Overview

Preamble: PESS and its mandate

1. Context: Innovation and economics
2. Indicators of creation of new knowledge
3. Deployment: barriers and remedies
4. Summary and conclusions
Preamble: PESS and its mandate

DDG-NE: Planning and Economic Studies Section
1) Planning and Capacity Building Unit
Develop & disseminate models, train experts, apply in TC on national energy strategies; INIG: Pre-feasibility
2) 3E Analysis Unit (Energy-economy-environment)
   - Technoeconomic analyses
   - Geologic disposal of RW and CO2: workshop, book, CRP
   - CC and energy systems: same
   - NP - sustainable development
   - Life cycle emissions (CO2/GHG)

2) 3E Analysis Unit (Energy-economy-environment)
   - Sustainable energy development
   - CC and Nuclear Power: Annual Indicators for NE Development (INED)
   - Book: Energy for Development IAEA Scientific Forum
   - UN & others: IPCC LAs in WGII, WGIII AR4, AR5, SREX
   - UN CSD: Rio+20 Conference
1. Context: Innovation and economics

Schumpeter:

**Invention**: new idea:
science – basic research – public good – public finance

**Innovation**: marketable products/processes:
applied science – targeted research – private good (patents) – private finance

**Diffusion**: spread across markets → impact on economy and society

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1. Context: Innovation and economics

Stages in technological R&D&D&D to Commercial Utilization:

**Basic research**: discoveries (materials sci, chemistry,)

**Applied research**: inventions, improvements

**Development**: producing working prototype

**Demonstration**: testing, scaling up, proving feasibility
   < “valley of death” >

**Deployment**: implementation in pre-commercial stage

**Commercial utilization**: widespread use, diffusion

Reality: overlaps, iterations, feedbacks between stages
1. Context: Innovation and economics

Nuclear industry – current challenges:
- Operation safety
- Waste disposal – resource use
- Proliferation, diversion of N material
- Costs, competitiveness

➔ Public acceptance
Globally shared concerns
  – global cooperation to find solutions
AND: Globally shared opportunities:
need for low-C tech, supply security, price stability, etc.

<table>
<thead>
<tr>
<th>R&amp;D stage</th>
<th>Type of TD</th>
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<tbody>
<tr>
<td>Basic research</td>
<td>science-driven innovation</td>
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<tr>
<td>Applied research</td>
<td>science-driven + ITC</td>
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<tr>
<td>Development</td>
<td>induced technology change</td>
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<tr>
<td>Demonstration</td>
<td>induced technology change</td>
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<tr>
<td>Deployment:</td>
<td>learning by doing, some ITC</td>
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<tr>
<td>Commercial utilization</td>
<td>LbD</td>
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LbD: learning/experience curves, cost-free < happens>
ITC: triggered by relative prices (direct/indirect); requires investments (costs); knowledge capital explicit/tacit; <pulled>
  funds largely private sources, depends on appropriability
SDI/TC: generated by public S&T policy <pushed>
  fostered by public R&D funding, creating public good
1. Context: Innovation and economics

Point #1:
Generic patterns of technological R&D cycle →
need to be adopted to special features of SNES

Type of TD in R&D stages:
- funding requirements: magnitude, source (priv/pub)
- knowledge generated: public or proprietary

2. Indicators of creation of new knowledge

SNES: NPR and NFS – develop simple models and indicators

Here example:
Indicators Based on Creation of New Knowledge
- Input and Output
2. Indicators of creation of new knowledge

[CRE-I1] (inputs) intramural R&D expenditures by sector of performance, by source of funds, and by type of R&D

[CRE-I2] (inputs) extramural R&D expenditures

[CRE-I3] (inputs) government funded R&D expenditures

[CRE-I4] (inputs) the number of R&D researchers and technicians in the field

[CRE-I5] (inputs) number of research-purpose reactors being used

[CRE-O1] (outputs) number of scientific publications in field

[CRE-O2] (outputs) number of patent in the field

2. Indicators of creation of new knowledge
CRE-I3: Gov’t-funded R&D on nuclear fission

[Graph showing data on government-funded R&D on nuclear fission from 1974 to 2004 for Canada, France, Japan, Korea, Sweden, United Kingdom, United States, and IEA total.]
2. Indicators of creation of new knowledge
CRE-I5: Number of research reactors used

CRE-O1: Scientific publications in nuclear power and associated fuel cycle field (1000s)
2. Indicators of creation of new knowledge

NP and FC: work in progress; so far: vast data problems (private)
What are the meaningful input and output indicators?
Obvious place to start: anything usable from ITC representation?
Broader approach: R&D allocation for SD (N)energy innovation
Portfolio models: for competing ideas/directions: IF reasonable
(gu)es(s)timates of funds needed, probability of success, time required, value of outcome
Game theory models: technologies, probabilities, payoffs
EneTech models: hypothetical technologies \( \rightarrow \) total system cost;
many sensitivity runs + exog estimates of R&D investment needs \( \rightarrow \) identify promising directions
Real challenge: how to model discoveries and true inventions (no one knows today) – futures studies surprise methods?

2. Indicators of creation of new knowledge

Point #2: models of SD innovation are needed
Options to include results into general economic (CGE) or energy sector (PE) models: depend on model type & detail
Highly aggregated: one parameter or one equation
More detailed: reduced form representation of SDI model
Initially: improving existing parameters, adding new ones – exogenous (simple but does not account for costs)
Later: new equation, knowledge multiplier (more explicit but requires understanding of technology outcome: remote from SDI)
3. Deployment: barriers and remedies

Recall: scheme of technological R&D&D&D to CA

Deployment: implementation in pre-commercial stage
Commercial utilization: widespread use, diffusion
Reality: overlaps, iterations, feedbacks between stages

Regional cooperation: in deployment and CA phases
→ closer look at deployment

3. Deployment: barriers and remedies

Across stages of technology development process:
Funding: magnitude increases; Depl: jump, varies widely
Objectives: more focused; Depl: THE technology as demonstrated by the prototype
Sources: more concentrated; Depl: owners, later imitators
and: public-private shares shift towards private

Note: general patterns, but: variations across technologies, exceptions, special cases
3. Deployment: barriers and remedies

Deployment: beginning of commercial distribution
SNES demonstrated, potential for competitiveness promising
but: barriers ➔ What is special about SNES?

*General* technology R&D outcomes:
reduce (priv) costs, increase quality of product/service
➔ users adopt them when \( \frac{B_n}{C_n} > \frac{B_0}{C_0} \): colour tv, cell

**SNES**: may or may not do the above, but:
- deliver public good (energy supply security)
- mitigate an externality (GHGs)
- other benefits, but: remote in time, magnitude of investmts

Barriers: analyze ➔ understand ➔ alleviate; not always $$

3. Deployment: barriers and remedies

**Barrier 1: Cost**
Problems: public-good features of SNESs not valued, externalities of competitors not penalized
Indicators: econ. value of supply security, soc. cost of C
Remedies: performance standards, portfolio requirement
Problems: early phase of the experience curve ➔ realistic expectations for cost reductions from LbD
Analytical tools: life cycle (S-curve) and learning curve ➔ use them as monitoring tools (not prediction tools)
Remedies: direct support, public procurement, technology transfer assistance
3. Deployment: barriers and remedies

Life cycle (S-curve): penetration (volume, market share)
Once new T starts picking up (annual increase in V or MS): \(\rightarrow\) start reducing direct support

Learning curve (experience): unit cost reduction per doubling cumulative production
Once unit costs start approaching those of incumbent technologies \(\rightarrow\) start reducing direct support

*In contrast:* if no learning despite deployment (flat or sluggish learning curve) \(\rightarrow\) shift private investment and public support back to R&D: improve cost, performance

### Barrier 2: Market structure
Problems: monopolistic/oligopolistic market, entry barriers, inertia
Indicators: number of sellers (tech. owners/providers), market shares of largest, 3-5 largest sellers (>50%?)
Diversity index: \(SWI = -\sum X_i \ln X_i\)
Shannon-Wiener Index (SWI):
\(X_i\): the market share of supply source i
Remedies: direct intervention: market share targets; information to distributors and consumers; go for niche markets
3. Deployment: barriers and remedies

Barrier 3: Capital stock inertia
Problems: slow turnover of capital stock, old stock largely depreciated: $MC_o < MC_n$; more lucrative to refurbish old than to install new
Indicators: absolute/relative weighted average/mean age (relative to economic/technical life) performance (efficiency) weighted average age
Remedies: pre-announced dynamic performance standards: improve or retire; direct subsidy for retirement of old capacities
→ Not clear how these would work for SNES

Barrier 4: Infrastructure
Problems: incompatibility with existing storage, distribution, delivery equipment and networks, or: infrastructure does not exist
Indicators: ??
Remedies: direct public investment or indirect support to private investments to develop infrastructure; ratio depends on public/private nature of T
Problems: special features of T; eg, release, proliferation
Remedies: R&D in SNES itself or infrastructure to handle special features
3. Deployment: barriers and remedies

Barrier 5: Regulation
Problems:
  inadequate/incompatible planning and licensing procedures, standards, etc.
Indicators: ??
Remedies:
  regulatory innovation; updating standards
  flexible and adaptive regulatory regimes

Barrier 6: Public acceptance
Problems:
  ignorance, outdated or spurious information, justified or unfounded fears, NIMBY
Indicators: self-reported knowledge, factual knowledge, public attitude, willingness to participate in DM
Remedies:
  labeling, performance indicators, information provision, economic and social incentives for host regions
### 3. Deployment: barriers and remedies

#### Barrier 7: Financing

**Problems:**
- gap between economic and financial Cs/Bs of SNES transaction costs: Ts delivered in smaller projects: transaction costs higher, but value at risk smaller
- and: risks pooled from several projects → lower premia
- risks: T itself, costs, market, regulatory, public acceptance: diverse and different depending on T

**Indicators:** many; relevance/choice depends on context of application

**Remedies:** direct or indirect financial support; innovative FIN schemes, PPPs, venture capital

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#### 3. Deployment: barriers and remedies

**Point #3:**
Importance of deployment: the probe of the pudding … from technical feasibility to economic viability to commercial competitiveness

but: if the probe fails, trouble may be elsewhere: barriers

Barriers: often not cost or investor disinterest; 7 types

Barriers: more R&D may or may not help to alleviate them

Proper ratios of R&D vs Deployment costs are difficult to estimate: number and intensity of iterations across phases of the R&D cycle differ widely across technologies AND: cross-fertilization from other T: e.g., isotopes
### 3. Deployment: barriers and remedies

#### Point #3 cont:
- Precondition to deployment: solid demonstration units (expensive and limited learning from units quasi-permanently down)
- Potential pitfalls in deployment support:
  - too early provision: lock-in immature T, block more promising ones
  - too early phase-out: drop a potentially useful T
  - too late phase-out:
    - IF T successful: distort market competition
    - IF T unsuccessful: throw good money after bad
- S-curves and learning curves: useful monitoring and assessment tools in balancing R&D vs deployment

### 4. Summary and conclusions

- Nuclear industry: most interconnected globally
- esp. negative events: anywhere → impacts everywhere
- Joint concerns: proliferation resistance to resource availability
- Implication: combination of competition and cooperation in innovation/R&D to operation (WANO)
- and international organizations and projects:
  - IAEA, OECD NEA, GIF, many others
4. Summary and conclusions

Costs and competition:
- with other resources/technologies: fossil, renewables
- among NP technologies: LWR vs FR now
  increasing complementarity in the future (CFS FR)
Innovation: SNES concepts – need for basic research
  → public good, collaboration (free riders?)
Innovation: SNES designs – development & demo:
  → public good, collaboration (free riders?)
Innovation: SNES PPs – demonstration & deployment:
  → private good, competition

4. Summary and conclusions

Innovation in NE:
  imperative: safety and proliferation resistance
  necessary: economics and sustainability
  ➔ Complex multi-attribute problem: all necessary
Economics of innovation: increase efficiency by
  international cooperation in R&D&D&..?
http://www.iaea.org/OurWork/ST/NE/Pess/

...atoms for peace.