



Fusion Factsheet



By Dr Melanie Windridge
August 2021

- **What is fusion?**
- **Why fusion?**
- **Why now?**
- **Private fusion**
- **Myth busting**

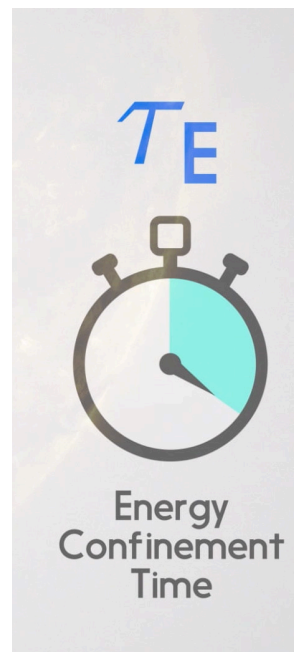
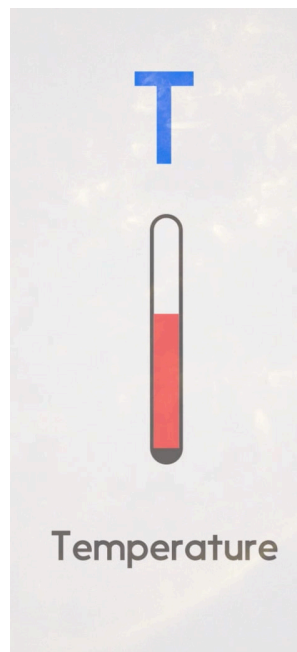
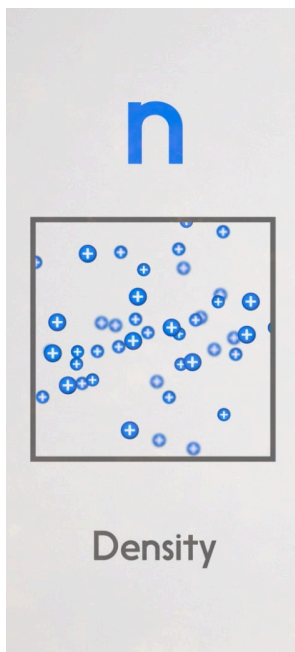
What is fusion?

Fusion is happening constantly the sun and the stars - small particles joining together to make larger ones and releasing lots of energy.

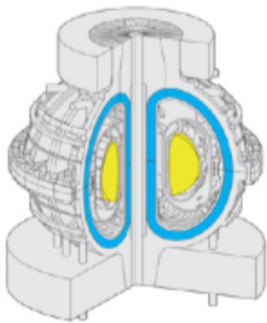
Scientists are replicating this process on Earth.

Immense gravity compresses the core of the sun to high densities and temperatures. On Earth we have to do it differently.

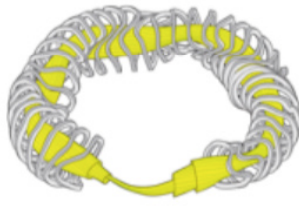
The key thing is to get the fusion fuel dense enough and hot enough for long enough for fusion to occur.



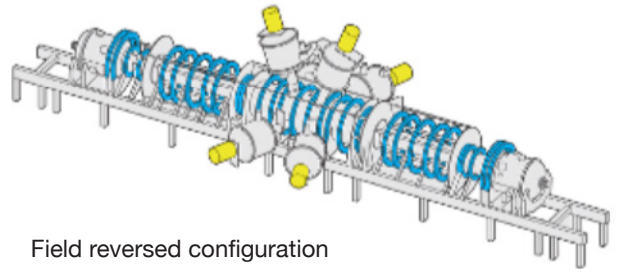
There are a variety of approaches...



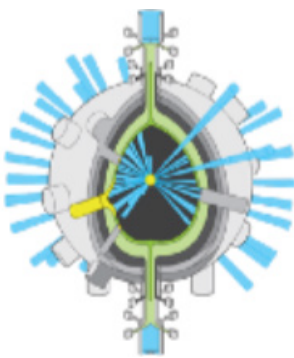
Tokamak



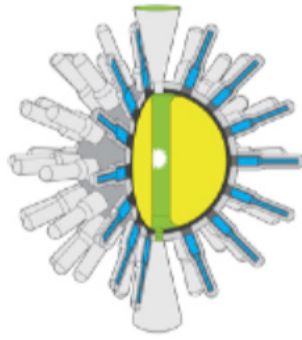
Stellarator



Field reversed configuration



Inertial Confinement (laser) Fusion

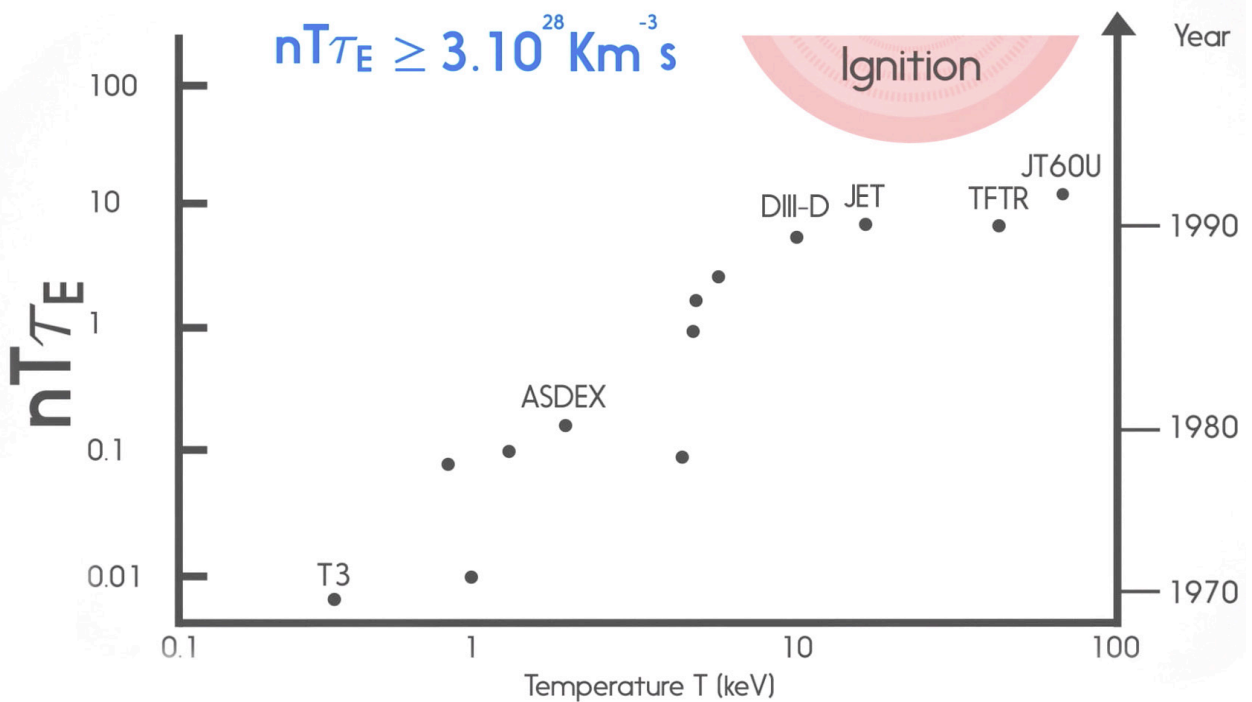


Magneto-inertial (target) fusion

(Designs by Chris Philpot)

So far the tokamak concept has made the most progress. This graph shows how close various tokamaks have come to "ignition".

This is when the temperature, density and confinement time together are high enough for fusion reactions to occur and sustain themselves.



Why Fusion?

- High energy density:
1kg fusion fuel =
10 million kg fossil fuel
- Globally distributed fuels

Abundant

- Non-variable electricity
available on demand

Dispatchable

Safe & Clean

- No meltdown
- No long lived radioactive waste
- No CO₂

Flexible

- Alternative outputs:
 - Industrial heat
 - Hydrogen
 - Desalination
 - Marine/space propulsion

Why now?

I believe the next ten years or so are going to be really interesting for fusion energy, and here's why:

Various factors are coming together to drive us towards fusion commercialisation.

- Good understanding of plasma physics
- Tokamak concept well understood, others being investigated
- Close to exceeding break even $Q=1$ (more energy out of fusion reaction than put in)

Mature Science

- Computing - including machine learning and AI
- High temperature super conductors
- Improvements in lasers
- Advanced manufacturing

Enabling Technology

Climate Urgency

- Extreme weather events
- Public calls for action: Extinction Rebellion, school strikes
- Desire for greater sustainability and new energy options
- Government net zero targets

Private Investment

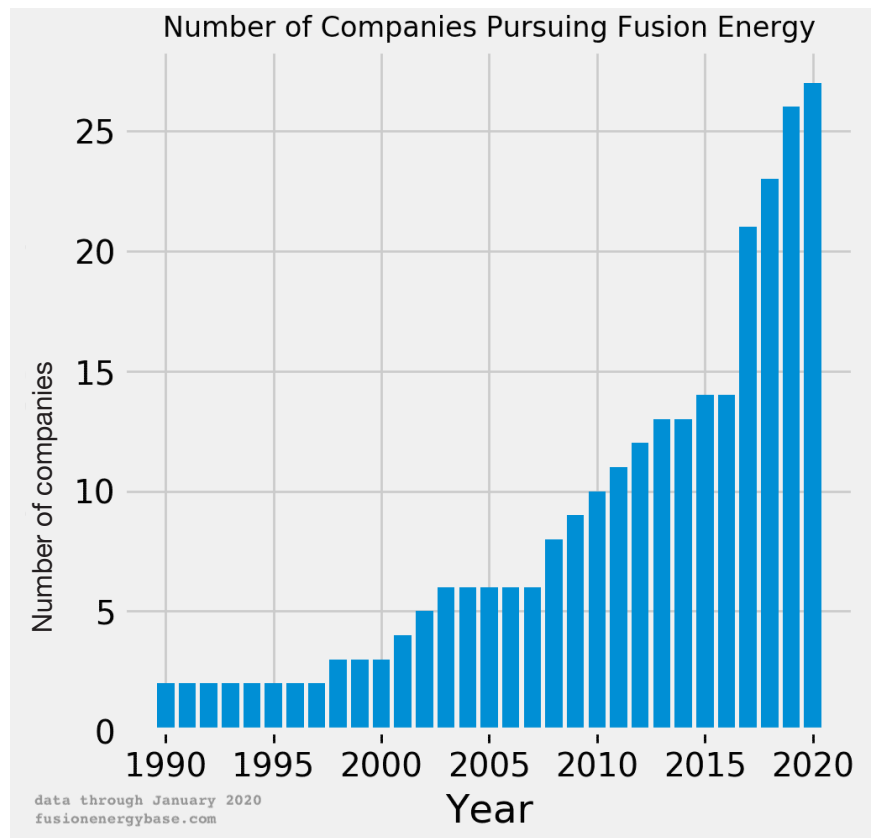
- Increasing private investment
- More private companies → more knowledge
- Fusion Industry Association founded 2018
- Governments taking notice → public-private partnerships

Private Fusion

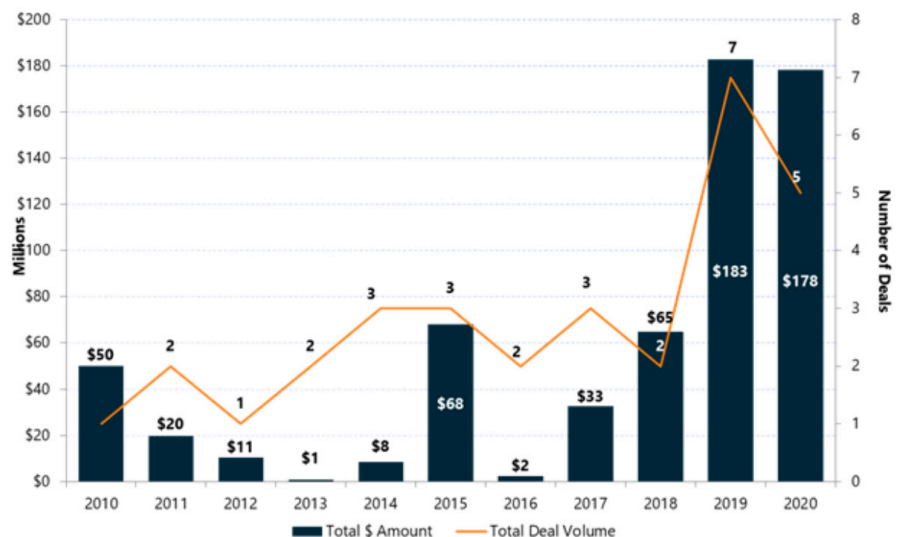
In the 2010s the number of private fusion companies increased rapidly.

Investment into the private fusion companies also increased over the decade.

It is set to further increase as companies become more established and governments such as the USA implement public-private partnership programmes to help reduce investment risk and enable private companies to share the expertise and facilities of publicly-funded laboratories.



Venture Investment into Private Fusion Companies, June 2020 (Cleantech Group)



Myth busting

Myth 1

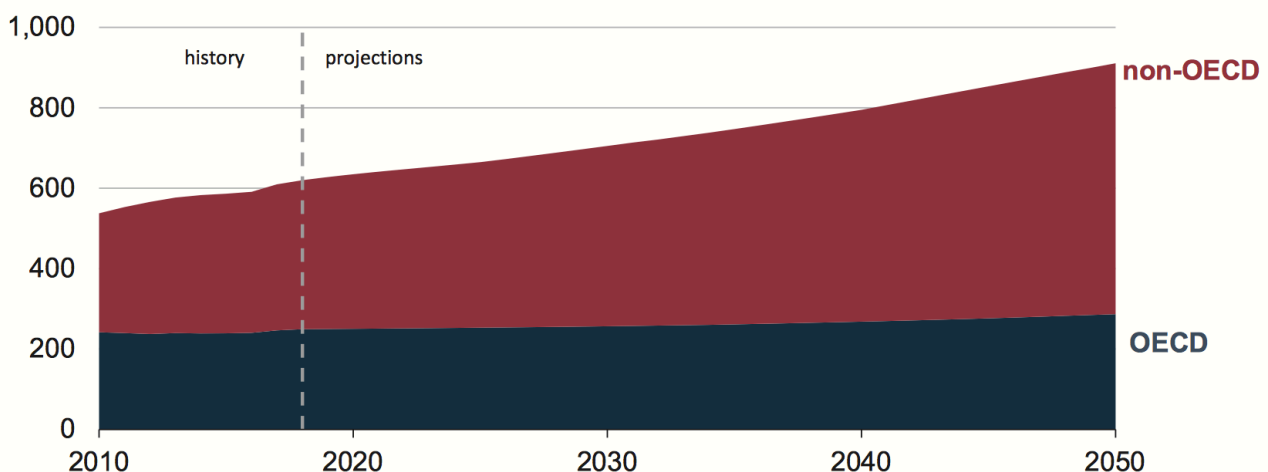
“We don’t need fusion because we’ve got renewables.”

It’s great that renewables are doing so well and their share of primary energy is increasing. I think we need to use everything we can. But global energy demands are increasing more than renewables are

increasing—so we still need more. We also need to decarbonise sectors that cannot easily be electrified, like industry, aviation and shipping. Non-electric sectors make up over 80% of global primary energy.

World energy consumption rises nearly 50% between 2018 and 2050

World energy consumption
quadrillion British thermal units



Myth 2 -

“Fusion will come too late to meet climate change targets so we should be investing in other, already established technologies.”

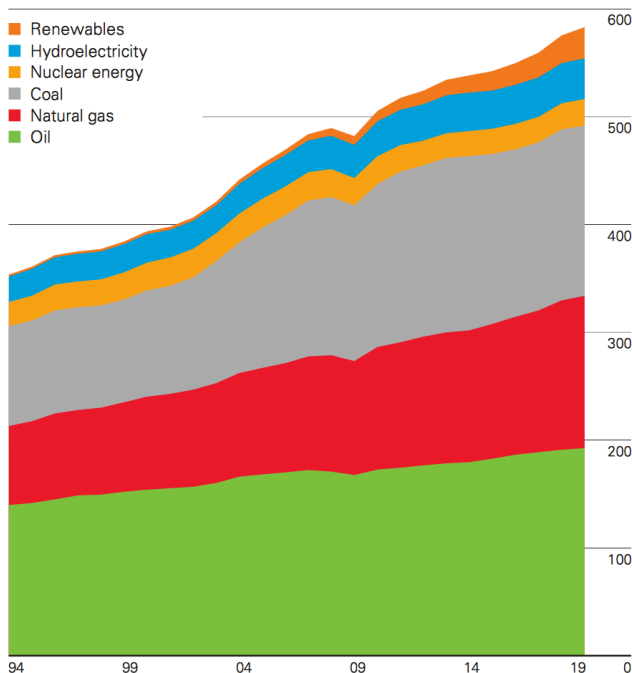
Without a technology like fusion, meeting the climate change targets will be incredibly tough (see the graphs below for the challenge we face).

Decarbonising primary energy at today’s level is a huge challenge. But global energy consumption is predicted to rise by nearly 50% by 2050, according to the International Energy Outlook 2019, so we need to be thinking about decarbonising for a future, higher level.

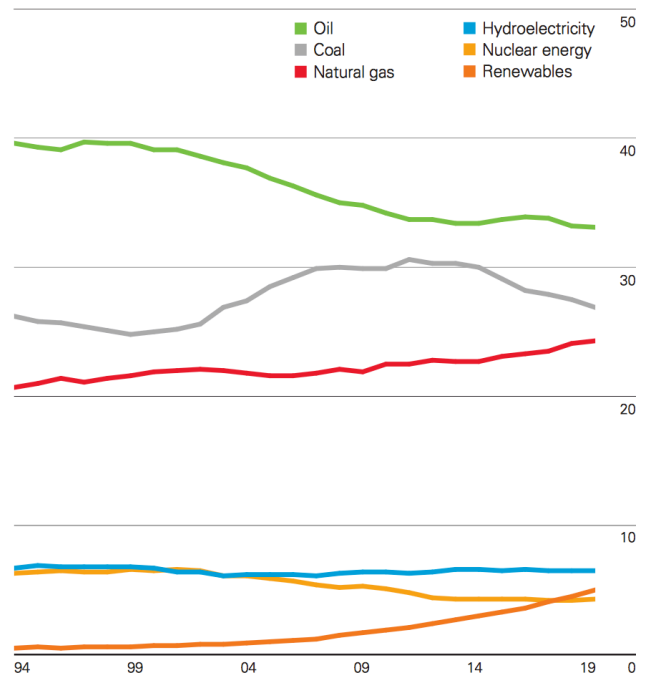
Even if fusion comes too late to contribute to 2050 targets, it will be necessary for the beyond-2050 targets. I believe that we can’t afford not to develop fusion in time to contribute to 2050 climate targets.

We don’t know when fusion will be ready, but private companies are targeting “soon enough to matter” — aiming for electricity pilot-plant demonstration in the early 2030s and commercial roll-out thereafter. This will require dedication, investment and government/public support.

World consumption
Exajoules



Shares of global primary energy
Percentage



Myth 3.

“New private companies will beat the government-funded labs to fusion.”

Competition can be stimulating, but partnerships will be required to get to commercial fusion. It's not a situation of “them and us”. Increasingly public and private are coming together, collaborating. Even beyond achieving energy breakeven and demonstrating the viability of fusion, new auxiliary technologies and materials will be needed for a commercial power plant. Private companies

will benefit from the knowledge and expertise in universities and government-funded labs. An imperative going forward is for governments to set up structures or programmes to facilitate and encourage public-private partnerships, so that research and technologies can make their way out of laboratories and into the commercial space.

“I would like nuclear fusion to become a practical power source. It would provide an inexhaustible supply of energy, without pollution or global warming.”

Stephen Hawking

“Nuclear fusion has the potential to be a game-changer in a world that needs some game-changers.”

Nicola Daly, Legal & General Capital

“Fusion energy has enormous potential, offering an inexhaustible source of zero-carbon energy and helping us to cement the UK's position as a science superpower.”

Amanda Solloway, UK Science Minister

“Innovation in this area could eventually realize economic opportunities worth trillions—yes, that's with a “t”—of dollars for our country.”

US Representative Don Beyer