

CPR1000 Design, Safety Performance and Operability

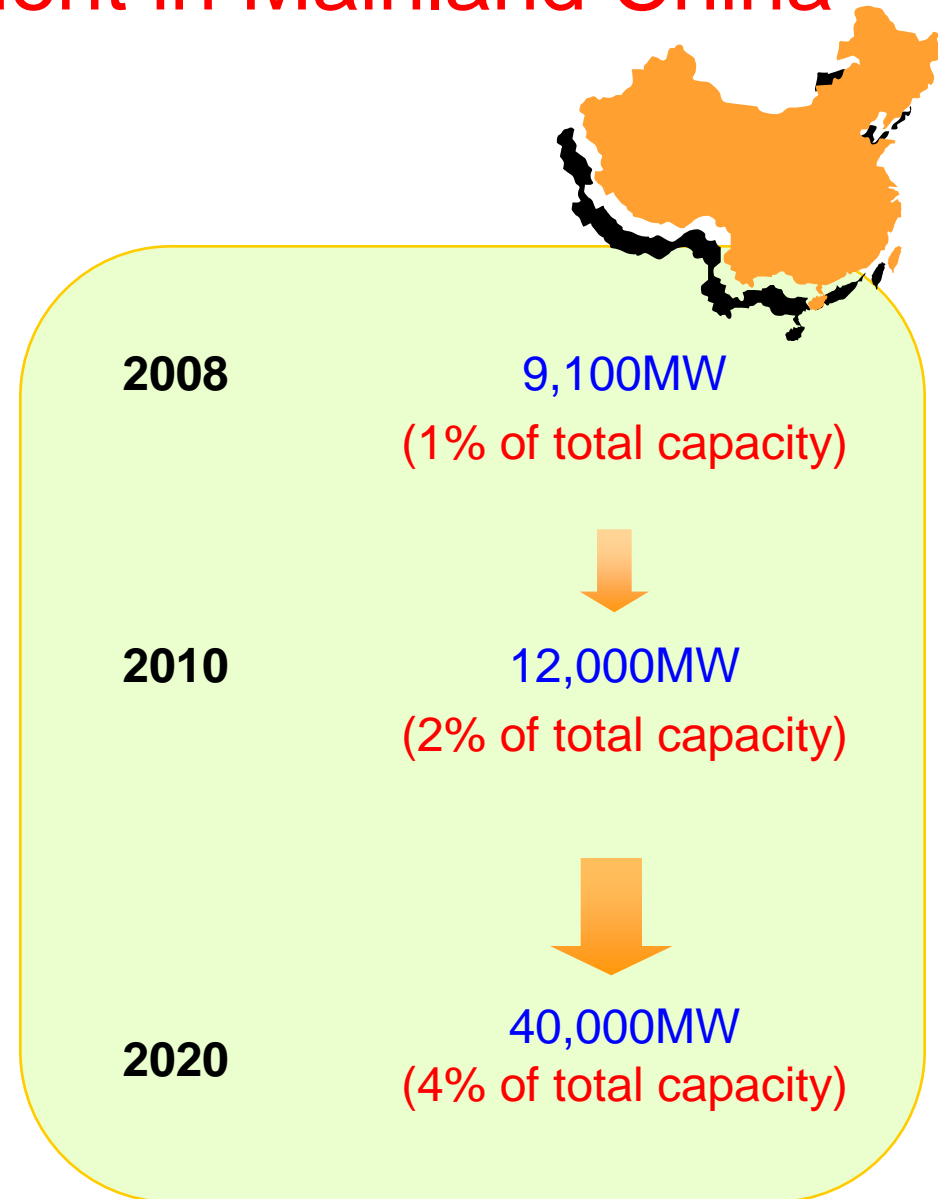
5 July 2011

Contents

1. Nuclear Power Development in China
2. *CPR 1000* Design Features
3. Safety Performance & Operability

Nuclear power development in Mainland China

- First civil nuclear reactor, Qinshan, commissioned in Feb 1994
- First commercial scale nuclear power station, Daya Bay, commissioned in May 1994
- By 2020, target installed capacity in China is 40 GW
- Chinese Government officials recently indicated a higher national target of 60~70 GW (5% of total installed capacity)



Operating Nuclear Units in China

<u>Owner</u>	<u>NPP</u>	<u>Gross Power</u> (MWe)	<u>Total</u> (MWe)	<u>Reactor Type</u>
CGNPC	Daya Bay	2x984	6,108	PWR(M310)
	Lingao I	2x990		PWR(M310)
	Lingao II	2x1080		PWR(CPR1000)
CNNC	Qinshan I	300	5,670	PWR
	Qinshan II	3x650		PWR
	Qinshan III	2x700		PHWR
	Tianwan	2x1060		VVER
CPIC	NIL			
Mainland Total			11,778 MWe	

CGNPC – China Guangdong Nuclear Power Co.

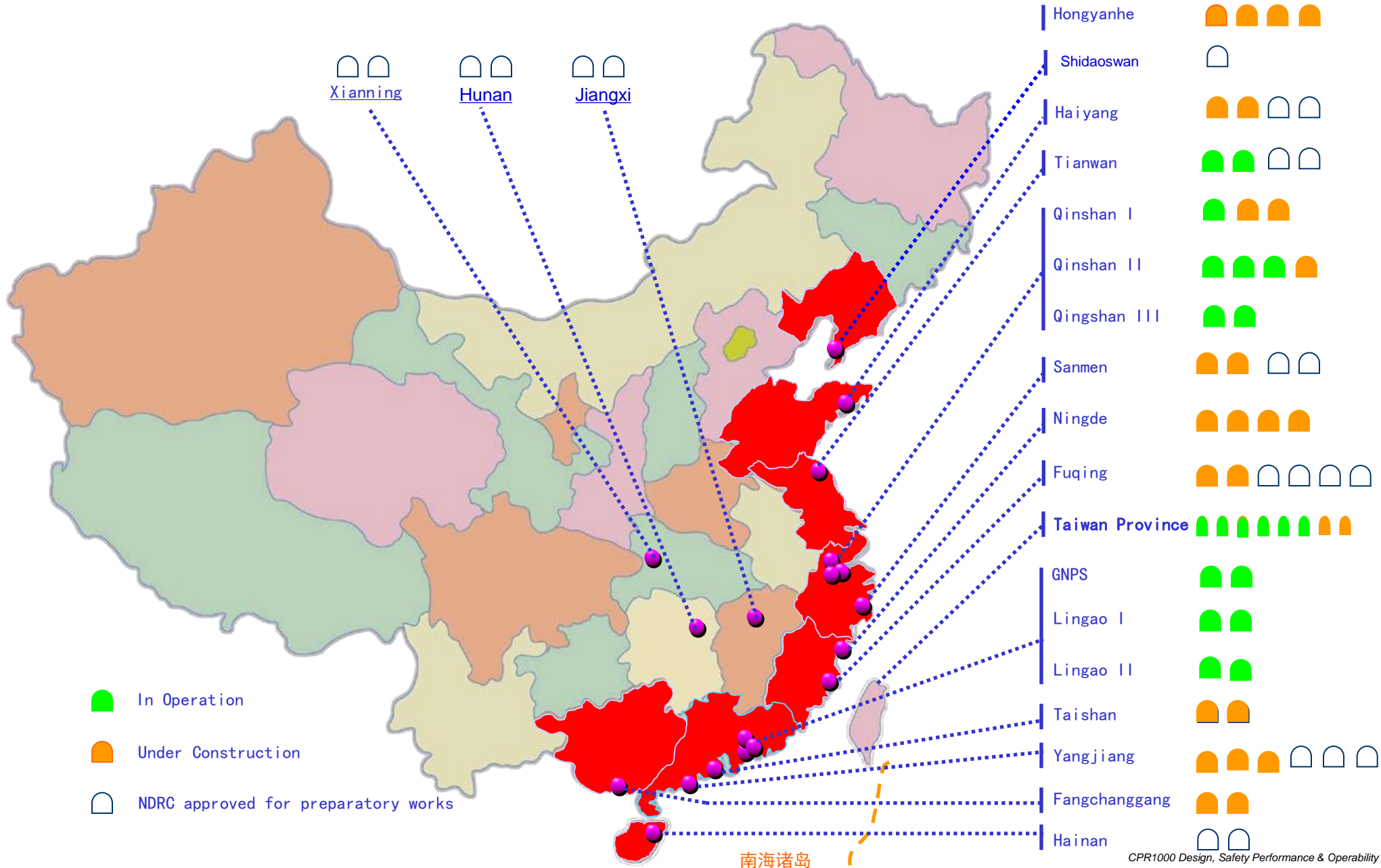
CNNC – China National Nuclear Co.

CPIC – China Power International Co.

China Nuclear Projects Under Construction / Preparation

<u>Owner</u>	<u>Name of NPP</u>	<u>Gross Power (MWe)</u>	<u>Total (MWe)</u>	<u>Reactor Type</u>
CGNPC	Hongyanhe	4×1080	29,760	CPR1000
	Ningde	4×1080		CPR1000
	Yangjiang	$(3+3) \times 1080$		CPR1000
	Taishan	2×1750		EPR
	Fangchanggang (Hongsha)	2×1080		CPR1000
	Lufeng	6×1080		CPR1000
	Xianning (Dafan)	2×1250		AP1000
CNNC	Qinshan II	1×650	20,250	PWR
	Qinshan I Ext (fangjiashan)	2×1080		PWR
	Sanmen	4×1250		AP1000
	Fuqing	6×1080		PWR
	Tianwan II	2×1080		PWR
	Hunan	2×1250		AP1000
	Hainan	2×650		PWR
CPI	Jiangxi	2×1250	7500	AP1000
	Haiyang	4×1250		AP1000
Total	Shidaowan Pebble bed 200MW		60,210 MWe	

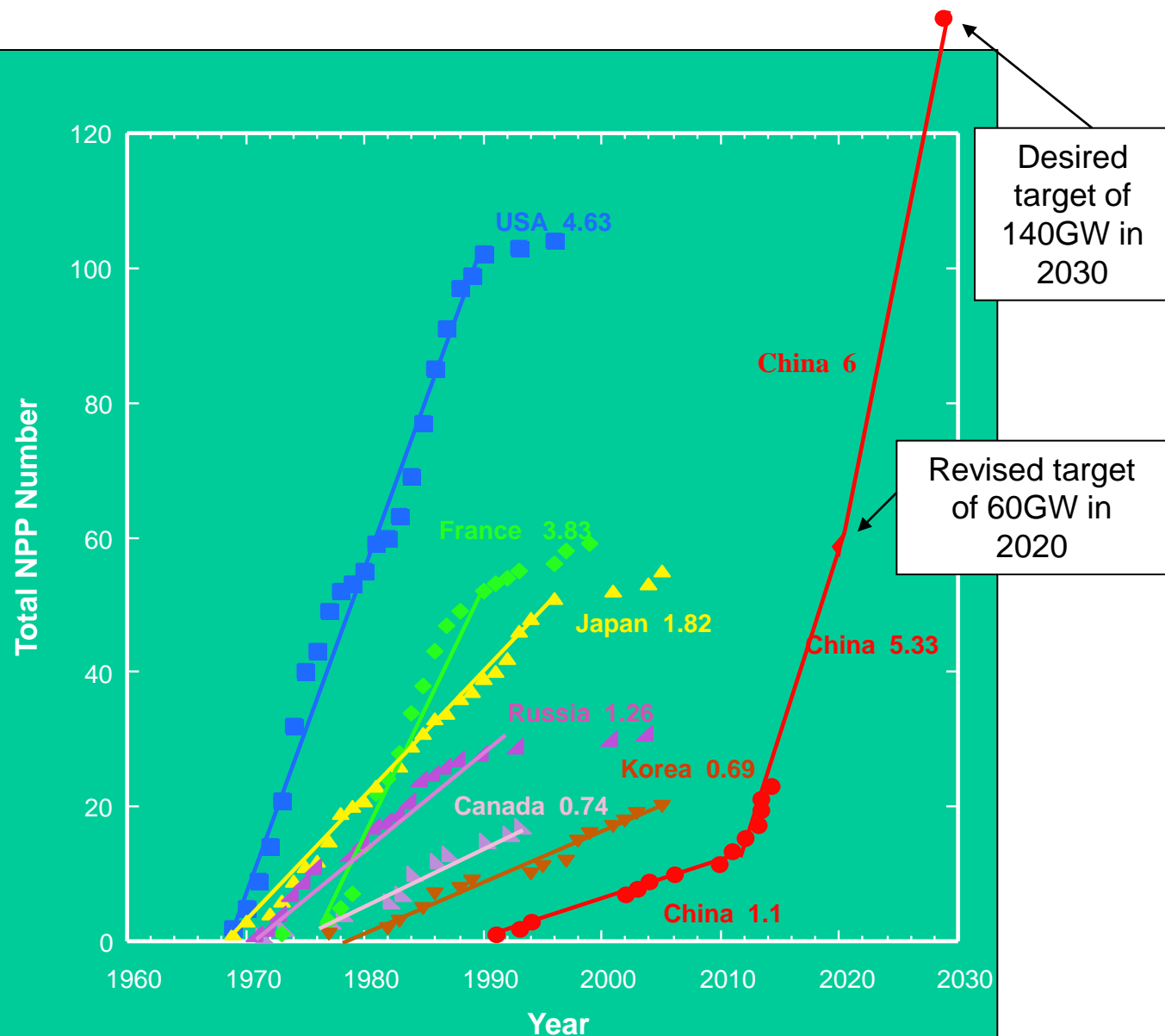
Geographical Locations of China NPP



Projected Rate of NPP Construction in China

If the objective of China is to build about 200 more plants to achieve its presently stated goal to be about 25% nuclear, then at the presently desired rate of 5.5GW per year it would take 29 more years.

(Data for graph from Nuclear News, March 2001 and NEI website).



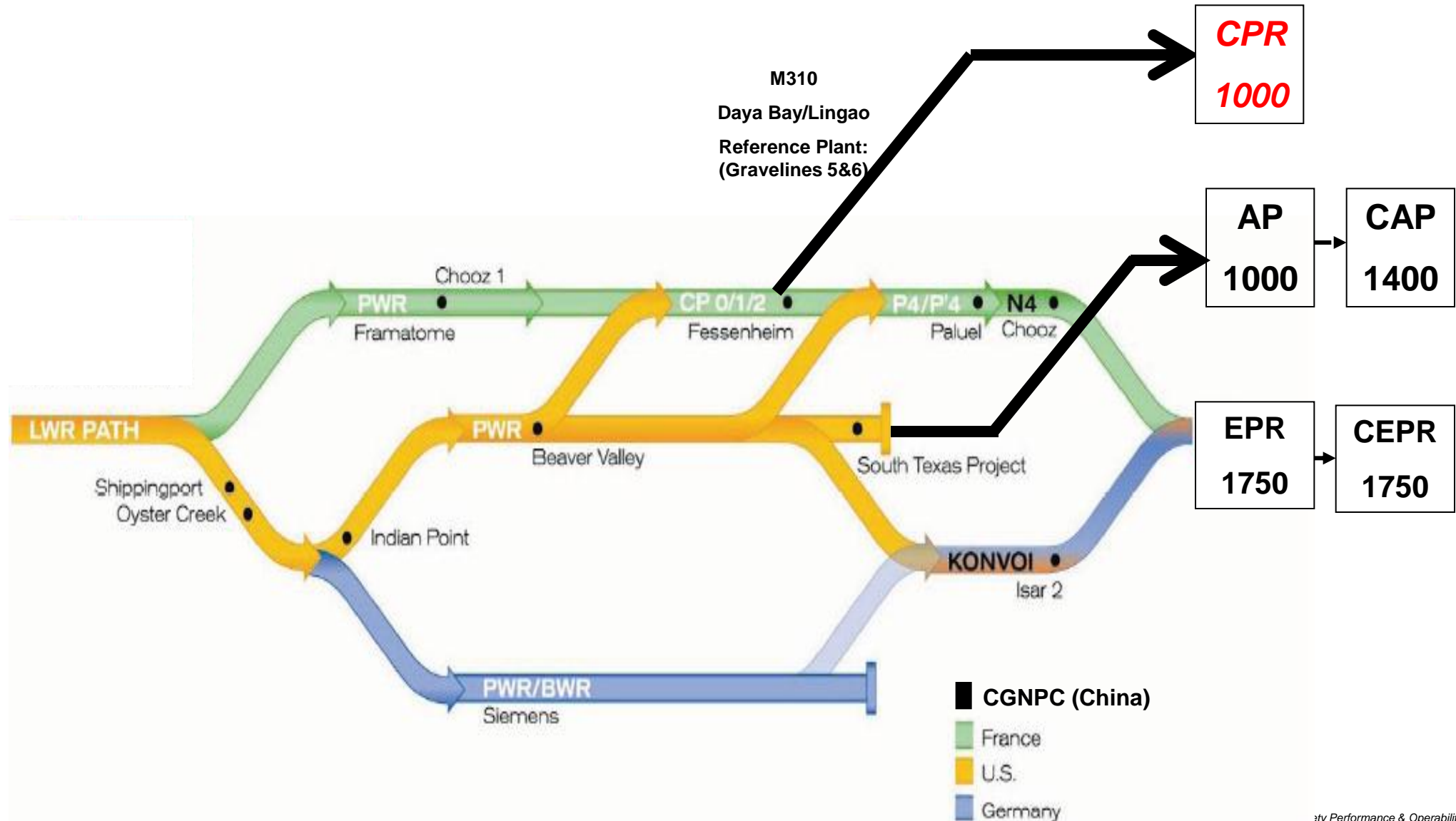
Nuclear equipment Manufacturing Capability in China

	Supplier	2009	2010	2011	2012	2013
Reactor Pressure Vessel	China First Heavy Industry	5	5	5	5	5
	Dongfang Electric	3	5	5	5	5
	Shanghai Electric	2	2.5	3	3	4
	Total	10	12.5	13	13	14
Steam Generator Set	Harbin Electric	2	2	4	4	4
	Dongfang Electric	3	5	5	5	5
	Shanghai Electric	2	2	3	3	4
	Total	7	9	12	12	13
Turbine Set	Harbin Electric	2	4	4	4	4
	Dongfang Electric	4	5.5	8	8	8
	Shanghai Electric	2	4	6	6	6
	Total	8	13.5	18	18	18
Generator Set	Harbin Electric	0	1	2	4	4
	Dongfang Electric	3	5.5	5.5	5.5	5.5
	Shanghai Electric	2	4	6	6	6
	Total	5	10.5	13.5	15.5	15.5

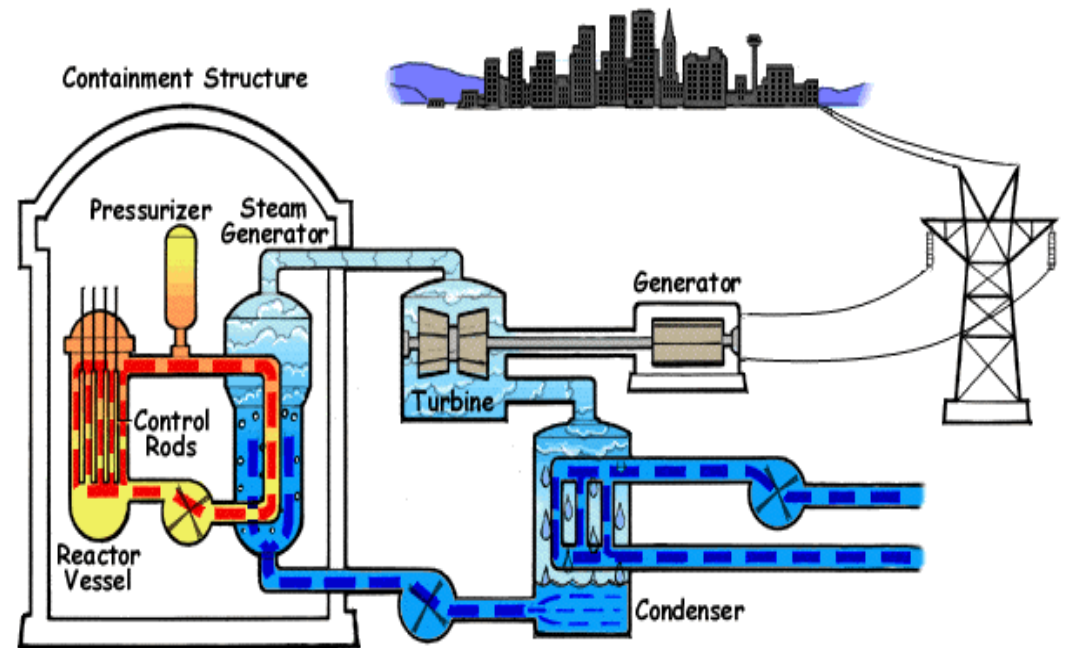
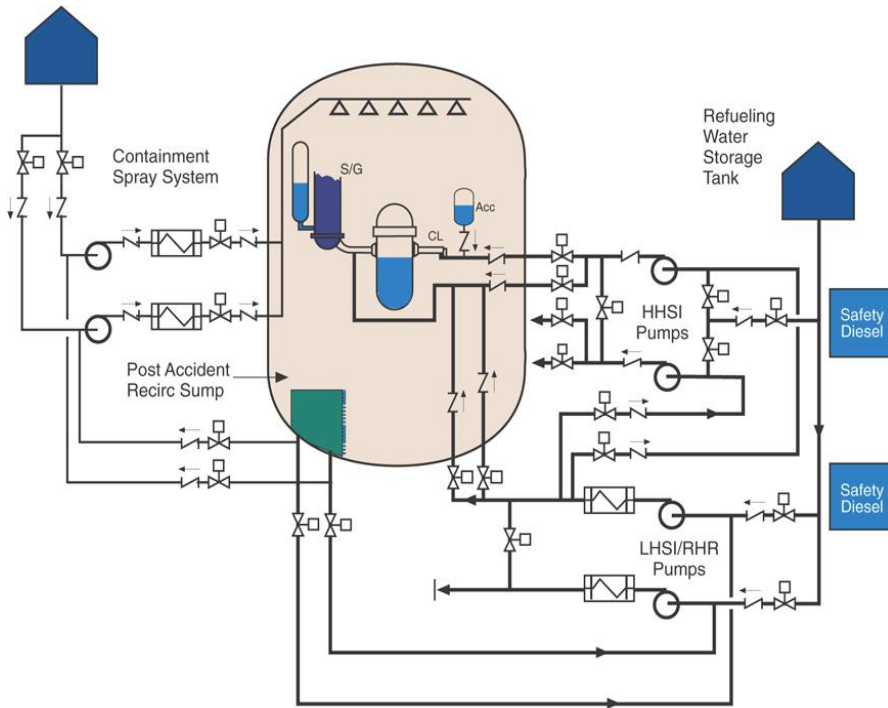
Contents

1. Nuclear Power Development in China
2. *CPR 1000* Design Features
3. Safety Performance & Operability

CGNPC Technology Advancement / Choice



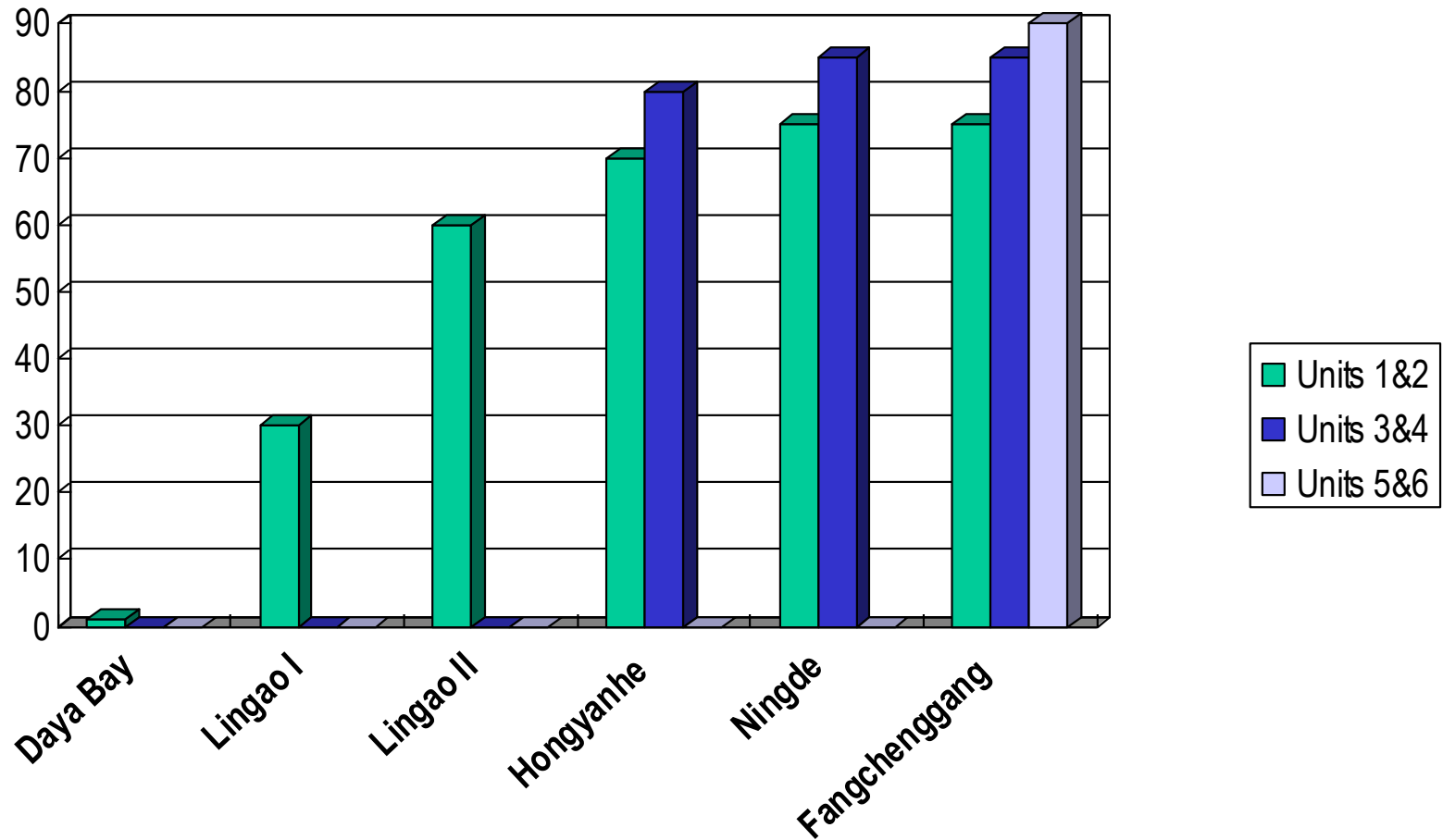
CPR 1000 – CGNPC's Standard PWR



Daya Bay and Lingao Project Data

	Daya Bay Unit 1 and 2	Lingao Units 1 and 2	Lingao Unit 3 and 4
Unit Capacity	2×984MWe (PWR)	2×990MWe (PWR)	2X1080MWe (PWR)
Design Life	40 years	40 years	40 years
Construction Duration	81 Months	67.5 Months	58 Months
Project Costs	4.072 billion USD	3.7 billion USD	< 3.5 Billion USD
Nuclear Island equipment supply	FRAMATOME	FRAMATOME	Dongfang
Convention Island equipment supply	GEC-ALSTHOM	ALSTOM	Dongfang
<ul style="list-style-type: none"> Lingao 1 and 2 took reference to Daya Bay design with upgrades and increased self-reliance. 11% of NI part, 23% of CI part and 50% of BOP are made in China. Lingao 3 & 4 have design upgraded and implement 50% & 70% self-reliance respectively. Lingao 3 & 4 have the digital control and protection installed on reactors and DCS on the CI and the turbines / generator sets changed to the half-speed (1500rpm) standard. Lingao 5 & 6 are planned to be built about 1/2 km east of Lingao 3 & 4. 			

CGNPC Equipment Localization Program



A Typical Project of 6 Units Constructed in Succession

Milestones	Unit 1	Unit 2	Unit 3	Unit 4	Unit 5	Unit 6
	Month					
First Concrete (FCD)	0	8	21	29	41	49
Containment Dome in Place	21	29	42	50	62	70
Cold functional Tests	43.5	51.5	64.5	72.5	84.5	92.5
Fuel Loading	50.5	58.5	71.5	79.5	91.5	99.5
Criticality	52	60	73	81	93	102
Commercial Operation (COD)	56	64	77	85	97	105

Future target construction duration (FCD – COD) is 52 months.

CPR 1000 Design Features

•CGNPC's new projects adopt the *CPR 1000* design developed by China Nuclear Power Design Company, a CGNPC subsidiary. Lingao phase 2 nuclear power station is the demonstration project for *CPR 1000* design.

•*CPR 1000* is built on the basis of Daya Bay and Lingao nuclear power stations, bringing in their operating experience which leads to a number of modifications. In turn, Daya Bay makes reference to units 5 & 6 of the Gravelines nuclear power station of EDF, which belongs to the French 900 MW class PWR that has 28 operating units in France since 1980, with more units in Belgium, South Africa and Korea.

Reactor type	3-loop PWR
Design life	40 (+20) years
Seismic design	Mercalli scale VIII (0.2 g horizontal)
Gross power	1086 MWe
Net power	1021 MWe
Fuel cycle	18 months
Design capability factor	87%
Net station efficiency	35.1%
Operation mode	Load-following
Control & protection	DCS

RCS Technical Data

<p>RCS design improvements:</p> <ul style="list-style-type: none"> •The RPV core region is a ring forged construction, the change will eliminate the need to expose a welded joint to irradiation and material embrittlement, to inspect a major weld at the RPV and shorten the production time for a time-critical component. •More stringent specifications are applied to RPV material, to reduce contents of undesirable impurities such as copper, sulphur and phosphorous. This will facilitate the future licensing application for extending the design life of the RPV beyond 40 years. •PZR relief valves are also functioning as pressure reducing valves under severe accident situation. 	Rated core thermal power	2895MWt
	Rated NSSS thermal power	2905MWt
	RCS thermal-hydraulic design flow rate	22840 x 3
	RCS mechanical flow rate	24740 x 3
	RCS design pressure	17.23 MPa
	RCS operating pressure	15.5 MPa
	RCS design temperature	343 deg C
	RPV inlet temperature	292.4deg C
	RPV outlet temperature	327.6 deg C
	RPV average temperature	311.0 deg C
	PZR design pressure	17.23 MPa
	PZR design temperature	360 Deg C
	PZR capacity (cold)	39.75 m ³

Reactor Core Technical Data

Fuel assembly	17x17 AFA 3G
Fuel rods per assembly	264 (M5)
Grids per assembly	11 (8+3)
No. of FA per core	157
Active core height	3.658m
Fuel enrichment	4.5%
Average linear power density	186 W/cm
Peak power factor	2.25
BNBR	1.20
CDF	1.30×10^{-5}
Discharge burnt-up	52,000 MWd/t
No. of RCCA	61 (49 black +12 gray)
RPV inlet / outlet temperatures	292.2 / 327.6deg C
RPV Avg - Tavg	310.0 deg C
High pressure safety pumps (HHSI)	3
Design pressure / temperature / flow rate (design/max)	21.2MPa/120°C/(34/160m³/h)
Low pressure safety injection pumps (LHSI)	2
Design pressure / temperature / flow	2.2MPa/150°C/850m³/h
SI accumulators design press/temp/operating water volume	4.93MPa/120°C/31.3-33.2m³

Steam Generator Technical Data

Primary Side	Design pressure	17.23 MPa
	Design temperature	343 Deg C
	No. of U tubes	4474
	U tube material	Inconel 690
	U tube outside diameter and wall thickness	19.05mm / 1.09mm
	Heat transfer surface	5430m ²
Secondary Side	Main steam flow rate	1613 kg/sec
	Pressure at main steam outlet	6.71 MPa
	Temperature at main steam outlet	283 Deg C
	Moisture at main steam outlet	<0.25%
	Design pressure	8.6 MPa
	Design temperature	316 Deg C
	Main feed water temperature	226 Deg C

Containment building Technical Data

Design pressure	0.52 MPa
Design temperature	145 Deg C
Internal diameter	37 m
Total containment height	55.88 m
Wall thickness	0.9 m
Net internal volume	49400m ³
Design leakage rate	0.3% per day
Containment spray pumps	2
Design spray flow rate	850m ³ / hour
Design recirculation rate	1050m ³ / hour
Passive hydrogen re-combiners	30
Containment filtration and exhaust system	Shared with 2 units
Containment spray additive	NaOH

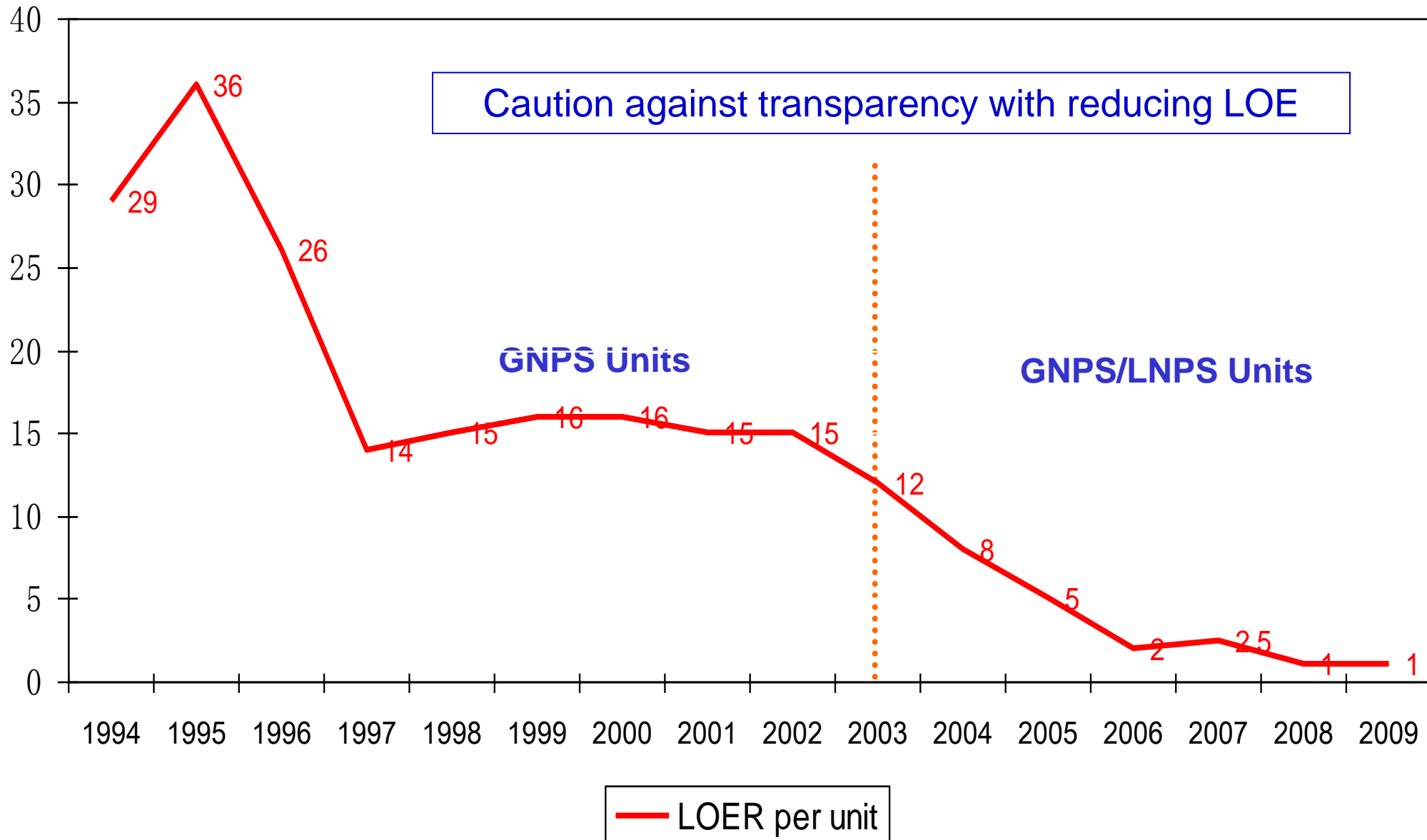
Turbine/generator Technical Data

Steam flow rate	1536.5 kg/s
Pressure at turbine stop valve	6.43 MPa
Temperature at turbine steam stop valve	280.1 Deg C
Moisture at turbine steam stop valve	0.47 %
Generator rated output	1086 MWe
Power factor	0.9
Condenser BP	5.78 KPa
Condenser inlet steam temperature	35.48 Deg C
Condenser inlet steam moisture	10.41 %
Cooling water flow rate	60 M3/s/unit
Cooling water inlet temperature	25 Deg C
Protection and control	DCS

Contents

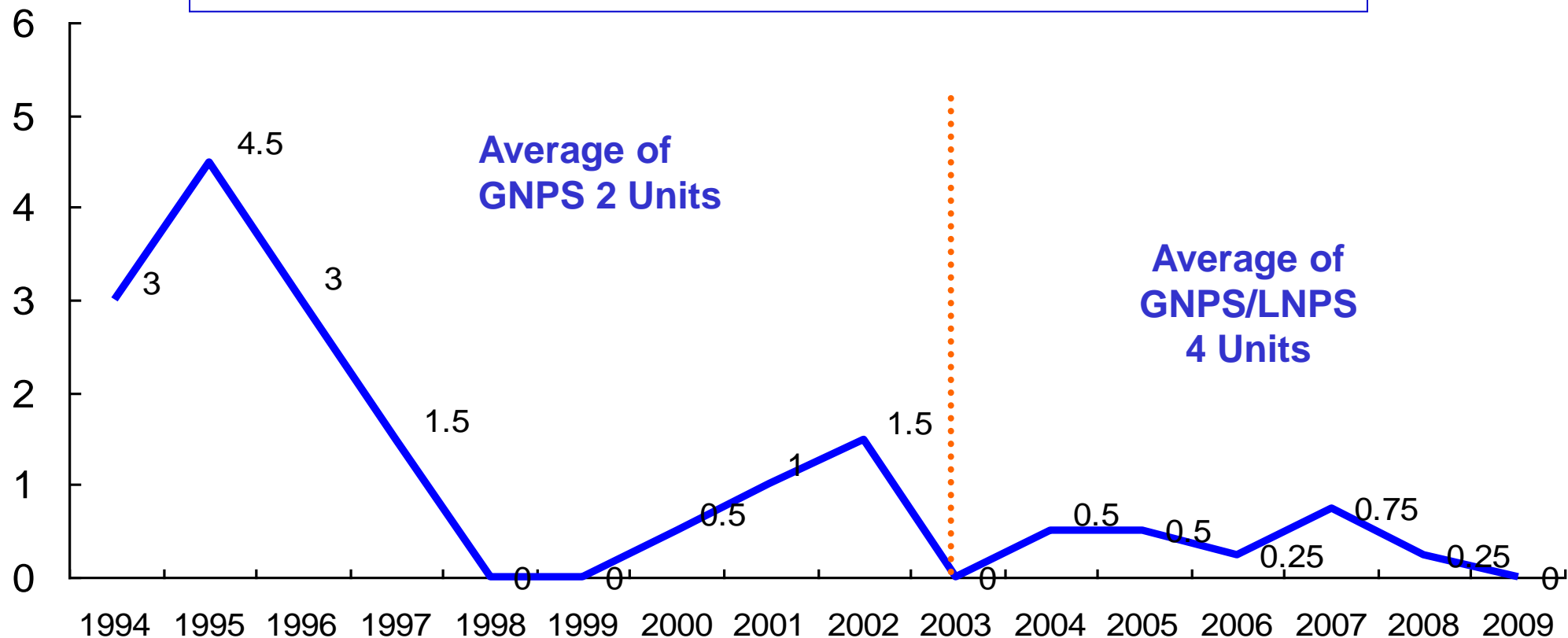
1. Nuclear Power Development in China
2. *CPR 1000* Design Features
3. Safety Performance & Operability

Licensing Events



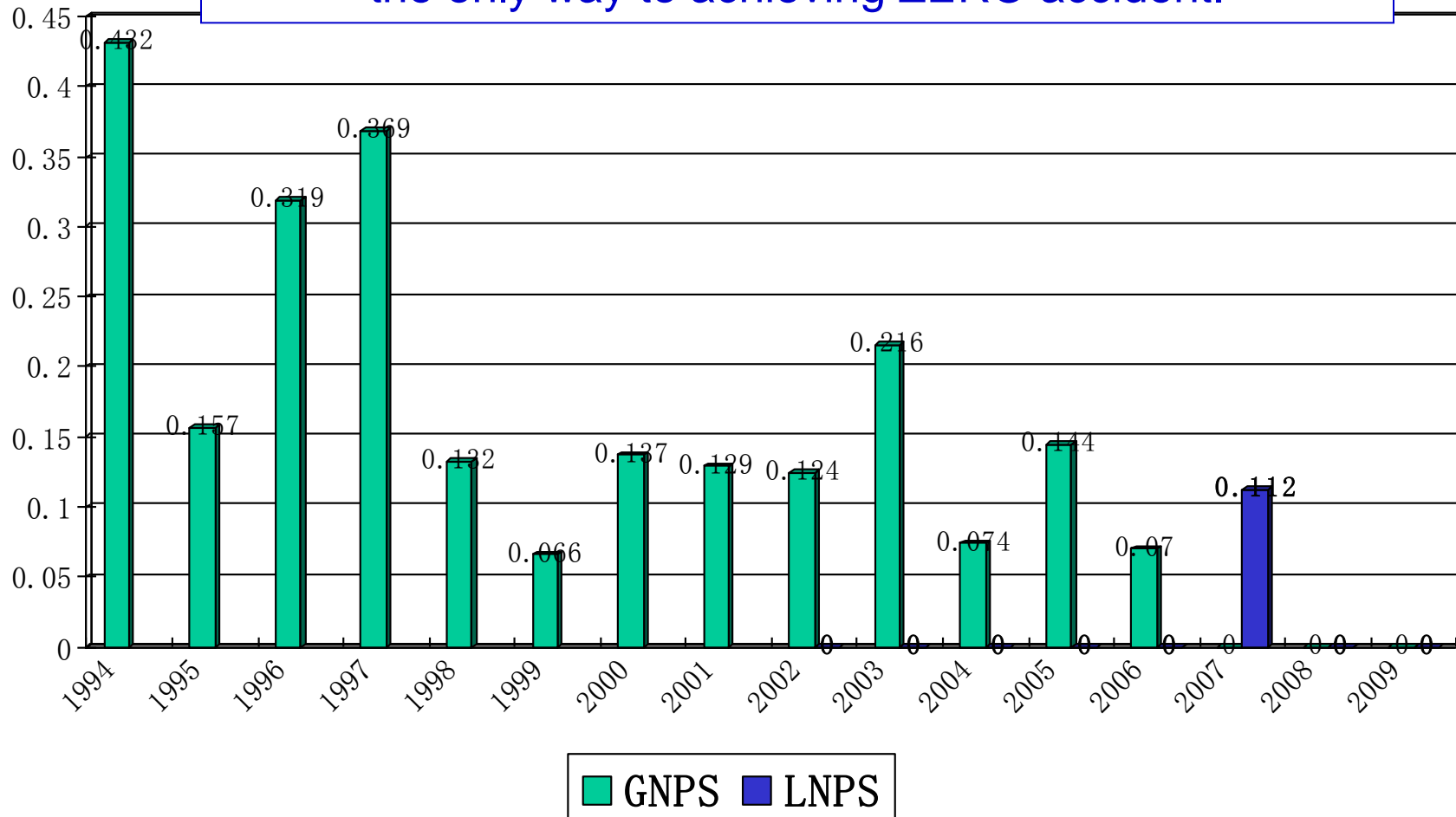
Unplanned Automatic Scrams

Stay focusing on operations of plants and attentive to details for scram reduction



Industrial Safety

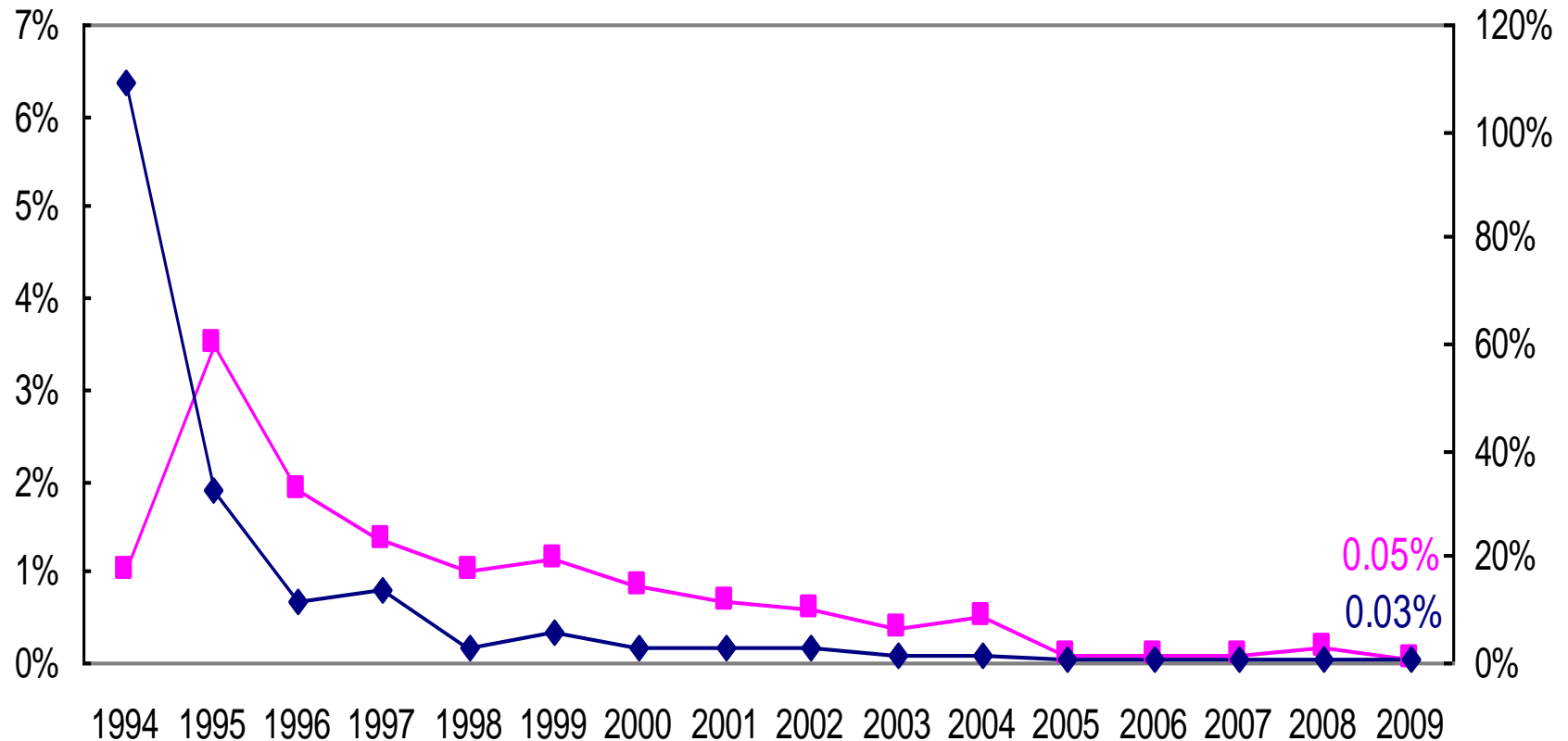
Reinforcing the desired behavior by the management is the only way to achieving ZERO accident.



Note: accident rate per 200,000 man-hours.

Gas and Effluent Treatment and Release

Gas and Effluent are released in a controlled manner such that no near- and long-term impacts to the environment.

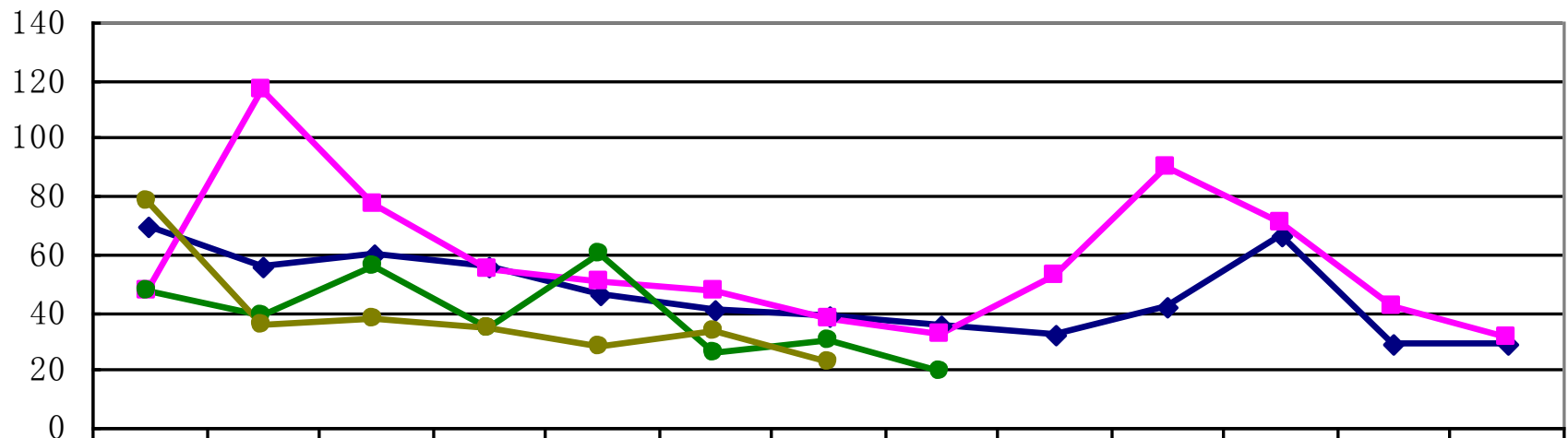


Note:

- 1) the national limit of annual radioactive liquid release is 700GBq;
- 2) the national limit of annual radioactive gaseous release is 1140TBq;

Outage Duration

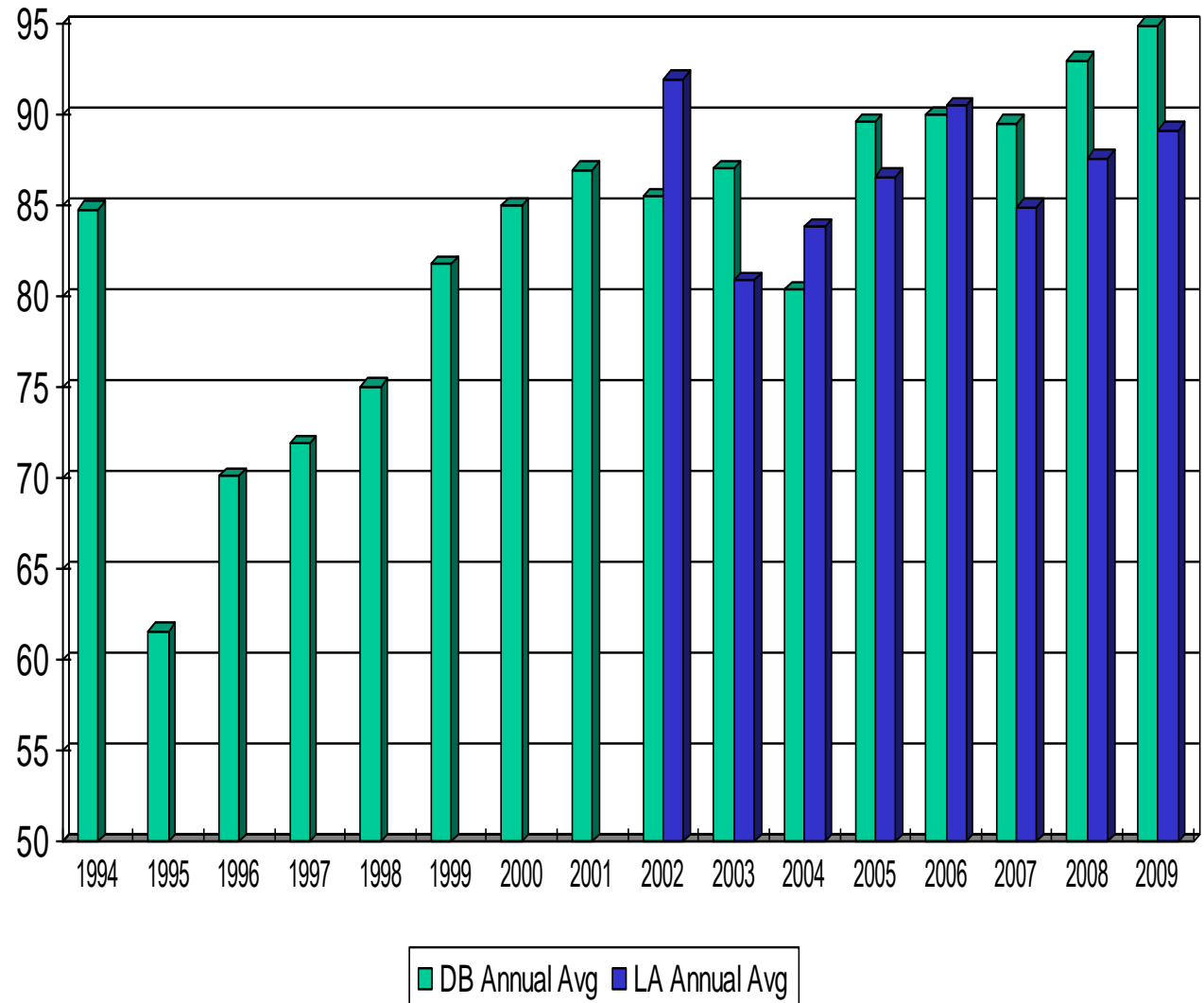
Standardizing / instituting the outage processes is key to improving outage performance

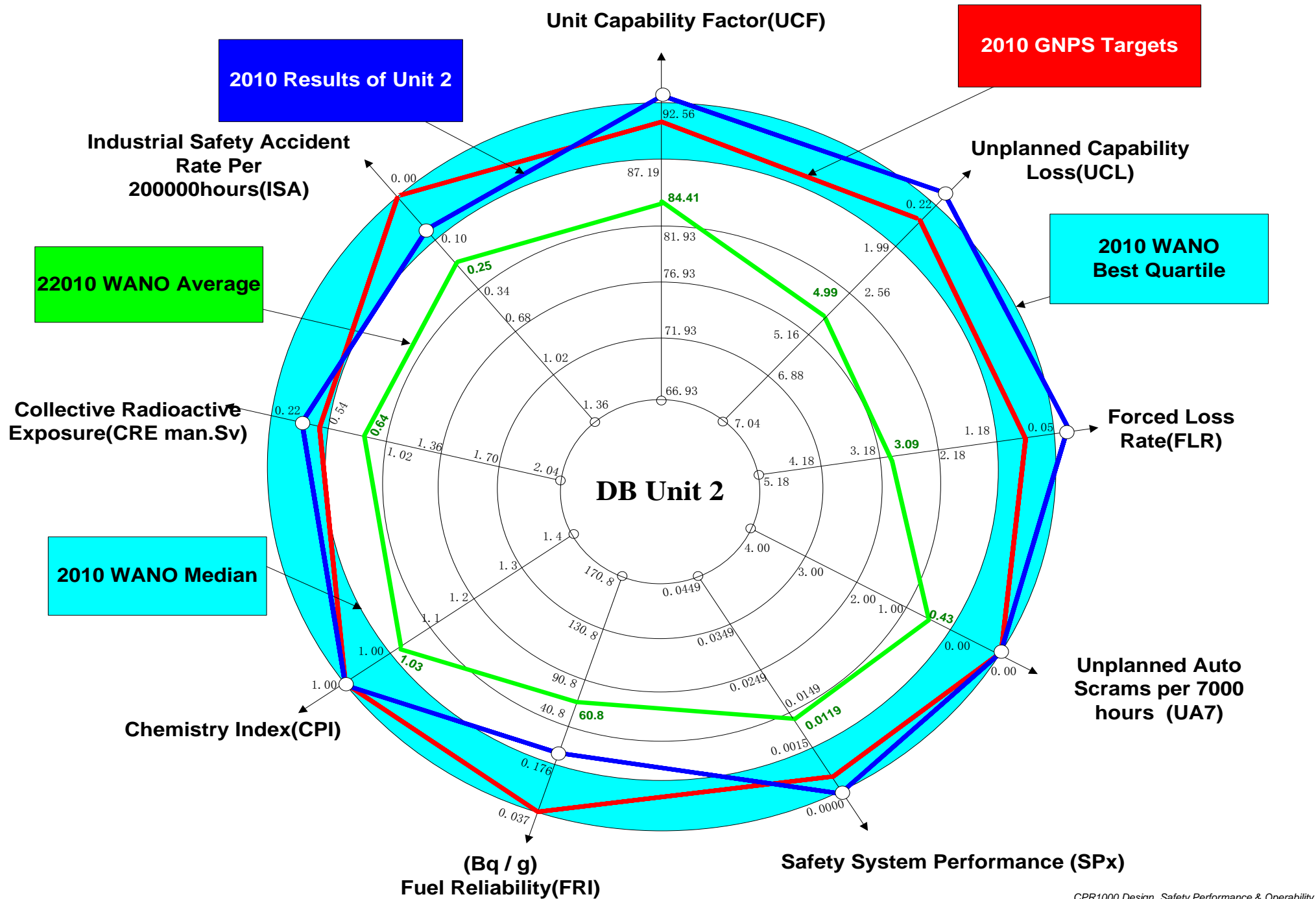


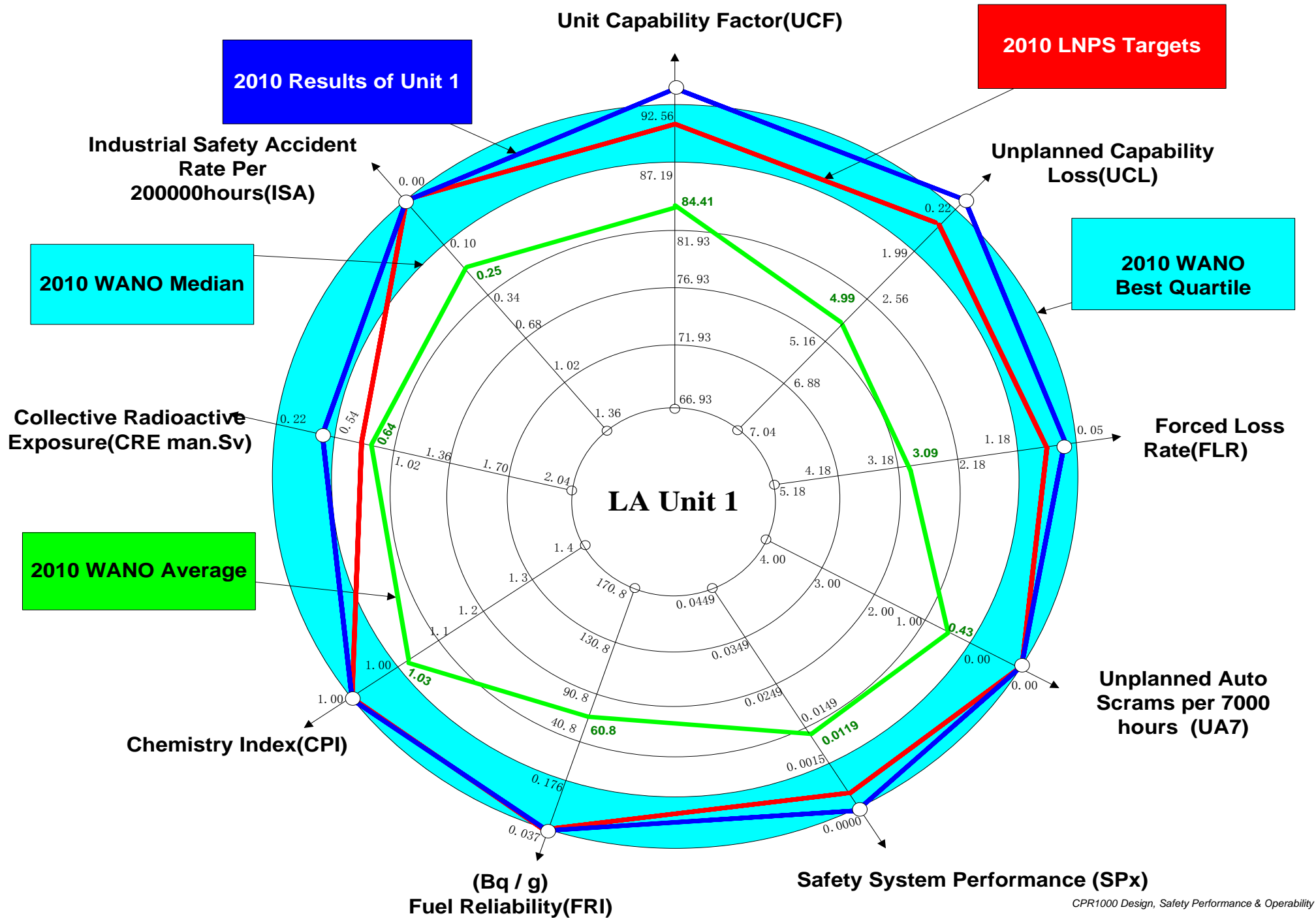
	1	2	3	4	5	6	7	8	9	10	11	12	13
D1#	70	56	60	56	46	41	38	35	32	42	66	28.5	29.36
D2#	47	116	77	55	50	47	37	32	52	90	71	42	30.46
L1#	47	38	56	34	60	25.92	29.92	19.7					
L2#	78	35	37	34	27.49	33.49	22.94						

DB and LA Annual Average Load Factors

Commitment to assimilating world experience in equipment problems or good work practices in equipment reliability management.







2010 LNPS Targets

2010 Results of Unit 2

Unit Capability Factor(UCF)

Unplanned Capability Loss(UCL)

2010 WANO Best Quartile

2010 WANO Average

Collective Radioactive Exposure(CRE man.Sv)

Forced Loss Rate(FLR)

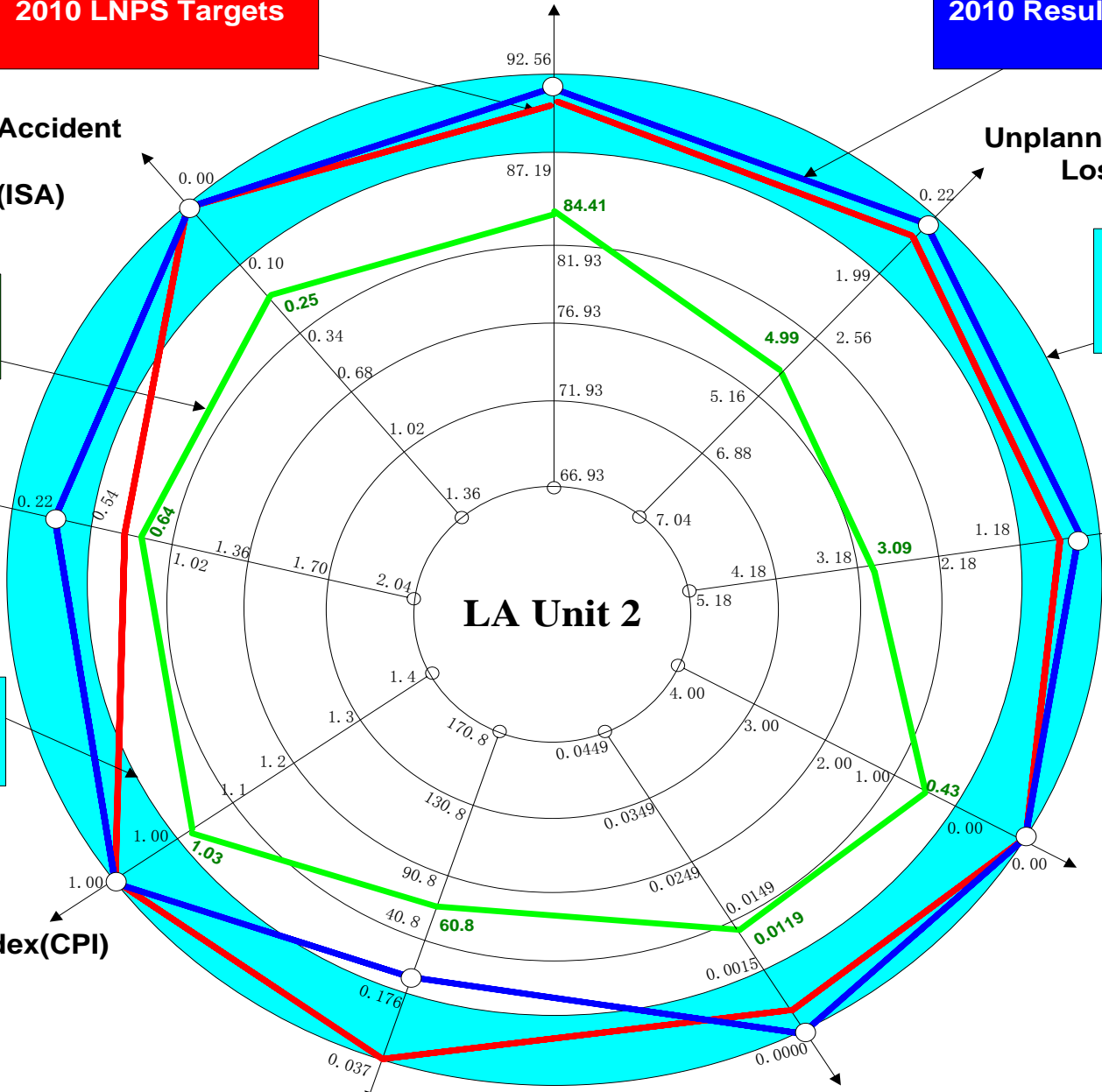
2010 WANO Median

Unplanned Auto Scrams per 7000 hours (UA7)

Chemistry Index(CPI)

Safety System Performance (SPx)

**(Bq / g)
Fuel Reliability(FRI)**

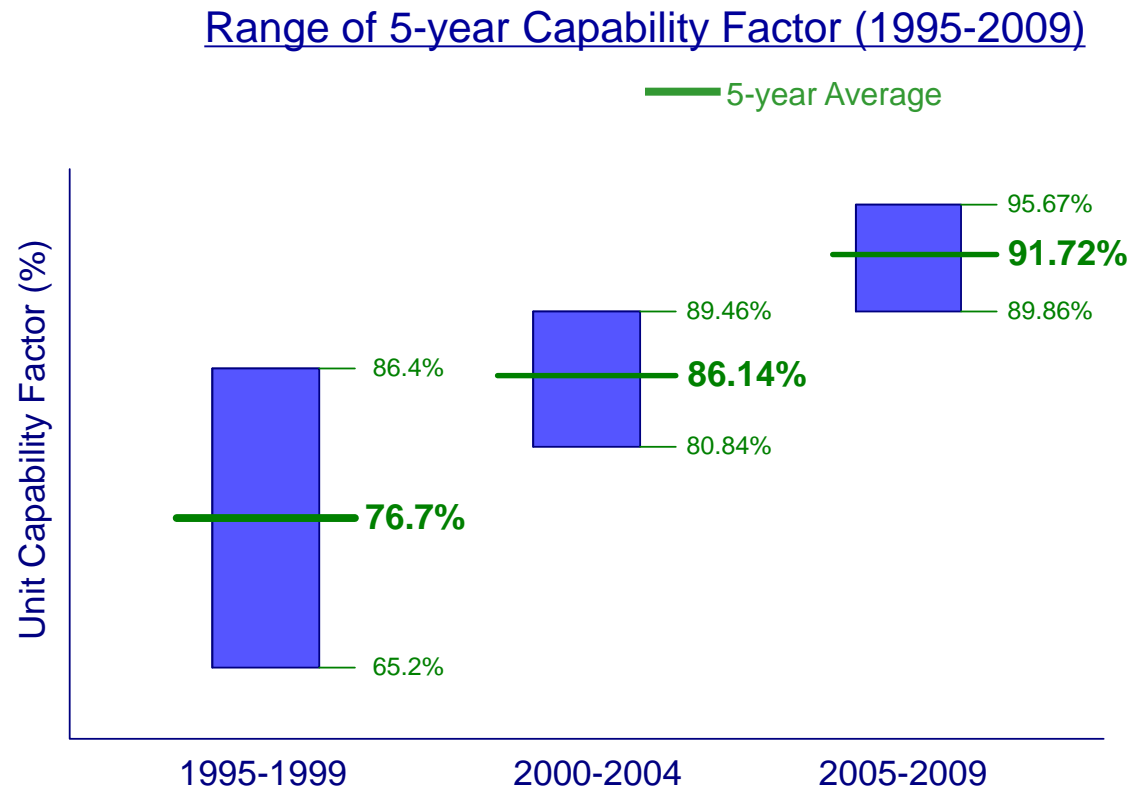


LA Unit 2

Increasing Daya Bay Generation Capability

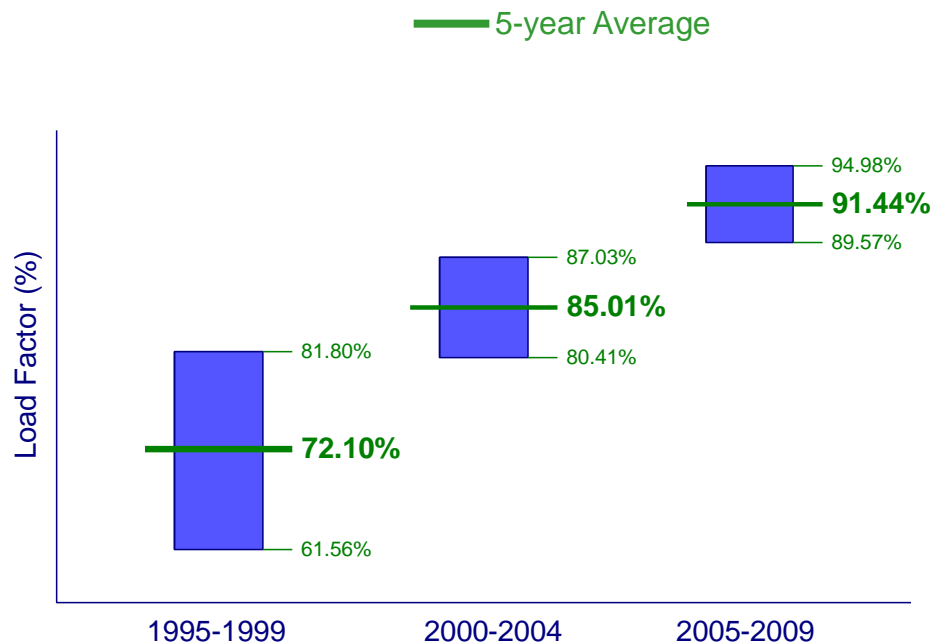
Sustaining the Performance Improvement of the Fleet:

- Identify the best method
- Standardizing it
- Continue improving it
- Transfer the improvements company-wide

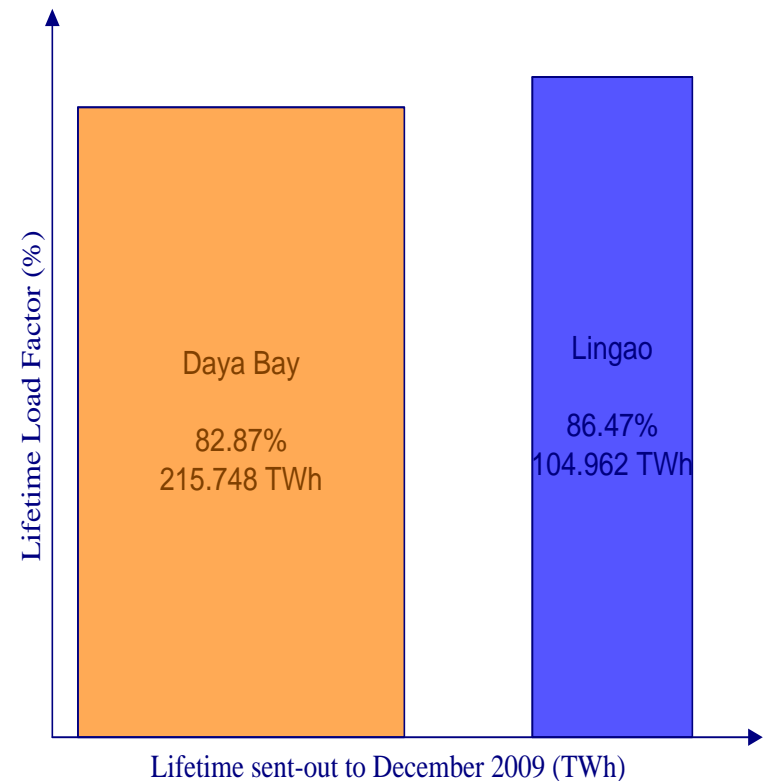


Replicating & Sustaining the Improvements Across Every Unit CGNPC Operate

Range of 5-year Load Factor (Daya Bay 1995-2009)



Lifetime Average Load Factor and Electricity Sent-out



Post-Fukushima Actions

The Universal Necessity of Reliable Backup Cooling

- Every nuclear reactor requires reliable post-shutdown cooling;
- Some advanced reactor designs will soon accomplish this using the natural physical principle of convection;
- But for the world's current reactor fleet, post shut-down heat removal depends on external power;
- Backup cooling systems are a critical non-nuclear aspect of nuclear technology, and
- Fukushima has imprinted on us indelibly how essential this function is to the safety and future of nuclear power.
- Our commitment to ensuring its reliability – in every reactor everywhere – must be absolute.

John Ritch, DG of WNA

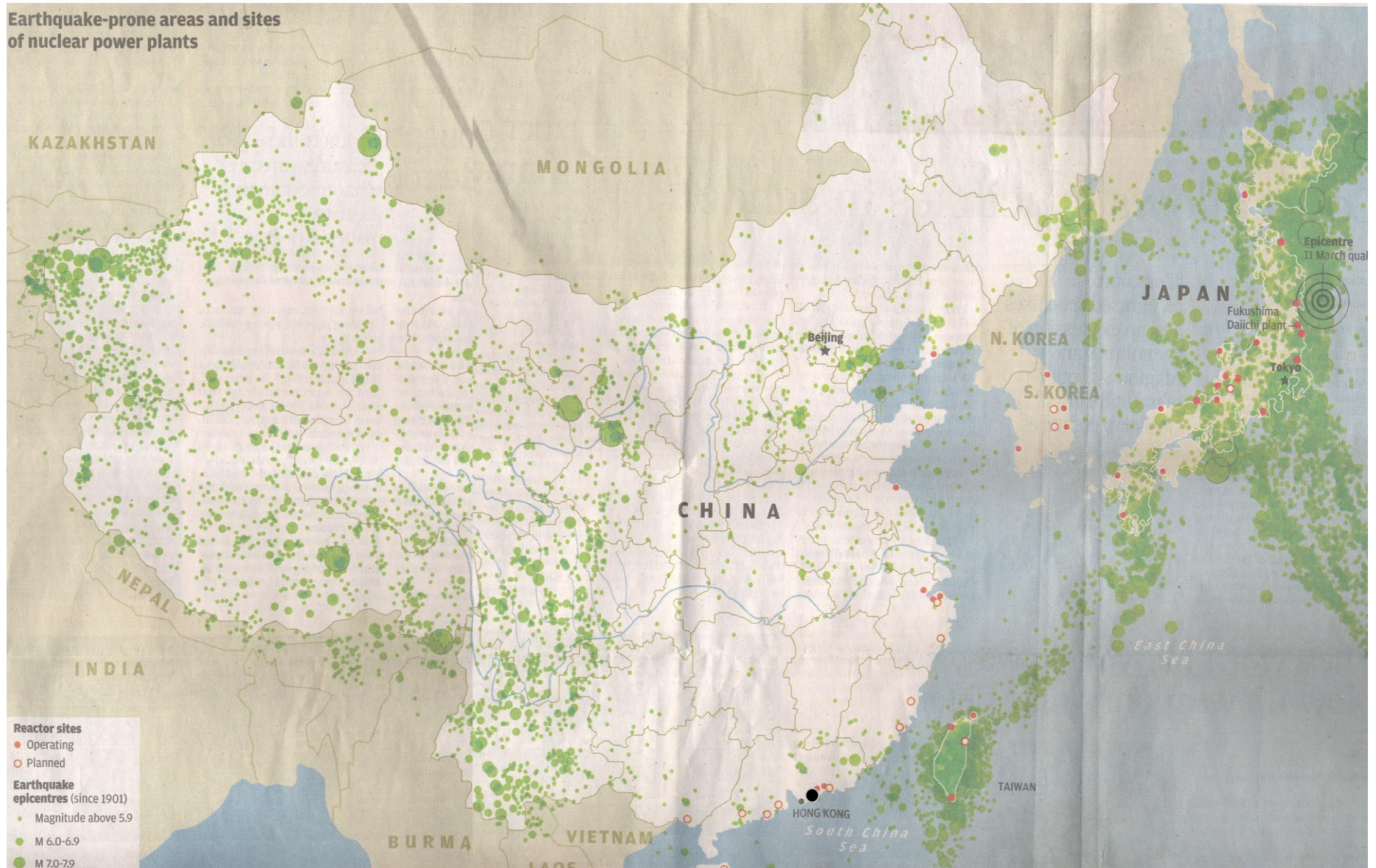
Post-Fukushima Actions

- Self-assessments on all operating units and new builds
- Assessment by NNSA
- Enhancement on anti-flooding program
- Review on anti-super-typhoon program
- Review on station black-out program
- Review on operator abilities on establishing, maintaining, and enhancing natural circulation for decay heat removal in case of accident.
- Enhance the defense-in-depth backup system to sustain post-shutdown cooling under all possible circumstances. This includes measures to regain AC power in the event of blackout, to flood-proof diesel generators, to ensure adequate battery coping times, and to secure fall-back water sources and pumping systems.
- Review / optimize safety and efficiency in spent fuel management.

Enhancing Operator Fundamental Training

- In spite of all the various automatic control and protection systems used to assist the operator in the safe generation of electricity from a nuclear power plant, the operator himself is the most important aspect of safe plant operation. By his inaction or inappropriate action, he may invalidate the accident analyses performed in the FSAR, which could lead to potentially unacceptable consequences. Through technical specifications, plant administrative requirements, and plant procedures, the operator not only validates the various accident analysis assumptions, but also improves upon the overall plant response predicted in the FSAR for the various initiating events.
- The operator must also be fully aware of the status of core cooling and the available core cooling mechanisms at all times. In case of an accident, it is vital to maintain core cooling so as not to further jeopardize the core status. Thus, he must understand why core cooling mechanisms are necessary, how these work, how these can be evaluated for effectiveness, and how these can be improved upon. The operator refresh-training is structured that regular team discussion be conducted on the core thermal limits and their bases, and various aspects of natural circulation, including potentially degrading phenomena.

Daya Bay is away from the earthquake –prone Areas



Historical Record of Earthquakes within 150km of Day Bay

- Reactors built on hard rock foundations to minimize seismic shaking
- The nearest capable fault line >20 km away
- The quakes of 7.2 Richter scale in 2006 at Taiwan did not trigger the Seismic alarm at Daya Bay reactors

Between 0288 and 2011, there were 46 earthquakes with MS scale <7	
Scale Range	No. of Quakes
> 1 < 3	10
> 3.1 < 4	11
> 4.1 < 5	18
>5.1 < 6	6
> 6.1 < 7	1

Daya Bay is 1000km away from the joint of the two plates



Tsunami Effect to Day Bay



Earth-quake intensity at epic-center	Tsunami wave height	Rise in water level in HK (DB)
Chile (9.5)	25m	0.33m
South of Taiwan (7.1)	0.9m	0.1m
Indonisia (9.0)	34m	Nil
Japan east coast (9.0)	14m	0.2m

Thank You

Residual Heat After Shutdown (from Full Load)

