Review of Initial Markets for Fusion Energy

Or any new heat source

January 22, 2021

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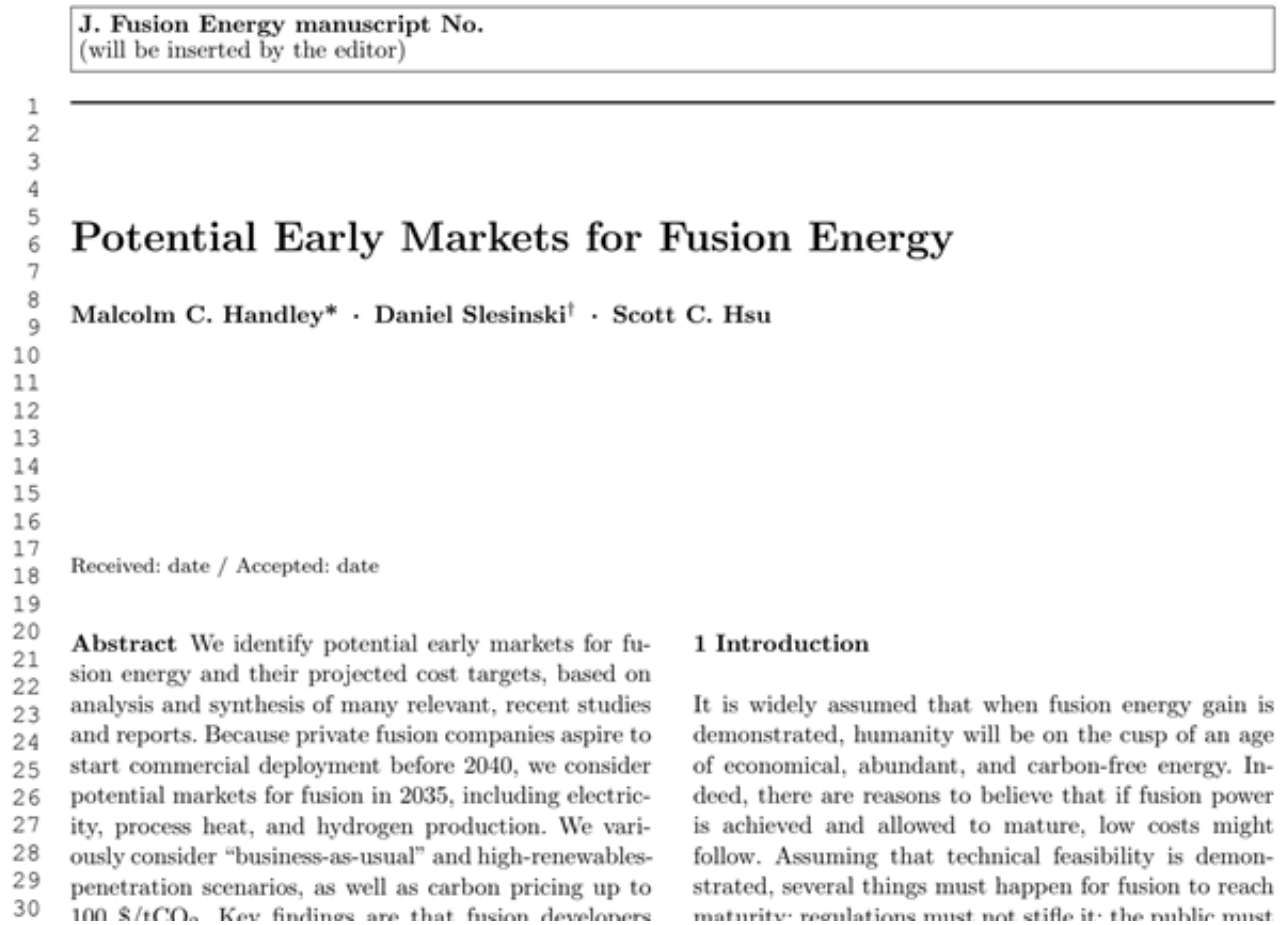
A bit about me

- Used to be a software engineer
- Started Strong Atomics
- Formerly T2M at ARPA-E for fusion



J. Fusion Energy manuscript No.
(will be inserted by the editor)

Potential Early Markets for Fusion Energy

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Received: date / Accepted: date

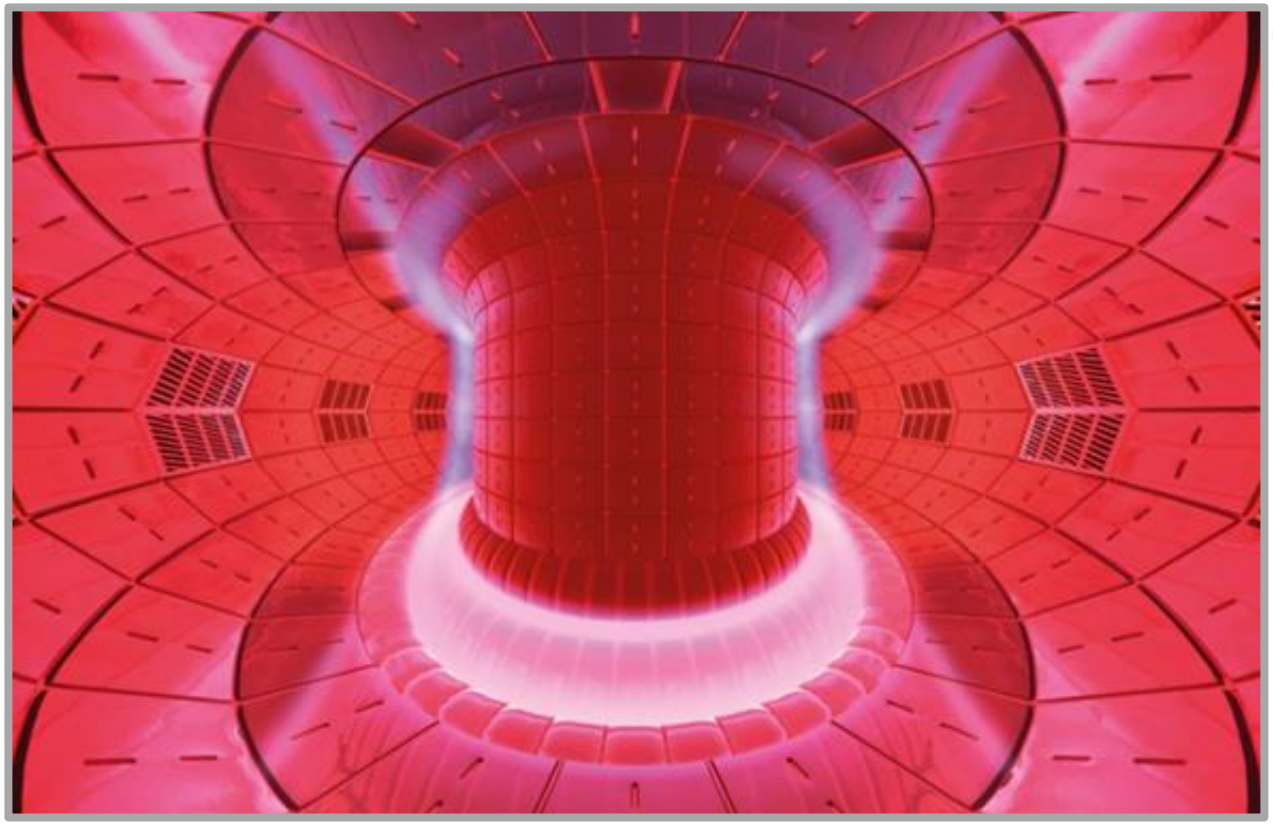
Abstract We identify potential early markets for fusion energy and their projected cost targets, based on analysis and synthesis of many relevant, recent studies and reports. Because private fusion companies aspire to start commercial deployment before 2040, we consider potential markets for fusion in 2035, including electricity, process heat, and hydrogen production. We variously consider "business-as-usual" and high-renewables-penetration scenarios, as well as carbon pricing up to 100 $/tCO$_2$. Key findings are that fusion developers

1 Introduction

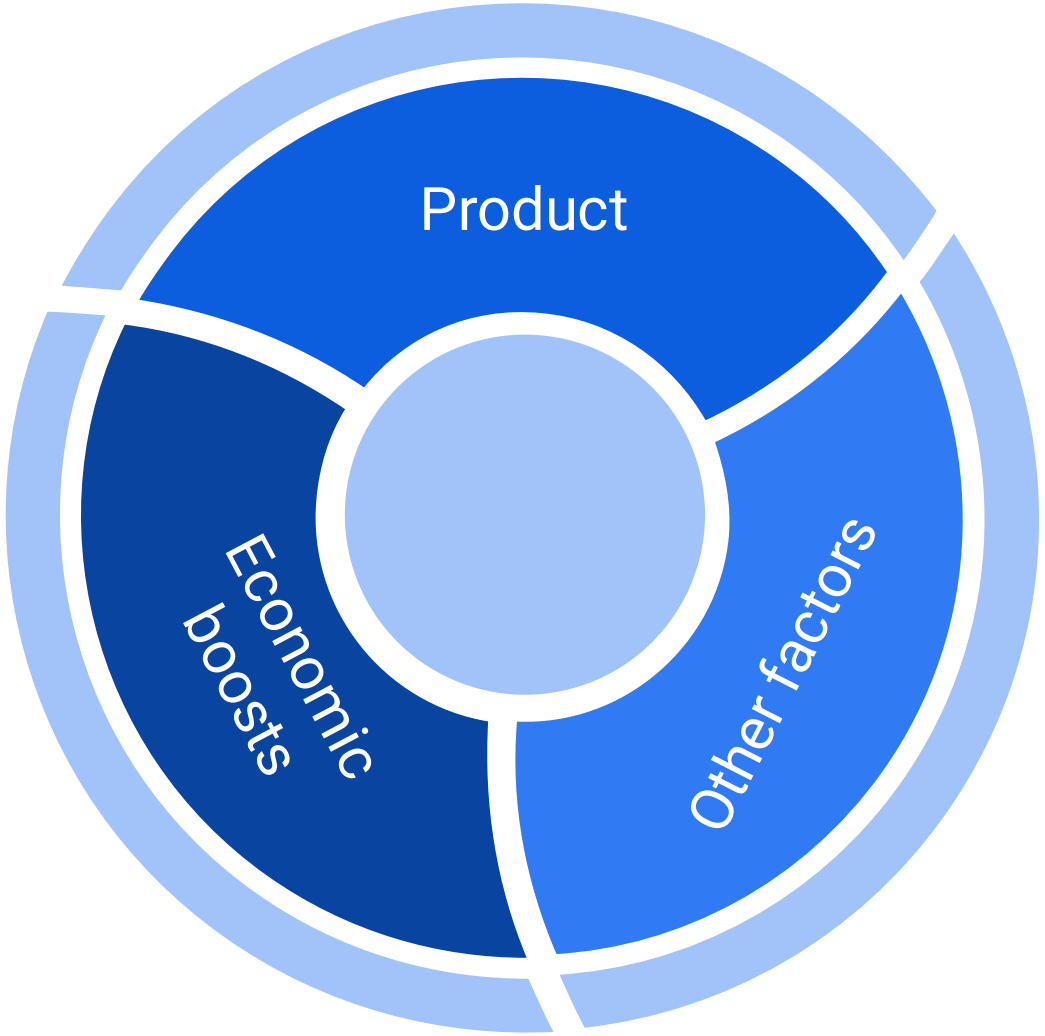
It is widely assumed that when fusion energy gain is demonstrated, humanity will be on the cusp of an age of economical, abundant, and carbon-free energy. Indeed, there are reasons to believe that if fusion power is achieved and allowed to mature, low costs might follow. Assuming that technical feasibility is demonstrated, several things must happen for fusion to reach maturity: regulations must not stifle it; the public must

Goals for the market study

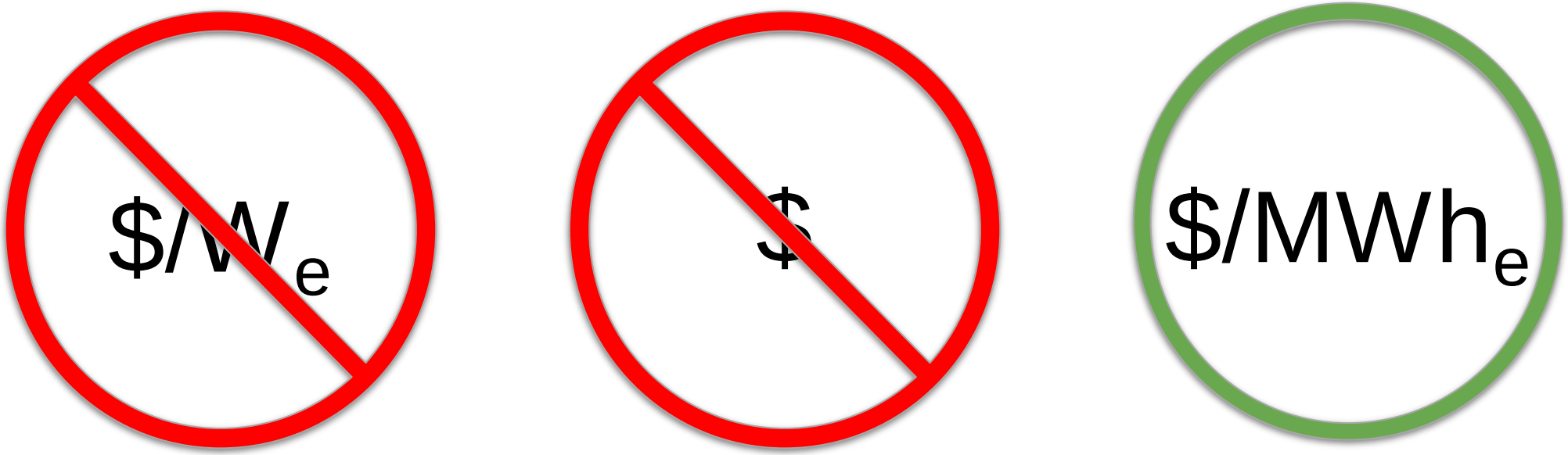
- Suggest initial markets
  - 2035
  - Carbon tax up to 100 $/tCO$_2$
  - Looking for existing markets
- Audience:
  - Companies
  - Investors
  - Larger fusion community
- Suggest market requirements and price enhancements



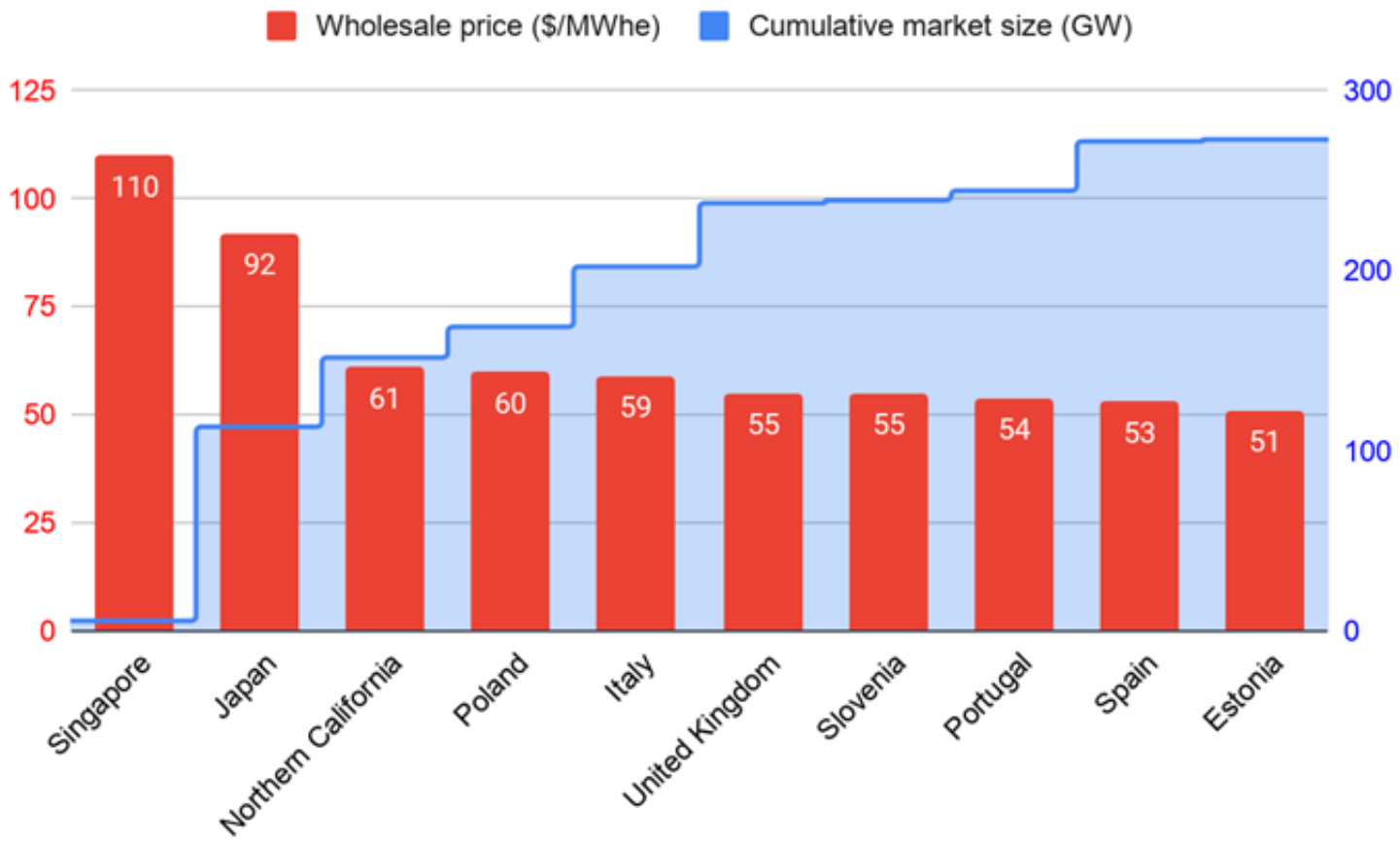
Factors to consider for selecting initial markets



Results are in $/MWh$_e$



Electricity: Consider early markets where prices are high



Other factors:

- Population density
- Nuclear technological capabilities
- Capacity payments
- Renewable capacity

Electricity: Thermal storage fills out the duck curve

High renewables lower the capacity factor for firm power

↓

Big increase in LCOE for fusion

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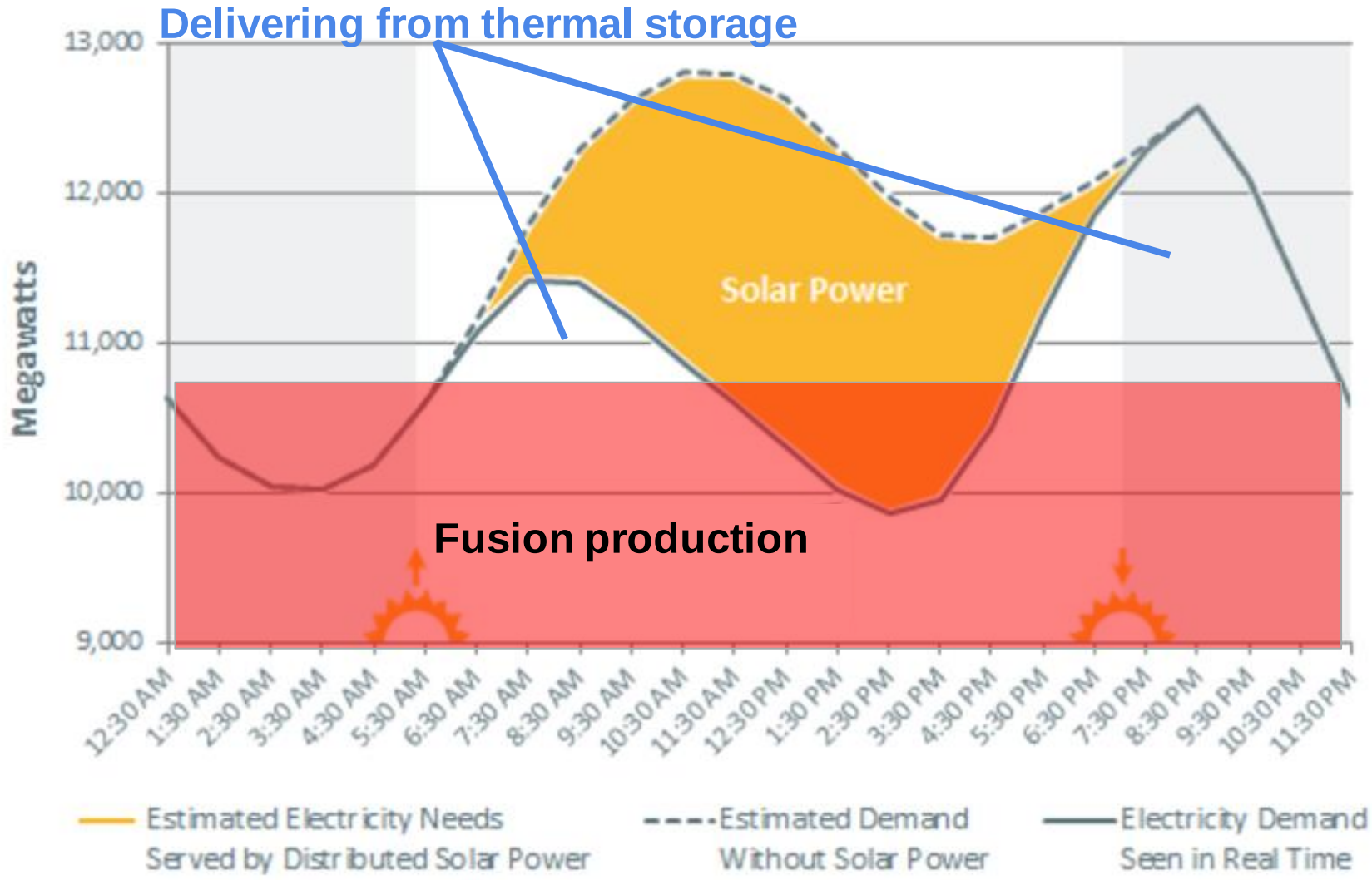
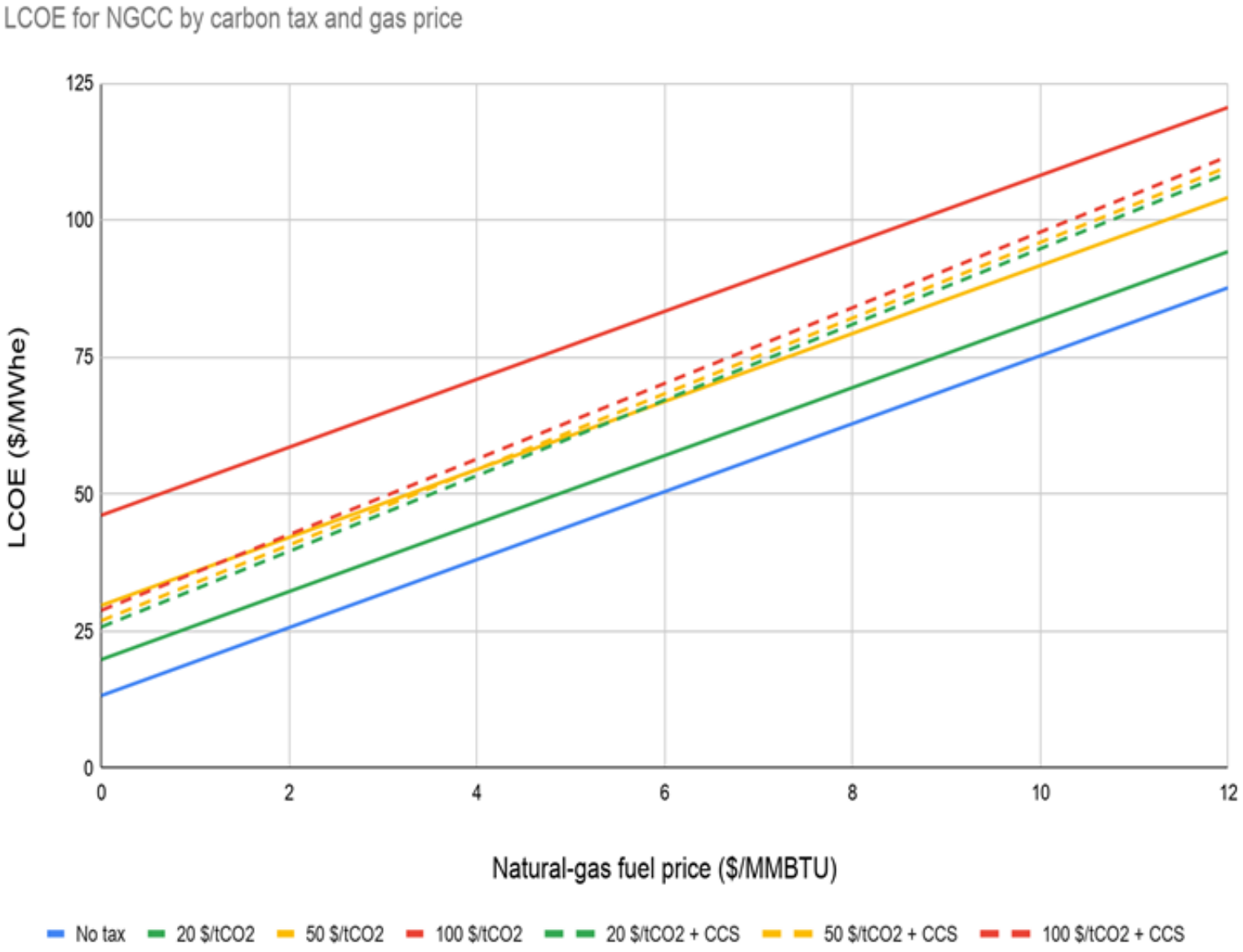
Integrated thermal storage might reduce LCOE by ~40%



Source: ISO New England

Electricity: Must compete with natural gas in the long term



LCOE Benchmarks

- Lazard: 44–68 $/MWh$_e$
- EIA: 38–67 $/MWh$_e$
- DOSCOE: 17–28 $/MWh$_e$

Target for fusion: 50 $/MWh$_e$?

Process heat market will mostly be inaccessible to fusion

Tough market in general:

- Dependent on local customer
- Competing against free fuel
- Needs high temps

But: some promising markets, including remote mines:

- Repeat customers
- High price
- Tolerant of downtime

Hydrogen could provide a small early market

Heating:

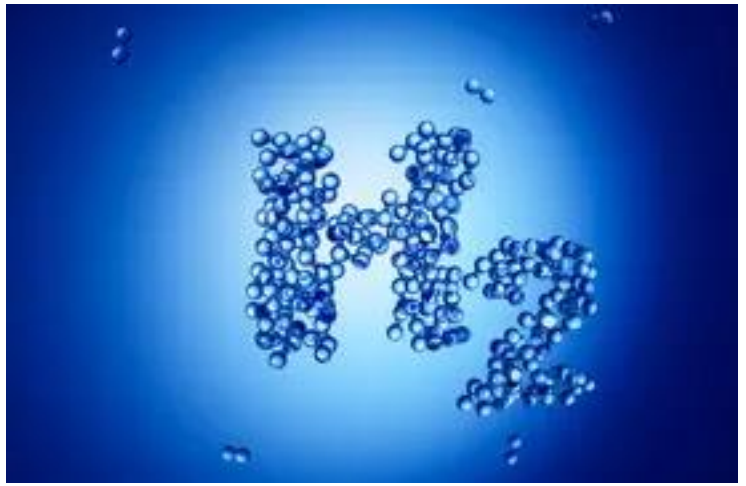
- Japan: 78 $/MWh$_e$ (3.5 $/kg$H_2$)
- Europe: 66 $/MWh$_e$ (3.0 $/kg$H_2$)

Energy companies ready to build hydrogen plant if fusion is “the right price”

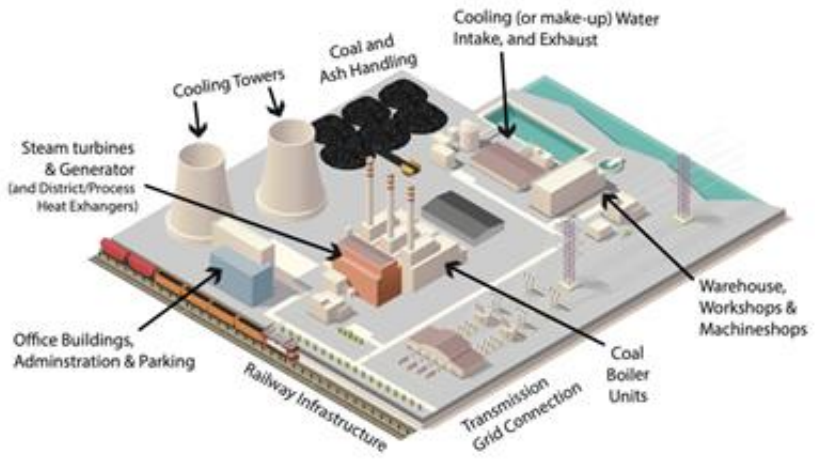
Firm power is less important than for electricity—more competition from renewables

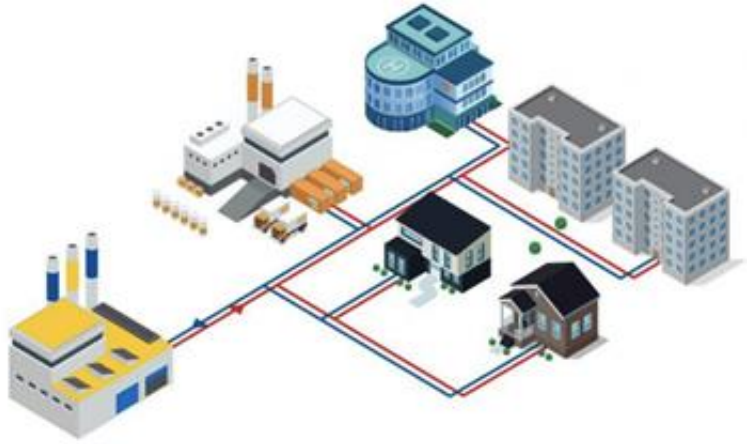
No obvious early markets in:

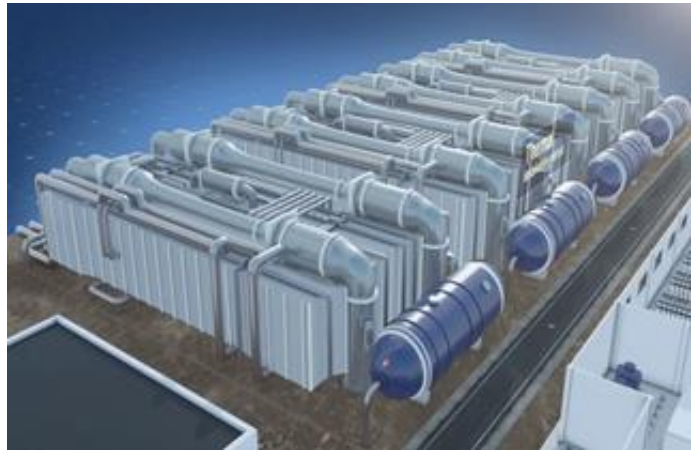
- Ammonia, Methanol
- Oil refining
- Steel refining



Economic boosts





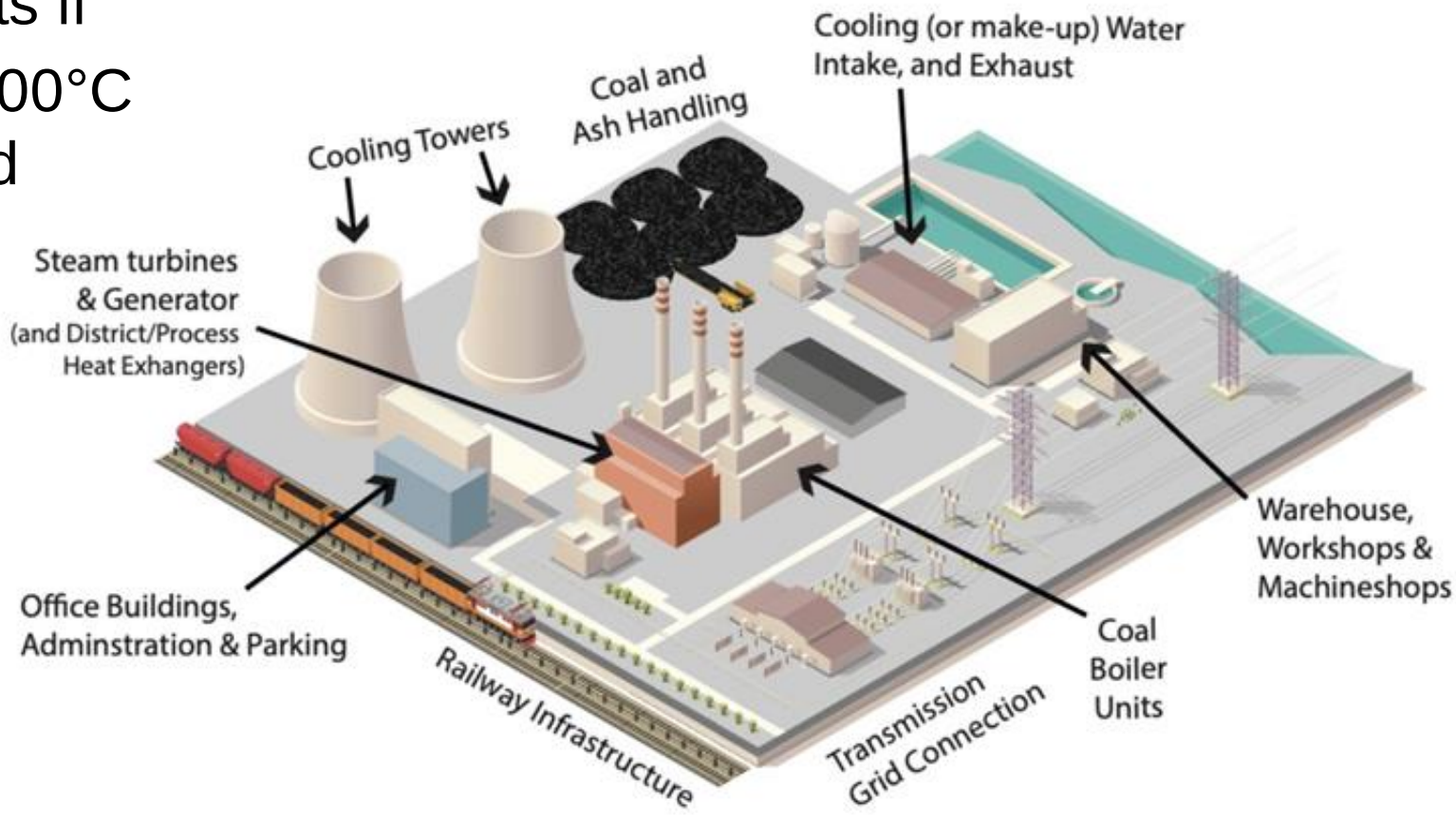


Retrofitting coal plants could significantly reduce capex

Save up to 30% of capital costs if

- Fusion delivers steam at 500°C
- Coal plant is < 20 years old

Fusion and fission are the best fits for repowering most coal plants



S. Qvist, P. Gladysz, L. Bartela, A. Sowizdzal, Energies 14, 120 (2021). https://doi.org/10.3390/en14010120

Direct Air Capture provides opportunity to reduce cost

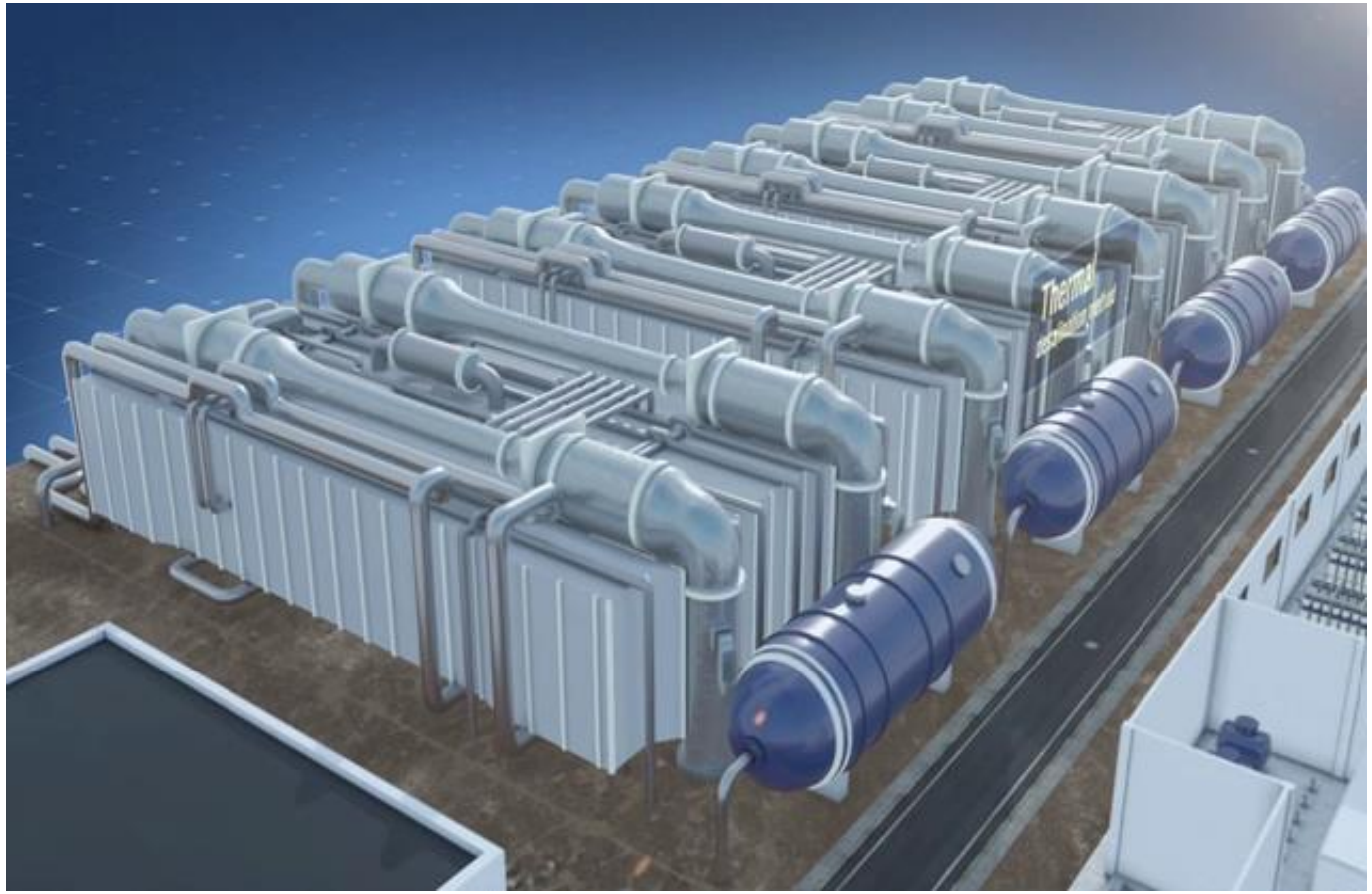
Potential to reduce fusion LCOE by 35% through cogeneration

- Fusion supplies DAC plant free heat and electricity
- DAC plant generates revenue equal to cost per ton of CO_2

Desalination is cheaper with fusion

Thermal desalination methods require heat at about 100°C

Providing waste heat from fusion could cut O&M for desalination by about half

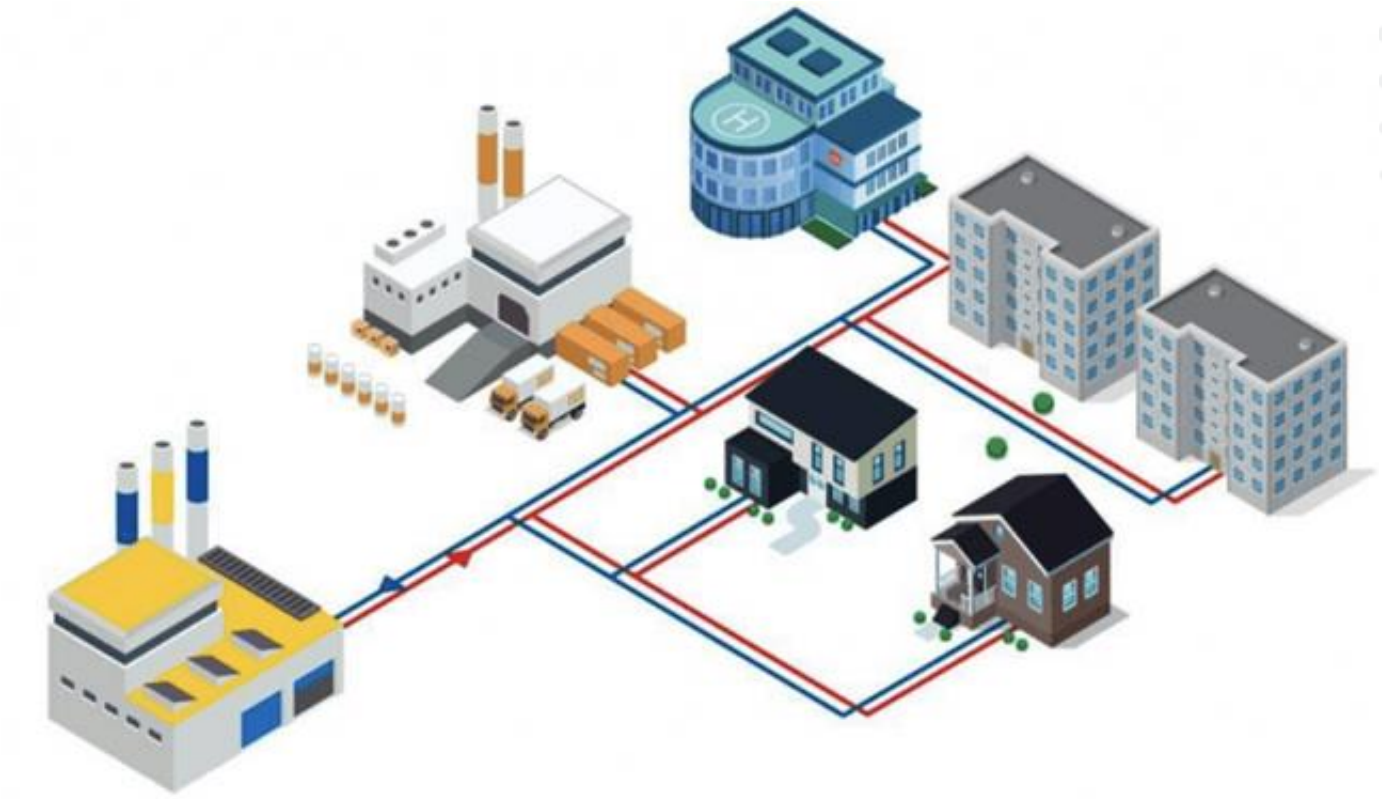


District heating could provide a unique market for fusion

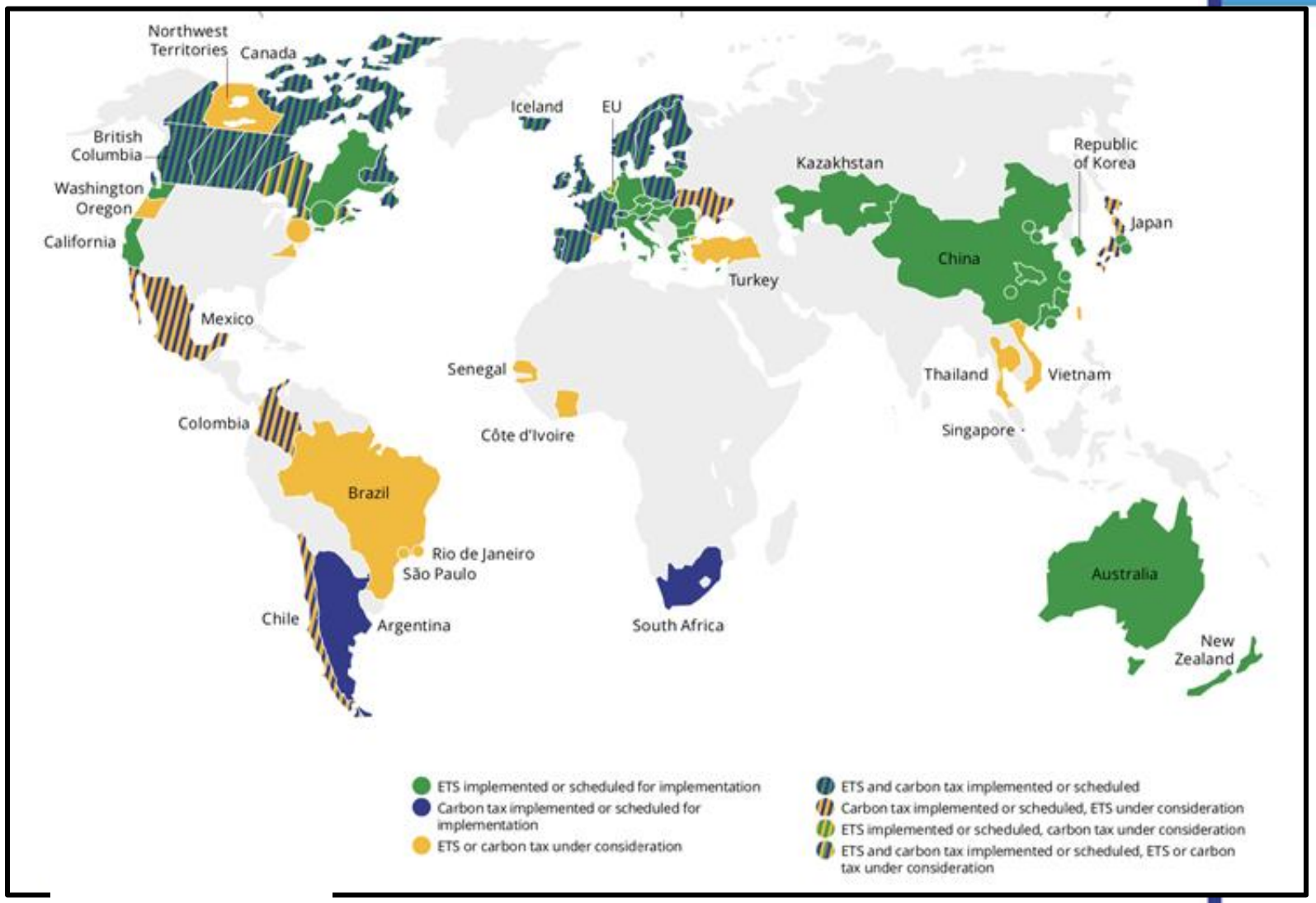
Individual cities can use multiple GW_t

Fusion plants might be closer to demand than fission

Early market requires finding a large heat network to supply



Carbon taxes will affect analysis



CARBON PRICING INITIATIVES AROUND THE WORLD

57 implemented or scheduled for implementation

46 NATIONAL
28 SUBNATIONAL
jurisdictions

11 $GtCO_2e$ = 20%
of GHG emissions covered

51%
< US$10/$tCO_2e$

Range of prices in existing initiatives
US$1 - 127/$tCO_2e$

51% of the emissions covered are priced < US$10/$tCO_2e$

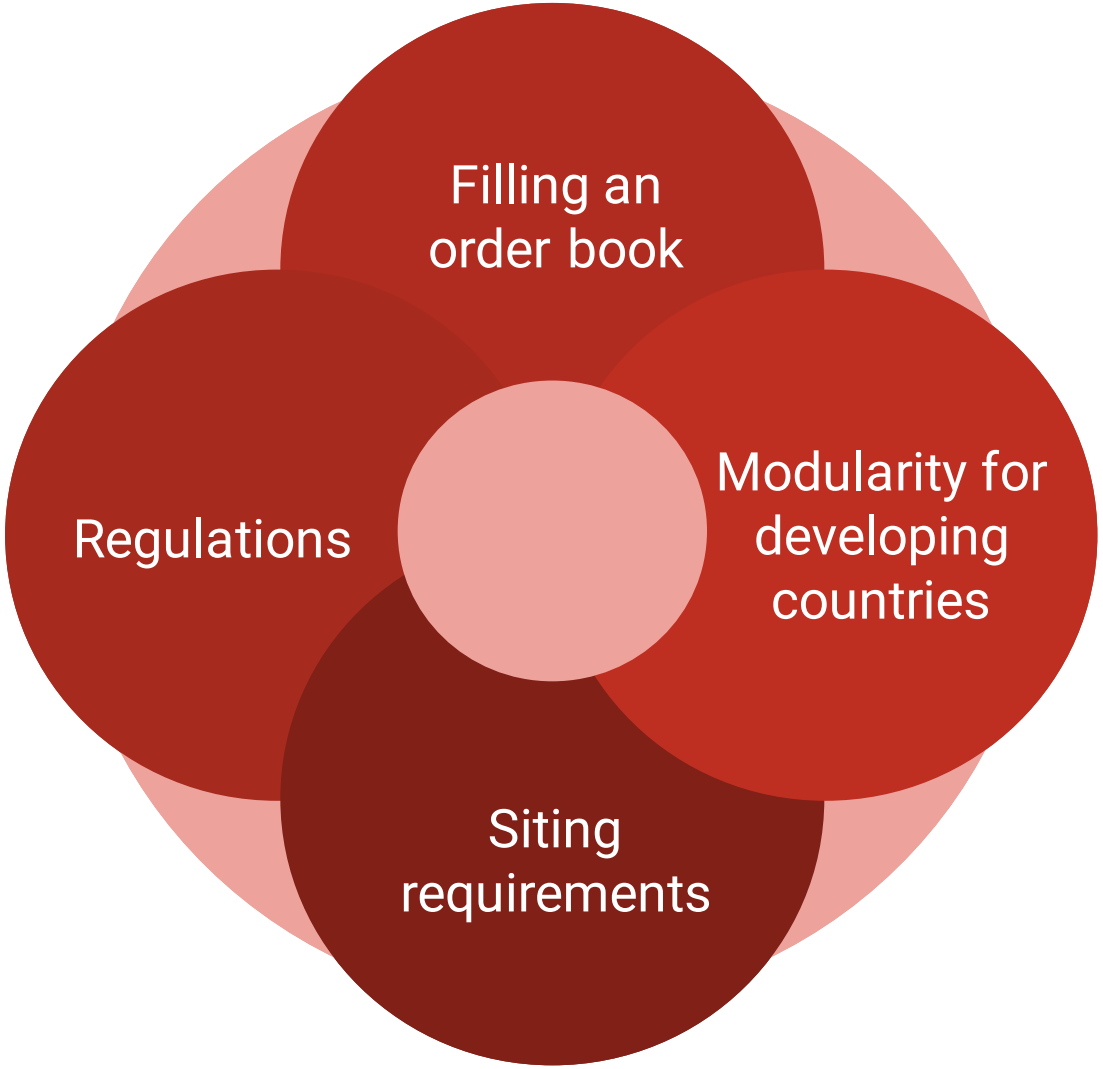
US$44 BILLION
raised in carbon pricing revenues in 2018.

As of April 1, 2019

[World Bank's State and Trends of Carbon Pricing 2019]

arpa·e
CHANGING WHAT'S POSSIBLE

Other factors



Conclusions

- Grid **electricity** presents the most promising early market
  - For early development, look to countries with high costs of electricity
  - For longer term, 50 $/MWh is a good benchmark that opens up most markets
  - Integrated thermal storage will be needed to compete in markets with high renewables
- The **process heat** market will be challenging in the short term and long term
  - There may be special circumstances where fusion could work well
- In areas where **hydrogen** is expensive, fusion could be a good fit
  - A market would be available in Japan if fusion can cost 78 $/MWh
  - To reach larger markets worldwide, fusion would need to be half that cost
- Various **economic boosts** could help initial fusion deployment
- **Carbon taxes** will benefit fusion in all scenarios

Questions?