Shaping Today's and Tomorrow's Energy

AP1000 Technology, Lessons Learned from the First of A Kind Projects & Readiness for Implementation in Bulgaria

Julie Gorgemans

Director AP Technology Deployment, Global Engineering Services

Westinghouse Electric Company

Westinghouse

Energy Systems

A portfolio of innovative solutions

AP1000® PWR

1100+ MW_e

Most advanced nuclear technology operating in the world today with record-setting performance

TECHNICAL CAPABILITIES

- Passive Safety Systems
- Simplified Active Systems
- Proven NSSS Components; Canned Motor Pumps
- Compact Footprint
- Modular Construction
- Digital I&C and Advanced Control Room
- Load Follow Capability
- Global Licensing Pedigree

eVinci Microreactor™

5 MW_e

Microreactor designed for safe and reliable electricity and heat generation

TECHNICAL CAPABILITIES

- 5 MWe + ~8MWth @ 200C cogeneration
- Minimum 8 year refueling cycle
- Transportable for ease of installation and elimination of spent fuel storage on site
- Cost-competitive plant lifecycle
- Minimal onsite personnel
- Mature technology, manufacturing, and regulatory readiness
- High speed load following capability

AP300™

300 MW_e

Only SMR based on deployed, operating & advanced reactor technology

TECHNICAL CAPABILITIES

- 300MWe (900MWth) 1-loop PWR with demonstrated reliability
- Based on the fully licensed & operating AP1000 technology
- Utilizes identical passive safety systems used in the AP1000 reactor to maintain safe shutdown condition
- Ultra-compact, simplified design reduces construction timeframes
- Maximizes use of established supply chain
- Less than 0.4 acres needed for safety related buildings

Pumped thermal energy storage

Innovative design coupled with tested technology

TECHNICAL CAPABILITIES

- Advanced Supercritical Carbon Dioxide (sCO2) Technology
- Efficient heat pump and heat engine cycle
- Unique, Patented Thermal Storage Solution
- Engineered concrete thermal batteries
- Low-cost materials; Printed Circuit Heat Exchangers (PCHE)
- Power turbine and low-temperature compressor are derivatives of existing designs
- Heat exchangers, piping, valves, controls are of similar design to existing SCO2 systems

21st Century Nuclear Plant Features – 1000+MW Class
Key Feature #1 – Passive Safety Approach

The AP1000 plant design has a **unique capability to respond to extreme, Fukushima-like events** due to three fundamental safety advancements:

1. **The AP1000 plant self actuates:** for station blackouts, critical systems, structures and components automatically achieve a fail-safe configuration without the need for operator action or AC/DC power.
2. **The AP1000 plant is self sufficient:** The passive approach to safety eliminates the importance of AC power and cooling supply.
3. **The AP1000 plant is self contained:** Systems, structures and components critical to placing the reactor in a safe shutdown condition are protected within the steel containment vessel which is protected by a robust shield building.

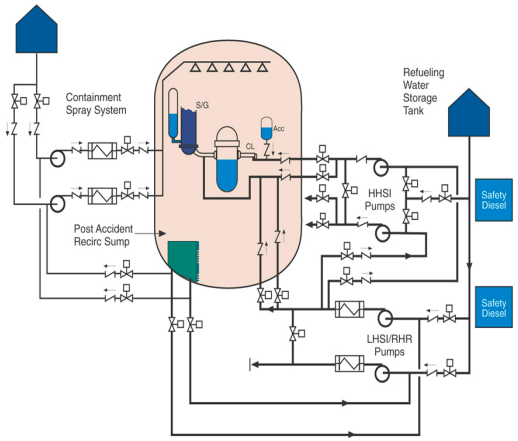
The AP1000 plant introduced a novel passive safety concept that relies on simplifications to achieve an unparalleled level of protection against extreme and unforeseen events

21st Century Nuclear Plant Features – 1000+MW Class
Key Feature #1 – Passive Safety Approach Impact on Construction Quantities

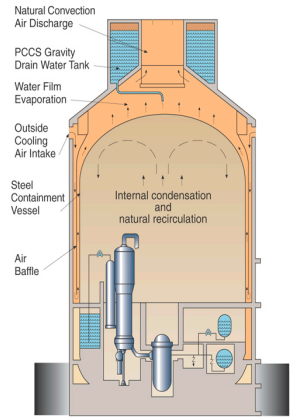
- **Passive safety systems located inside containment/shield building**
- **Active non-safety systems optimized for normal operation**
- **Significantly reduces safety-related quantities due to simplification**

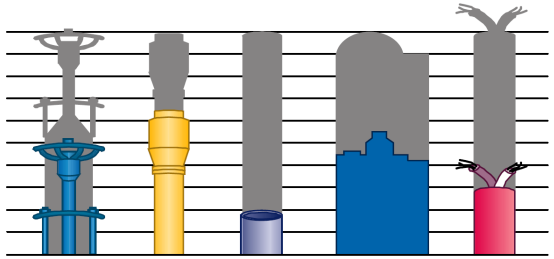
Plant	Safety Related Footprint	Safety Related Footprint (m^2) per MWe
AP1000 Nuclear Island	3,015 m^2	2.6
AP300 Nuclear Island	1,420 m^2	4.7
NuScale 6-Module Reactor and Control Building	~3,960 m^2	9.0
EPR	~13,100 m^2	8.2

Standard PWR

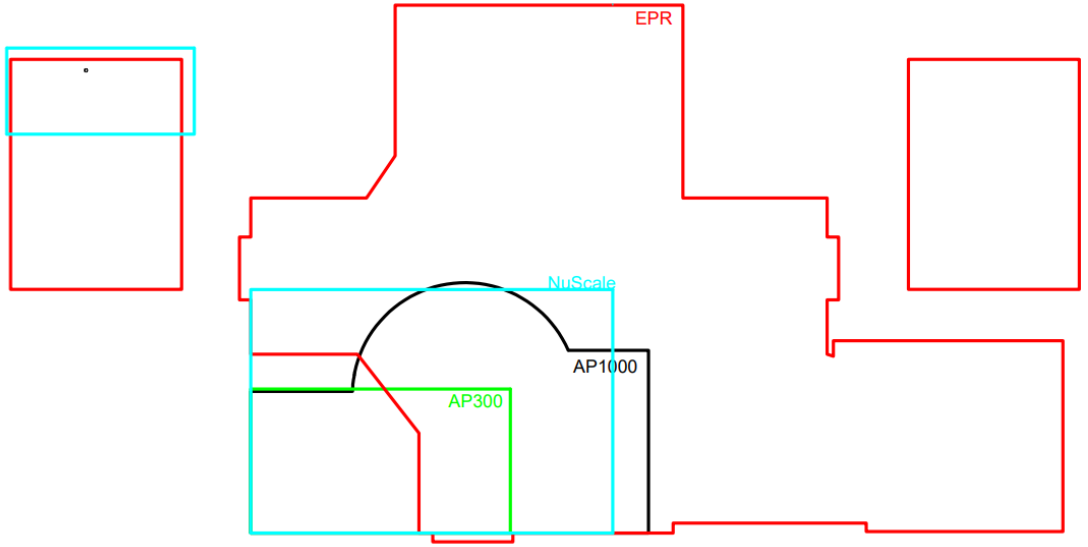


AP1000 PWR





50% Fewer Valves | 35% Fewer Pumps | 80% Less Pipe | 45% Less Seismic Building Volume | 85% Less Cable



Notes:
- Net power output for AP1000 (Haiyang) and EPR (Olkiluoto) from World Nuclear Association; NuScale 77 MWe power gross/module provided from www.Nuscalepower.com (net MWe per NuScale SMR Technology: An Ideal Solution for Repurposing U.S Coal)
- NuScale NI footprint per NuScale DCD (https://www.nrc.gov/docs/ML2300/ML23001A016.pdf); EPR footprint per Hinkley Point C Site Parameter plan HINK-A1-SL-00-GA-002 (https://infrastructure.planninginspectorate.gov.uk),EPR footprint includes Emergency Diesel Generator buildings.

21st Century Nuclear Plant Features – 1000+MW Class
Key Feature #2 - Modular Construction Approach

Shorter construction schedule – Improved quality – Reduced field work

Factory production of modules

Transport Modules

On-site module assembly

Plant Operation

Site Survey and Preparation

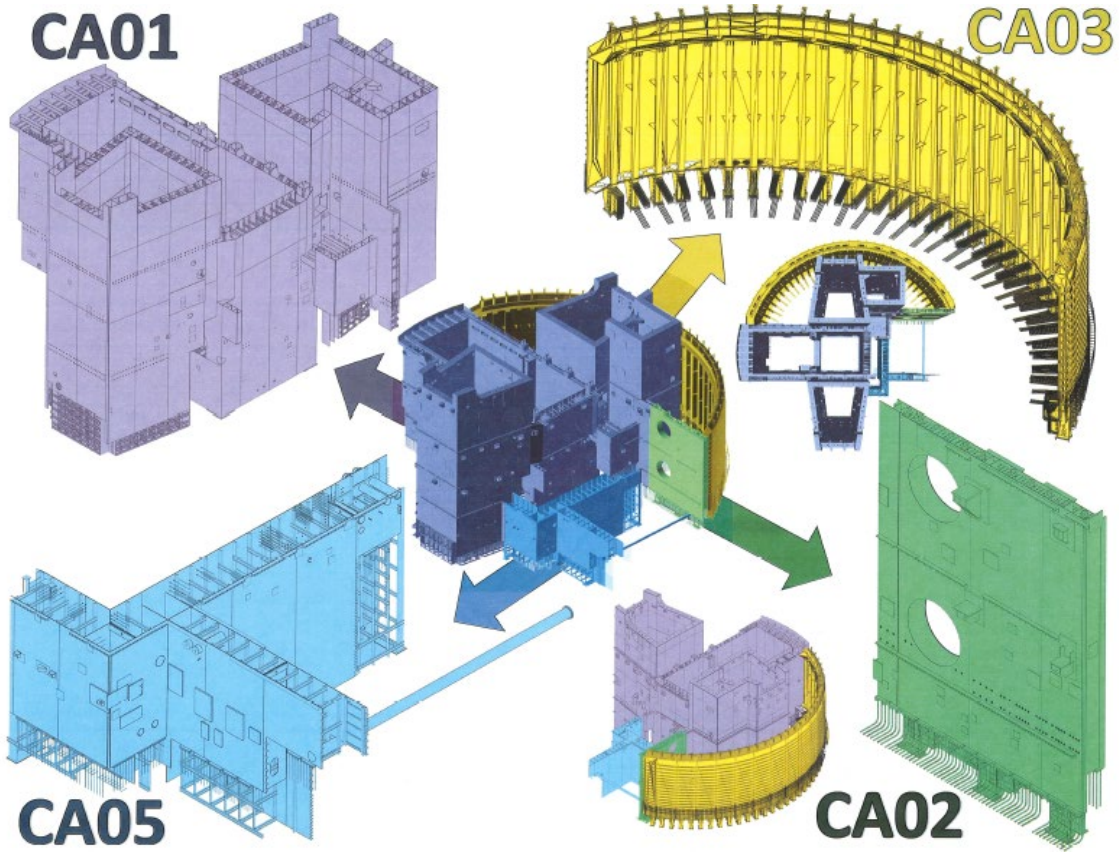
Site Construction

Construction and module assembly

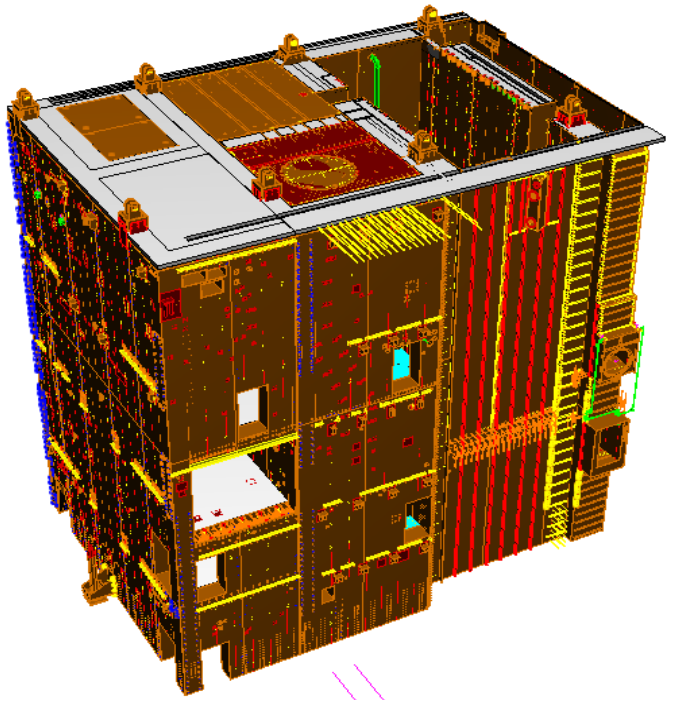
Requires pre-engineering and early procurement – More work done in parallel

21st Century Nuclear Plant Features – 1000+MW Class
Key Feature #2 - Modular Construction Approach Large AP1000 Modules

Containment Building



Auxiliary Building

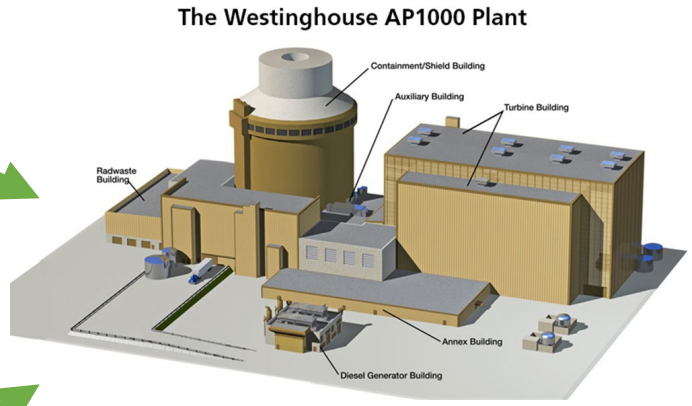


21st Century Nuclear Plant Features – 1000+MW Class
Key Feature #3 – Reliable Flexibility in Operation

AP1000 Plant Flexible Performance provides a Unique capability to stabilize modern, renewable heavy electrical grids

- District Heating -

- Flexible sizing for individual regional needs
- Reference 500 MWt District Heating Capacity (sufficient for heating up to 60,000 households), up to 175 °C (350 °F) Hot Water
- Additional 1.0 million metric tons (2.23 billion pounds) of CO_2 emission elimination during the cold months, otherwise come from coal
- Cogen Thermal Efficiency Value ~46% (from 33.5% power production only efficiency)



- Energy Storage -

- Optimized Turbine Island for enhanced grid stabilization effect
- Allow to run reactor at 100% power, with load shifting capability between 86 - 114% Nominal Electric Power
- Energy Storage Efficiency of 70% for reference daily cycle (14 hours charging, 2 hours nominal, 8 hours peak production)
- Can be integrated with District Heating for Winter/Summer flexible mode

- Water Production-

- Produce 270,000 m^3/day to ~ 1 million m^3/day of desalinated water
- Power the world biggest desalination plant, while supplying electricity to surrounding cities
- Uses 5% ~ 10% of generated electricity
- Based on Seawater Reverse Osmosis (SWRO) Systems

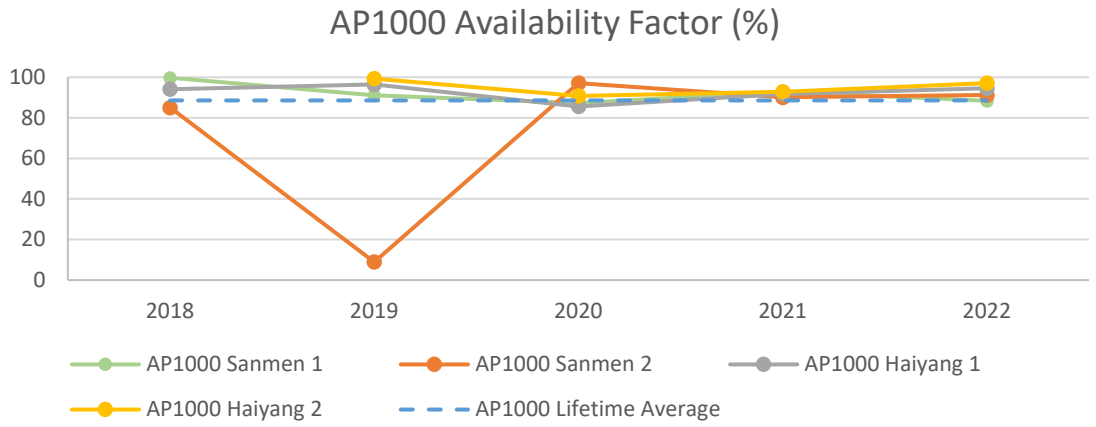
Reference Configuration – Electricity Production -

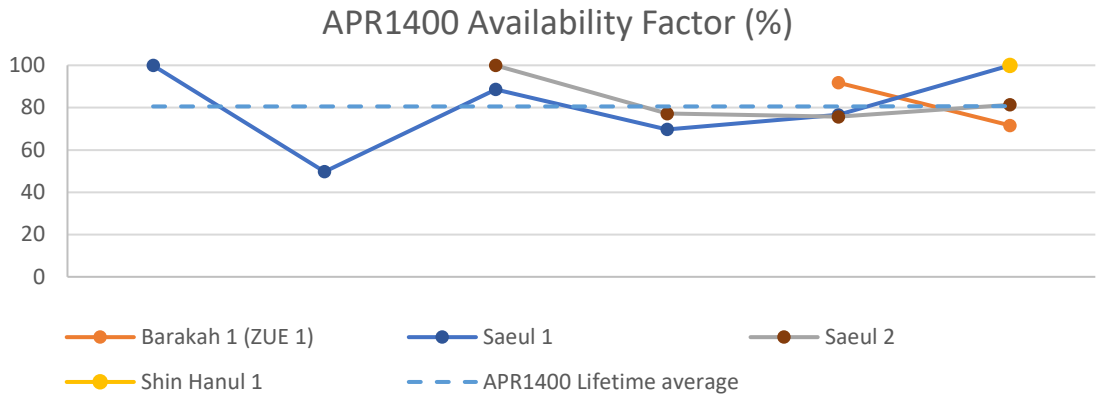
- 3,400MWt Rated Reactor, 1,150MWe(*) Nominal Net Electric Power
- 3.9 to 9.7 million metric tons (8.7 to 21.3 billion pounds) CO_2 emission offset per year otherwise come from natural gas or coal
- Unique fast load change capabilities to support variations in grid demand

- Hydrogen Production-

- Reference Configuration uses electricity (100MWe) and steam (0.5% of Hot Reheat Steam) to produce up to 50 metric tons (115,000 lbs) of H_2/day
- High Temperature Electrolysis Process

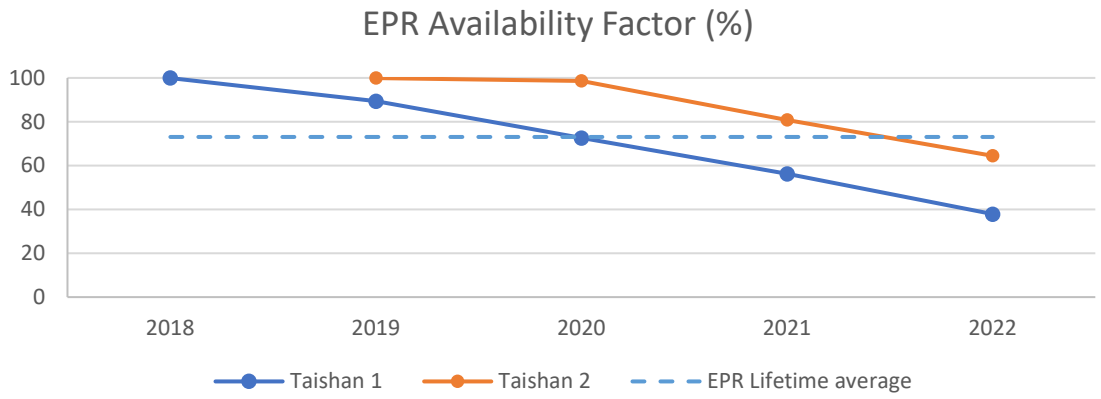
21st Century Nuclear Plant Features – 1000+MW Class
Key Feature #3 – Reliable Flexibility in Operation





Comparison of Lifetime Operation Availability Factors

Technology / Operating Units	Average Lifetime Operation Availability Factor
AP1000 Plant (Sanmen 2, Haiyang 1&2)	92.5%*
APR-1400 (Saeul 1&2, Barakah 1, Shin Hanul 1)	80.7%
EPR (Taishan 1 & 2)	73.1%



1) Source of data is IAEA Power Reactor Information System: https://pris.iaea.org/PRIS/CountryStatistics
2) Availability data for Barakah 2 & Olkiluoto 3 not yet available in the IAEA PRIS
3) Shin Hanul 1 (APR1400) has only operated less than 1 month after Commercial Operation Date in 2022.

21st Century Nuclear Plant Features – 1000+MW Class
Key Lessons Learned and Challenges

China → Vogtle → Future Projects

- **Procurement/FOAK equipment**
  - FOAK manufacturing issues (e.g. reactor coolant pumps, reactor coolant loop piping, reactor vessel internals, modules)
  - Suppliers (from a quality & experience) selection and qualification process
- **Critical timing of Engineering Completion**
  - Percent engineering complete at time of contract signing
- **First time regulatory challenges**
  - Challenges encountered with being first new plant built according to Part 52 licensing process (Vogtle)
  - Regulatory holds on protection and safety monitoring system (PMS) shipment associated with new digital testing requirements and fuel load permit issuance (China)
- **Construction Planning Effectiveness**
  - Effective Construction planning and work package structure; integration of design and work package
- **Commissioning**
  - FOAK testing issue resolution extended duration between start of hot functional testing and readiness for fuel load

Continuous Lessons Learned provide improvements for future projects

Thank You

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