1) *What is the total required electrical power - taking into account all the relevant infrastructures on the Iter site - for a fusion reaction in ITER in 2025 (first plasma) and in 2035 (atomic plasma)? (In MW)*

Is it accurate to say that a total of 440 MW - again taking into account all the relevant infrastructures on the Iter site - are required for a plasma reaction (Mr. Benfatto quoted by American journalist Steven Krivit)? Or is M. Claessens accurate when he writes that Iter will require a total of 600 MW in order to launch a 30 seconds fusion reaction (2018, P. 107)

To answer this question accurately – that is, not to be misleading – absolutely requires the answer to be placed in the context of ITER's mission – both what it is, and what it is <u>not</u>. That mission is generally expressed as "to demonstrate the scientific and technological feasibility of fusion power for peaceful purposes at an industrial scale."

This ITER mission has been translated to multiple design parameters, the most important of which are as follows:

(1) to produce a Q ≥ 10 [in which "Q" is the ratio of thermal output from fusion power coming from the plasma versus the thermal heating input for the plasma] for pulses lasting for about 400 seconds;
(2) to produce a Q ≥ 5 at a "steady-state" condition, meaning a more continuous rate of fusion power in which the pulses are more evened out;
(3) to demonstrate the integrated operation of many of the technologies needed for a fusion power plant.

A critical reason for design parameters 1 and 2, above, is to create a "burning" (or largely self-heating") plasma, in which, following the initial input of heat from external heating systems, most of the heating is coming from the fusion reaction itself (i.e., from the helium nuclei, also referred to as alpha particles, which are produced from by the fusion reaction). This phenomenon of a controlled "burning plasma" has never existed in any of the previous tokamaks built by various countries, primarily because they were too small. The size of the ITER machine (together with the strength of the ITER magnets and the density of the ITER plasma) is specifically chosen to enable all ITER Member country scientists to be able to study a burning plasma.

Design parameter 3, above, must also be understood for context. Many of ITER's components and systems are "first-of-a-kind." In some cases, the essential technology has been used before (e.g., cryogenics, vacuum systems, superconducting magnets), but never at the size and scale of ITER. In other cases (including some elements of the heating systems, multiple diagnostics, etc.), the technology is a new approach. Hundreds of tokamaks have been built over the past six decades, but never at this scale and never integrating all of these technologies.

To understand the cost-efficiency of ITER, it is critical to appreciate that it is the "point of convergence" in the fusion R&D roadmaps of all ITER Members. Instead of each country doing what had been done in the past (individually pursuing R&D on multiple tokamak designs), ITER brings all of those efforts into a single machine.

This means that, when viewed through a narrow lens, ITER may appear cost-inefficient. For example, ITER has three heating systems, totalling more than 70 MW of thermal capacity as potential input power to heat the plasma – even though only 50 MW thermal input power is required by design – so that each type of heating system can be tested, singly or in combination, to determine the optimal heating system selection for future machines. Similarly, ITER has a very large number of diagnostic devices and systems – far more than would be expected for a commercial fusion device – so that the plasma characteristics can be exhaustively analysed, and (once again) in order to optimize the designs of future machines.

In this context, it is accurate to say that ITER is inefficient by design – but only when understanding that the costs of building an experimental research machine like ITER is far, far more cost-effective than for each of the 35 ITER Member countries to build their own ITER-sized machine as a precursor to commercial fusion plants.

Only in this context can expressions such as the "total required electrical power" be accurately characterized and understood.

- When the mission of ITER is mischaracterized as being a net electricity gain across the entire facility (as some have done), then the ITER outcomes can be mischaracterized as inefficient. But ITER is not designed to produce electricity, nor will it even have a turbine generator, because, by mission and by design, it is a testing facility that will enable integration of all the technologies needed for future machines. So in that sense, all the electricity used to power ITER's systems will be consumed – not used to produce electricity; but when understood in the context of ITER's mission as the convergence of 35 Member countries in fusion R&D, it is in fact a very cost-effective approach.
- When the cost of ITER – roughly 20 billion euros for construction – is mischaracterized as a projection of the cost of future fusion power plants, then it is correspondingly easy to mischaracterize the projected future costs of fusion-generated electricity. But when ITER's mission is understood – with multiple redundant systems incorporated, so that the relevant efficiency of each can be compared to the others – then it is easy to see that ITER's "inefficiency" as a research machine is in fact a huge cost-efficiency as a consolidated, globally collaborative research project.

So when you ask, specifically, "Is it accurate to say that a total of 440 MW - again taking into account all the relevant infrastructures on the Iter site - are required for a plasma reaction?" my answer is no, this is not accurate; and when taken out of context, it is especially misleading. The accurate answer is as follows:

a. As part of ITER's experimental design, which incorporates multiple (and sometimes redundant) systems, we will power some of those systems (such as cryogenics, cooling water, etc.) with the "Steady State Electrical Network," which has a capacity of approximately 120 MW of electricity. But please note: this is capacity, and actual use is expected to be significantly lower.
b. In addition, we will power the ITER magnets and multiple ITER heating systems with an additional "Pulsed Power Electrical Network," which has a capacity of approximately 320 MW of electricity (here again, actual use is expected to be much less). This power supply will be used during the ITER pulses, using a variety of configurations with differing electricity consumption

depending on which systems are being used for a given pulse, and later for a variety of experimental approaches to steady-state operation.

c. ITER will also test (as part of the pulsed power network, described in “b” above) “reactive power compensation” – which, in a commercial machine, will demonstrate how the unused portion of the 320 MW will be returned to the electrical grid for power efficiency (in addition to the electrical power output coming from the turbine-generator for a commercial machine).

For the statement you quote from Michel Claessens’ book: no, it does not appear to be accurate at all, in my view; but you are welcome to ask Mr Claessens for further explanation as to how he arrived at that statement.

Finally, to come back to your question #1 (“What is the total required electrical power - taking into account all the relevant infrastructures on the Iter site - for a fusion reaction in ITER in 2025 (first plasma) and in 2035 (atomic plasma)? (In MW)”): ITER’s First Plasma, scheduled for 2025, will not be a “fusion reaction.” It will be a test of the machine’s overall functionality, using conventional hydrogen, which does not result in a fusion reaction. This initial testing period will be a functional validation that all of the complex first-of-a-kind components and systems going into the ITER machine are working together properly. First Plasma and the ensuing testing period will be followed by additional periods of further less intensive assembly and increasingly intensive testing (what we call a “staged approach”). Within those stages, the first fusion reaction will be produced by a deuterium-deuterium reaction (which also causes fusion, but with somewhat different physics outcomes); and the final stage, scheduled to begin in 2035, will be “full fusion power” using deuterium-tritium fuel.

With that as context, the First Plasma testing will use most but not all of the systems described above, and as the stages progress, all the systems will eventually be incorporated. The precise electrical power required for any given experiment that follows will depend on the precise configuration of systems (in particular, the choice of heating systems and diagnostics) used in that experiment.

I hope, given the detailed explanation above, you will understand that it would be inaccurate and misleading to extrapolate ITER’s electrical consumption as an interpretation of the efficiency of the commercial fusion machines of the future. I also hope, given that your previous research and reporting demonstrates your thoroughness and considerable awareness of the broad spectrum of environmental responsibility and planetary stewardship, that you will consider ITER’s costs and size in the context of: (1) humanity’s global dependence on fossil fuels (e.g., Europe’s daily import of ~1 billion euros of petroleum, paying the equivalent of ITER construction every 20 days), and the urgent need for a carbon-free replacement capable of supplying concentrated “baseload” power; (2) the cost-efficiency of ITER’s approach, in which 7 Members (comprising 35 countries) deliberately choose to collaborate on a single pre-commercial industrial-scale machine, rather than each country pursuing its own machine design at this scale; and (3) the vast potential for fusion power to reduce and even eliminate more than a century of geopolitical tensions and conflicts focused on competition for access to fossil fuels, by enabling the use of a power-generating technology for which – uniquely among any baseload power generation source – the fuel (in water and lithium) is globally abundant and equally available to all.

I hope this is useful.

Warm regards,
Laban

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