Update of INPRO methodology in the area of economics

INPRO Dialogue Forum 8

IAEA HQs, Vienna, Austria. 26-29 August 2014

IAEA

International Atomic Energy Agency

Introduction:
UN Brundtland Commission Report (1987)

- The costs of construction and the relative economics of electricity generating stations - whether powered by nuclear energy, coal, oil or gas - are conditioned by the factors throughout the service life of a plant:
  - the cost of borrowing money to finance plant construction,
  - the impact of inflation;
  - the duration of the period of planning, licensing, and construction;
  - the cost of fuel and maintenance;
  - the costs of protective measures, to ensure safe operation; and
  - waste disposal costs (land, air, and water pollution containment) and the costs of dismantling at the end of service life.
- All these factors vary widely depending on differing institutional, legal, and financial arrangements in different countries. Cost generalizations and comparisons are therefore unhelpful or misleading.
- Nations should therefore look very closely at cost comparisons to obtain the best value when choosing an energy path.

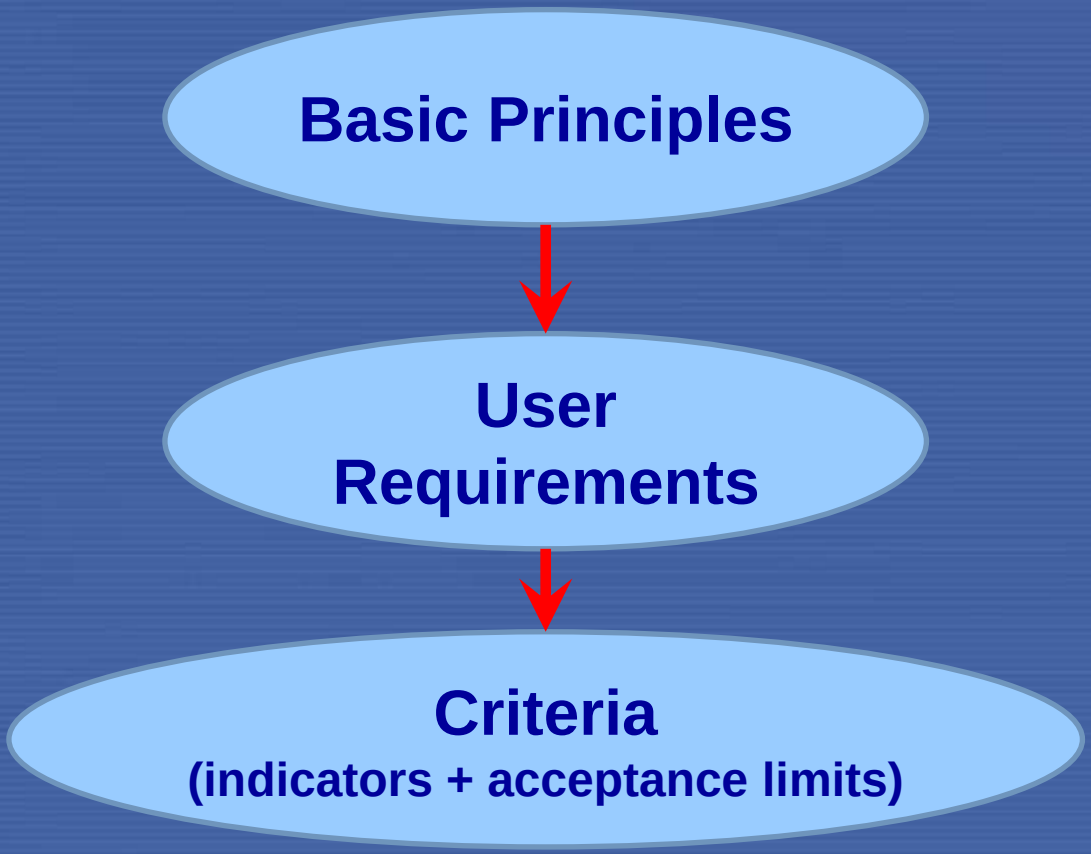
Introduction:
Scope of consideration of economics in INPRO

- INPRO considers economics of nuclear power from several viewpoints:
  - Direct economic assessment (area of economics of INPRO manual);
  - Economic spin-offs (cost-benefit studies in the area of Infrastructure);
  - Scenario studies for transitions from existing nuclear energy systems to future energy systems.
- INPRO manual on economics covers four issues:
  - Cost competitiveness;
  - Attractiveness for investments;
  - Risk acceptability;
  - Flexibility of design.
- Unlike other INPRO areas the INPRO assessment in the area of economics involves elements of analysis (calculations).

Introduction: INPRO methodology on economics in 2008-2012

- From 2009 forward INPRO methodology guidance on assessment in economics comprises two parts:
  - 'Fixed' part – INPRO manual:
    - Latest published list of criteria;
    - Latest published examples of analysis and assessment.
  - 'Flexible' part – NESA support package:
    - Training on INPRO methodology application;
    - Files of recommendations on input data search;
    - Examples of assessments;
    - NESA Economics Support Tool (NEST).
- Knowledge accrued through the use of 'flexible' part occasionally needs to be moved into updated manual.

Structure of the INPRO requirements



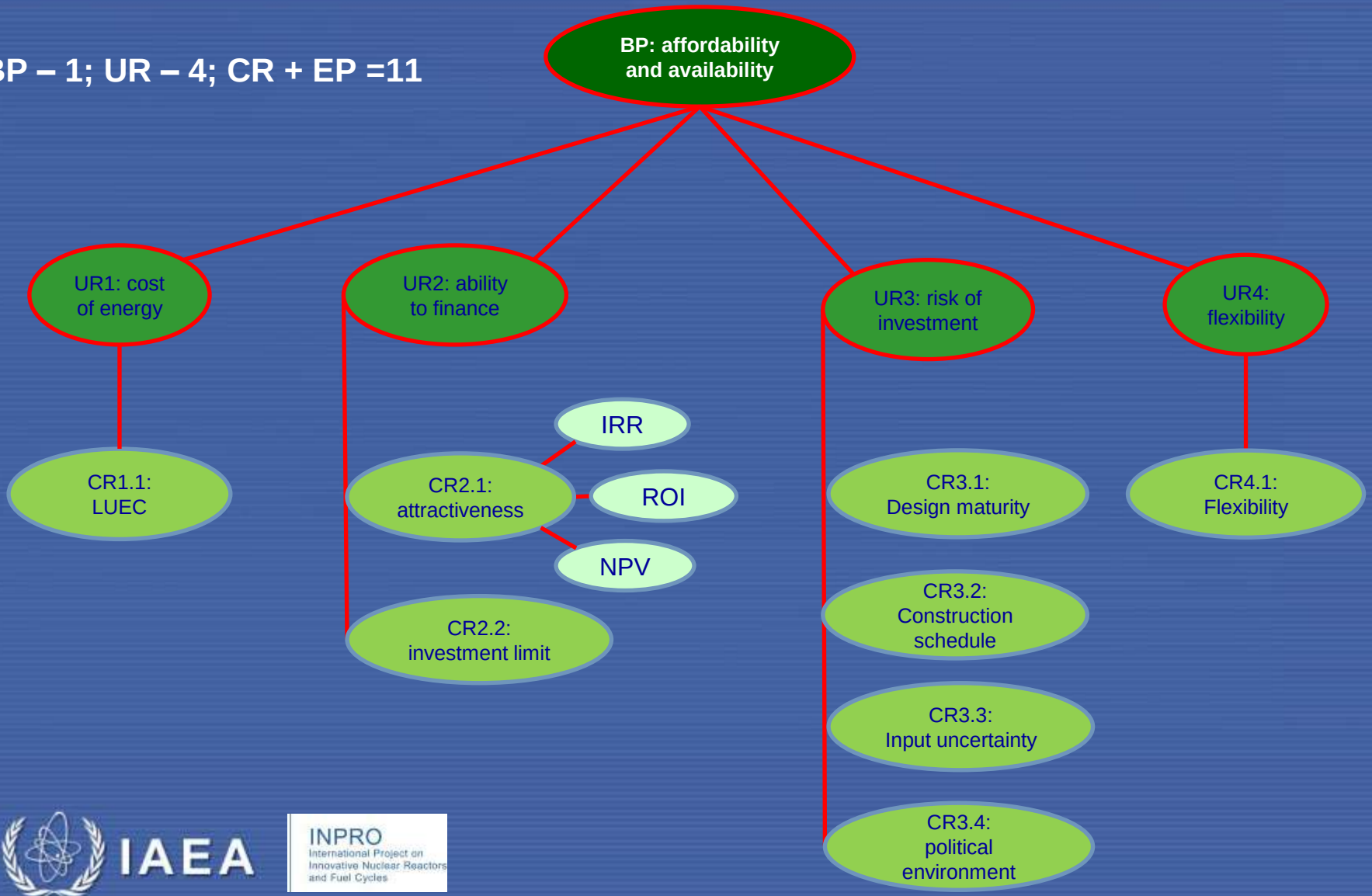
- goals for development of sustainable NES

- actions to be done to meet the goal

- assessor's tools to check whether the actions are done properly

Structure of the INPRO area of economics

BP – 1; UR – 4; CR + EP =11



IAEA

INPRO International Project on Innovative Nuclear Reactors and Fuel Cycles

Structure of the area of economics

- INPRO Basic Principle in the area of economics:

"energy and related products and services from Nuclear Energy Systems shall be affordable and available"

- Four User Requirements (UR1 to UR4) in the area of Economics:
  - UR1 (Costs of energy): electricity production by NPP must be competitive.
  - UR2 (Ability to finance): attractiveness of investment in NPP required.
  - UR3 (Risks of investment): risk of NPP investment must be acceptable.
  - UR4 (Flexibility): NPP design to adapt to different markets.
- Eight Criteria covering all aspects of those four UR.

Scope of INPRO area of economics: UR1

UR1: Cost of nuclear energy C_N should be competitive against alternatives C_A:

$$C_N < k \cdot C_A$$

- Factor k expected to be ~1, but could be > 1 based on country specific strategic considerations, e.g.:
  - Security/diversity of energy supply;
  - Stability of cost over long time frames: Protection from inflation and currency fluctuation; cost of uranium is small fraction of total cost;
  - Environmental impact.
- Levelized Unit Energy Costs (LUEC):
  - Standard technique for comparing different power plants with different relative cost components.

Scope of INPRO area of economics: UR1

- Input for LUEC calculation:
  - Cost data (cost to build, operate, maintain, etc.);
  - Construction time, cash flows and discount rate;
  - Plant lifetime and load factor.
- 3 main contributors to cost of energy (C_N and C_A):
  - Capital costs (most important contributor for nuclear and renewables);
  - Operating and maintenance costs (O&M);
  - Fuel costs (most important contributor for fossil power).
- Other factors to be taken into account in costs:
  - Allowances for replacements (C_N and C_A);
  - For nuclear power: waste management costs and decommissioning costs;
  - For fossil power plants: carbon taxes;
  - For wind and solar plants: cost of backup power plant.

Optimizing the combination of power generation sources is part of energy system planning.

Scope of INPRO area of economics: UR2

UR2: To finance nuclear power - investment in NPP should be attractive and funds for NPP should be available:

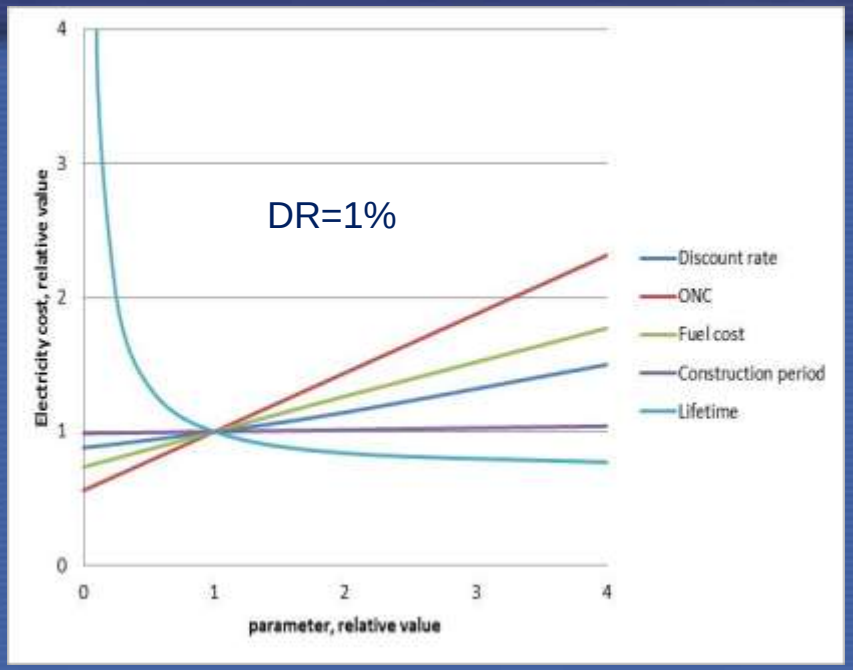
- Attractiveness of NPP to (private) investors to be checked via financial figures of merit:
  - Internal rate of return (IRR);
  - Return of investment (ROI);
  - Net present value (NPV).
- Need for sufficient capability of investor to raise funds (total investment) for NPP, which depends on:
  - Type of investor - private or government;
  - Financing arrangements;
  - Size and revenues of energy system/utility;
  - Size of the grid.

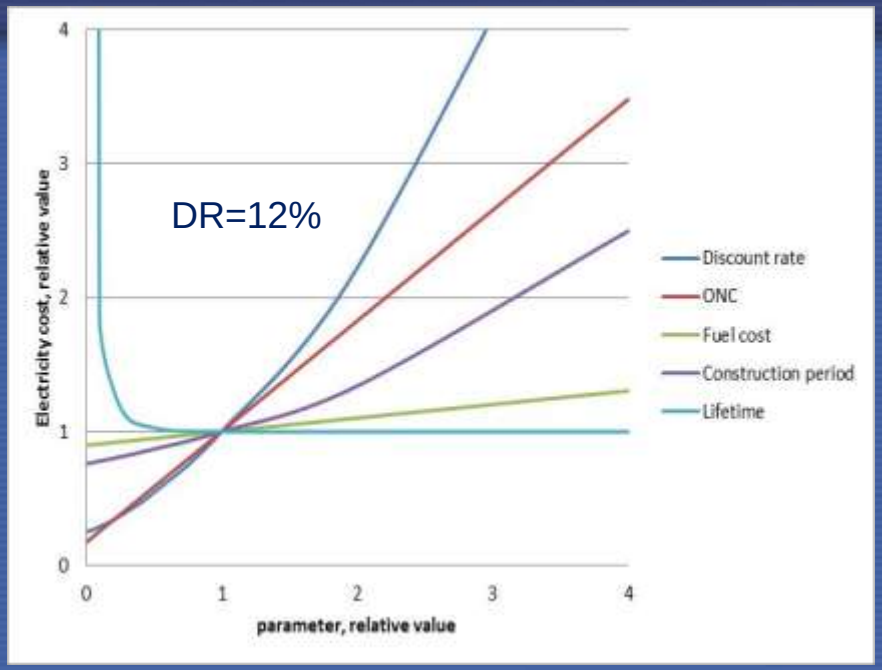
Scope of INPRO area of economics: UR3

UR3: Investment risk of nuclear power:

- Risk influenced by maturity of design that is characterized by:
  - Licensing status;
  - Project construction and commissioning times.
- Determination of robustness of the economic analyses results - need for sensitivity study, e.g. for discount rate, construction time, etc
- Need for long term political commitment to nuclear power (should be assessed in INPRO area of Infrastructure).

Cost sensitivity diagrams





- Example: ONC=5000 $/kW, Construction period – 5 a, Lifetime=60 a;
- Influence of reactor lifetime is limited within a certain range depending on DR;
- Overnight cost and fuel cost are the most sensitive parameters at low DR and at higher discount rates – DR;
- Moderate influence of fuel cost at higher discount rates:
  - At 12% discount rate modern PWR using uranium mined from seawater will be competitive against 50% more expensive innovative reactor with any (i.e. 0) fuel cycle cost.

IAEA

INPRO
International Project on Innovative Nuclear Reactors and Fuel Cycles

Scope of INPRO area of economics: UR4

UR4: Flexibility of innovative nuclear energy systems:

- Innovative components of a NES under development should be adaptable to different markets;
- Flexibility achievable by use of different fuels, e.g. MOX.

INPRO economics manual update history and status

- In July 2012 INPRO steering committee initiated the project to technically update INPRO methodology;
- In November 2012 kick-off meeting was organized in Vienna;
- For the INPRO methodology area of economics 30 specific comments were received (plus 44 general comments for all areas of the methodology) and taken care of in update;
- In February 2013 updated report on economics was distributed for discussion internally and externally to participants of kick-off meeting. Received proposals were incorporated into the report;
- In August 2013 manual was approved by the IAEA Publication Committee;
- Published in August 2014 as NE series report NG-T-4.4.

Technical updates in INPRO manual on economics

- Demonstration of a link between UN concept of sustainable development and INPRO methodology in the area of economics;
- Simplification of manual structure by separating description of:
  - INPRO assessment method of economics of a nuclear power plant and
  - Calculation of economic parameters necessary for assessment.
- Addition of detailed description of methods (available in the NEST code) on how to calculate basic economic functions such as LUEC, IRR, ROI, NPV, and total investment:
  - For different fuel cycles, i.e. once through or (partly) closed, uranium or MOX fuel;
  - For different types of power plants, i.e. reactors (thermal or fast), fossil, renewables, including groups of power plants;
  - Several models for calculation are available including models based on MIT and Harvard University approach;
  - Examples of results of NEST calculations are available.

Technical updates in INPRO manual on economics (cont.)

- Inclusion of latest references (IAEA, OECD, etc.) available in the area of economics of nuclear power.
- Definition of relationship of INPRO assessment in the area of economics and an energy system planning study using IAEA tools.
  - Energy system planning sets out anticipated growth of energy demand in a country. It identifies available energy supply options including the potential role of a national nuclear energy system;
  - Such an energy system planning study is a prerequisite for a country embarking on (or enlarging) a nuclear power program and for an INPRO assessment of economics;
  - The INPRO assessment of economics following an energy system planning study adds to transparency of the results of an energy system planning study;
  - INPRO tool NEST enables the performance of sensitivity studies of important input parameters such as discount rate, construction period, etc.

Ongoing activities

- Performance of sensitivity studies using all options and a range of plausible input data;
- Two types of sensitivity studies:
  - Influence caused by peculiarities of a given model: e.g. introduction of insurance fee (3%) and real estate tax (3%) yields 47% rise of electricity cost calculated via Harvard approach;
  - Influence caused by variations of specific input parameters.
- Evaluation of results of this study with the goal to provide recommendations for an INPRO assessor on what option to use depending on the nuclear energy system assessed.

Example of NEST calculation using different models

- Calculation of basic economic functions using different models available in NEST (PWR, once-through fuel cycle, DR=7%)

Parameter	units	NPP		
		Version 1	Version 2	Version 3
LUEC	mills/kWh	74.9	74.0	72.9
NPV (at PUES=80 mills/kWh)	$/kWe	607	718	839
IRR (at PUES=80 mills/kWh)	%/100	0.076	0.078	0.079
ROI (at PUES=80 mills/kWh)	%/100	0.093	0.090	0.091
total investment	billion $	6.15	5.90	6.15

Version 1 – model developed in TECDOC-1575 (INPRO methodology manual published in 2008);
Version 2 – model based on University of Harvard study approach;
Version 3 – model based on MIT study approach.

- Note: NEST version 1 demonstrates good coherence with GIF ECONS model (ΔLUEC~0.5%).

Conclusion

- On-going INPRO methodology update project is focused on making the guidance more transparent, efficient and ‘user friendly’;
- Update of economics manual has been performed in 2013;
- Work on further improvement of INPRO assessment method is going on in all areas.

Thank you for your attention!

a.korinny@iaea.org

IAEA

INPRO
International Project on
Innovative Nuclear Reactors
and Fuel Cycles