Fusion: expensive yet cheap, slow yet fast!

Niek Lopes Cardozo
Guido Lange
Gert-Jan Kramer

TU/e Technische Universiteit Eindhoven University of Technology

Where innovation starts

1000 commercial plants (Gen.3)

100 commercial plants (Gen.2)

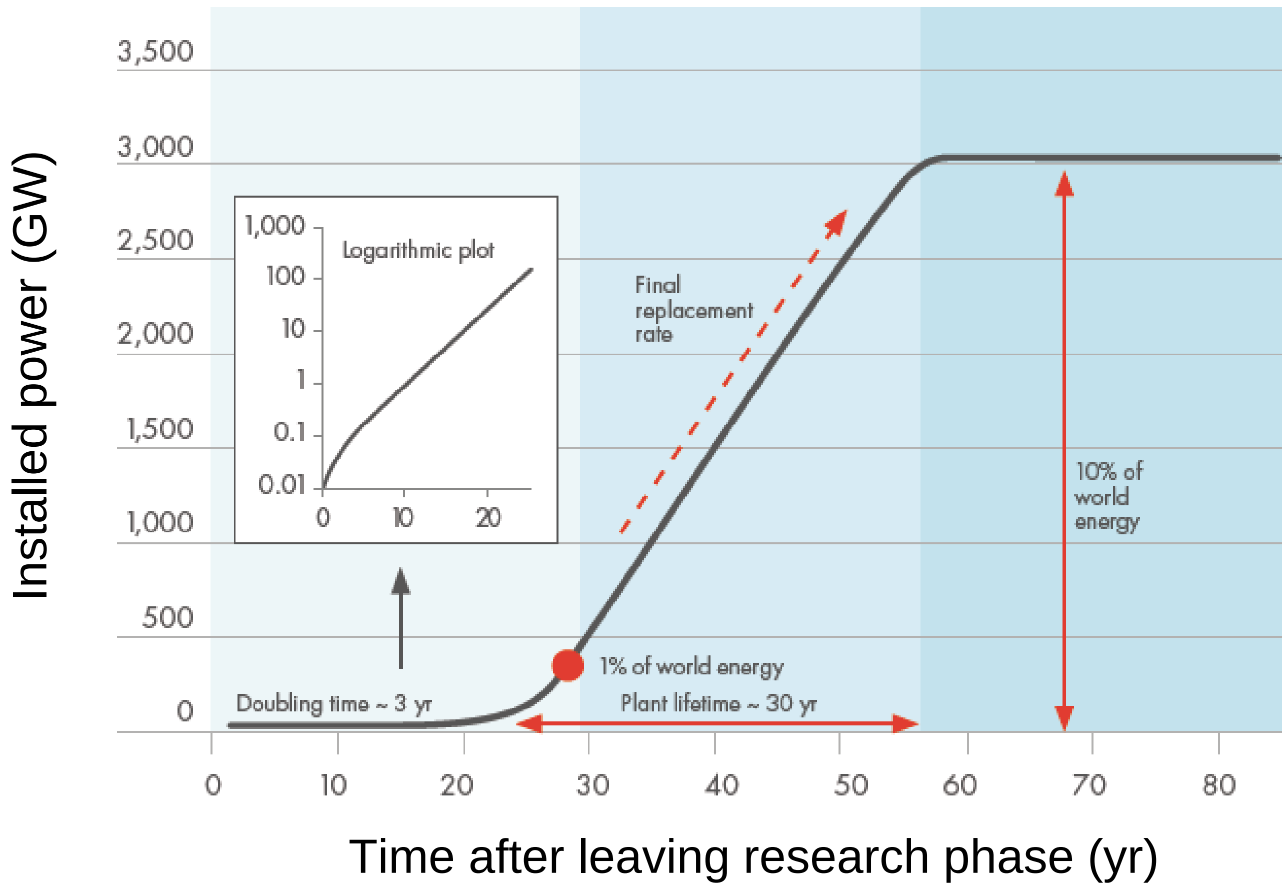
10 commercial plants (Gen.1)

3 DEMOnstration plants

ITER (10-fold power multiplication)

JET (scientific experiment, no energy production)

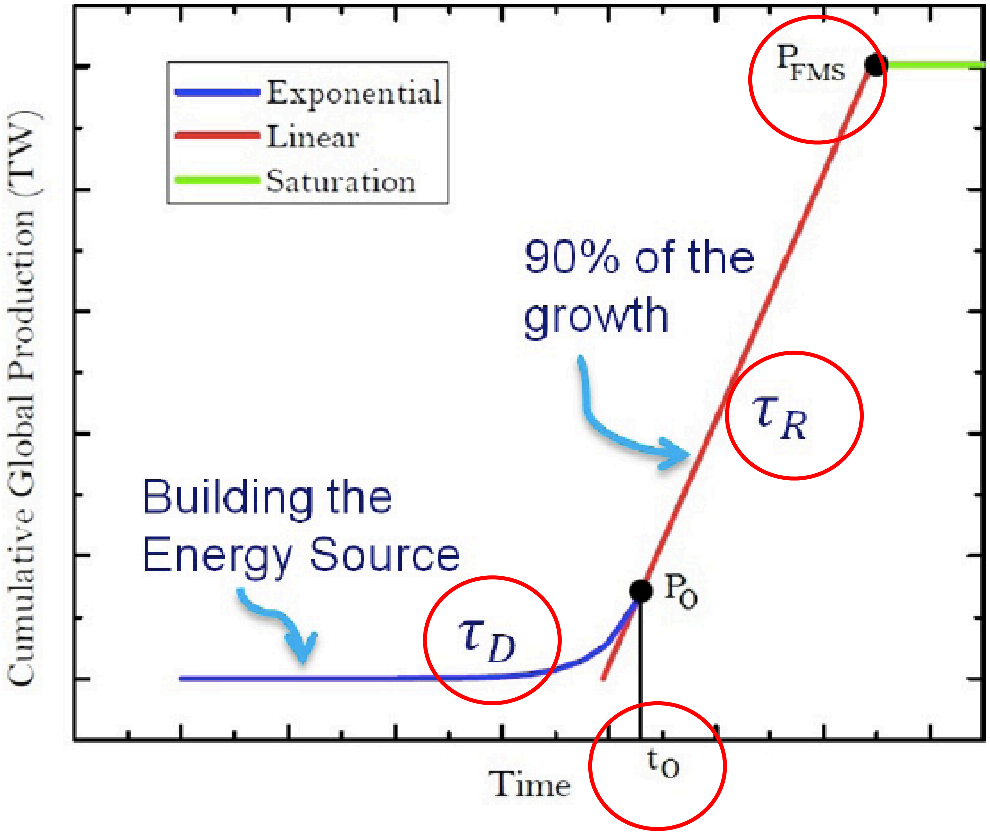
The fastest possible development path



Note: the slope of this curve is given by the industrial 'plant-building' capacity. E.g. the number of solar panel factories. Therefore the slope must vary smoothly

From NLC, Lange & Kramer, The colors of energy

Universal development: 4 parameters only



Final Market Share:
P_{FMS}: typically 10-20% of World Energy Demand

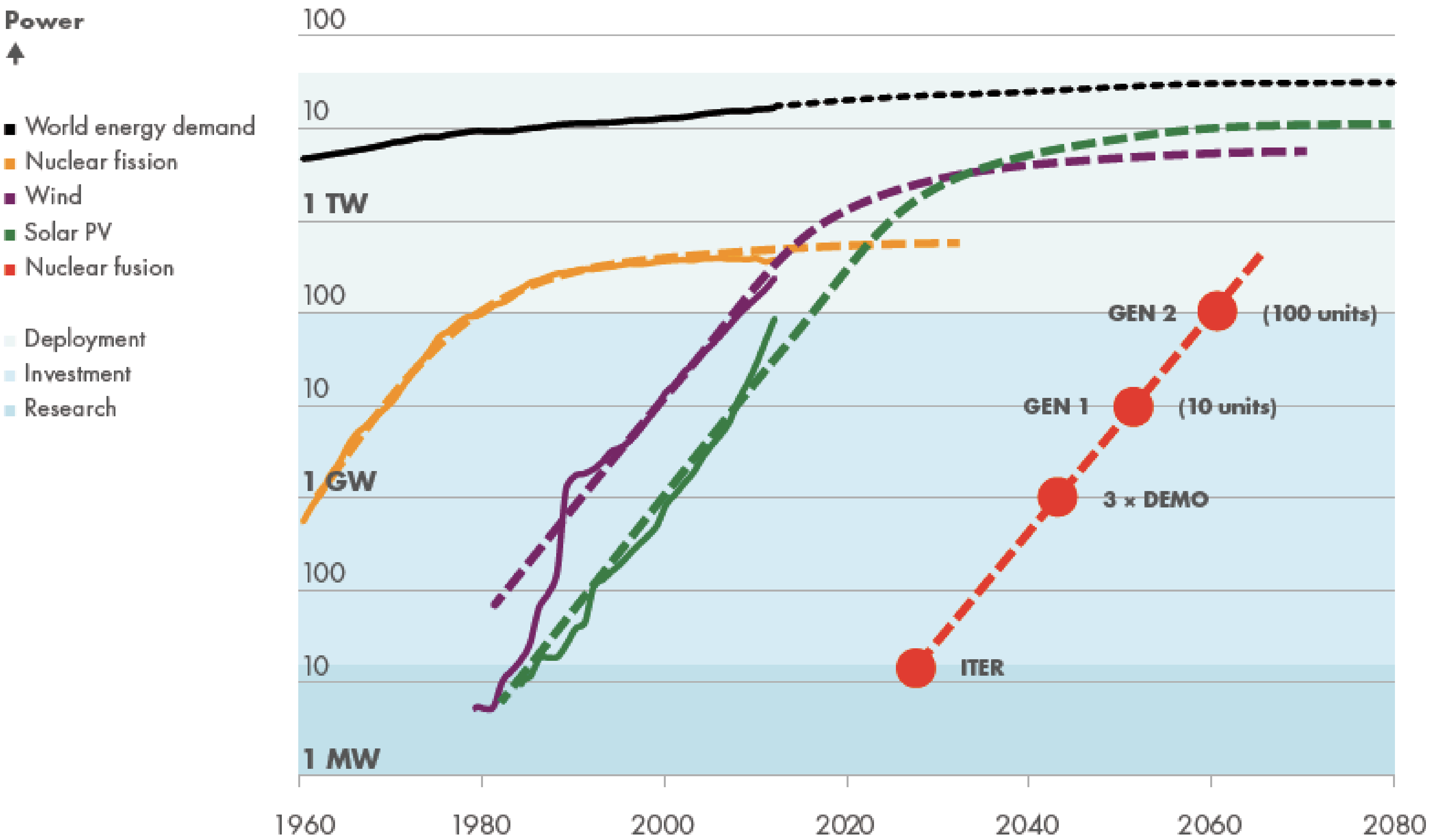
Linear growth: replacement time
τ_R : typically 30 -50 years

Exponential growth: doubling time
τ_D : typically 2-4 years

Plus the trivial parameter to fix the time frame (t_0)

Does historical data bear out this universal behaviour?
Does Fusion follow the same universal development curve?

Universal development curve, historical data, & fusion



From NLC, Lange & Kramer, The colors of energy

Technische Universiteit Eindhoven University of Technology

Exponential growth phase: energy production irrelevant

- The energy production in the exponential phase is irrelevant

  Obvious: since the exponential growth stops at typically 1% of the final capacity, i.e typically 0.1 % of world energy demand.

- Even stronger: if the *doubling time* is shorter than the *energy payback time* the net energy production is *negative* during the entire exponential growth phase.

  This is e.g. the case for photovoltaic.

- All of this is not a criticism.

  It just states that a system has to go through a growth phase before it starts to produce.

  This phase builds the industrial capacity needed to build and maintain the future park.

  Energy production during this phase is irrelevant.

→ Exponential growth phase: investment in a future energy source.

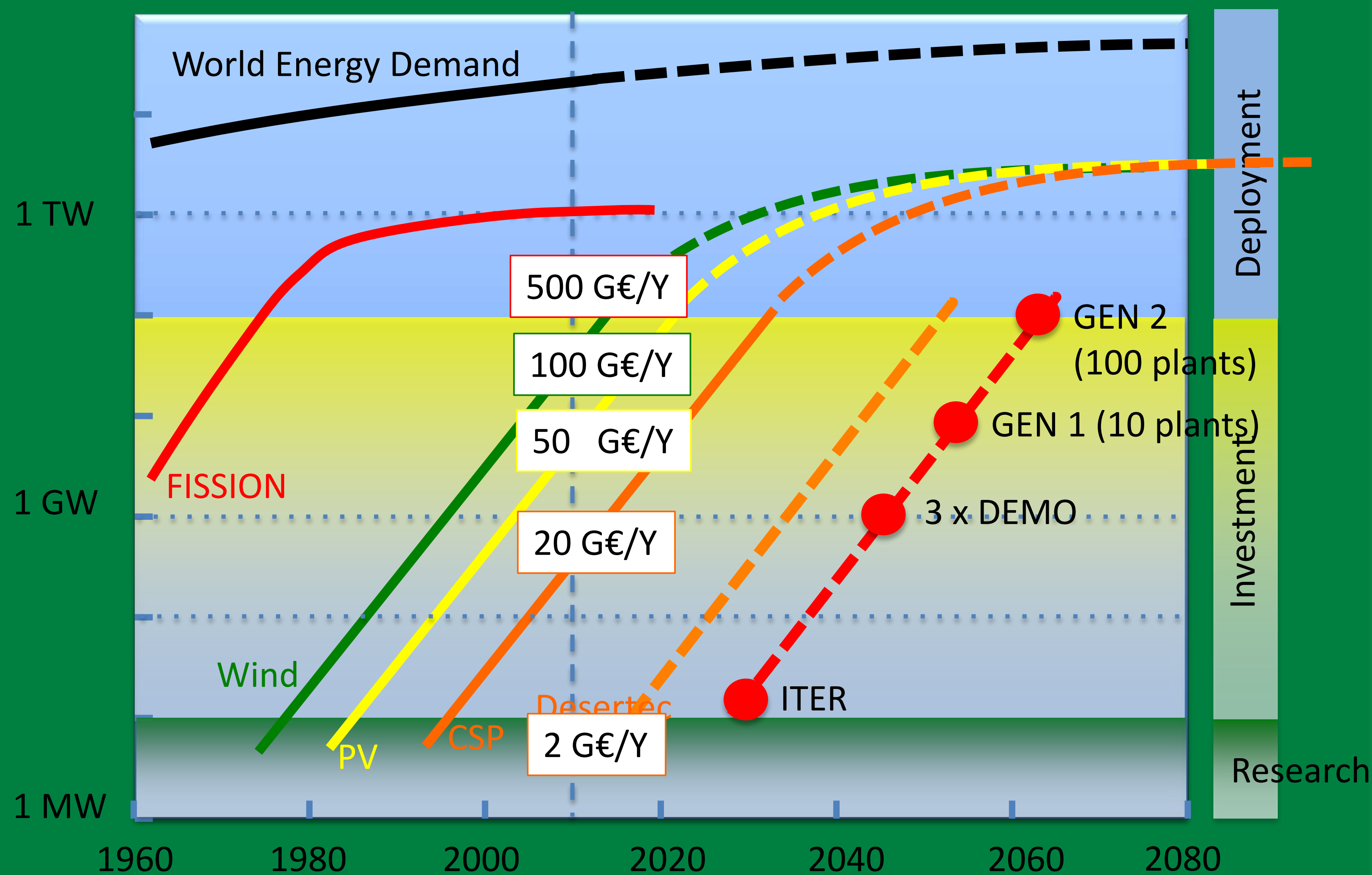
→ How big is the investment, moneywise? And who pays this?

Overnight cost: $ per Watt installed power.

Source: IEA

[technology]	[$/W]	Load factor	[$/W$_{eff}$]
• Wind	2.5	0.3	10
• Wind-off-shore	6	0.4	15
• Solar Thermal	5	0.2	25
• Solar PV	5	0.2	25
• Nuclear	6	0.9	7
• Conv. Gas	1	1	1

The cost of the development of an energy technology



ERDA-76/110/1
UC-20

FUSION POWER

BY MAGNETIC CONFINEMENT

PROGRAM PLAN

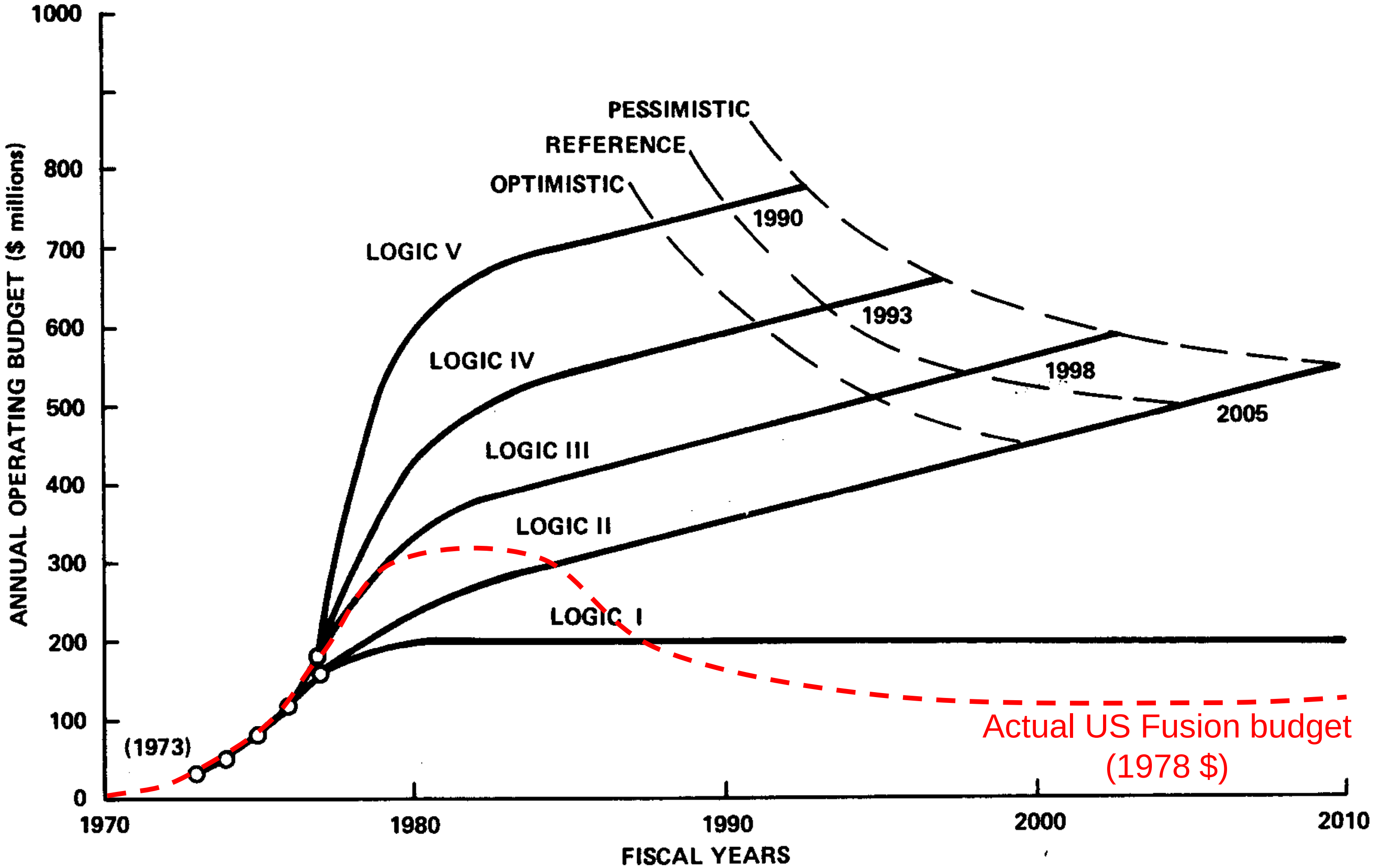
VOLUME I

SUMMARY

JULY 1976

Prepared by the
Division of Magnetic Fusion Energy
U.S. Energy Research and Development Administration

Also published in Journal of Fusion Energy, Vol. 17, No. 4, 1998, S. O. Dean



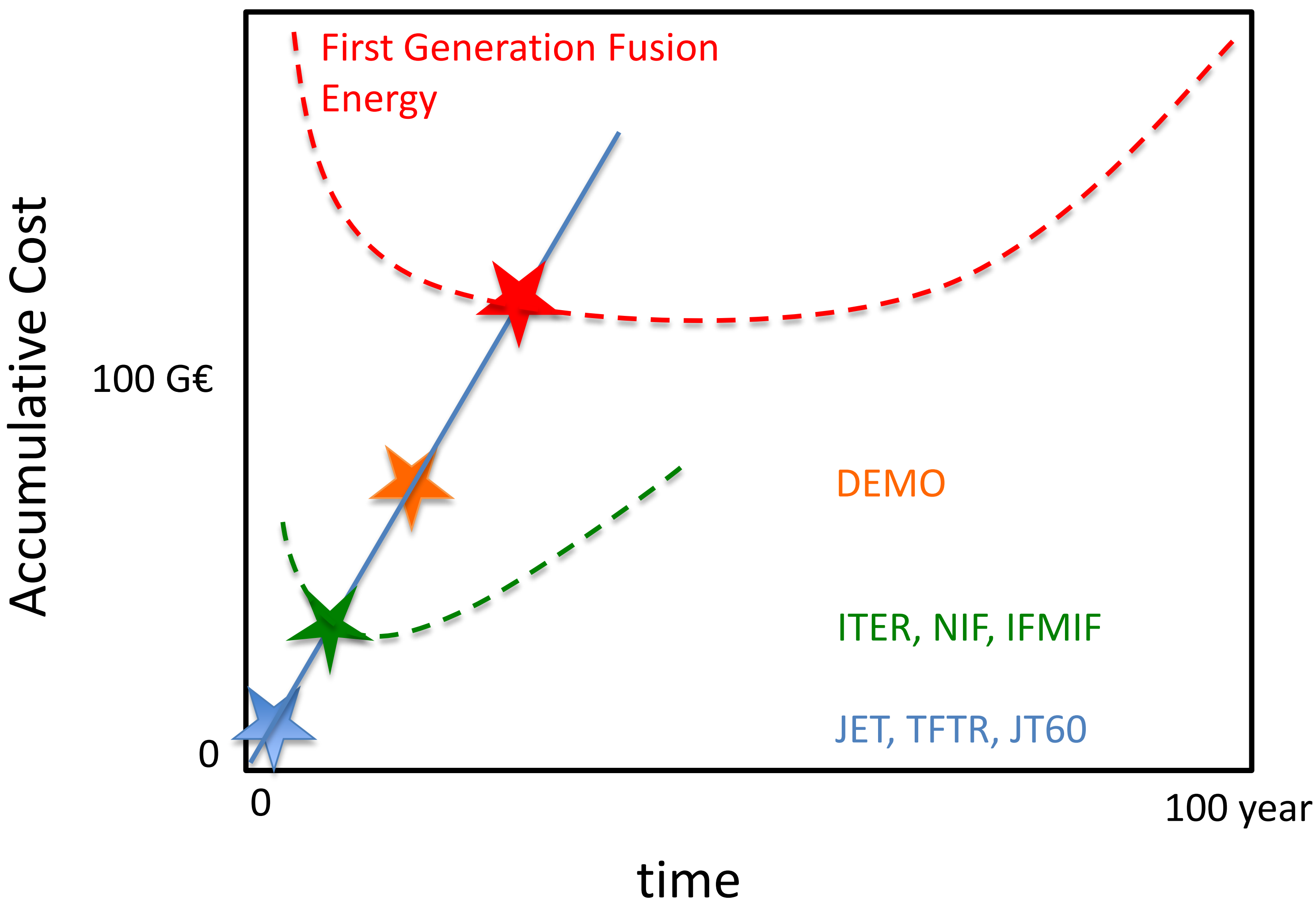
FUSION R&D PROGRAM OPERATING BUDGET AND LOCI OF DEMO OPERATING DATES FOR LOGIC I THRU V

Figure II-2

Logic IV became the basis for the MFE Act of 1980

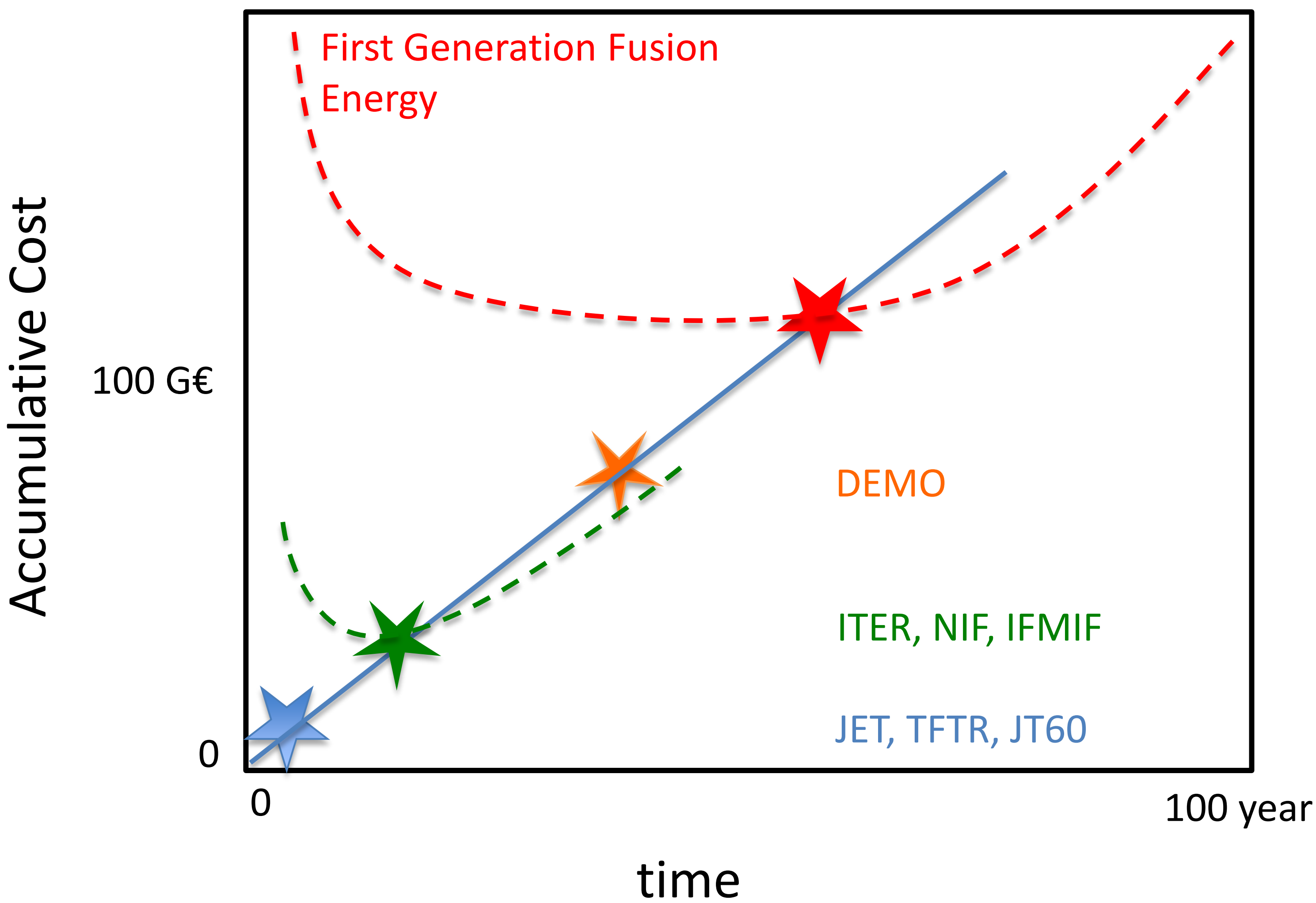
The development of fusion or any other new energy source requires an investment.

How fast you get it depends on you annual spending.



The development of fusion or any other new energy source requires an investment.

How fast you get it depends on you annual spending.



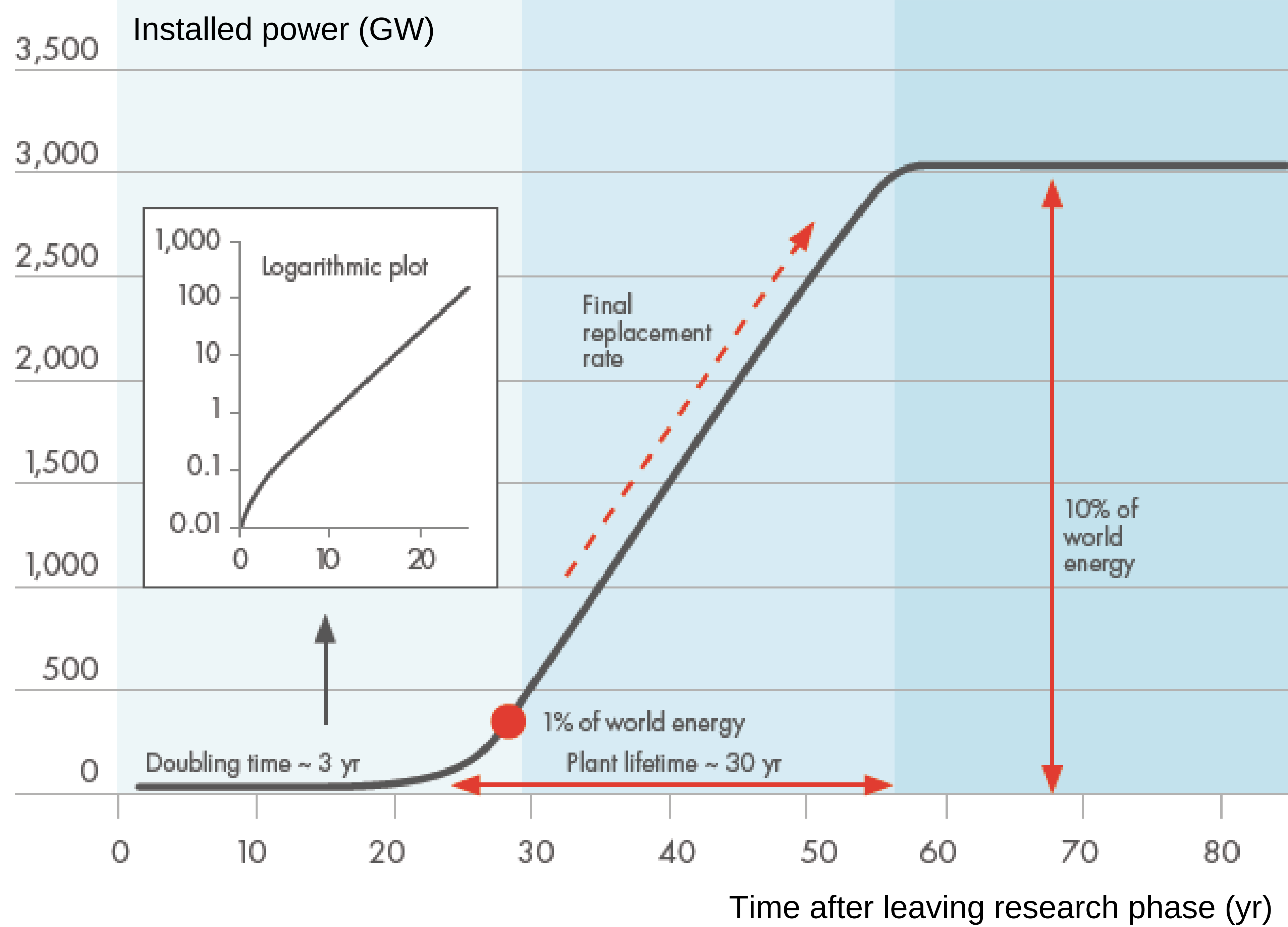
Conclusion

- Fusion Road Map is fully comparable to other energy options
- Fusion is somewhat late, but certainly not ‘far too’ late
- → Slow (start) yet Fast (if adequately funded)

- 2000 Billion Euro to take a new energy technology through its exponential growth; upfront investment, spent over about 40 years
- Fusion not different from other technologies.
- Present spending on fusion: average for the stage of development.
- → Expensive (lot of money) yet Cheap (for new energy)

- The development of fusion does not take time. It takes money.

MUST STICK TO THE ROADMAP!



Installed power (GW)
3,500
3,000
2,500
2,000
1,500
1,000
500
0
1,000
Logarithmic plot
100
10
1
0.1
0.01
0
10
20
Final
replacement
rate
10% of
world
energy
1% of world energy
Doubling time ~ 3 yr
Plant lifetime ~ 30 yr
0
10
20
30
40
50
60
70
80
Time after leaving research phase (yr)