41	56	166	262	256	213	175	85	28	6	0	0	0	1289
20: Assembly, RH Equipment, Water Cooling	0	13	9	31	35	58	56	81	81	22	13	20	38	459
30: Cryoplant, Pumping and Tritium Plant	0	0	0	1	10	6	5	25	59	36	25	29	25	220
40: Coil and Heating System Power Supplies	0	4	1	10	9	25	64	89	79	24	0	0	0	305
50: Heating Systems, Diagnostics, CODAC	0	0	0	0	13	5	35	48	105	62	28	28	14	338
60: Buildings and Site Facility	37	27	61	47	38	41	26	57	20	13	6	7	5	385
Total	78	101	237	350	362	349	361	385	372	163	73	84	82	2996

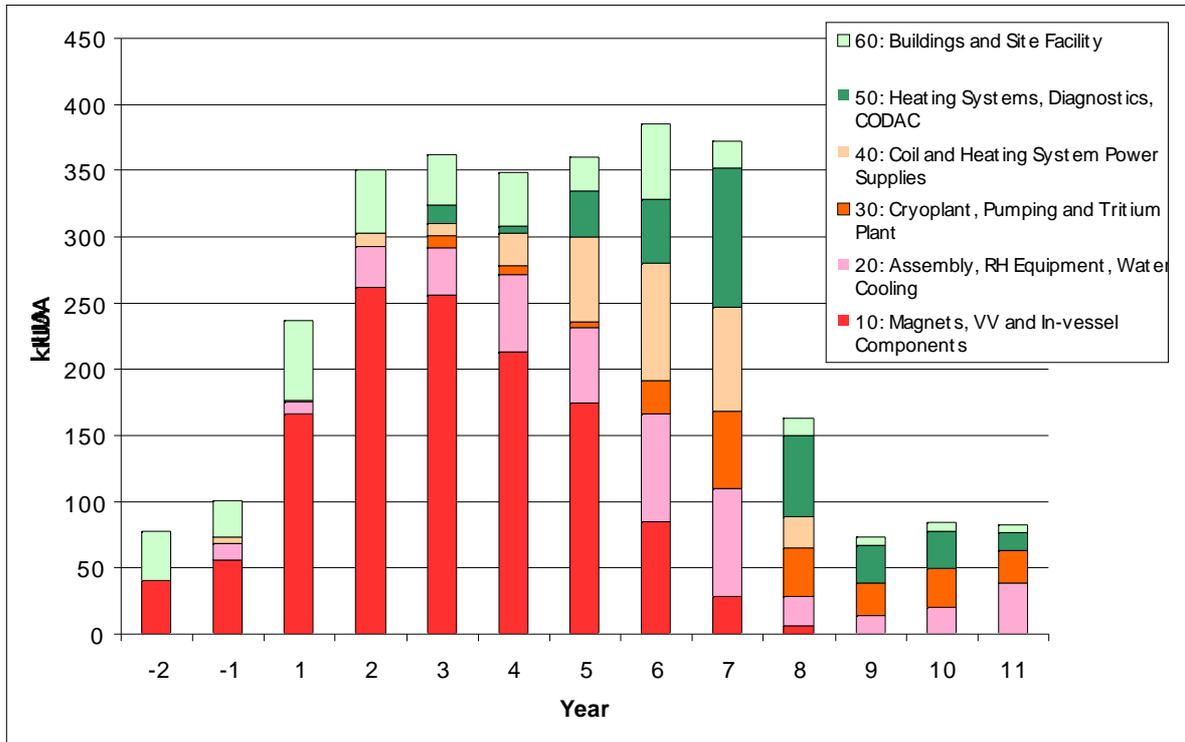


Figure 7.1.7-1 Cash Flow Diagram for Direct Capital Cost including Spares and Deferred Items

7.2 Resources for ITER Operation

Operation costs for ITER include the following items:

- Project personnel,
- Energy costs during operation,
- Fuel costs (largely hypothetical),
- Spare parts, maintenance and material/capital improvements.

Some of the above costs are related directly to the usage the machine receives, whereas others depend directly on the project duration. An estimate of the above costs therefore is based on the operation scenario for the device described in Chapter 6.

7.2.1 Project Manpower Costs

Manpower costs of permanent staff on site and cost of extra manpower brought in from time to time to aid in maintenance of the device are costed assuming an average level of 200 professionals and 400 support staff (clerical, technicians and CAD), at 150 IUA and 75 IUA respectively per year; thus the annual personnel cost is about 60 kIUA.

The permanent professional and support staff aboved are expected to operate and maintain the facility, and support the experimental programme, for example diagnostics, or installation and testing of the blanket modules. However, visitors to the site to conduct experiments (experimentalists or theoreticians) are not included in the manpower cost: their costs are assumed borne by the Parties. This is consistent with including the cost of diagnostics in the construction or operating costs, but not the Laboratories staff having the responsibility of their procurement.

7.2.2 Energy Costs

Electric power costs, which not only include the power required for pulse operation, but also must cover energy consumption during various levels of standby/maintenance of the machine, depend on aspects of the load time profile and on the characteristics of the national electricity network of the host site. Whereas electric peak power to be delivered, and the average power to be made available over a certain time period, place a premium on the cost of energy consumed, the consumption dominates the cost in any well-provisioned site. Thus the electricity costs can be estimated knowing the steady state power levels required in the various operating states, and the fraction of time spent in those states, superimposing the integral of the pulsed power demand when in the plasma operating state.

A typical scenario is shown in Table 7.5. The steady state power loads are representative values over the whole life of the plant, but are somewhat uncertain. Similarly the time devoted to maintenance (or conversely to burn/dwell) as also difficult to specify at this stage. For this reason ranges are given, with the implications noted. A unit cost of 0.05 IUA/MWh is used.

Table 7.2.2-1 Key Features of Electricity Cost Calculation

	Low	Nominal	High
Steady state power loads			
Plasma operating state (POS)	100	100	100
Short-term standby (STS)	70	80	90
Short-term maintenance (STM)	50	60	70
Long-term maintenance (LTM)	30	35	40
Time usage (lifetime average)			
In LTM	0.25	0.375	0.5
In STM	0.5	0.375	0.25
Average annual cost over 20 year life (kIUA)	24.7	29.1	34.0

The most sensitive parameters of this calculation are shown above. The results are not sensitive to the average burn time, or to the details of the operation stages over the years, since the integral burn time is constrained to deliver the nominal fluence. Typical yearly cost variations from the average, at various operation stages, are below 5 kIUA.

7.2.3 Fuel Costs

Fuel costs include deuterium and tritium burnt during operation, plus that lost by decay of the inventory (taken as 2 kg) during plant operation. The deuterium cost is negligible at 2 IUA/kg. There is no market for tritium for the quantities required, and thus tritium may have little or no monetary value. Nevertheless a largely hypothetical 10 kIUA/kg for tritium purchase is used. The total tritium received on site during the first 10 years of operation, according to table 6.2.5.1., amounts to 6.7 kg. The total consumption of tritium during the plant life time may be 16 kg to provide a fluence of 0.3 MWa/m² in average on the first wall; this corresponds, due to tritium decay, to a purchase of about 17.5 kg of tritium.

Therefore the fuel costs are in average 6.7 kIUA per year during the first ten years, and probably 11.5 kIUA per year after.

7.2.4 Capital Improvement, Spare Parts, Maintenance Costs

Analysis of the expected capital costs to keep the ITER facility in the required effective state has shown that very different ratios (annual cost against the initial investment) should be considered for the different systems, going from almost 0% (e.g. magnets) to 10% (for RF power generators and diagnostics), up to 15% (e.g. computers).

Considering all systems, the required maintenance cost amounts to 2.5% of the initial investment, about 70kIUA per year. To this cost should be added investments deferred initially to operation costs and the cost of replacement of the divertor high heat flux components (possibly five times during the plant life time). This leads to a total of 90kIUA per year in average during operation.

7.2.5 Conclusion: Average Annual Operation Costs

In summary, the ITER average annual operation costs amount to about 60 kIUA for the personnel permanently on site, 30 kIUA for the energy consumption, 8 kIUA for the tritium purchase and 90 kIUA for spare parts, maintenance and improvements, i.e. a total average per year of 188 kIUA. Again this value will depend on the ITER site, mostly through the electricity cost (assumed to be 0.05 IUA/MWh), and on the specific arrangement between the Parties on how to support the personnel cost.

7.3 ITER Decommissioning Costs

The policy proposed for the ITER decommissioning has been described in Chapters 2.11 and 6.3. The technical implementation and schedule have been detailed according to a credible option. Even if the Host Party may consider other options, the global cost to be borne should not change drastically as long as a full dismantling of the machine is not required before the vacuum vessel activity has decayed substantially.

The ITER facility, because of the remote maintenance implemented during operation, offers initially most of the tools, procedures, and even trained staff, to accomplish the decommissioning operations. This capacity is an essential element in keeping their cost down.

The manpower estimate is based on the requirements for the dismantling of the main active parts of the ITER facility only. The non-active parts are not considered, because their residual values are probably higher than their dismantling costs.

For the technical operations and their schedule in two active phases described in Chapter 6.3, the estimated integrated work force over 11 years amounts to about 2,800 manyears. The average cost per manyear is rated at 90 IUA as a mix of different staff categories. In addition, it is assumed that new hardware may be required to replace a few aging tools, or to enhance the hot cell, and radwaste processing efficiency. For this purpose, one third of the manpower cost is put as an AFI, as observed in previous experience.

Other costs (dependent on the Host country) are not included in the present estimate:

- radwaste disposal,
- components and facilities salvage value after dismantling where applicable (e.g. materials below “clearance”),
- non-active parts dismantling and salvage value,
- site restoration,
- financing-related costs, if spending is made at a later stage.

Under the assumptions and limitations listed above, the estimated cost for decommissioning amounts to 250 kIUA for manpower costs and 85 kIUA for possible hardware costs.

7.4 Summary

For reference, a summary of the cost estimates for all phases of ITER plant lifetime is set out in the table below and compared with estimates for the 1998 design. This summary is subject to all the qualifications and considerations outlined above.

In particular the construction cost estimates:

- assume the agreed Site Requirements and Site Design Assumptions, and are thus valid for a generic site,
- include the policy for additional heating and diagnostics procurement set out in 7.1.5.3.1 and 2,
- exclude costs associated with site hosting, notably, the provision of land, off-site facilities and all service supplies up to the boundary fence,
- exclude items deferred beyond the start of operation.

The average yearly operation cost estimates include permanent staff costs on site to operate and maintain the facility, but exclude the cost of visitors (physicists) to conduct the experimental programme of ITER.

Table 7.4-1 Overall Project Cost Summary

	ITER-FEAT (1) kIUA	Ratio 1/2 %	ITER/1998 Design (2)
<u>Construction costs</u>			
A) Direct capital cost	2755	49.2	5603
B) Management and support	477	61.2	780
C) R&D during construction	60-80	~ 50	150
<u>Operation costs</u> (average/year)			
A) Permanent personnel	60	66	90
B) Energy	~ 30	50	~ 60
C) Fuel	~ 8	40	~ 20
D) Maintenance/improvements	~ 90	50	~ 180
Total	188	54	350
<u>Decommissioning cost</u> <u>(total)</u>	335	110	~ 300