STATUS REPORT ON THE ARIES FUSION NEUTRON-SOURCE STUDY

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BACKGROUND AND APPROACH

- **The purpose of this study is to assess the potential and competitiveness of a fusion neutron source as an intermediate-term application of fusion energy research, on the path to fusion power systems**

- **The study began with a concept definition phase which consisted of the following four tasks:**

(1) A market assessment to identify the most useful application and product

(2) An assessment of the engineering and nuclear performance characteristics of the various options proposed for neutron-source applications

(3) System studies to assess the economic characteristics of MFE-based fusion neutron-source applications

(4) An assessment of the environmental, safety and licensing implications of fusion neutron-source applications

- **The intent of the concept definition phase is to determine if any of the fusion neutron-source applications offer sufficient promise to warrant detailed design and development path consideration**

OBSERVATIONS

(1) The use of fusion neutrons for the transmutation of nuclear waste scored very high in the market assessment and therefore, was chosen as the focus of the concept definition phase

(2) There is no established set of objectives and metrics by which to compare the three options for transmutation of nuclear waste

(3) The neutronic performance characteristics of the transmutation options are to a large extent dependent on blanket design and processing mode, and to a lesser extent dependent on the neutron source

OBSERVATIONS (continued)

(4) The most fundamental distinction among the neutron-source options is associated with the issue of criticality, i.e., fission systems operate in a critical mode, while fusion and accelerator systems provide external neutron sources, which drive subcritical blanket assemblies

(5) Subcritical assemblies offer several operational advantages compared to critical assemblies, including deeper burnup of waste, and flexibility in engineering design and power control

(6) To first order the estimated cost of neutrons for transmutation of waste applications is comparable for all three options

OBSERVATIONS (continued)

(7) The estimated cost of electricity is significantly higher for the fusion waste transmuter than for a pure fusion power system because of the assumptions of lower capacity factor and fewer safety credits. However, the primary goal of the transmuter is disposition of waste and any sale of electricity should be viewed as an offset to the capital and operational costs for the transmutation mission

(8) The external neutron-source options offer the potential of improved safety compared to the fission option. These advantages relate to reduced risk of criticality events and the physical separation of the neutron source and the radioactive inventory

OBSERVATIONS (continued)

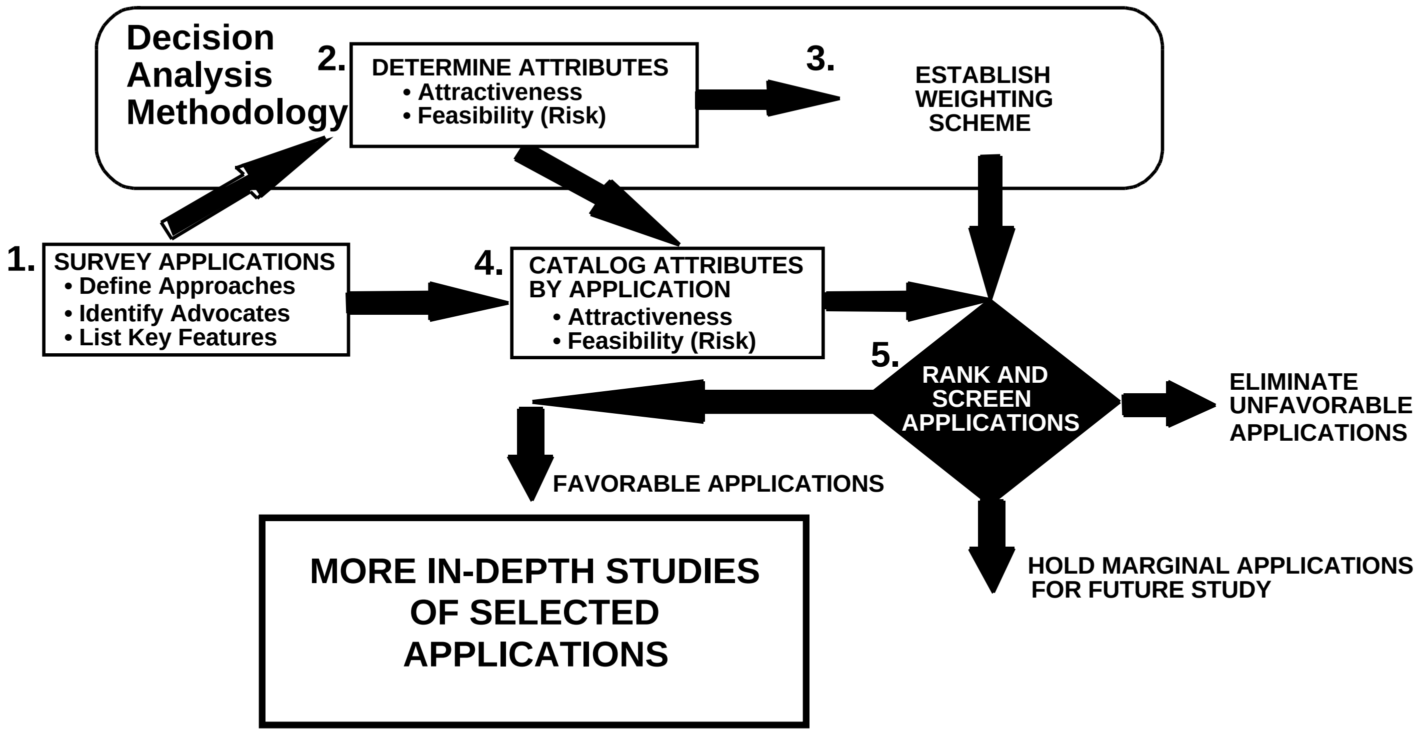
(9) The impact of these potential safety advantages in terms of economic implications and public perception is yet to be determined

(10) A fusion-based system could provide a viable option for the transmutation of nuclear waste. The extent to which the fusion community should pursue and promote such an application of fusion is more a matter of policy than technical feasibility

List of Neutron Applications

Transmutation
Breed fissile fuels (energy-suppressed mode) for use in complementary fission plants
Produce energy in a subcritical fissionable blanket
Transmute fission nuclear wastes to stable elements or short-lived isotopes
- Plutonium
- Minor actinides (Elements 89-103)
Create tritium
Create radioisotopes
Direct usage
Conduct neutron activation testing
Alter material properties
Use for detection and remote sensing
Conduct radiotherapy
Conduct neutron radiography or tomography
Thermal Conversion
Generate electricity
Generate process heat
Dissociate water into hydrogen and oxygen
Electrolysis or high temperature electrolysis of water to create hydrogen and oxygen
Desalination

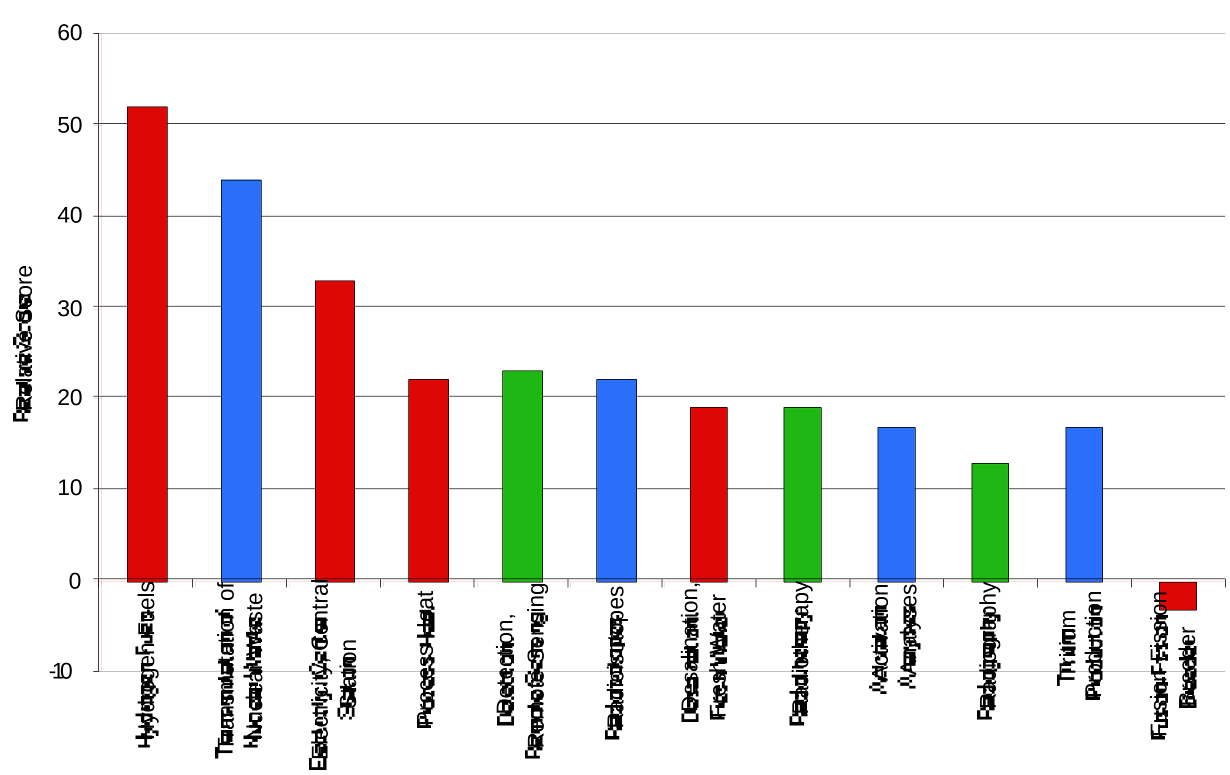
Assessment of Neutron Source Applications



Decision Criteria Attributes

Market Factors	Relative Value
Necessity	High (3)
Uniqueness	High (3)
Market Potential	High (3)
Environmental Factors	**Relative Value**
Depletion of Valued Resources	High (3)
Environmental Impact	High (3)
Economic Factors	**Relative Value**
Competitive Product	Moderate (2)
Improvement in GNP	Low (1)
Risk Factors	**Relative Value**
Investment for Return of Capital	Moderate (2)
Maturity of Technology	Moderate (2)
Time to Market	Moderate (2)
Public Perception Factors	**Relative Value**
National/Company Prestige	High (3)
Public/Governmental Support	High (3)

Ranked Weighted Values Of Fusion Products



Fuel cycle options

Feedstock

- Weapons material (^{239}Pu) as sole source
- Fission waste as sole source
- Weapons material as makeup feed
- Minor actinides only (no Pu or U in feedstock)

Disposition scenario

- Power producing mode (high conversion ratio)
- Moderate destruction mode (conversion ratio of 0.5-1)
- Maximum destruction mode (non-uranium fuel, high burnup reactivity loss)
- Pu denaturing (i.e., producing radioactive byproducts that contaminate the Pu)

Processing mode

- batch vs. continuous processing
- once-through vs. multiple recycle

Key Neutronic Performance Parameters

- Conversion ratio (ratio of production to destruction of actinides)
- Peak and average ^{239}Pu discharge burnup (MWd/g)
- Consumption rate (kg/yr)
- Loading rate (kg/yr)
- Discharge fraction of ^{239}Pu
- Fraction of original Pu destroyed
- Fission-to-capture ratio
- External neutron source strength (MW)
- Inventory of ^{239}Pu and total actinides (within core and plant total)
- Total and fast neutron flux (n/cm^2s)

Na-cooled IFR Parameters

	conventional	moderate burner	pure burner
Conversion ratio	1.15*	0.54	0
Net TRU** consumption rate (kg/yr)	–33*	110	231***
Peak discharge burnup (MWd/g)	0.151	0.160	0.450
Average discharge burnup (MWd/g)	0.107	0.118	0.334
Burnup reactivity loss (%Δk)	0.03	2.9	3.2
Fuel cycle length (months)	23	12	12
Equilibrium discharge %^{239}Pu	63	58	52
^{239}Pu inventory (tonnes)	1.81	2.14	4.52
Heavy metal inventory (tonnes)	22.7	13.9	7.47
Peak linear power (W/cm)	320	280	155

* could be tailored for TRU consumption =0
** TRU=transuranic
*** 231 kg/yr = maximum achievable

REMAINING ACTIVITIES TO COMPLETE THE NS STUDY REPORT

- Table comparing the waste destruction capabilities of the three options (fission, fusion, accelerator) - (M.T.)

- Fusion option based on the CAT D-D fuel cycle (M.T., E.C., R.M.)

- Assessment of the benefits of deep burn (M.T., E.C.)

- System study comparison of D-T and CAT D-D options (R.M., E.C.)

- Examine the use of capital cost vs COE as a metric for assessing NS applications (R.M)

REMAINING ACTIVITIES (continued)

- The impact of variations in Q & capacity factor on performance (capital cost, cost per mole of neutron, etc.) (R.M.)
- Representative capital costs for ATW & IFR options (R.M.)
- Representative costs per mole of waste destroyed (R.M., E.C.)

If OFES should decide on a followup to the NS study, the following activities would be proposed

- Identify a reference set of objectives, metrics & goals

- Select a fusion configuration & blanket option consistent with the above

- Develop a design to a level comparable with previous ARIES designs

- Develop a roadmap for implementation based on the ATW roadmap