Development of an Integrated Framework to Evaluate GNEP's Market Deployment and Potential for Proliferation Resistance

John Lee, Ann Reisman**,** Vatsal Bhatt, and Michael Todosow

Brookhaven National Laboratory

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Agenda

- Objectives of Study
- Introduction of Global Nuclear Energy Partnership (GNEP)
  - Objective and Principles
  - Advantages and Challenges
- Description of Analytical Approach and Methodology
  - Schematics of Integrated Framework
  - Nuclear Material Proliferation Factors
  - Energy-Material U.S. MARKAL Model
  - Scenario Definition: Reference and GNEP Technology
- Quantification of GNEP's Reduction in Weapons Potential
- Proposal to Study the Global Impact of GNEP
  - Global Nuclear Energy Demand & Proliferation Concern
  - International Agreement on Nuclear Fuel/Material/Technology
  - ETP-MARKAL for Evaluating Global Impact of GNEP

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Objectives of Study

- Develop an integrated framework to quantify nuclear proliferation risk and to analyze the potential of GNEP to enhance proliferation resistance of nuclear technology
- Demonstrate the proposed framework with the U.S. MARKAL model
- Discuss the global application of the framework

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GNEP Objectives and Principles

To develop and deploy advanced nuclear recycling and reactor technologies for meeting growing global energy demand, while reducing the risk of nuclear weapons proliferation and the need for nuclear waste disposal. GNEP seeks to pursue and accelerate international cooperation to:

- Expand nuclear power to help meet growing energy demand in an environmentally sustainable manner
- Develop, demonstrate and deploy advanced nuclear fuel recycling technologies that do not separate plutonium and limit the need for geological repository by reducing nuclear waste
- Develop, demonstrate and deploy advanced, proliferation resistant reactors for global applications
- Establish international agreement on fresh and spent nuclear fuel transactions to limit enrichment and reprocessing technologies
- Develop, in cooperation with the IAEA, enhanced nuclear safeguards to effectively and efficiently monitor nuclear materials and facilities, to ensure commercial nuclear energy systems are used for peaceful purposes

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GNEP Advantages and Challenges

Advantages:

- Ease of fuel fabrication with enhanced passive safety and reduced radioactive hazards
- Proliferation risks are reduced by the high radioactivity of the fuel/materials. These bundled materials are extremely difficult to separate for making weapons
- Drastically reduced wastes produced contain no plutonium or other actinides, which decay to a radioactive level of the original ore in about 300 years
- The onsite reprocessing of fuel makes materials storage simpler and reduces the security risk associated with their transportation

Challenges

- Higher capital and O&M costs for GNEP technologies, which may be offset by lower front-end fuel cost and back-end waste management cost
- Most of the GNEP technologies have not yet demonstrated on a commercial scale, requiring significant government economic incentives for their early deployment

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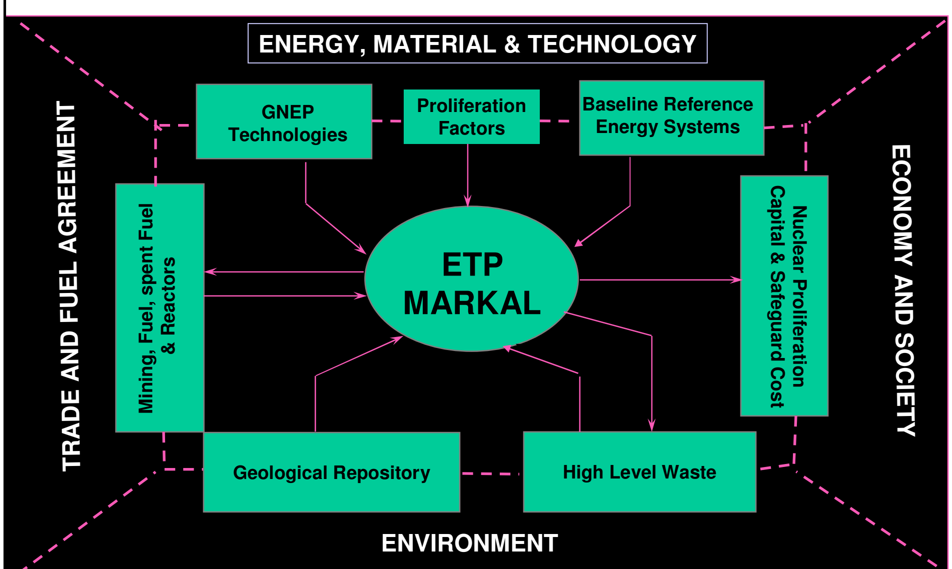
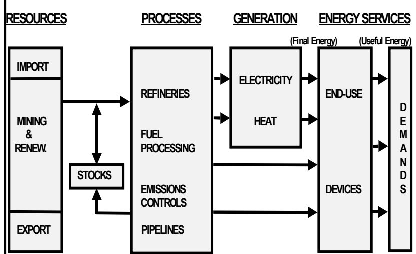
Schematics of the Integrated Framework GNEP Scenario



Integrated Market Based/Technology Specific Approach: The MARKAL Model



- Utilizes a ***bottom-up*** approach to represent and characterize ***technology specific portfolios*** of the entire energy - material flow system
- Provides a ***dynamic*** and ***integrated framework*** to assess ***market competition***, ***technology diffusion*** and ***material/emission/waste accounting***
- Generates time-dependent ***least cost solution*** (at partial equilibrium) on life cycle basis to study ***long-term*** energy system developments and trade over multiple regions.

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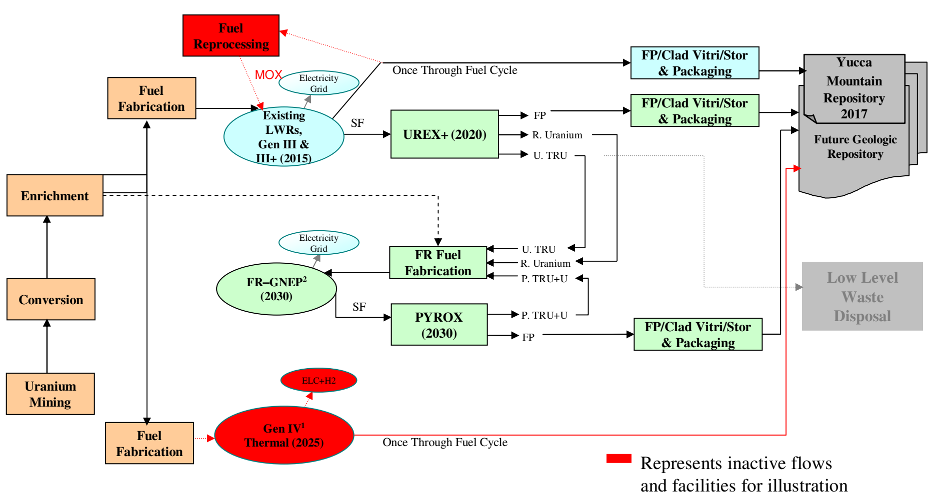
Modeling Nuclear Economy in US MARKAL A Schematic Technology Representation



Notes: 1. Gen IV Thermal Technologies use VHTR as a surrogate, 2. FR-GNEP Technology Covers: SFR
Abbreviations: SF: Spent Fuel, FP: Fission Product, H2: Hydrogen, ELC: Electricity, U. TRU: Transuranics from UREX+, P. TRU+U: Transuranics plus Uranium from PYROX, R. Uranium: Reprocessed Uranium
Source: (Shropshire, et al., 2006).

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Nuclear Material Proliferation Factors[1]

Nuclear Material Proliferation Factors					
	A	B	C	D	E
Material	Composition Factor (0 to 1)	Technology Factor (0 to 1)	Intrinsic Barrier Factor (0 to 1)	Significant Quantity (Kg)	Nuclear Proliferation Index
Thermal Fuel	0.3	0.3	0.9	80.0	1.013
Spent Thermal Fuel	0.8	0.8	0.5	160.0	2.000
GNEP Fuel	0.8	0.2	0.8	80.0	1.600
Spent GNEP Fuel	0.3	0.2	0.8	200.0	0.240
Transuranics from UREX+	0.8	0.2	0.3	10.0	4.800
Transuranics from PYROX	0.8	0.2	0.3	10.0	4.800
Reprocessed Uranium	0.2	0.3	0.9	300.0	0.180
MOX fuel	0.8	0.9	0.5	160.0	2.250
Spent MOX fuel	0.8	0.3	0.9	200.0	1.080
Separated Civil Pu	0.8	1.0	0.9	8.0	90.000
Definition					
A Fissile material suitability for weapon use					
B Ease to manufacture into a weapon					
C Ease to divert from the facility					
D Minimum quantity to make a weapon					
E Weapons potential per ton of material (E = 1000xAxBxC/D)					

1. Factor development based on "Nuclear Material and Proliferation Connection" (Reis et al, 2004) and "Methodology for Proliferation Resistance for Advanced Nuclear Energy Systems," (Yue et al, 2006)

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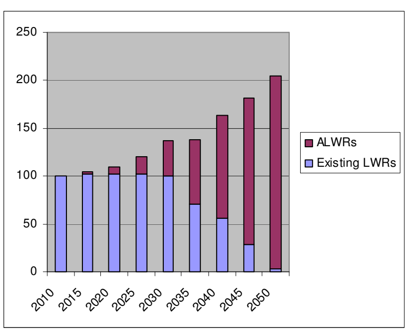
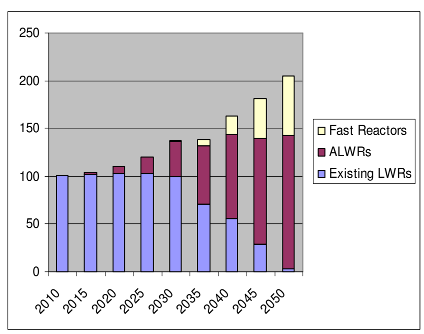
Nuclear Market Deployment by Technology (GW) MARKAL Output by Scenario

NE Reference Case[1]



GNEP Scenario[2]



[1]US MARKAL model output based on DOE NE GPRA Scenario (Bhatt et al,2006)
[2]Maximum GNEP deployment under the constraint of thermal spent fuel availability to UREX +.
The total nuclear capacity in this scenario is fixed to that of the NE Reference Case

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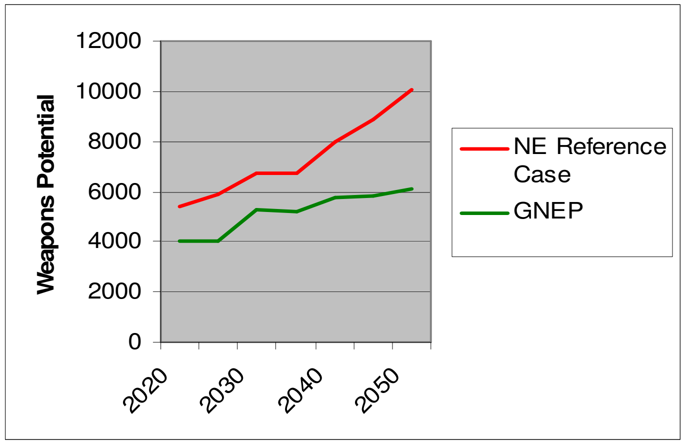
Weapons Potential: NE Reference Case vs. GNEP Scenario



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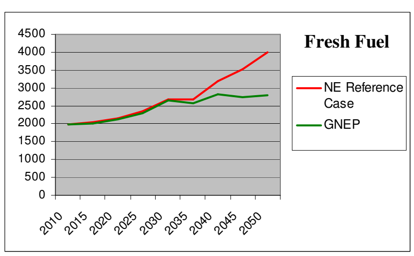
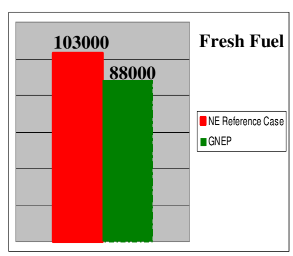
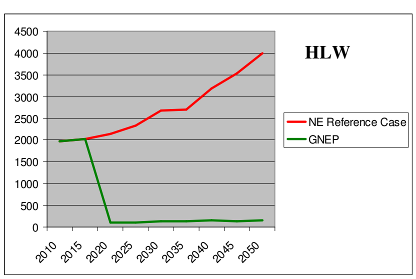
Flow of Fresh Fuel & High Level Waste (Ton)

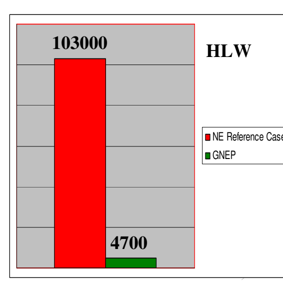
Annual

2020-2050 Cumulative









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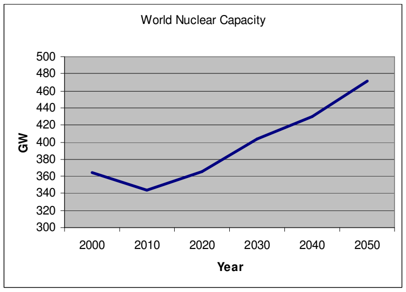
A Proposal to Study the Global Impact of GNEP: Some Justifications



Sources: (IEA,2006) and (Draft, Lee et al, 2007 Draft)

- Global nuclear energy demand is projected to grow significantly in this century
- Nuclear proliferation concerns are higher in regions with emerging nuclear economies (e.g., breakout concern, Pu cycle)
- Proliferation significance of international agreement on nuclear material/technology arrangements needs to be understood

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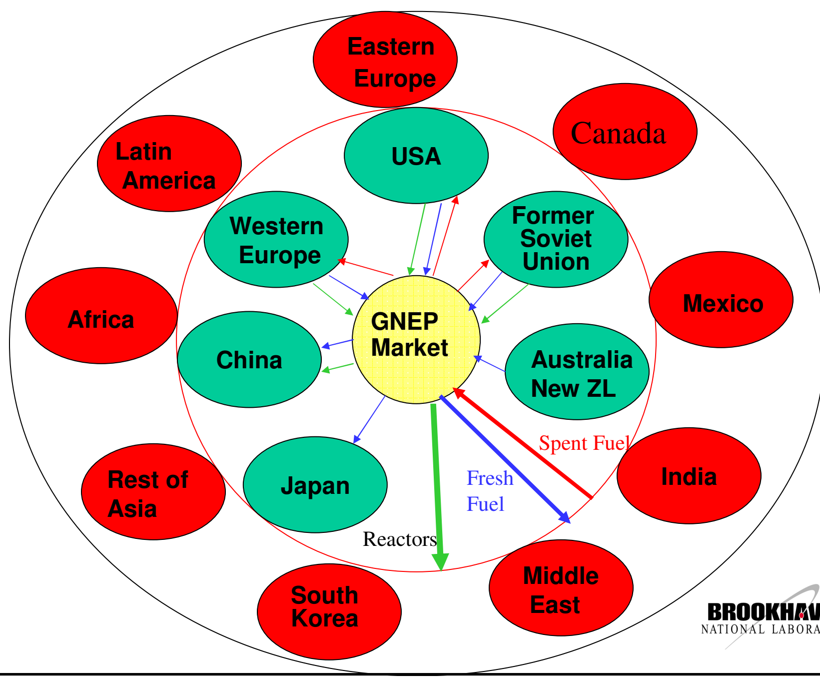
An Illustrative Global Nuclear Network in ETP MARKAL



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Modeling the Global Nuclear Network in ETP MARKAL

The proposed analytical approach involves the following steps:

1. Update nuclear sector flows and data in ETP MARKAL database
2. Develop the GNEP fuel cycle and material flows in selected regions
3. Incorporate nuclear proliferation factors into the ETP MARKAL database
4. Develop global and inter-regional markets for nuclear technology/material flows in ETP MARKAL to facilitate the assessment of the impact of potential international agreements on nuclear economy
5. Conduct model calibrations, runs, and analyses

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Reference

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