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Worldwide Status of Nuclear New Build and Major SMR Activities

ANS Trinity Section
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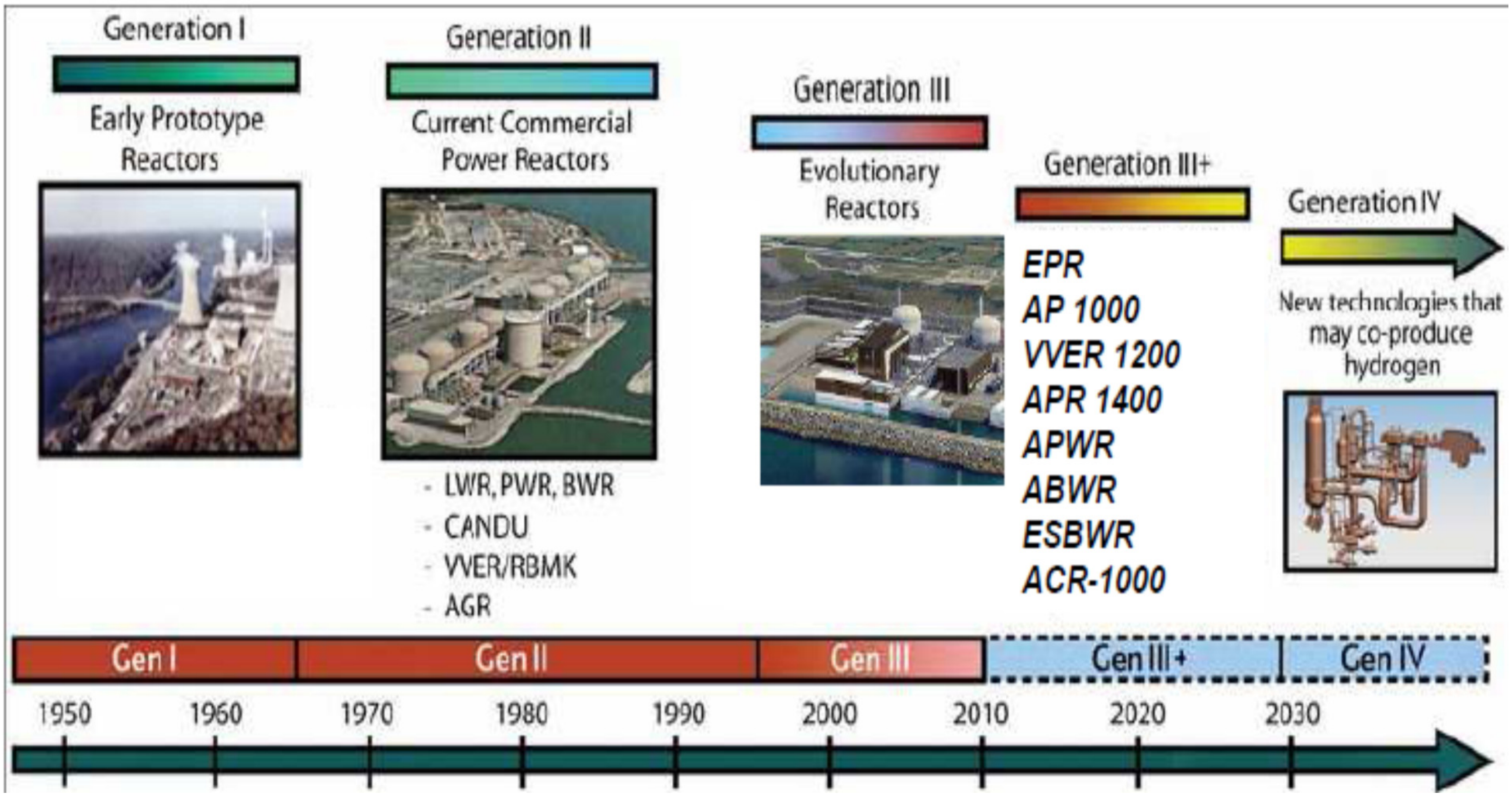
Albuquerque, NM

11921 Rockville Pike, Suite 100
Rockville, MD 20852 USA
Telephone: (301) 984-4400
Facsimile: (301) 984-7600
www.excelservices.com
donald.hoffman@excelservices.com

Worldwide Status of Nuclear New Build

Commercial Gen-III/III+ Technologies

Overview - Evolution of Large Commercial NPP Designs



Commercial Gen III/III+ NPP Designs offered today (1000 – 1700 MW)

– ABWR1370	GE-Hitachi, Toshiba
– EU-ABWR1600	Toshiba
– ESBWR1550	GE-Hitachi
– EPR1600	AREVA
– AP1000	Westinghouse
– APR1400	KHNP
– APWR1700	Mitsubishi
– VVER1200 (V-392, V-491)	Atomstroyexport (ASE)
– ACR1000	CANDU Energy
– ATMEA1100	AREVA/Mitsubishi
– CAP1400	SNPTC

in operation / under construction

Characteristics of Gen III/III+ Plants

- Improved Safety
- Improved Licensing
- Improved Economics
- Improved Construction
- Improved Operations
- Improved Standards
- Reduced Uncertainties
- First-Of-A-Kind Engineering (FOAKE)

Characteristics of Gen III/III+ Plants (2)

- Improved Safety
  - 4 Safety Trains
  - Aircraft Crash Protection (Double Containment)
  - Severe Accident Mitigation (Core Catcher)
  - Digital I&C Systems
  - Significantly Lower CDF and LRF Values
  - Some Passive Safety System Features
- Improved Licensing
  - Standardized Designs (DCD approval)
  - Streamlined Licensing Process (e.g., COL, GDA)

Characteristics of Gen III/III+ Plants (3)

- Improved Economics
  - Standardized, Simplified, Robust Design
  - Higher Plant Efficiency
  - 60 years Plant Life (80 years anticipated)
  - 90+% Capacity Factor
- Improved Construction
  - Modular Design
  - Prefab of Systems and Components off-site
  - Open Top Construction

Characteristics of Gen III/III+ Plants (4)

- Improved Operations
  - Less Operational Radioactive Waste
  - Less Doses to Plant Staff
  - Less Maintenance (fewer active systems)
  - Shorter Outages (typically 15 days)
- International Standards
  - Compliant with IAEA QA and Safety Guides
  - Compliant with EPRI URD
  - Compliant with EUR
  - Further Benefits from Code Harmonization

Characteristics of Gen III/III+ Plants (5)

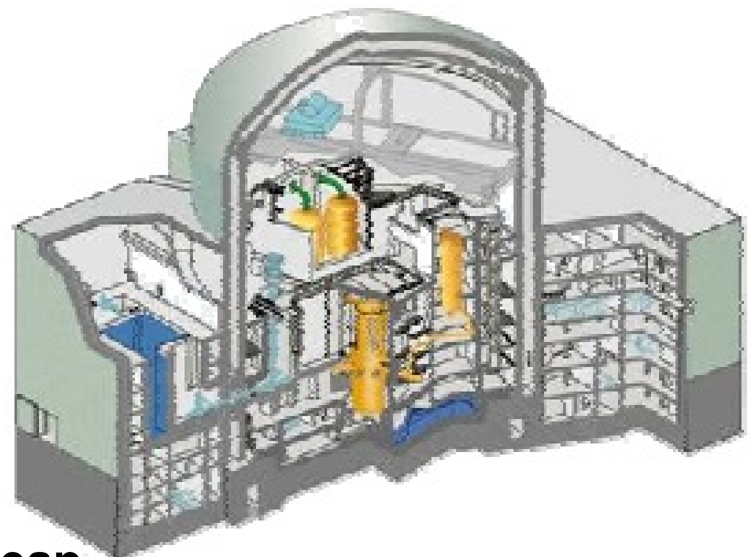
- Reduced Uncertainties for Owner/Investor
  - Anticipated as a result from all improvements
  - Not yet demonstrated for current Gen III/III+ NPPs
- First-Of-A-Kind Engineering (FOAKE)
  - So far FOAKE efforts much underestimated
  - Benefits from Standardization not yet reached
  - AP1000 in China may be first to achieve these benefits
  - Significant re-learning of NPP Construction Lessons

ABWR

- 3/4-Train Safety Systems
- Reactor Internal Pumps eliminate external loops
- Fully digital I&C
- Modularized design & some Prefab construction
- Integrated containment and reactor building
- Lowest Core Damage Frequency amongst Gen-III (except for ESBWR)
- Proven Capital and O&M cost structure (in Japan)
- No Steam Generators – reduced life time costs
- No external coolant loops and no core uncovery
- (4) in operation in Japan, (1) under construction in Japan, (2) on hold in Japan, (2) under construction in Taiwan

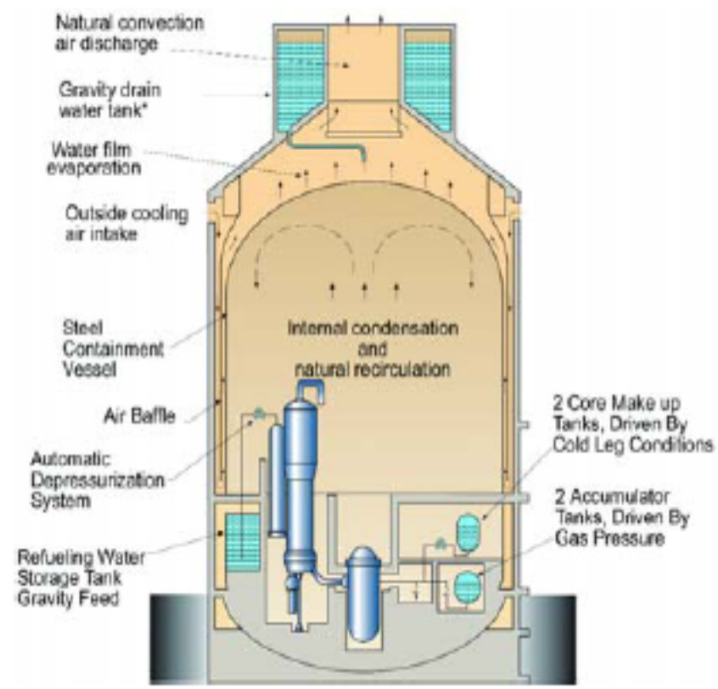
EPR

- 4-Train Safety Systems
- Double Containment to protect against commercial aircraft crash
- Core Catcher for severe accident mitigation
- Can run on a full MOX Core
- Higher Plant Efficiency (37%)
- Digital I&C (Siemens TELEPERM-XS)
- 10-15% less uranium consumption
- 15 days outages
- Above 90% life time capacity factor
- Robust design with small technology leap
- Under construction in Finland (1), France (1), China (2)



AP1000

- **Passive Safety Systems – use forces of nature (gravity, convection, natural circulation to improve safety and simplify systems)**
- **Passive systems for core cooling, containment isolation, residual heat removal and containment cooling**
- **No outside electricity needed for 72 hrs**
- **Number of pumps and safety class valves reduced by about 50%**
- **In-vessel retention of core melt**
- **Passive Containment Cooling system**
- **Proven PWR components**



- **(4) under construction in USA, (4) under construction in China**

APR1400

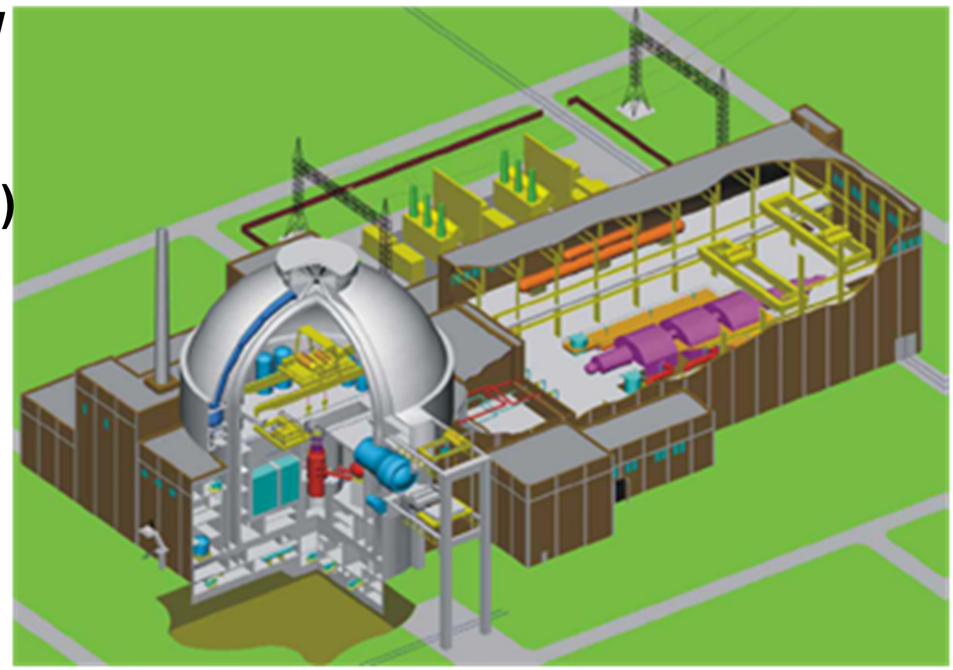
- Designed based on EPRI ALWR Requirements (URD)
- Up-rated power of 4,000 MWt (1,450MWe)
- 60-year design life
- Use of proven technology plus extensive testing
- Fully digitalized control system
- In-Containment Water Storage System (ICWRS)
- 4-Train Safety Systems
- Passive design features
- Prefab and modularized design
- Severe accident mitigation:
  - External RPV Cooling System
  - Cavity Flooding System
- World's largest 2-loop plant
  (2 hot-legs, 4 cold-legs, 2 SGs)
- World's largest 60Hz Turbine
- (4) under construction in UAE
  (4) under construction in S. Korea

APWR

- 4-Train Safety System (4 x 50%)
- Thermal Efficiency 39% in USA Version – 160 MWe extra from TG plant
  - means 30% larger heat transfer surface in SGs
  - last stage Turbine Blades increased from 54” to 70” length
- Core has extra Neutron reflector to improve fuel economy
- In-Containment Refueling Water Storage
- Can handle a full MOX fuel core
- 14 ft fuel length
- Reduced Staff exposure
- Fully Digital I&C
- Reduced Operational Waste
- PreFab and modularized design
- (2) under construction in Japan (now on hold)

VVER1200 – V-392M and V-491

- V-392M designed by Moscow Atomenergoproekt Institute, and two Units under construction at Novovoronesh-II site – for Russian market
- V-491 designed by St.Petersburg Atomenergoproekt Institute, and two Units under construction at Leningrad-II site – for Export/satisfies EUR
- VVER1000 stretched to 1200 MW
- 60 years service life
- Higher thermal efficiency (35.7%)
- 4-loop design /horizontal SGs
- Most recent VVER1000 exports:
  - in China (Tianwan-1/2)
  - in India (Kudankulam-1/2)
  - in Iran (Busher-1)
- (4) under construction in Russia
- (4) on order in Turkey (Akkuyu)

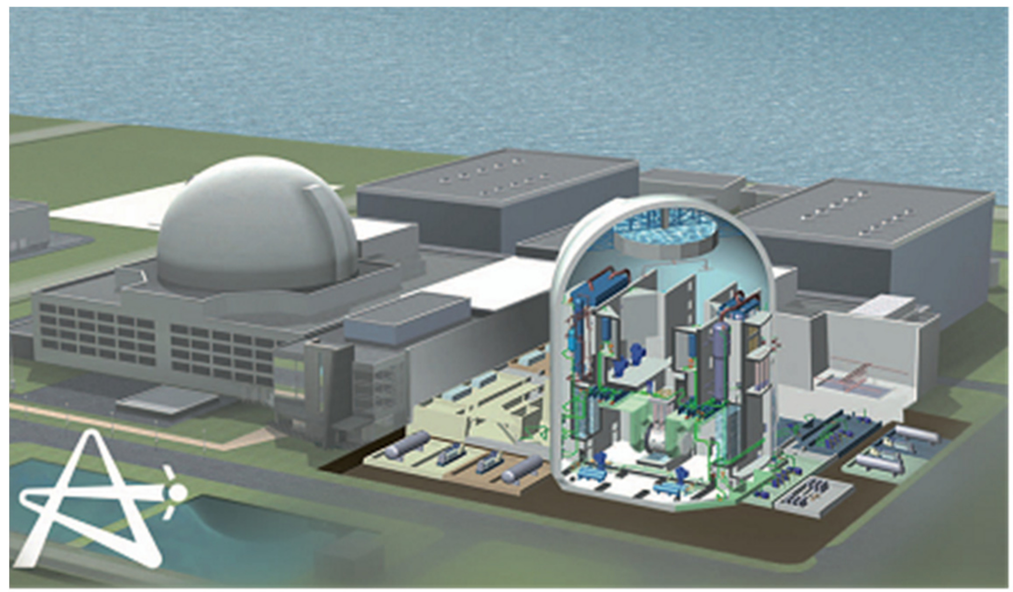


ESBWR

- **Simpler safer BWR using passive concepts to the max**
- **No Operator action required for up to 72 hours**
- **11 ABWR systems eliminated from ESBWR**
- **25% of pumps, valves and motors eliminated**
- **Passive Residual heat transfer to atmosphere**
- **Using best features of existing BWRs / ABWR**
- **Core Damage Frequency 1.7E-8, lowest amongst Gen-III**
- **Reduced construction costs and schedule**
- **Reduced O&M costs**
- **Prefab and modular design reduce construction costs**
- **None on order nor under construction**

ACR1000

- 1165 MWe advanced CANDU (evolutionary development)
- Light-water-cooled, heavy-water-moderated
- 2.4% enriched uranium in fuel achieves 20 MWd/kgU burnup (4.0% enriched fuel to achieve 40 MWd/kgU burnup / future target)
- 60% reduced heavy water inventory, can burn MOX, Thorium fuels
- 4-Loop design
- Strengthened containment building (single wall)
- Reactor Vault is waterfilled (Core catcher function)
- None under construction, and none on order



Key Features – Gen III/III+ Designs

Major Features	*ABWR*	*EPR*	*AP1000*	*APR1400*	*APWR*	*VVER1200 V-491*	*ESBWR*	*ACR1000*
Vendor	GE-Hitachi Toshiba	AREVA	Westinghouse	KHNP	Mitsubishi	Rosatom	GE-Hitachi	AECL
Output, MWe	1370	1600 (Finland) 1700 (USA)	1117	1400	1538 (Japan) 1700 (USA)	1200	1535	1165
Plant Efficiency, %	35	37	34	35	35 (Japan) 39 (USA)	36	35	36
Design Life, years	60	60	60	60	60	60	60	60
Construction goal, months from 1st Concrete to COD	48 44 (in Japan)	51	42	48	46	54	42 estimate	42
First Unit COD	1996 (Japan)	2014 (Taishan)	2014 (Sanmen)	2016 (S. Korea)	On hold (Japan)	2013 (Russia)	No order	No order
Extensive use of PreFab modules	Yes	No	Yes	Yes	Yes	No	Yes	Yes
Digital I&C	GE	Siemens TELEPERM-XS	ABB ADVANTAGE	Korean	MHI	Siemens TELEPERM-XS	GE	Dual computer
Containment	Single	Double	Single	Single	Single	Double	Single	Single
Safety Systems	3/4-train active	4-train active	4-train passive	4-train active	4-train active	4-train active	4-train passive	4-train active
Core Catcher function	Partially	Yes	In vessel	No	No	Yes	Partially	Partially
Fuel Lattice type	10x10	17x17XL	17x17XL	16x16	17x17XL	Hexagonal	10x10 short	43-rod
Discharge Burnup, MWd/kg	60	62	62	62	62	49 (VVER1000) 65 (VVER1200)	60	20 40 (future)
Steam Generators	n/a	4 U-tube	2 U-tube	2 U-tube largest in world	4 U-tube	4 horizontal	n/a	4 U-tube

Overview of Worldwide Gen-III/III+ New Build Trends and Order Books

Current NPP Constructions
excluding domestic Chinese, Indian NPPs

Vendor	Plant	Type	COD	Status
AREVA	Angra 3	Gen II Konvoi	2016	Under construction, restarted after 20 years
AREVA	Calvert Cliff 3	EPR1700		On hold
AREVA	Flamanville 3	EPR1600	6/16	Under construction, 7 yrs delay
AREVA	Olkiluoto 3	EPR1600	6/16	Under construction, 7 yrs delay
AREVA	Penly 3	EPR1700		On hold (politics)
AREVA	Taishan 1	EPR1700	12/13	Under construction
AREVA	Taishan 2	EPR1700	11/14	Under construction
ASE	Belene 1	VVER1000		2008 contract canceled
ASE	Belene 2	VVER1000		2008 contract canceled
ASE	Kundankulam 1	VVER1000	12/13	Under construction, near startup, 5 years delay
ASE	Kundankulam 2	VVER1000	6/14	Under construction, near startup, 5 years delay
ASE	Leningrad 2-1	VVER1200	2014	Under construction
ASE	Leningrad 2-2	VVER1200	2016	Under construction
ASE	Mochovce 3	VVER 440	2013	Under construction, near startup
ASE	Mochovce 4	VVER 440	2014	Under construction, near startup
ASE	Novovoronesh 2-1	VVER1200	2014	Under construction
ASE	Novovoronesh 2-2	VVER1200	2015	Under construction
ASE	Rostov 2	VVER1000	3/10	Under startup
ASE	Rostov 3	VVER1000	2015	Under construction
ASE	Rostov 4	VVER1000	2017	Under construction
ASE	Tianwan 3	VVER1000	2017	Under contract
ASE	Tianwan 4	VVER1000	2018	Under contract
ASE	Akkuyu-1/2/3/4	VVER1200	2020-26	Under contract; first BOO Contract

Current NPP Constructions (2)
excluding domestic Chinese, Indian NPPs

Vendor	Plant	Type	COD	Status
GE-H	Lungmen 1	ABWR	2013	Under construction, near startup, 10 years delay
GE-H	Lungmen 2	ABWR	2014	Under construction, near startup, 10 years delay
Hitachi	Ohma	ABWR	2016	Under construction (1st restart after Fukushima)
Hitachi	Shimane 3	ABWR	12/13	Under construction (on hold), near startup
KHNP	Shin Kori 1	Gen II OPR1000	12/13	Under construction
KHNP	Shin Kori 2	Gen II OPR1000	12/14	Under construction
KHNP	Shin Kori 3	APR1400	9/15	Under construction
KHNP	Shin Kori 4	APR1400	9/16	Under construction
KHNP	Shin Kori 5	APR1400	12/18	Firm plans
KHNP	Shin Kori 6	APR1400	12/19	Firm plans
KHNP	Shin Ulchin 1	APR1400	12/15	Under contract
KHNP	Shin Ulchin 2	APR1400	12/16	Under contract
KHNP	Shin Wolsong 1	Gen II OPR1000	3/13	Under construction
KHNP	Shin Wolsong 2	Gen II OPR1000	1/14	Under construction
KHNP	UAE-1	APR1400	6/17	Under construction
KHNP	UAE-2	APR1400	6/18	Under construction
KHNP	UAE-3	APR1400	6/19	2010 contract
KHNP	UAE-4	APR1400	6/20	2010 contract
Mitsubishi	Tsuruga 3	APWR1538	3/16	Under construction, on hold
Mitsubishi	Tsuruga 4	APWR1538	3/17	Under construction, on hold
Mitsubishi	North Anna 3	APWR1700	2018	Canceled, replaced by ESBWR
Mitsubishi	Comanche Peak 3	APWR1700	2017	Firm plans, waiting on EPC Contract, COL and LG
Mitsubishi	Comanche Peak 4	APWR1700	2018	Firm plans, waiting on EPC Contract, COL and LG

Current NPP Constructions (3)
excluding domestic Chinese, Indian NPPs

Vendor	Plant	Type	COD	Status
Toshiba	Higashi Dori 1 (TEPCO)	ABWR	3/17	Under contract, on hold
Toshiba	South Texas 3	ABWR	2017	Canceled (cheap shale gas)
Toshiba	South Texas 4	ABWR	2018	Canceled (cheap shale gas)
Westinghouse	Haiyang 1	AP1000	5/14	Under construction
Westinghouse	Haiyang 2	AP1000	3/15	Under construction
Westinghouse	Sanmen 1	AP1000	11/13	Under construction
Westinghouse	Sanmen 2	AP1000	9/14	Under construction
Westinghouse	Vogtle 3	AP1000	2018	Under construction
Westinghouse	Vogtle 4	AP1000	2019	Under construction
Westinghouse	Summer 2	AP1000	2018	Under construction
Westinghouse	Summer 3	AP1000	2019	Under construction
Westinghouse	Watts Bar 2	Gen II PWR 1100	2016	Under construction, restarted after 20 years
Westinghouse	Taohuajiang 1	AP1000		Firm plans
Westinghouse	Taohuajiang 2	AP1000		Firm plans
Westinghouse	Da fan 1	AP1000		Firm plans
Westinghouse	Da fan 2	AP1000		Firm plans
Westinghouse	Peng ze 1	AP1000		Firm plans
Westinghouse	Peng ze 2	AP1000		Firm plans
Westinghouse	Haiyang 3	AP1000		Firm plans
Westinghouse	Haiyang 4	AP1000		Firm plans

Status 2013: Under Construction worldwide: (4) BWRs and (36) PWRs; plus CHINA alone (30) PWRs
Data Source: IAEA, WNA, EXCEL

Worldwide Status of Nuclear New Build

Type	MW	Vendor	Current Status
ABWR	1370	GE-Hitachi Hitachi-GE Toshiba	4 in operation in Japan 1 under construction in Japan (2 on hold) 2 under construction in Taiwan 2 on hold in USA (South Texas-3/4) 4 planned in UK (Horizon)
EU-ABWR	1600	Toshiba	2 offered in Finland (TVO, Fennovoima)
ESBWR	1550	GE-Hitachi	1 offered in Finland (TVO)
AP1000	1100	Westinghouse	4 under construction in China 4 under construction in USA 8 more planned in China
APR1400	1450	KHNP	4 under construction in South Korea 4 under construction in UAE
EPR	1650	AREVA	2 under construction (Finland/France) 2 under construction in China 2 on order in India 4 planned in UK 0 in USA
APWR1700	1700	Mitsubishi	2 under construction in Japan (on hold) 3 planned in USA (Luminant, Dominion)
VVER1200	1180	Rosatom (ASE)	4 under construction in Russia 4 on order in Turkey 15 on Rosatom's order book
CAP1400	1500	SNPTC	1st Unit at Rongcheng (Construction 2013 to 2018) 100% Chinese IP rights; to be exported worldwide

Worldwide Trends of Nuclear New Build

(excl. China/India domestic – but with Fukushima impact estimated)

Region	Trend	NNB Projects	Comments
North America	→	(4) reactors (AP1000s) under construction; (1) Gen-II reactor under construction	US Nuclear Renaissance halted by cheap Shale Gas (not Fukushima). Canada on hold (AECL sold off).
South America	↔	(2) Gen II reactors to be completed (Angra-3, Atucha-2)	Planning stage (Mexico, Brazil, Chile, Argentina)
Europe	↗	(4) Reactors under construction; (22) planned	Finland (1+2), Sweden (0+2), UK (0+8), France (1+0), Switzerland (0+0), Czech Republic (0+2), Slovakia (2+2), Bulgaria (0+1), Italy (0+0), Poland (0+2), Hungary (0+2), Lithuania (0+0), Romania (0+1)
Russia	↗	(7) Under construction; (15) on Rosatom order book	Steady growth, but slower than before. Fukushima measures to be implemented.
MENA	↗	(4) Under construction; (1) in Iran; (4) on order (Turkey)	Accelerating growth expected. UAE (4) under construction. Turkey (4) on order. Slowed down plans in Egypt, Jordan, Saudi Arabia.
Asia	↗	(30) PWRs under construction in China; (4) in South Korea; (2) in Taiwan; (1) in Japan	Slower growth in China and India. Fukushima measures to be implemented. No change in South Korea and new countries (eg Vietnam), (1) under construction in Japan. Stop in Thailand, Indonesia.

Emergence of China onto World Markets

- 2012 has become a game-changing year in NPP world markets, due to confluence of key events:
  - Fukushima slowed down all Western NPP markets
  - Cheap Shale Gas halted US nuclear renaissance
  - China completed process of "digesting/improving" foreign NPP technologies ➔ with Chinese IP rights, allowing for future export into world markets of:
    - AP1400 ➔ CAP1400 (SNPTC)
    - Daya Bay / 3-Loop PWR ➔ ACPR1000 (CGNPC)
  - $/kW overnight of CAP1400 / ACPR1000 inside China are ~ 1/3 to 1/2 of AP1000 or EPR outside China

CHINA – Mega New Build Market

Plant	Province	MWe gross	Reactor model	Project control	Construction start	Operation
Hongyanhe units 2-4	Liaoning	3x1080	CPR-1000	CGNPC, with CPI	**4/08**, **3/09**, **8/09**	2013, 2014
Ningde units 2-4	Fujian	3x1080	CPR-1000	CGNPC, with Datang	**1/08**, **1/10**, **9/10**	2013, 2014, 2015
Fuqing units 1&2	Fujian	2x1080	CPR-1000	CNNC	**11/08**, **6/09**	11/13, 9/14
Yangjiang units 1-4	Guangdong	4x1080	CPR-1000	CGNPC	**12/08**, **8/09**, **11/10**, **11/12**	8/13, 2014, 2015, 2017
Fangjiashan units 1&2	Zhejiang	2x1080	CPR-1000	CNNC	**12/08**, **7/09**	12/13, 10/14
Sanmen units 1&2	Zhejiang	2x1250	AP1000	CNNC	**3/09**, **12/09**	3/14, 8/14 or 9/15
Haiyang units 1&2	Shandong	2x1250	AP1000	CPI	**9/09**, **6/10**	5/14, 3/15
Taishan units 1&2	Guangdong	2x1770	EPR	CGNPC	**10/09**, **4/10**	2014, 2015
Shandong Shidaowan	Shandong	210	**HTR-PM**	Huaneng	**12/12**	2016

CHINA – Mega New Build Market (2)

Plant	Province	MWe gross	Reactor model	Project control	Construction start	Operation
Fangchenggang units 1&2	Guangxi	2x1080	CPR-1000	CGNPC	**7/10**, **2011**	2015, 2016
Fuqing units 3&4	Fujian	2x1080	CPR-1000	CNNC	**7/10**, 2011*	7/15, 5/16
Tianwan units 3&4	Jiangsu	2x1060	VVER-1000	CNNC	**12/12**, 10/13	2017, 2018
Fuqing units 5&6	Fujian	2x1100	ACP1000	CNNC	2014	
Changjiang units 1&2	Hainan	2x650	CNP-600	CNNC & Huaneng	**4/10**, **11/10**	2014, 2015
Hongyanhe units 5&6	Liaoning	2x1080	ACPR1000	CGNPC, with CPI	2013?	2016-
Yangjiang units 5&6	Guangdong	2x1080	CPR1000+	CGNPC	2013*	2017
Fangchenggang units 3-6	Guangxi	4x1080	ACPR1000	CGNPC	late 2014?	

CHINA – Mega New Build Market (3)

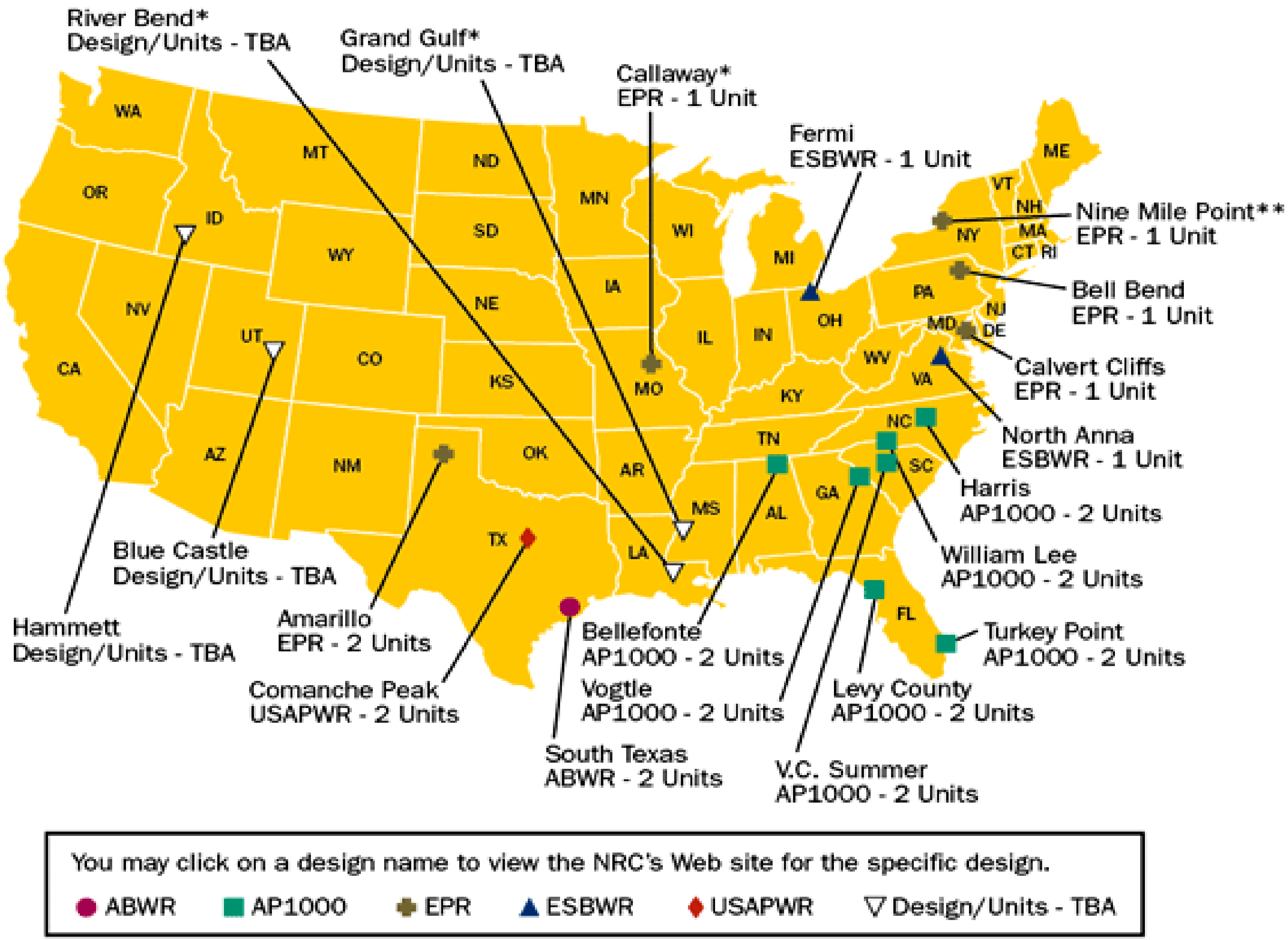
Plant	Province	MWe gross	Reactor model	Project control	Construction start	Operation
Ningde units 5&6	Fujian	2x1080	ACPR1000	CGNPC	?	
Xudabao / Xudapu units 1&2	Liaoning	2x1250	AP1000	CPI, with Datang	delayed	
Sanmen units 3&4	Zhejiang	2x1250	AP1000	CNNC	?	
Haiyang units 3&4	Shandong	2x1250	AP1000	CPI	2010?	
Sanming units 1&2	Fujian	2x880	BN-800	CNNC	2013	2019, 2020
Zhangzhou units 1&2	Fujian	2x100	**ACP100**	CNNC & Guodian	2015	
Tianwan units 5&6	Jiangsu	2x1080	CPR-1000	CNNC	12/12, 8/13	
Lufeng (Shanwei) units 1&2	Guangdong	2x1250	AP1000	CGNPC	2014?	
Shidaowan units 1-2	Shandong	2x 1400	**CAP1400**	Huaneng	4/2014	2018

30 PWRs currently under construction

EMERGING NUCLEAR COUNTRIES
CHALLENGES

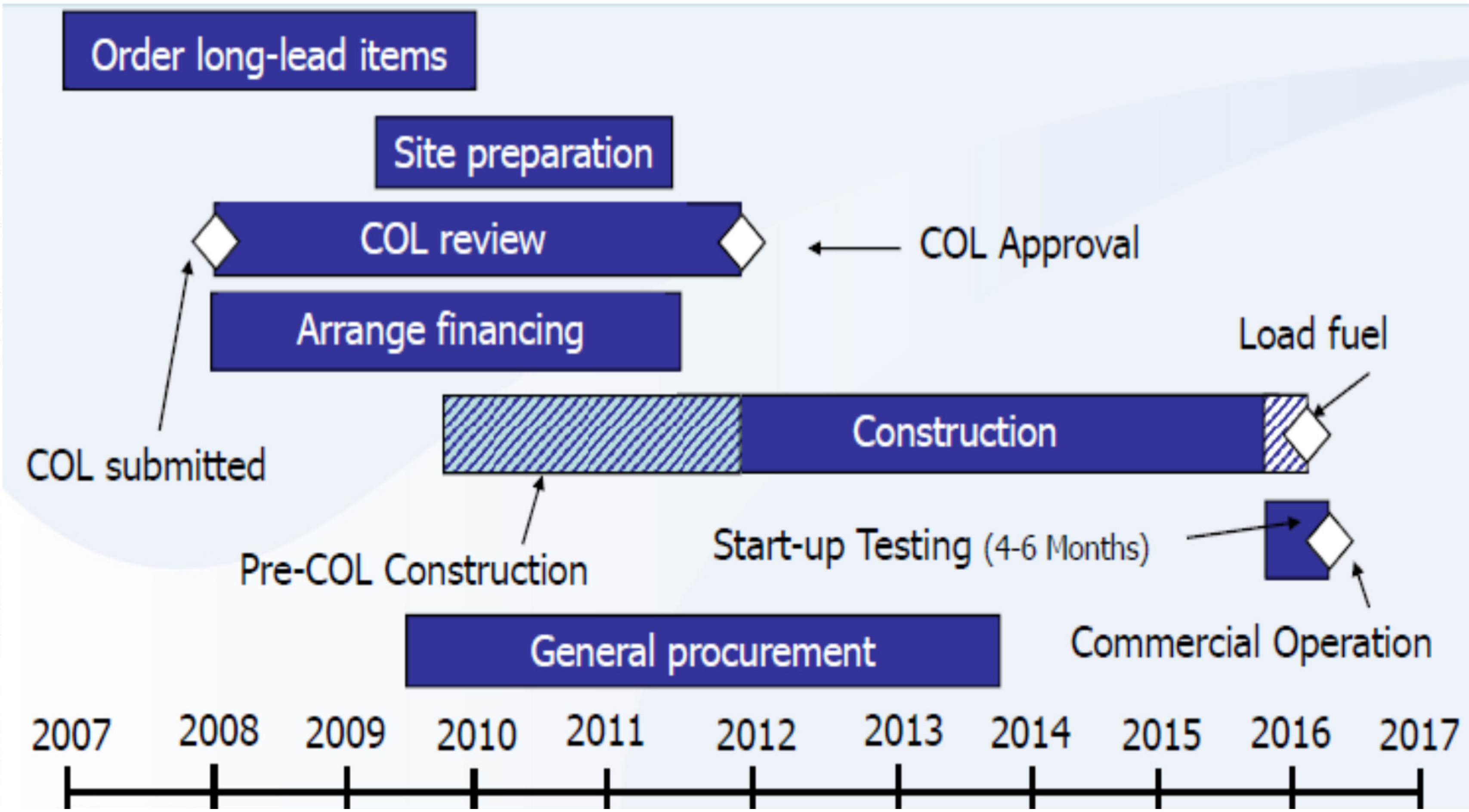
- Most important challenges before a Nuclear New Build project can start:
  - Building a domestic nuclear infra-structure (Regulatory Authority)
  - Building a Legal Framework (Atomic Law, Nuclear Regulations)
  - Signing the required International Agreements
  - Implementing appropriate domestic Nuclear Liability Law
  - Addressing the serious Financing challenges (in today's "climate")
  - Generating international confidence in nuclear non-proliferation/security
  - Political will, public support & acceptance
  - Training & education, capacity building of domestic nuclear work force
- Constructing domestic Storage Facilities (for Nuclear Waste, Used Fuel and Decommissioning Waste)

US New Gen-III/III+ Projects



*Review Suspended
**Review Partially Suspended

Schedule for Gen-III/III+ NPPs in US



U.S. COL Application Status

(Source: NRC March 29, 2013: "Under review" means schedule to be revised or suspended)

Company	Site	NPP-type (#Units)	COL Submittal	NRC COL Status
Constellation-UniStar	Calvert Cliffs-3	EPR (1)	Mar 2008	Under review
Constellation-UniStar	Callaway-2 Bell Bend Nine Mile Point-3	EPR (1) EPR (1) EPR (1)	July 2008 Oct 2008 Sept 2008	Suspended Under review Suspended
Dominion	North Anna-3	ESBWR(1) APWR1700 (1)	Nov 2007 Oct 2010	Resurrected 4/2013 Dropped
Detroit Edison	Fermi-3	ESBWR (1)	Sep 2008	Under review
Duke (incl. former Progress Energy)	Lee-1/2 Harris-2/3 Levy-1/2	AP1000 (2) AP1000 (2) AP1000 (2)	Dec 2007 Feb 2008 July 2008	Under review Under review Under review
Entergy	Grand Gulf-3 River Bend-2	ESBWR (1) ESBWR (1)	Feb 2008 Sep 2008	Suspended Suspended
NRG Energy	South Texas-3/4	ABWR (2)	Sep 2007	Under review
Florida Power &Light	Turkey Point -6/7	AP1000 (2)	June 2009	Under review
SC Electric & Gas	VC Summer-2/3	AP1000 (2)	Mar 2008	Issued
Southern Co	Vogtle-3/4	AP1000 (2)	Mar 2008	Issued
Luminant	Comanche Peak-3/4	APWR1700 (2)	Sep 2008	Under review
TVA	Bellafonte-3/4	AP1000 (2)	Oct 2007	Suspended

US New Build – Challenges

- Nuclear Renaissance in US has stalled:
  - Financial Risks too high to attract Investors in deregulated markets ($8-12B per reactor)
  - Only (2) projects are currently moving forward and have poured “first safety concrete”:
    - **Southern Co / Vogtle-3/4 — 2xAP1000**
    - **SC Electric & Gas / VC Summer-2/3 — 2xAP1000**
  - Cheap/abundant Shale Gas (not Fukushima) has halted the Nuclear Renaissance in USA
  - NRC has stopped issuing new build licenses in August 2012 in absence of an adequate Waste resolution – and plans restart of new build licenses in August 2014, if Waste Issues are adequately resolved.

Worldwide Status of Nuclear New Build

Major SMR Activities

SMR DEFINITIONS

A reactor can be Small or Medium Size and not Modular:

- **Small Size Reactors:** **10 – 300 MW [IAEA, DOE]**
- **Medium Size Reactors:** **300 – 700 MW [IAEA]**
- **Large Size Reactors:** **700 – 1700 MW [IAEA]**

Modular means a multi-modular NPP on a common base mat, with NPP modules added when needed. This is clearly the US market preference today.

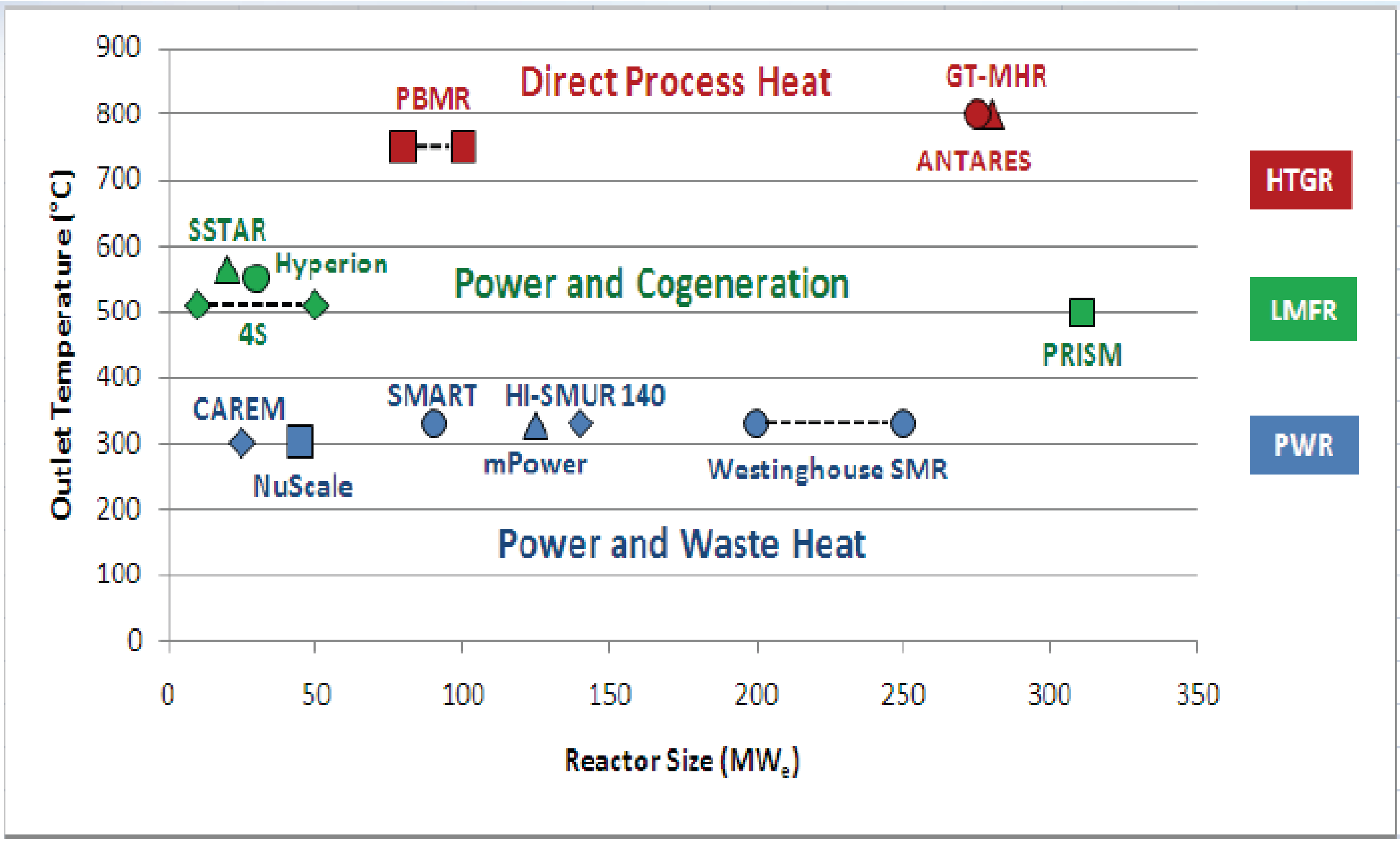
SMR Concepts – next 20 years

Source: WNA - Small Nuclear Power Reactors, June 2012

Name	Capacity	Type	Developer	COD est'd
KLT-40S	35 MWe	PWR	OKBM, Russia	2014
VK-300	300 MWe	BWR	Atomenergoproekt, Russia	open
CAREM	27-100 MWe	PWR	CNEA & INVAP, Argentina	2016
Westinghouse SMR	225 MWe	PWR	Westinghouse, USA - plan 5 SMRs	2021
mPower	125-180 MWe	PWR	Babcock & Wilcox/Bechtel, USA	2022
SMR-160	160 MWe	PWR	Holtec/Shaw, USA	2022
SMART	100 MWe	PWR	KAERI, South Korea	open
NuScale	45 MWe	PWR	NuScale Power/Fluor, USA	2022 Savannah River
ACP100	100 MWe	PWR	CNNC & Guodian, China	2018
RADIX MMR	10 MWe	PWR	Integrated PWR w/TRIGA Fuel	open
HTR-PM	2x105 MWe	HTR	INET & Huaneng, China	2015
EM2	240 MWe	HTR	General Atomics (USA)	~2030
SC-HTGR (Antares)	250 MWe	HTR	Areva (selected for NGNP Project in USA)	open
BREST	300 MWe	FNR	RDIPE, Russia	open
SVBR-100	100 MWe	FNR	AKME-engineering (Rosatom), Russia	open
Gen4 module	25 MWe	FNR	Gen4 (Hyperion until March 2012), USA	2022
Prism	311 MWe	FNR	GE-Hitachi, USA	open
ARC-100	125 MWe	FNR	Advanced Reactor Concepts (EBR-II copy)	open
4S	10-50 MWe	FNR	Toshiba (NRC pre-application review)	open

SMR Power Generation Markets

Source: Shaw Group Presentation



Worldwide Status of Nuclear New Build

Worldwide SMR Activities

SMRs under Construction

Source: WNA – Country Briefing

Russia:

Vilyuchinsk Floating NPP (KLT-40S, 2x40 MW) – Ship *"Academician Lomonosov"*
21,500 tonne hull, 144 m long and 30 m wide
Construction start 05/2009, Commercial Operation 2014 (<u>delay due to insolvency</u>)
2 x PWR (<20% U235) based on Icebreaker reactor design

SMRs under Construction (2)

Source: WNA – Country Briefing

SMRs under Construction (3)

Source: WNA – Country Briefing

Argentina:

Prototype CAREM *(Central Argentina Modular Elements Reactor)*
(simplified modular natural circulation PWR, integral Steam Generators, using standard 3.4% U235 PWR fuel, 27 MWe. Can be scaled to 150 MWe)
Construction start 2010, Commercial Operation – 2016 (beyond that no plans)

SMRs under Construction (4)

Source: WNA – Country Briefing

China:

Demonstration HTR-PM: (Shidaowan-1/2), using Pebble-Bed concept
2x105 MWe reactor units driving a single 210 MWe Turbine
EPC contract placed 10/2008, site work completed
Construction start – end of 2010. Startup planned 2015 (uncertainty beyond).

ACP100: Small Modular Integral PWR (shipped as one single Reactor Unit)
CNNC & Guodian is building (2) Demo Units at Zhangzhou - COD 2018
Cost of these first (2) Units is ~$800 Million
Construction start 2015, and 36-40 months needed to COD
57 PWR fuel assemblies, 7ft active length, integral Steam Generators
Integral PWR/passive design placed underground. Up to 8 Modular Units / Site.
60 years design life, 24 months refueling.

South Korea:

Prototype SMART: (System-integrated Modular Advanced Reactor)
65 MWth Prototype design completed (no construction)
Commercial SMART-100 has 330 MWth
SMART-100 FOAK SMR startup expected earliest by 2018+ (no customer yet)
Overnight construction cost target ~$5,800/kWe (equal to Gen-III/III+ NPPs)

US New Build Program Status

Near Commercial SMR Technologies

- B&W mPower (LOI)
- W SMR (LOI)
- Holtec SMR-160
- NuScale

DOE Next Generation Nuclear Plant

Near term SMR Concepts

- It seems that following US SMR designs have a chance to startup an SMR within 10 years (<u>COD 2022</u>):

mPower: 180 MWe, LOI for (2-6) SMRs / Clinch River. B&W has large experience from PWRs and “naval” SMRs. COD expected 2022.

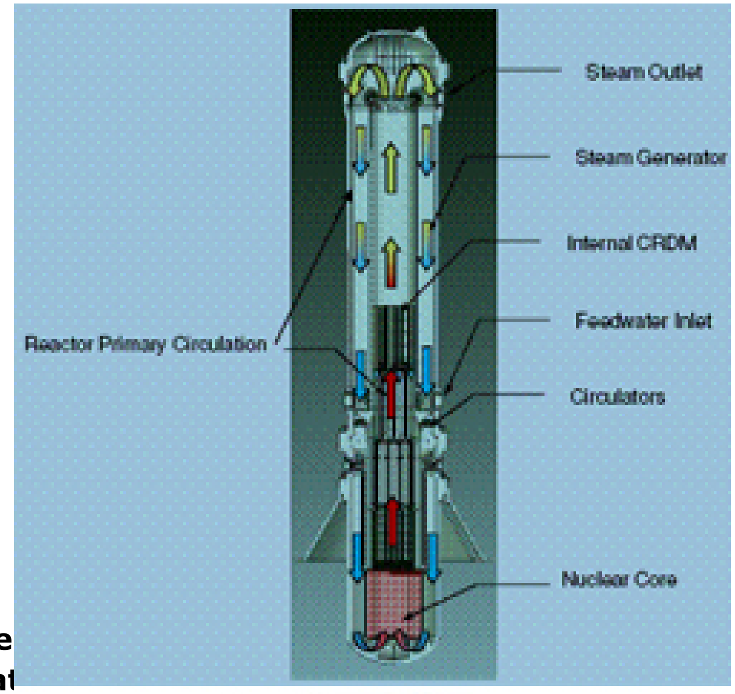
<u>W</u> SMR: 225 MWe, NextStart Alliance plans (5) SMRs at Callaway. Westinghouse has large experience in PWRs & “naval” SMRs. Planned startup is 2021 (<u>1st SMR in USA</u>)

SMR-160: 160 MWe, DOE Agreement to build (1) SMR at Savannah River. Holtec/Shaw have no commercial PWR vendor behind, and have never built a PWR or SMR.

NuScale: 45 MWe, DOE Agreement to build (1) SMR at Savannah River. NuScale/Fluor have no commercial PWR Vendor behind, and never built a PWR or SMR. Largest Scale Factor cost penalty.

B&W - mPower

Designer:	**Babcock & Wilcox Company (B&W)**
Electrical Output:	**180 MWe**
Outlet Conditions:	**327° C**
Coolant:	**Light water**
Fuel Design:	***Proprietary***
Refueling:	***Proprietary***
Letter of Intent:	**April 28, 2009**
Licensing Plan:	**Design Certification**
Expected Submittal:	**Q4 CY 2012**
Design Information:	**LWR with the reactor and steam gene located in a single reactor vessel locat underground containment.**
Status/Other Info:	**Pre-Application stage for Design Contr Document (DCD)**
Website:	**http://www.babcock.com/products/modular_nuclear/**



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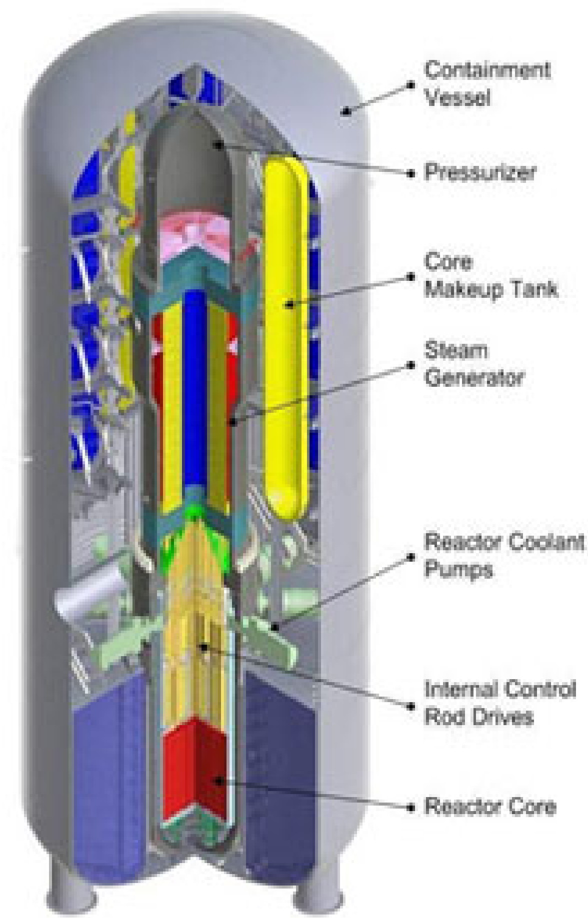
Westinghouse - SMR

Designer:	**Westinghouse**
Reactor Power:	**800 MWt**
Electrical Output:	**>225 MWe**
Coolant:	**Light-water**
Fuel Design:	**17x17 Fuel Assembly, < 5 wt% Enrichment**
Refueling:	**2 years**
Letter of Intent:	**Response to RIS 2011-02 Rev.1**
Licensing Plan:	**Design Certification**
Planned Submittal:	**September 2013**
Design Information:	**Modular design, integral pressurized water reactor with passive safety features and underground containment.**
Status/Other Info:	**Pre-application activities**
Website:	**http://www.westinghousenuclear.com/smr/index.htm**



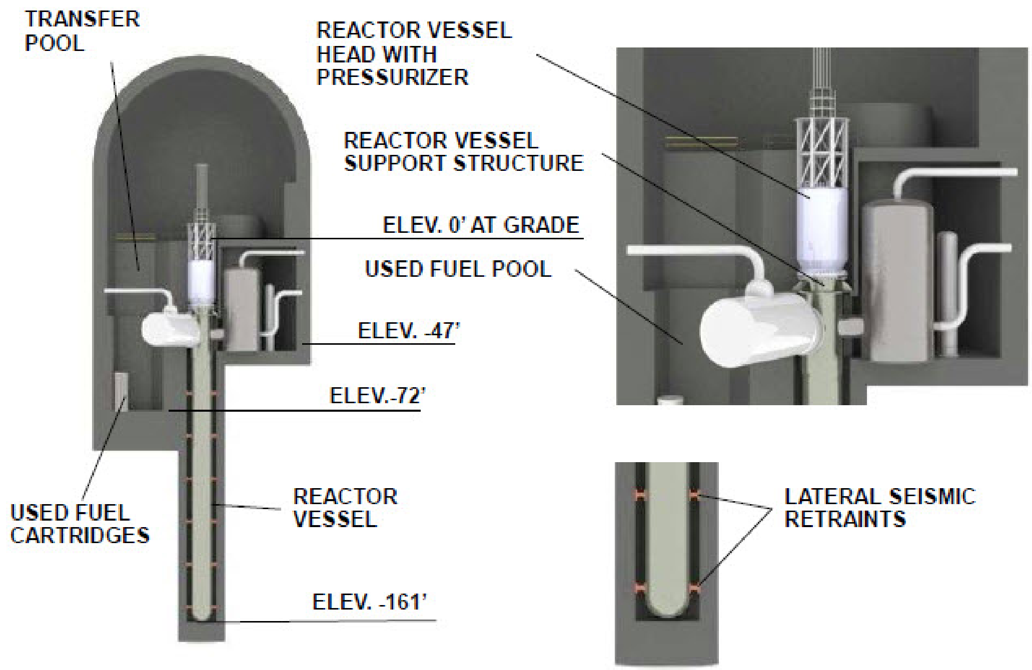
Holtec SMR-160

HI-SMUR Design Overview
HI-SMUR stands for Holtec Inherently Safe Modular Underground Reactor
Performance 469 MW Thermal
145 MW Electrical

Primary Loop Natural Convection
2250 psi
RV: 120' high, 8' ID, 9' OD

Core Design 37 assemblies
Standard 17x17 design,
< 5 wt% Enrichment
No soluble boron

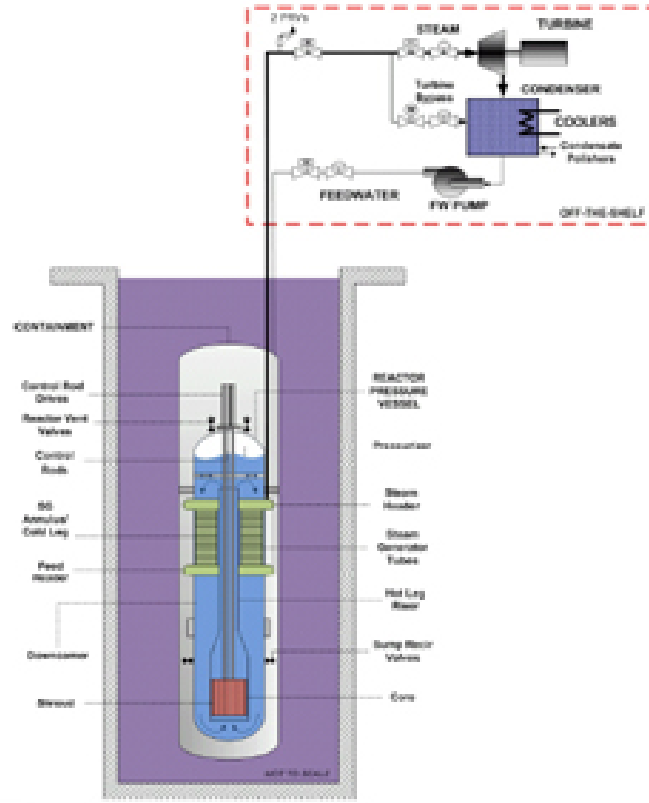
SGs Horizontal, integrally connected to RV
Two stages with superheaters



A new version was introduced at 160 MWe on July 23, 2012

NuScale

Designer:	**NuScale Power, Inc.**
Reactor Power:	**150 MWt**
Electrical Output:	**45 MWe**
Outlet Conditions:	**1500 psig, 575° F**
Coolant:	**Light Water**
Fuel Design:	**17 x 17 fuel bundles, 6', 4.95% enrichment**
Refueling:	**24 months**
Letter of Intent:	**January, 2008**
Licensing Plan:	**Design Certification**
Expected Submittal:	**Q2 FY 2012**
Design Information:	**Natural circulation light water reactor with the reactor core and helical coil steam generators located in a common reactor vessel. The reactor vessel is submerged in a pool of water.**
Status/Other Info:	**Pre-Application stage for Design Contrc Document (DCD). Based on MASLWR (Multi-Application Small Light Water Reactor) developed at Oregon State University in the early 2000s.**
Website:	**http://www.nuscalepower.com/**



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Fast Growing Interest in US in SMRs

There are several trends in Nuclear New Build market favoring smaller modularized NPP types:

- SMR has become accepted by public opinion (climate change)
- New large NPPs have become expensive ($8-$12B per reactor)
- Financing new NPPs has become difficult and LGs are needed (Utility Market Cap is too small compared to NPP investment risk)
- Large reactor size (1,700 MW) adds more capacity than often needed at a time (additional financial risk)
- Financial risks of cost/schedule overrun on large NPP projects
- SMRs can offer a “way out” for utilities to avoid above challenges

Fast Growing Interest in US in SMRs (2)

- U.S. Utility interest is growing rapidly in “small / modular” reactors that cost ~5 to 10x less, and can be put in operation in ~¼ to ½ of the time needed for a large reactor
- A utility could expand their production capacity in smaller more manageable increments, while receiving cash flow from reactor modules coming on-line
- Replication (factory ‘assembly line’) could bring costs down dramatically, while raising NPP quality significantly

Fast Growing Interest in U.S. in SMRs (3)

- Re-powering aging fossil sites (reusing assets such as environmental permits, transmission and water availability)
- SMR size fits easy with grid reliability requirements
- Re-establishing U.S. manufacturing base for nuclear components

Fast Growing Interest in US in SMRs (4)

Source: TVA Presentation Nov 2010

Construction Period Finance Drivers

	Large Unit (1100-1200 MW)	SMR (250 -280 MW)
Total escalated cost per unit	$5-7 Billion	$1.4 - 1.8 Billion
Construction duration First concrete to fuel load	46 mo.	30 mo.
Site preparation work	18-24 mo.	12-18 Mo.
Percent of EPC Contract Price Fixed	40-60%	60-80%

Less strain on balance sheet

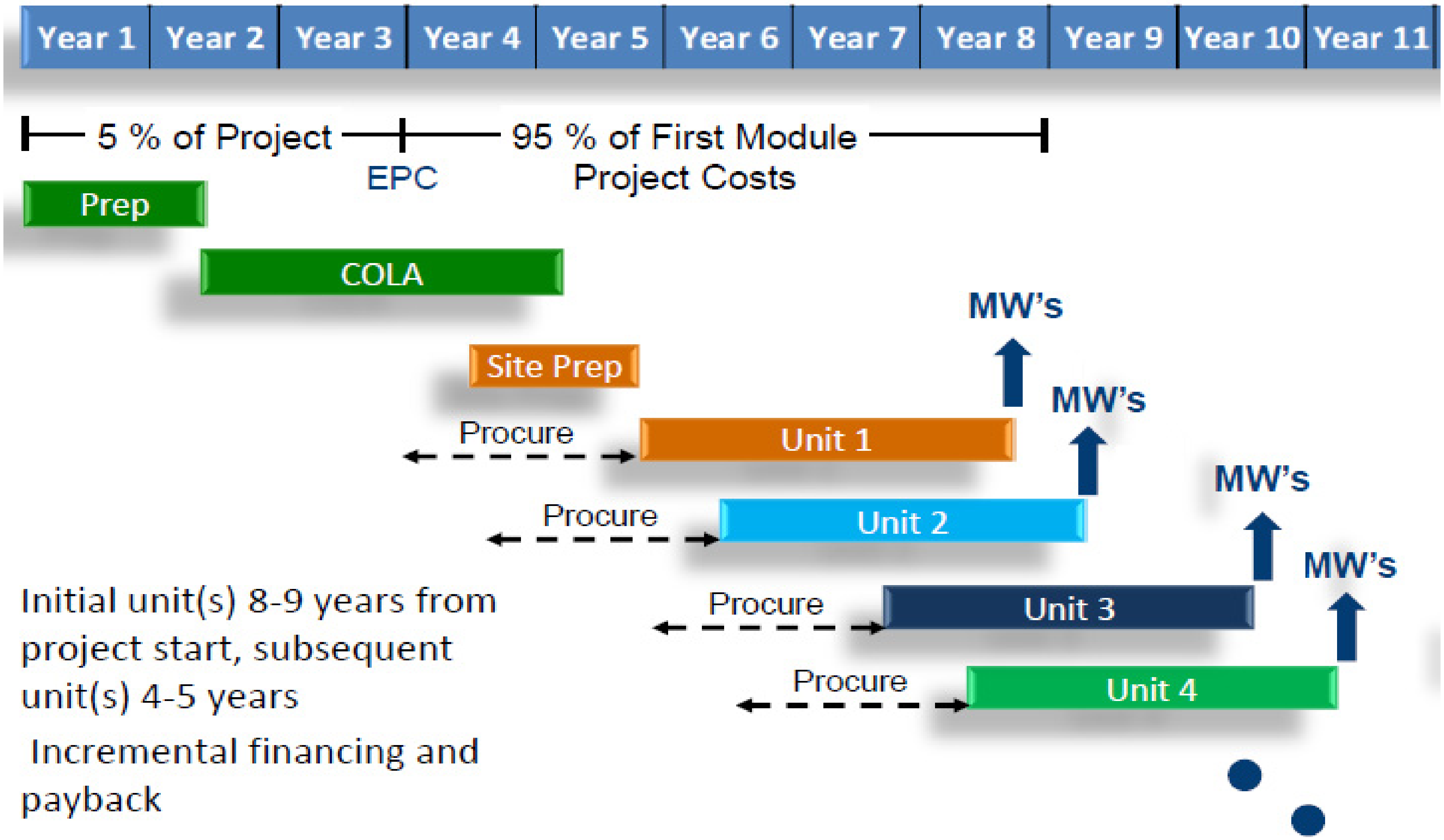
Quicker completion Less interest cost

Less risk

Lower cost of capital

Fast Growing Interest in US in SMRs (5)

Source: TVA Presentation Nov 2010

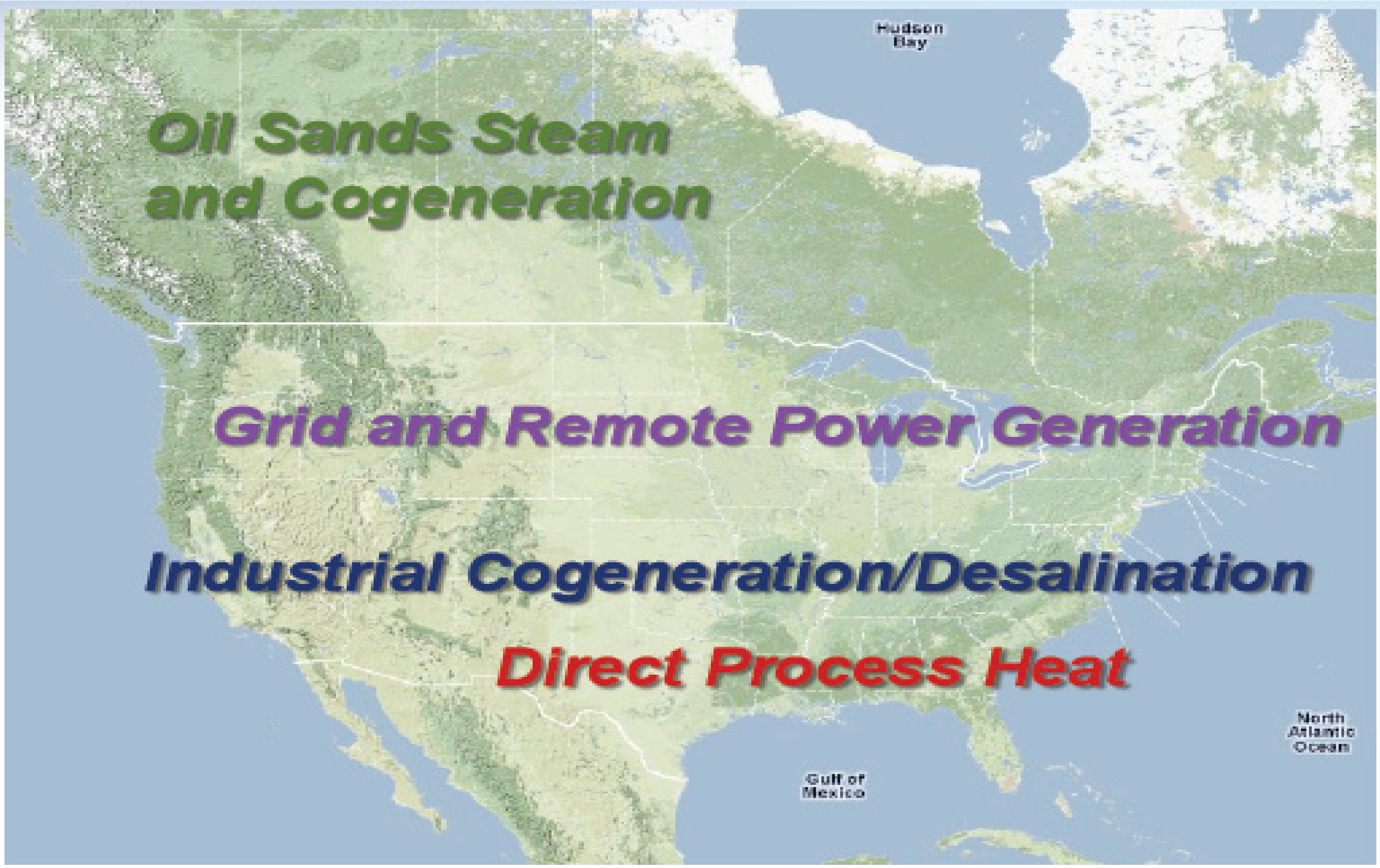


Initial unit(s) 8-9 years from project start, subsequent unit(s) 4-5 years

Incremental financing and payback

SMR Potential Markets in North America

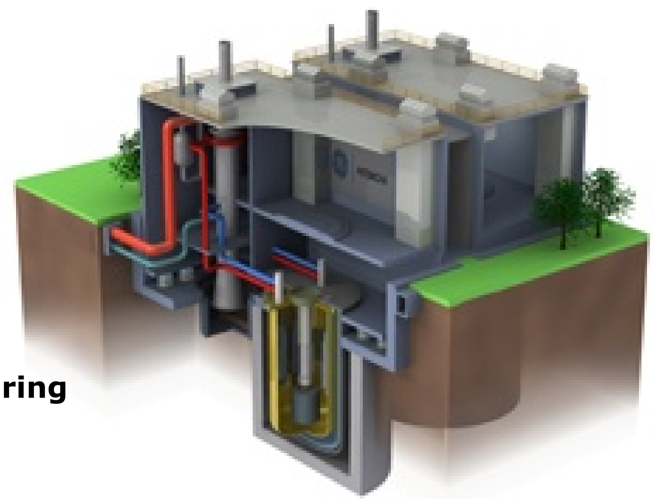
Source: Shaw Group Presentation



NRC is looking at these SMRs

- Light Water Reactor – '*familiar technology*'
  - mPower 180MW B&W
  - W SMR 225 MWe Westinghouse
  - NuScale 45 MW NuScale Power
  - HI-SMR 160 MW Pre-Application discussions
- Sodium Fast Reactor – '*less familiar*'
  - PRISM 311 MW GE-Hitachi
  - 4S 10 MW Toshiba
- Lead-Bismuth coolant – '*exotic technology*'
  - Gen4 (Hyperion) 25 MW now Gen4 Energy company
- Gas cooled reactor – '*prototype technology*'
  - PBMR 165 MW PBMR Ltd

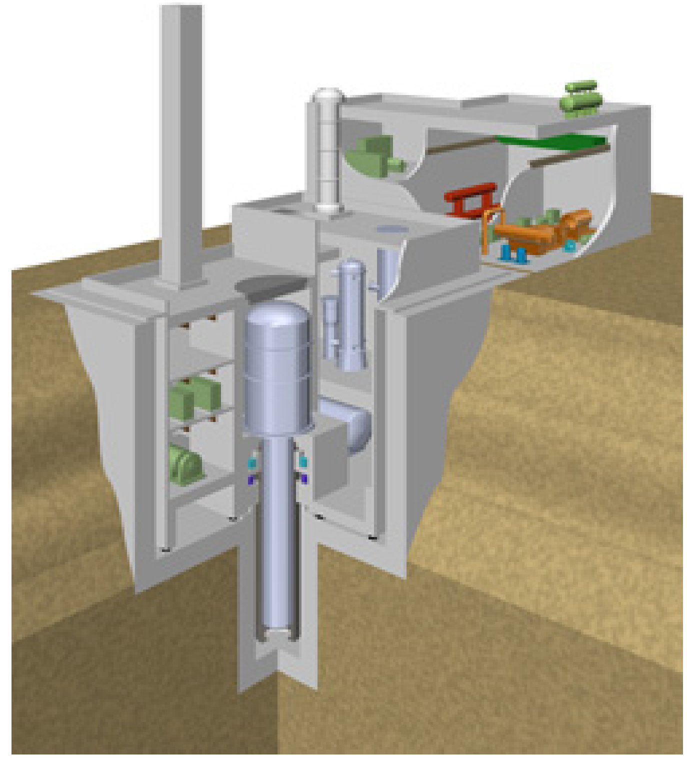
GE-Hitachi - PRISM



Designer:	**GE Hitachi Nuclear Energy (GE-H)**
Reactor Power:	**840 MWt**
Electrical Output:	**311 MWe**
Outlet Conditions:	**930° F**
Coolant:	**Liquid metal (sodium)**
Fuel Design:	**Metallic**
Refueling:	**12-24 months**
Letter of Intent:	**Updated March 15, 2010**
Licensing Plan:	**COL Prototype (long-term - Manufacturing License)**
Expected Submittal:	**First quarter 2012**
Design Information:	**Underground containment on seismic isolators with a passive air cooling ultimate heat sink. Modular design with two reactor modules per power unit (turbine generator).**
Status/Other Info:	**NRC staff conducted pre-application review in early 1990s that resulted in the publication of NUREG-1368, "Preapplication Safety Evaluation Report for the Power Reactor Innovative Small Module (PRISM) Liquid-Metal Reactor (January 1994)."**

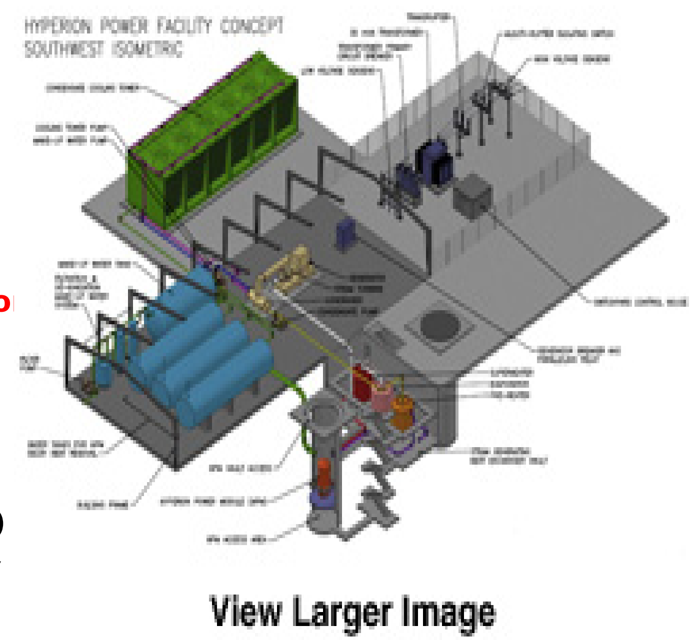
Toshiba – 4S

Designer:	**Toshiba Corporation**
Reactor Power:	**30 MWt**
Electrical Output:	**10 MWe**
Outlet Conditions:	**510° C**
Coolant:	**Liquid-metal (sodium)**
Fuel Design:	**18 hexagonal fuel assemblies - U-10%Zr Alloy with 19.9% enrichment**
Refueling:	**30 years**
Letter of Intent:	**Updated March 23, 2010**
Licensing Plan:	**Design Approval**
Expected Submittal:	**Second quarter 2012**
Design Information:	**Small, sodium-cooled, underground reactor**
Status/Other Info:	**Working with the city of Galena, AK as a potential COL partner.**



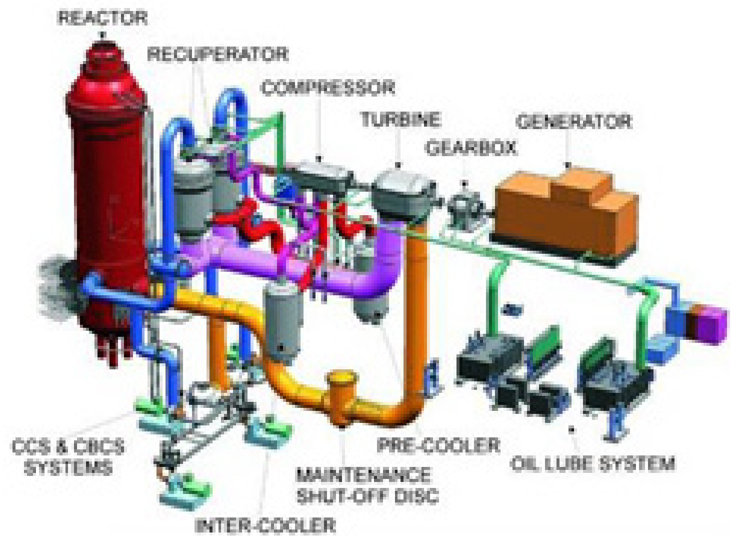
Gen4 – former Hyperion

Designer:	**Gen4 Energy, Inc.**
Output:	**25 MWe**
Outlet Temp	**500C**
Coolant:	**Lead-bismuth eutectic, primary secondary loops**
Fuel Design:	**Stainless steel clad uranium nitride**
Refueling:	**Entire reactor module replaced every 7 to 10 years**
Licensing Plan:	**Combined License (prototypical design) and/o Design Certification**
Design Information:	**The HPM is sealed at the factory, sited underground, and eventually returned to the factory for waste and fuel disposition after a useful life of seven to ten years. The principle materials in the core are uranium nitride (UN) fuel, stainless steel as the structural material, lead-bismuth eutectic (LBE) as the coolant, quartz as the radial reflector, B4C rods and pellets for in-core reactivity control and shutdown. The LBE permits ambient pressure operation of core, eliminating pressure vessel requirements.**
Status/Other Info:	**The outer diameter of the entire reactor system, including the outer reflector and coolant downcomer, is limited to 1.5 m to be able to seal the reactor vessel system at the fabrication facility and transport it to the site in a conventional nuclear fuel shipping cask. The total mass of the reactor vessel with fuel and coolant is <20 metric tons.**
Website:	**http://www.hyperionpowergeneration.com/**



PBMR Ltd – PBMR module

Designer:	**PBMR (Pty.), Ltd.**
Reactor Power:	**400 MWt**
Electrical Output:	**165 MWe**
Outlet Conditions:	**Up to 900° C (1652° F)**
Coolant:	**Helium**
Fuel Design:	**~450,000 low-enriched UO_2 TRISO particles in pebbles**
Refueling:	**Online**
Letter of Intent:	**Updated March 24, 2009**
Licensing Plan:	**Design Certification**
Expected Submittal:	**FY2013**
Design Information:	**Modular, gas-cooled, pebble bed reactor with online refueling that generates electricity via a gas or steam turbine and which may also be used for process heat applications.**
Status/Other Info:	**Licensing of a demonstration plant in South Africa is being reconsidered. Agreement with Chinese for cooperation in development.**
Website:	**http://www.pbmr.co.za/**



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NRC is not yet looking at

- Light Water Reactor – ‘*familiar technology*’
  - RADIX (10 MW) — Very Small (integral PWR/TRIGA Fuel)
- Sodium Fast Reactor – ‘*less familiar technology*’
  - ARC-100 (125 MW) — Based on EBR-II experience
    20 years fuel cycle, metal fuel
- Gas cooled reactor – ‘*prototype technology*’
  - EM2 (240 MW) — General Atomic He-cooled Fast Reactor. 12 years, $1.7 B needed for development. 30 yrs fuel cycle, runs on LWR spent fuel.

MAJOR CHALLENGES FOR US SMRs

- US-based SMRs have a long road ahead:
  - Licensing takes equal or longer than current LWRs (4-5 years)
  - **Licensing costs equal or more than current LWRs**
  - NRC resource limits review to 5-6 SMR designs next ten years
  - SMR licensing costs are minimum ~$150+ Million for 1st SMR design (and another ~$40-50M for each new SMR site license)
- Construction of 1st SMR takes 4-5 years
- Means 1st US SMR COD is earliest 2022 time frame (except for some SMRs on DOE/Savannah site)
- The fastest way to obtain an SMR Design Certification is to build/license a Pilot Plant (e.g., Savannah River, Clinch River, Callaway).

MAJOR CHALLENGES FOR US SMRs (2)

- NRC Resources to handle many different SMR designs
- Licensing schedule (~42 months for advanced LWRs)
- SMR Prototype testing requirements
- New NUREGs for SMRs
- Emergency Planning
- Staffing / manpower rules for SMRs
- Security & Non-proliferation (thousands of SMR sites)
- Nuclear Waste (non-standard fuel, many types)
- Multi-module licensing issues (e.g., aircraft protection)
- Manufacturing License (new)
- Insurance (Price Anderson)
- Financial Qualifications rules
- NRC Fee rule

MAJOR CHALLENGES FOR SMRs

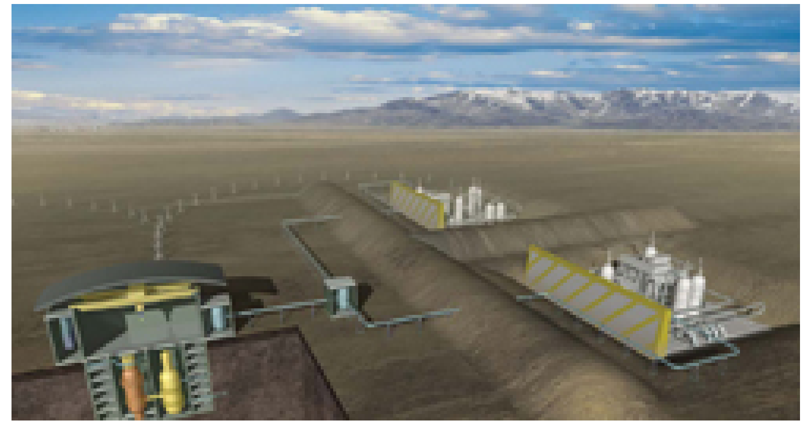
International

- Nuclear Rules and Regulations
  - internationally accepted SMR regulations needed (e.g., like FAA)
  - impractical to have individual SMR regulations in each country
  - current Part 810 puts US SMR Vendors at disadvantage overseas
- Nuclear Non-proliferation, Safeguards & Logistics
  - monitoring many (hundreds / thousands) of SMR Sites worldwide
  - many potentially “less stable countries” are SMR Prime Customers
- Nuclear Waste
  - Logistics with large number of new sites worldwide
  - Transports from large number of new sites worldwide
  - US does not allow take back of foreign SMR “Used Fuel”
  - Handling of “exotic” SMR Used Fuel
- Public Acceptance
  - What about <u>large</u> number of SMR sites in a country (‘NIMBY’)?

DOE Support of SMR Validation

- Savannah River (DOE Site) Agreements:
  - Hyperion (now Gen4 Energy) to build a pilot plant of their 25MW design (Fast Reactor using Uranium Nitride fuel and Lead-Bismuth Eutectic Coolant)
  - Holtec/Shaw to build a SMR-160 pilot plant (PWR)
  - NuScale / Fluor to build a NuScale pilot plant (PWR)
  - DOE/Savannah River is discussing with several other SMR vendors to build other SMR prototypes (Budget permitting)

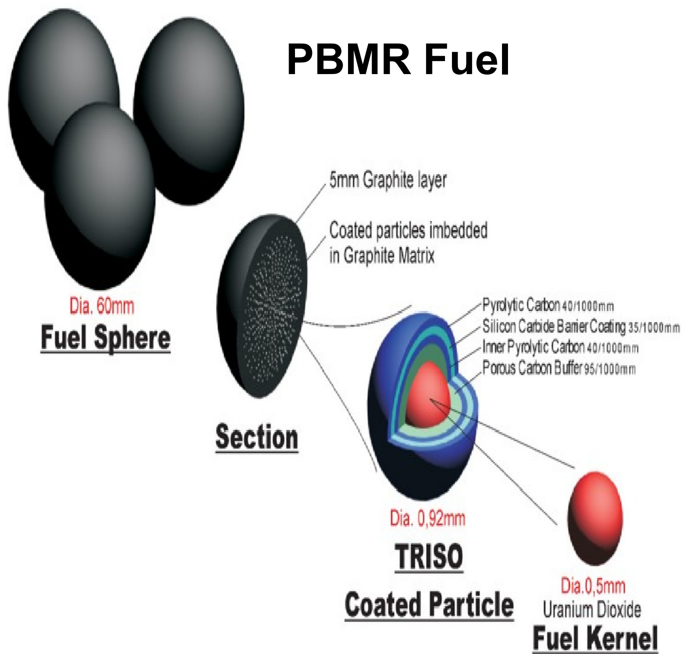
DOE Next Generation Nuclear Plant



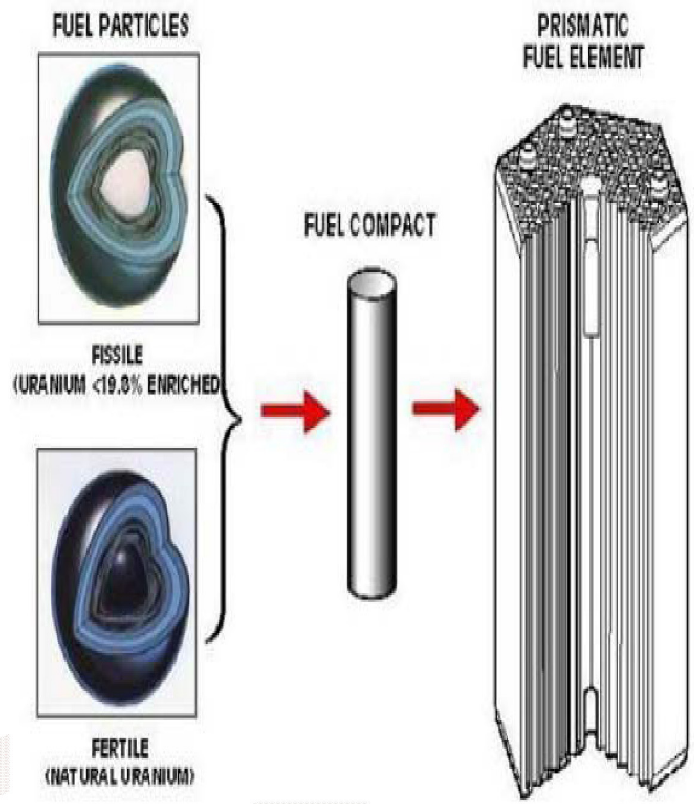
Sponsor:	**Department of Energy**
Designer:	**To be determined (TBD)**
Reactor Power:	**TBD**
Electrical Output:	**TBD**
Outlet Conditions:	**>750 C**
Coolant:	**Gas-cooled**
Fuel Design:	**Prismatic or Pebble Bed**
Refueling:	**TBD**
Letter of Intent:	**See NGNP Licensing Strategy Report to Congress (August 2008)**
Licensing Plan:	**Combined License**
Expected Submittal:	**FY 2013**
Design Information:	**DOE is currently selecting which reactor design will be used for the NGNP. NGNP is part of the Generation IV program.**
Status/Other Info:	**Required by Energy Policy Act of 2005. The staff has been working with DOE on the licensing strategy for the plant and provided the NGNP Licensing Strategy Report to Congress in August 2008.**
Website:	**http://www.ne.doe.gov/neri/neneriresearch.html**

DOE Next Generation Nuclear Plant (2)

PBMR Fuel



Prismatic Fuel – e.g., AREVA ANTARES, GA HTGR



SMR INSIGHTS - SUMMARY

- In the 1950's and 60's there existed a great number of more or less exotic/innovative reactor designs – all were Small or Medium size prototypes, which eventually developed/consolidated into the three (BWR, PWR, HWR) large size commercial NPP designs
- Today a 'second wave' of many different/familiar, innovative and/or exotic SMR designs are arriving – many created by enthusiastic newcomers and focusing on the multi-modular NPP concept
- High entry barriers and harsh market forces (design, methods, verification, licensing, new infrastructure costs, etc) will again force consolidation, and only very few SMR designs based on familiar technologies can become commercially viable in the near term
- SMR standardization, replication, factory-based fabrication and multi-modular NPP design - and alliances with large existing/credible NPP Vendors and Supply chains will be key success factors for SMRs

"Food for Thought – Economy Kills"

Kewaunee Shutdown – Economic Observations

- Plant type: 556 MW PWR [fully depreciated]
- Construction: $776 million (2007 dollars)
- Startup: 6/16/1974
- Licensed to: 12/21/2033 [without new investment]
- Shutdown: 5/7/2013 [because of Economics]
- Reason: Only Fuel and O&M Costs,
  but cannot compete with Shale Gas
  (no Buyer for Plant nor its electricity)

IS THERE A LESSON TO BE LEARNED?

A fully depreciated 556 MW NPP (2 x times SMR size) cannot compete with Shale Gas produced electricity!

QUESTIONS ?

Thank You!

EXCEL

SERVICES CORPORATION

Nuclear Engineering Consulting

Contact Information

EXCEL
SERVICES CORPORATION
Nuclear Engineering Consulting

Donald R. Hoffman
11921 Rockville Pike, Suite 100
Rockville, Maryland 20852 USA

+1 301 984 4400

donald.hoffman@excelservices.com

www.excelservices.com