Fusion Implementation Scenarios

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Socio-economics Aspects of Fusion Power
VLT Program Advisory Committee
Oak Ridge National Laboratory

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Fusion Scenario Development Objective

• Show that fusion can be an energy source for the 21st century

• Develop an understanding of the requirements for meeting this objective

• And the implications for resources and waste
We Have Assessed Fusion Implementation Scenarios for Both the U. S. and the World

- We need to study fusion implementation in the U. S. to be able to communicate with our constituency.

- In addition, it is a little easier to extrapolate and relate to the U. S. energy future.

- To the extent that we want to illustrate impacts on atmospheric carbon dioxide we need to look at total world scenarios.

- Clearly the biggest growth in demand will be for the developing economies.
Electricity Production

IIASA/WEC Scenario B

North American (Terawatts)

World (Terawatts)
| CALENDAR YEAR | 0 | 2 | 4 | 6 | 8 | 10 | 12 | 14 | 16 | 18 | 20 | 22 | 24 | 26 | 28 | 30 | 32 | 34 | 36 | 38 | 40 | 42 | 44 | 46 | 48 | 50 | 52 | 54 | 56 | 58 | 60 | 70 | 80 |
|---------------|---|---|---|---|---|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| ITER CONSTRUCTION | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| ITER OPERATIONS | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| DEMO GO | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| DEMO CONCEPT DESIGN | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| DEMO CONSTRUCTION | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| DEMO OPERATIONS | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| PROTO 1 GO | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| VNS GO | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| VNS CONCEPT DESIGN | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| VNS CONSTRUCTION | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| VNS OPERATION | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

Fig. 5. Fraction, $f$, of world energy sources expressed as $f/(1-f)$.

# Fusion Development

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Fusion Contributions to North American Electricity Production

- Doubling 7.5 yrs
- Doubling 5 yrs
- Doubling 10 yrs

North American Electricity Production

Terawatts
PCAST
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<th>Precedents for Energy Technology Implementation</th>
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<td>French Nuclear</td>
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<td>CANDU - ratio to Canadian Power</td>
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<td>CANDU - ratio to Ontario Power</td>
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Fusion Contributions to North American Electricity Production

North American Electricity Production

2%/year

1%/year

Terawatts

1990 2000 2010 2020 2030 2040 2050 2060 2070 2080 2090 2100 2110 2120 2130 2140 2150
Activated Waste
(U.S. Implementation)

Present Licensed Low-level Storage About $10^6$ M$^3$

- 2%/year
- 1%/year
Total Vanadium Required

Identified World Resource 30 Megatonnes

- 2% per year
- 1% per year

Megatonnes

Year:
- 2070
- 2075
- 2080
- 2085
- 2090
- 2095
- 2100
- 2105
- 2110
- 2115
- 2120
- 2125
- 2130
- 2135
- 2140
Vanadium Required Per year (for U.S.)

- Present U.S. Production
- Present World Production

Kilotonnes Per Year

- 2%/year
- 1%/year

Years: 2070, 2075, 2080, 2085, 2095, 2105, 2115, 2125, 2135, 2145, 2150
ProTo Phase

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<th>$T_{br}$</th>
<th>1.015</th>
<th>1.03</th>
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<td>$T_f$ kg</td>
<td>20</td>
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Ramp-Up Phase

$\frac{dP}{dt} = 20 \text{ GWe yr}^{-1}$

$P_o = 5 \text{ GWe}$
$T_o = 20 \text{ kg}$

$P_o = 10 \text{ GWe}$
$T_o = 40 \text{ kg}$

$P_o = 20 \text{ GWe}$
$T_o = 80 \text{ kg}$
The emission profiles shown in the last figure are projected to result in the following atmospheric concentrations (with corresponding labels) of carbon dioxide.
Projected Need for Non-carbon Producing Energy

New Non-emitting Energy Required for S750

1%/year of Total Energy
Conclusion

• The number of major fusion cycles (experimental facilities) required and the time to commit to these facilities will determine the development time.

• A go ahead on ITER and a VNS will be required soon to support the assumed development schedule.

• It will be difficult to have a significant impact on the electrical power production during this century with a doubling model for implementation unless the doubling time is less than 7.5 years.

• If we can implement fusion commercialization as aggressively as the French and Canadians fission commercialization we can have a significant impact this century (requires bullet 2).

• The projected waste production from aggressive fusion commercialization in the U.S. will rapidly exceed the present level of licensed low-level waste storage.

• Aggressive fusion commercialization will require increases in production of resources such as vanadium.