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International Atomic Energy Agency

Atoms for Peace and Development

IAEA RTA Key Element 4: Technical Characteristics and Performance

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OUTLINE

- Technical Characteristics
- RTA Key Element 4: Technical Characteristics and Performance
- **RTA TABLE FOR KEY ELEMENT 4**
  - **How to complete?**
  - **Examples**

Day 2: Tuesday, 11 June 2019		
15:30	**IAEA RTA Key Element 4:** Technical Characteristics and Performance [IAEA NP-T-1.10, Pg. 34] **Case Study**	Mr Matthias Krause Mr Frederik Reitsma Ms Tatjana Jevremovic IAEA **Teams**

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Technical Characteristics

Evaluation of designs based on ability to reliably meet needs:

- *Technical data evaluation*
- *Reliability analysis*

Retasland has established desired technical characteristics

- Firstly, **does the design meet the requirements?**
- Distinguishing criteria: ***is there a preferred specification beyond the requirement?***
- **How reliable is this information? Is the technology proven? Is the construction schedule proven?**

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IAEA NP-T-1.10, Pg. 34

RTA Key Element 4:
Technical Characteristics and Performance

Technical characteristics affecting the plant design:

- **Importance factor range suggested: Per key topic**

Key topics	Suggested importance factor range	
	Large WCRs	SMRs*
Unit size	High	High
Plant lifetime	Low/Medium	Low
Proven technology	High	High
Standardization	Medium	High
Simplification	Medium	High
Constructability	Low	Low
Operability, inspectability, maintainability and reliability	Medium	Medium
Plant availability and capacity factors	High	High
Manoeuvrability	Dependent on locale	Dependent on locale
Major systems and component evaluations	Dependent	Dependent

* As proposed during the CM on RTA refinement, May 2019

RTA Key Element 4:
Technical Characteristics and Performance

Technical characteristics affecting the plant design:

- ***Evaluation expectations and relative comparisons*****:** Ensure that each technology holder's plant design is consistent with the desired technical criteria and can be reliably accomplished with a proven design.
  - Technology evaluation and relative comparisons is to ensure the chosen design optimally meets desired technical criteria (e.g. generating capacity, availability, lifetime).
  - This evaluation should also address factors related to the proveness of designs to meet these criteria.

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Example: Plant Specifications

Not only "does the design meet the requirement?" but, *"is there a preferred specification beyond the requirement?"*

Initial technical requirements

What is the desired **power level**?

What are the plant's **load following capabilities**?

Distinguishing criteria

How valuable is a higher than required power ***for this case***?

Is there an advantage to lower power ***for this case***?

Is there a need for flexible operation ***for this case***?

Is there an advantage to being more flexible than necessary ***for this case***?

Example: Proven Technology and Constructability

What is the current status of the technology?

- Increases in number of years operating can provide confidence in proven technology.

Look at the construction schedule of plants:

- Was the construction delayed?
- How long and at what additional cost?
- How long did it actually take to build?

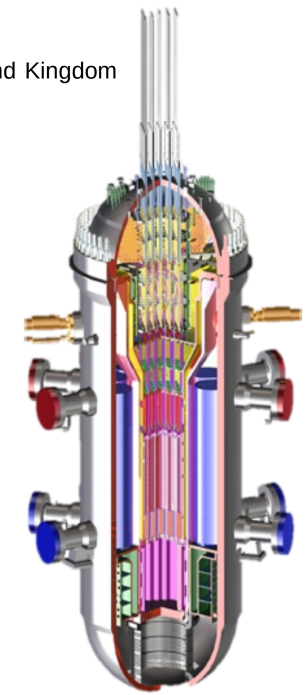
Current Status on SMART, HTR-PM and NuScale Booklet and ARIS database

Example: Proven Technology and Constructability

Current Status on SMART

March 1999	Conceptual design development
March 2002	Basic design development
June 2007	SMART-PPS (Pre-Project Service)
July 2012	Technology verification, Standard Design Approval (SDA)
March 2012	First step of Post-Fukushima corrections and commercialization
September 2015	Pre-project engineering agreement signed between Republic of Korea and Kingdom of Saudi Arabia for the deployment of SMART in the Gulf country

Construction period of less than three (3) years from first concrete to fuel load is predicted



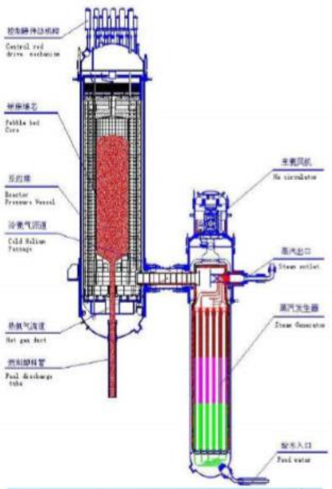
MAJOR TECHNICAL PARAMETERS	
Parameter	**Value**
Technology developer, country of origin	Korea Atomic Energy Research Institute (KAERI), Republic of Korea
Reactor type	Integral PWR
Coolant/moderator	Light water / light water
Thermal/electrical capacity, MW(t)/MW(e)	330/100
Primary circulation	Forced circulation
System pressure (MPa)	15
Core inlet/exit temperatures (^{0}C)	296/323
Fuel type/assembly array	UO_2 pellet/17x17 square
Number of fuel assemblies	57
Fuel enrichment (%)	< 5
Fuel burnup (GWd/ton)	< 60
Fuel cycle (months)	36
Main reactivity control mechanism	Control rod driving mechanisms and soluble boron
Approach to engineered safety systems	Passive
Design life (years)	60
Plant footprint (m^2)	90000
RPV height/diameter (m)	18.5/6.5
Module weight (metric ton)	1070 (including coolant)
Seismic design	> 0.18 g automatic shutdown
Distinguishing features	Coupling with desalination and process heat application, integrated primary system,
Design status	Licensed/certified (standard design approval)

Example: Proven Technology and Constructability

Current Status on HTR-PM

2001	Launch of commercial HTR-PM project
2004	Standard design of HTR-PM started
2006	HTR-PM demonstration power plant approved as one of National Science and Technology Major Projects
2006	Huaneng Shandong Shidaowan Nuclear Power Co., Ltd, the owner of the HTR-PM, established by the China Huaneng Group, the China Nuclear Engineering Group Co. and Tsinghua University
2006–2008	Basic design of HTR-PM completed 2009 Assessment of HTR-PM PSAR completed
2012	First Pour of Concrete of HTR-PM
2013	Fuel plant construction started
2014	Qualification irradiation tests of fuel elements completed
2015	Civil work of reactor building finished
2016	RPV and core barrel etc. delivered, installation of main components ongoing
2017	Fuel plant achieved expected production capacity
2019	First operation expected

The preliminary safety analysis report (PSAR) was reviewed by the licensing authorities during 2008-2009. The Construction Permit was issued in December 2012. Final approval of the FSAR is expected soon.



MAJOR TECHNICAL PARAMETERS	
Parameter	**Value**
Technology developer, country of origin	INET Tsinghua University, People's Republic of China
Reactor type	Modular pebble bed high temperature gas-cooled reactor
Coolant/moderator	Helium/graphite
Thermal/electrical capacity, MW(t)/MW(e)	2x250/210
Primary circulation	Forced circulation
System pressure (MPa)	7
Core inlet/exit temperatures (°C)	250/750
Fuel type/assembly array	Spherical elements with coated particle fuel
Number of fuel spheres	420,000 (in each reactor module)
Fuel enrichment (%)	8.5
Fuel burnup (GWd/ton)	90
Fuel cycle (months)	On-line refueling
Main reactivity control mechanism	Control rod insertion
Approach to engineered safety systems	Combined active and passive
Design life (years)	40
Plant footprint (m^2)	--
RPV height/diameter (m)	25/5.7(inner)
Seismic design	0.2 (g)
Distinguishing features	Inherent safety, no need for offsite emergency measures
Design status	Under construction

Example: Proven Technology and Constructability

Current Status on NuScale

2003	Initial concept developed and integral test facility operational
	2007 NuScale Power was formed
2011	Fluor Corporation became major investor and strategic partner for plant construction
2012	Twelve-reactor simulated control room was commissioned
2017	Design certification application was submitted to the US Nuclear Regulatory Commission
2018	NRC completed Phase 1 of design certification application review
2022	NuScale design certification approval expected
2026	First commercial NuScale plant targeted to be operational in Idaho

NuScale submitted a design certification application to the US Nuclear Regulatory Commission in January 2017. Phase 1 of the review was completed in April 2018 and design approval is expected in mid-2022. The first anticipated plant owner, the Utah Associated Municipal Power Systems, has a target commercial operation date of 2026 for the first plant that is expected to be built in Idaho.

MAJOR TECHNICAL PARAMETERS	
Parameter	**Value**
Technology developer, country of origin	NuScale Power, LLC, USA
Reactor type	Integral PWR
Coolant/moderator	Light water / light water
Thermal/electrical capacity, MW(t)/MW(e)	160/50
Primary circulation	Natural circulation
System pressure (MPa)	12.8
Core inlet/exit temperatures (°C)	258/314
Fuel type/assembly array	UO_2 pellet/17x17 square
Number of fuel assemblies	37
Fuel enrichment (%)	< 4.95
Fuel burnup (GWd/ton)	> 30
Fuel cycle (months)	24
Main reactivity control mechanism	Control rod drive, boron
Approach to engineered safety systems	Passive
Design life (years)	60
Plant footprint (m²)	140000
RPV height/diameter (m)	17.8/3.0
Module weight (metric ton)	~700 ton
Seismic design	0.5g peak ground accelerations
Distinguishing features	Unlimited coping time for core cooling without AC or DC power, water addition, or operator action
Design status	Under regulatory review

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RTA Key Element 4: Table

Examples provided for the first 5 Key Topics

Key element: 4. Technical Characteristics and Performance (Importance per Key Topic)						%
10 Key topics	%	Rationale for percentage	HTR-PM	NuScale	SMART	Rationale for score
Unit size						
Plant lifetime						
Proven technology						
Standardization						
Simplification						
Constructability						
Operability, inspectability, maintainability and reliability						
Plant availability and capacity factors						
Manoeuvrability						
Major systems and component evaluations						

%	Represents the importance of the key topic
Rationale for percentage	Requires explanation for quantified importance
Rationale for score	Requires explanation of the scoring range:

5 High achievement of criteria
3 Medium achievement of criteria
1 Low or no achievement of criteria, or no information available

RTA Key Element 4: Table

Key element: 4. Technical Characteristics and Performance (Importance per Key Topic)						%
Key topics	%	Rationale for percentage	HTR-PM	NuScale	SMART	Rationale for score
Unit size		• Flexibility in meeting goals with addition of units				
Plant lifetime		• No current information on life extensions • Large impact on returns				

1

RTA Key Element 4: Table

Key element: 4. Technical Characteristics and Performance (Importance per Key Topic)						%
Key topics	%	Rationale for percentage	HTR-PM	NuScale	SMART	Rationale for score
Proven technology		• Important factor for safety • No operating SMR plants • NOAK policy				
Standardization		Impact on costs, unit consistency, meeting design specifications, etc.				

1

RTA Key Element 4: Table

Key element: 4. Technical Characteristics and Performance (Importance per Key Topic)						%
Key topics	**%**	**Rationale for percentage**	**HTR-PM**	**NuScale**	**SMART**	**Rationale for score**
Simplification		• Ideal for newcomer countries • Enhancement to safety by design				

1

RTA Key Element 4: Table

Key element: 4. Technical Characteristics and Performance (Importance per Key Topic)						%
Key topics	%	Rationale for percentage	HTR-PM	NuScale	SMART	Rationale for score
Unit size	10	• Flexibility in meeting goals with addition of units				
Plant lifetime	10	• No current information on life extensions • Large impact on returns				

2   1

RTA Key Element 4: Table

Key element: 4. Technical Characteristics and Performance (Importance per Key Topic)						%
Key topics	**%**	**Rationale for percentage**	**HTR-PM**	**NuScale**	**SMART**	**Rationale for score**
Proven technology	10	• Important factor for safety • No operating SMR plants • NOAK policy				
Standardization	10	Impact on costs, unit consistency, meeting design specifications, etc.				

2

1

RTA Key Element 4: Table

Key element: 4. Technical Characteristics and Performance (Importance per Key Topic)						%
Key topics	**%**	**Rationale for percentage**	**HTR-PM**	**NuScale**	**SMART**	**Rationale for score**
Simplification	10	• Ideal for newcomer countries • Enhancement to safety by design				

2

1

RTA Key Element 4: Table

Key element: 4. Technical Characteristics and Performance (Importance per Key Topic)						%
Key topics	**%**	**Rationale for percentage**	**HTR-PM**	**NuScale**	**SMART**	**Rationale for score**
Unit size	10	• Flexibility in meeting goals with addition of units				5. Can directly meet scaling goals with incremental upgrade flexibility (many steps). 4. Additional flexibility due to small unit size, permitting incremental upgrade few steps). 3. Generation goals can be met appropriately. 2. Restrictive deployment options due to unit size. 1. Incapable of scaling to meet goals.
Plant lifetime	10	• No current information on life extensions • Large impact on returns				5. >80 years 4. >70 years 3. 50–70 years 2. <50 years 1. < 30 years (half of life by time for mid-term goals)

2 1 3

RTA Key Element 4: Table

Key element: 4. Technical Characteristics and Performance (Importance per Key Topic)							%
Key topics	%	Rationale for percentage	HTR-PM	NuScale	SMART	Rationale for score	
Proven technology	10	• Important factor for safety • No operating SMR plants • NOAK policy				5. Currently under construction. 4. Construction plans established. 3. FOAK plant construction plans begun. 2. FOAK plant is expected, but no official framework established. 1. Retasland plant will be FOAK.	
Standardization	10	Impact on costs, unit consistency, meeting design specifications, etc.				5. Full, experienced (by Retasland plant construction time) factories and manufacturing facilities and scaling cost projections well established. 3. Established standardization of major equipment. 1. Non-standard or insufficient standardization in supply chain or no information provided.	

2 1 3

RTA Key Element 4: Table

Key element: 4. Technical Characteristics and Performance (Importance per Key Topic)							**%**
Key topics	**%**	**Rationale for percentage**	**HTR-PM**	**NuScale**	**SMART**	**Rationale for score**	
Simplification	10	• Ideal for newcomer countries • Enhancement to safety by design				5. Applies inherent and passive principles to greatly simplify the system, enhancing safety and simplifying operation. 4. Applies inherent and passive principles to enhance safety for widened range of events. 3. Applies inherent and passive principles to significantly enhance safety. 2. Simplifications made to design, with some impact on safety. 1. Little or no significant simplifications over existing designs.	

2 1 3

RTA Key Element 4: Table

Key element: 4. Technical Characteristics and Performance (Importance per Key Topic)						%
Key topics	%	Rationale for percentage	HTR-PM	NuScale	SMART	Rationale for score
Unit size	10	• Flexibility in meeting goals with addition of units		5 (12 x 50)	1 (2 x 100)	5. Can directly meet scaling goals with incremental upgrade flexibility (many steps). 4. Additional flexibility due to small unit size, permitting incremental upgrade few steps). 3. Generation goals can be met appropriately. 2. Restrictive deployment options due to unit size. 1. Incapable of scaling to meet goals.
Plant lifetime	10	• No current information on life extensions • Large impact on returns		3 (60 years)	3 (60 years)	5. >80 years 4. >70 years 3. 50–70 years 2. <50 years 1. < 30 years (half of life by time for mid-term goals)

2 1 4 3

RTA Key Element 4: Table

Key element: 4. Technical Characteristics and Performance (Importance per Key Topic)						%
Key topics	%	Rationale for percentage	HTR-PM	NuScale	SMART	Rationale for score
Proven technology	10	• Important factor for safety • No operating SMR plants • NOAK policy		3 (planned FOAK in Idaho, USA)	4 (Preproject agreement made with Saudi Arabia)	5. Currently under construction. 4. Construction plans established. 3. FOAK plant construction plans begun. 2. FOAK plant is expected, but no official framework established. 1. Retasland plant will be FOAK.
Standardization	10	Impact on costs, unit consistency, meeting design specifications, etc.		1 (No information) **See question (1)**	1 (No information) **See question (1)**	5. Full, experienced (by Retasland plant construction time) factories and manufacturing facilities and scaling cost projections well established. 3. Established standardization of major equipment. 1. Non-standard or insufficient standardization in supply chain or no information provided.

2 1 4 3

(1) Please provide information regarding the estimated scaling unit costs, supply chain manufacturers and their experience with manufacturing of specific components/systems, and any non-standard components/systems necessary for construction of the plant. Additionally, provide any information regarding the differences to these in comparison to FOAK plants or other pre-Retasland plants.

RTA Key Element 4: Table

Key element: 4. Technical Characteristics and Performance (Importance per Key Topic)							%
Key topics	%	Rationale for percentage	HTR-PM	NuScale	SMART	Rationale for score	
Simplification	10	• Ideal for newcomer countries • Enhancement to safety by design		5 (integrated primary system, passive safety systems, natural circulation coolant flow, large heat sink provides long term cooling)	3 (integrated primary system, passive safety systems, forced circulation)	5. Applies inherent and passive principles to greatly simplify the system, enhancing safety and simplifying operation. 4. Applies inherent and passive principles to enhance safety for widened range of events. 3. Applies inherent and passive principles to significantly enhance safety. 2. Simplifications made to design, with some impact on safety. 1. Little or no significant simplifications over existing designs.	

2 1 4 3

Case Study Toolkit

Teams

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Thank you!