Tech-to-market introduction

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Outline

- Fusion’s value proposition
- From gain to the grid
- Fusion’s market
- Financing
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Renewables + storage is too expensive

Analyzing Energy Technologies and Policies Using DOSCOE

Solar Tribune
Renewables are slow to deploy

Figure 1.3: Electricity growth (kWh per year per capita) based on actual data for added power capacity in various countries

- **Nuclear Sweden 1974-1983**: 730
- **Nuclear France 1979-1988**: 627
- **Nuclear US 1981-1990**: 548
- **Natural Gas US 2001-2010**: 548
- **Coal China 2005-2014**: 339
- **Solar & Wind Spain 2003-2012**: 120
- **Solar & Wind Germany 2007 - 2016**: 98
- **Solar & Wind Denmark 2007 - 2016**: 92

Average added kWh per capita per year
Fusion is a promising alternative to fusion

<table>
<thead>
<tr>
<th></th>
<th>Fission</th>
<th>Fusion</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Method</strong></td>
<td>Splitting atoms</td>
<td>Combining atoms</td>
</tr>
<tr>
<td><strong>Waste</strong></td>
<td>Long- and short-lived</td>
<td>Short-lived</td>
</tr>
<tr>
<td><strong>Meltdown</strong></td>
<td>Possible</td>
<td>Impossible</td>
</tr>
<tr>
<td><strong>Proliferation</strong></td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td><strong>Cost</strong></td>
<td>Low-high</td>
<td>Lower</td>
</tr>
<tr>
<td><strong>Demonstrated</strong></td>
<td>Yes</td>
<td>No</td>
</tr>
</tbody>
</table>
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From gain to the grid

Optimistic post-gain roadmap:

- Demo: $2B, 10 years
- Bankability: $5B, several plants

Still have:

- Market risk
- Financing risk
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Market exists for expensive fusion, grows as price drops

The likely addressable market for fusion in the 2030s amounts to ~465 GW globally, with a much bigger potential of ~2,720 GW if fusion can compete with fossil fuels below $60/MWh

Total estimated addressable market for fusion (GW) at different price levels in a high electrification scenario

Wholesale electricity prices vary widely:
- Singapore: 13¢/kWh
- Germany: 6¢/kWh
- Texas: 3¢/kWh

Source: SystEmiq analysis. Note: Based on high power demand scenarios (Shell Sky Scenario). Country analysis for 7 countries: Brazil, China, France, India, Japan, UK, USA. Proxy analysis by archetype for 11 countries: Colombia, Germany, Italy, Indonesia, Israel, Malaysia, Philippines, Singapore, Spain, South Korea, Taiwan, Thailand, Vietnam.

Electrification and decarbonization: the role of fusion in achieving a zero-carbon power grid
Lower-cost fusion might dominate the market
A carbon price further expands the market for fusion

Some current prices

- EU: floats, currently around €25/ton
- California: $15/ton
- British Columbia: $30/ton
Estimated prices fit these markets

- Benchmarking on fission, Bechtel conservatively estimates $4-13/W, plant possible for <$1B

- Companies’ estimates are much lower: $2-5/W

- Rough modeling suggests LCOEs of 3-6¢/kWh
Process heat could be a large market for fusion

- Process heat is about 20% of energy usage
- Renewables produce electricity, which is inefficient to turn into heat
- Fission can address ~20% of this market (150MWth in US, 640MWth globally) but siting restrictions make this hard to address
- Small, safe, high-temp fusion could win here
- But competing with gas requires cheap fusion or a price on carbon (gas is ~3¢/kWth)
Design the right reactor

- Firm, but flexible, power
- Produce high temps, not direct generation of electricity
  - Provide process heat
  - Integrate thermal storage instead of ramping for market timing
- Competitive in some markets initially ($, not just $/W and $/MWh)
- Evolve to be cheaper with quantity or learning in preference to size
- Flexible siting
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Milestones can facilitate investment

- COTS milestones and awards supported SpaceX, but also Sierra Nevada

- FDA approval milestones are critical for biotech fundraising

- Can ARPA-E set similar milestones for fusion companies?
None of this matters without insurance and financing

- Without project finance, plants don’t get built
- Without insurance, project finance isn’t available
- Early investors take this into account
- NetPower struggled to raise $150M to build a 50MW plant
What else?

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