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Joint ICTP-IAEA School of Nuclear Energy Management

8 - 26 August 2011

Commissioning, Operation and Life Management of NPPs

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NUCLEAR POWER INFRASTRUCTURES, CONSTRUCTION & COMMISIONNING

August 2011

Nuclear Power Division

Ki-Sig Kang / V. Nkong-Njock

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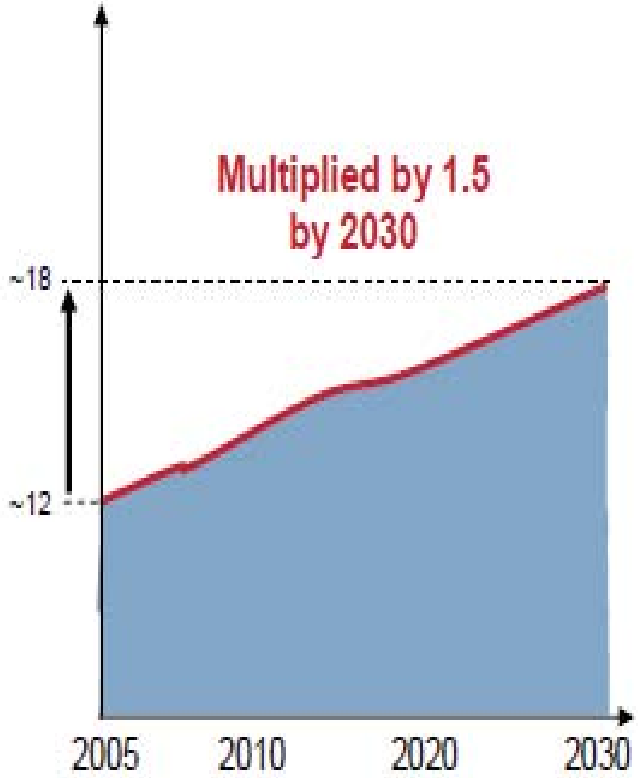
3 challenges for the world energy sector

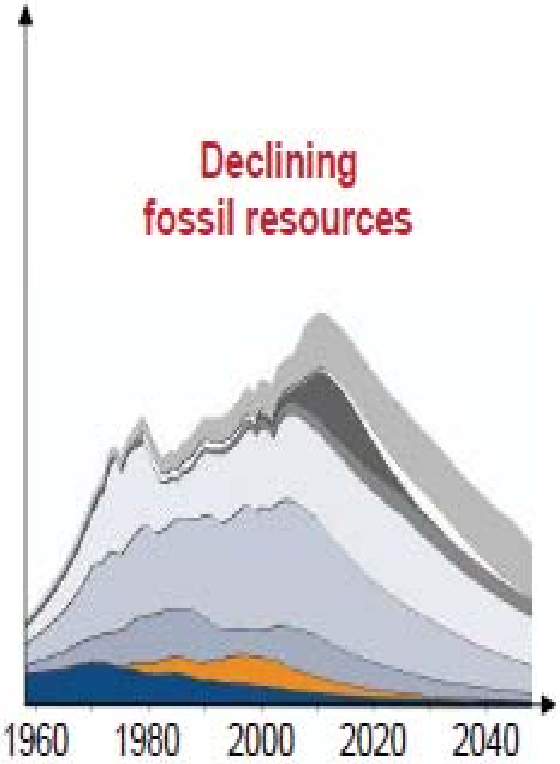
Energy demand

World energy demand (Gtoe / y)



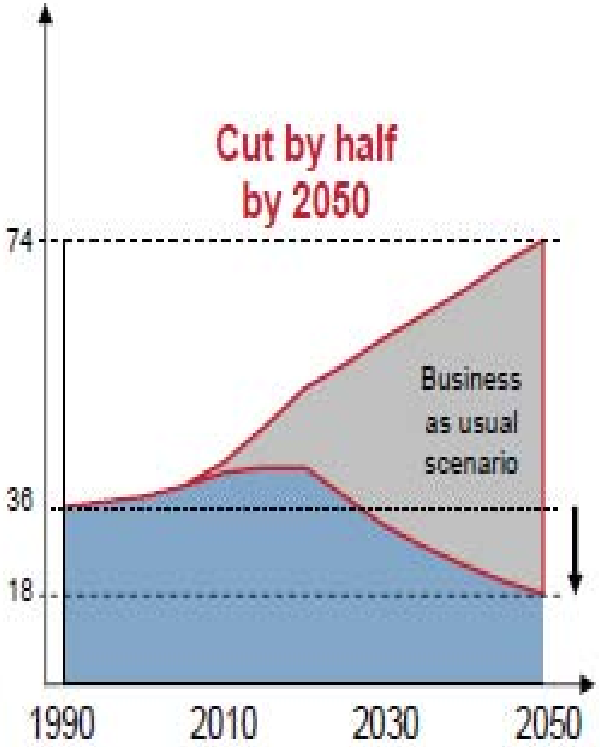
Oil & Gas availability

Oil and gas world energy supply
(Gtoe / y)



GHG emissions

World GHG emissions
(GtCO2eq / y)



Challenges & Opportunities : Before

- Growing energy need
- Climate change
- Energy security
- Fossil fuel price rise

And Nuclear Power

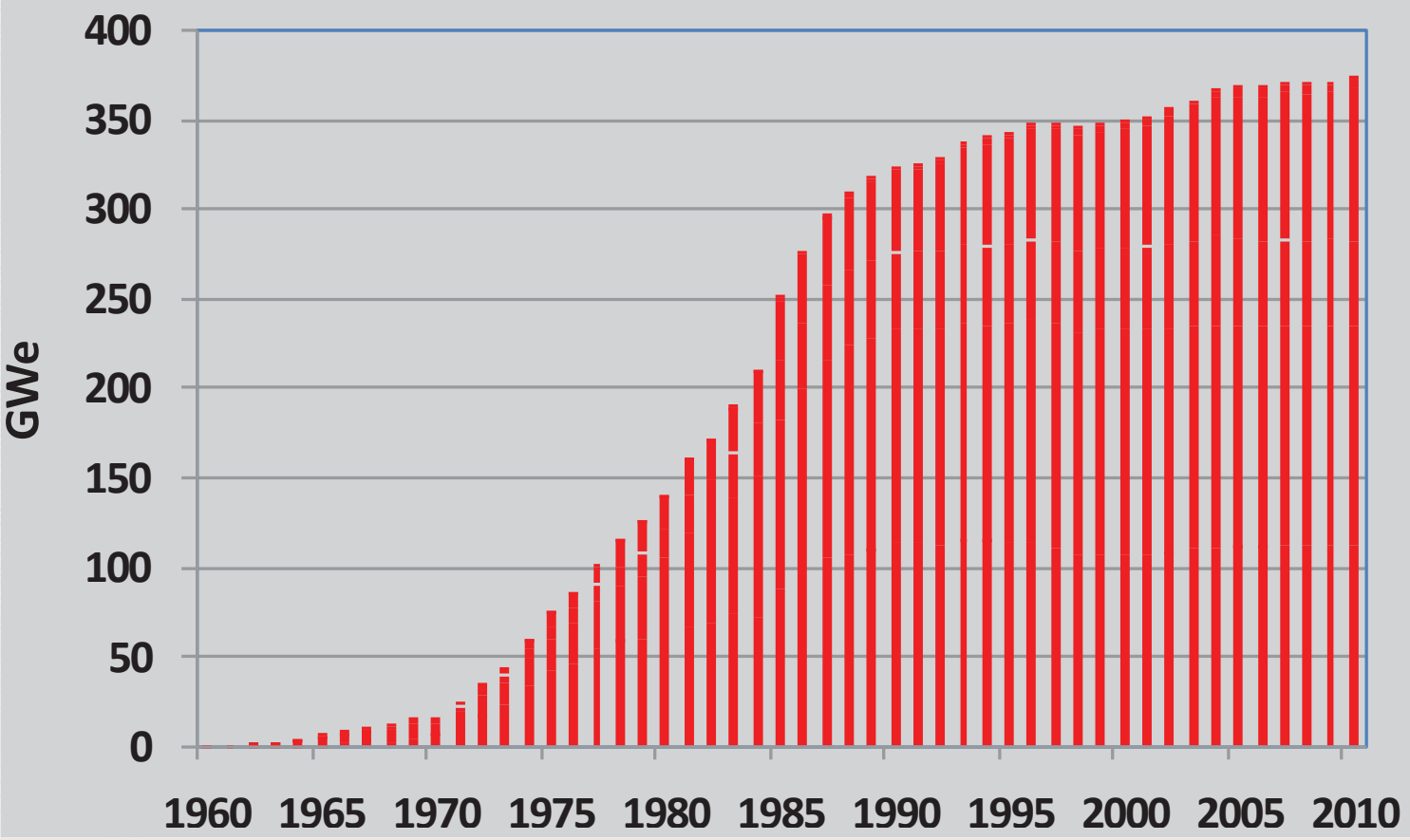
- Improved operations, good economics and safety record

In spite of

- Economic crisis

Nuclear power early 2011

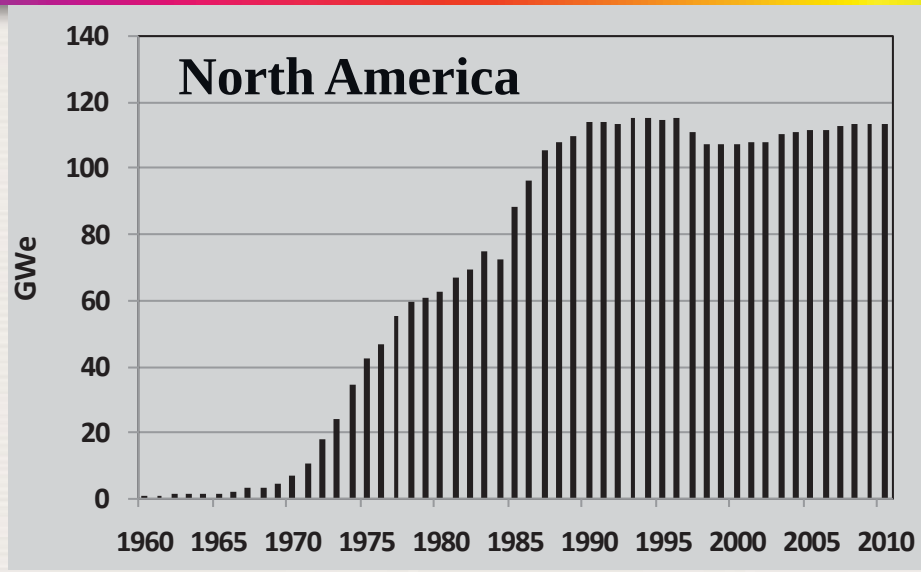
On 10 March 2011, 442 nuclear power plants (NPPs) operated in 29 countries worldwide, with a total installed capacity of 375 000 MWe.

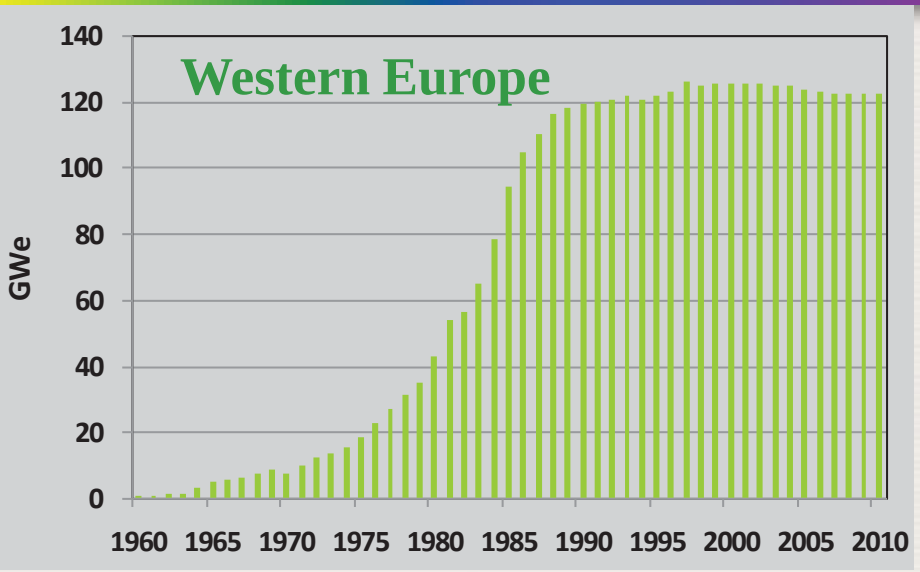


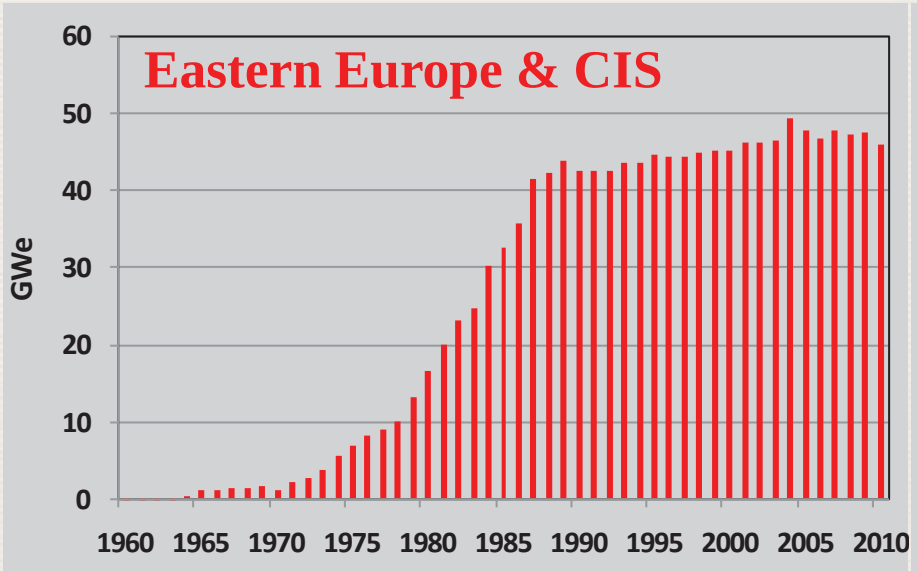
"Where does nuclear power go from here?"

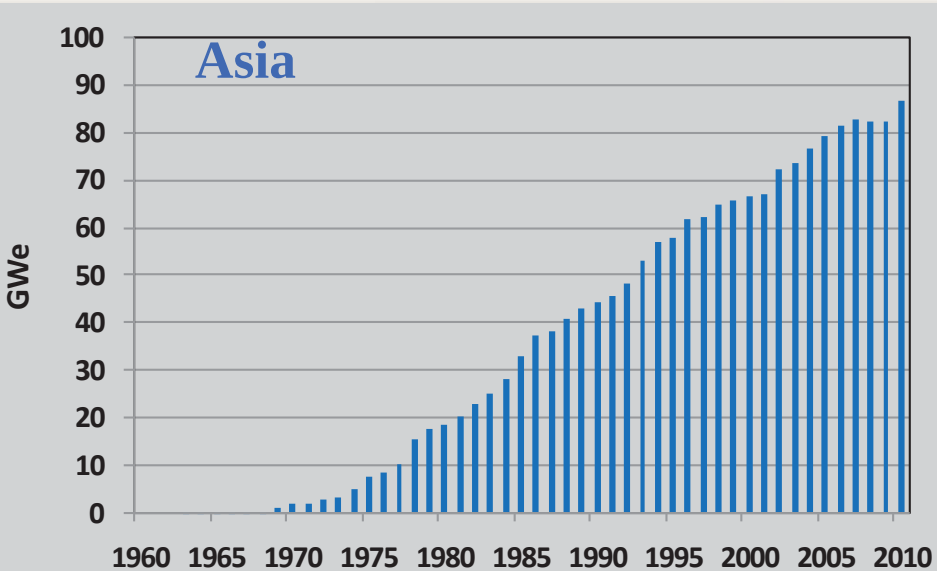
64 NPPs under construction or not completed

Development of regional nuclear generating capacities









PROSPECTS

Description	Number in 2008	Number in 2010
Not planning to introduce nuclear power plants, but interested in considering the issues associated with a nuclear power programme	16	31
Considering a nuclear programme to meet identified energy needs with a strong indication of intention to proceed	14	14
Active preparation for a possible nuclear power programme with no final decision	7	7
Decided to introduce nuclear power and started preparing the appropriate infrastructure	4	10
Invitation to bid to supply a nuclear power plant prepared	1	
New nuclear power plant ordered		2
New nuclear power plant under construction	1	1
Total	51	65

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From "International Status and Prospects" 2008 and 2010

Challenges & Opportunities : Today

- Growing energy need
- Environmental Protection & Climate Change
- Energy security
- Fossil Fuel Price Volatility
- Need for low-cost base load electricity

In spite of

- Fukushima accident

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Nuclear Power after Fukushima

(as of August 2011)

IAEA PROPOSAL (Ministerial Conference on NS, Vienna, June 2011)

- Need to strengthen the IAEA Safety Standards
- Need to systematically and regularly review the safety of all NPPs
- Concern about national regulatory bodies which play a crucial role in ensuring safety. All countries should ensure that their regulatory bodies are as effective as possible.
- Need to strengthen the global emergency preparedness and response systems
- Need to enhance IAEA's role in receiving and disseminating information.

Nuclear Power after Fukushima

(as of July 2011)

- Driving forces underlying the renaissance in interest prevail ?
- Countries with existing NPPs reassess their Safety Features (stress tests, etc.)
- Assessment of expansion/introduction of NP
- New safety regimes expected from lessons learned
- Project delays and fewer plants built in the short-term
- Economics of potential retrofits & new NPPs uncertain
- Potential shift to SMRs

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Nuclear power after Fukushima

(as of July 2011)

- Continued use of existing NPPs contested in Germany
- Continued use of NP in principle not contested in other countries
- New build contested in Japan, Italy and Switzerland
- A lot will depend on the
  - Transparency and effectiveness of dealing with the aftermath in Fukushima
  - Short- and long terms impacts on the local population
  - Full appreciation of causality
  - Availability and economics of alternatives
- More Importance of **National Position** & **Stakeholder Involvment**

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MILLESTONE "STEPWISE" APPROACH

ISSUES	MILESTONE 1	MILESTONE 2	MILESTONE 3
National position			
Nuclear safety			
Management	CONDITIONS	CONDITIONS	CONDITIONS
Funding and financing			
Legislative framework			
Safeguards			
Regulatory framework			
Radiation protection			
Electrical grid			
Human resources development			
Stakeholder involvement			
Site and supporting facilities			
Environmental protection			
Emergency planning			
Security and physical protection			
Nuclear fuel cycle			
Radioactive waste			
Industrial involvement			
Procurement			

What makes nuclear power unique?

- Scale
  - ➢ Cost / Investment Cost
  - ➢ Development / Construction Period
- Safety
- Public Perception / Public Relations
- Regulatory Environment
- Fuel Cycle
- Site Security
- International Features
  - ➢ Treaty Regimes / Legal Framework
  - ➢ Cross-Border
  - ➢ Non-Proliferation

✓ **Interdependence of the Nuclear Industry**

✓ **Impact of Success/Failure**

✓ **Being Part of the "Nuclear Club"**

❖ **Commitment to Excellence**

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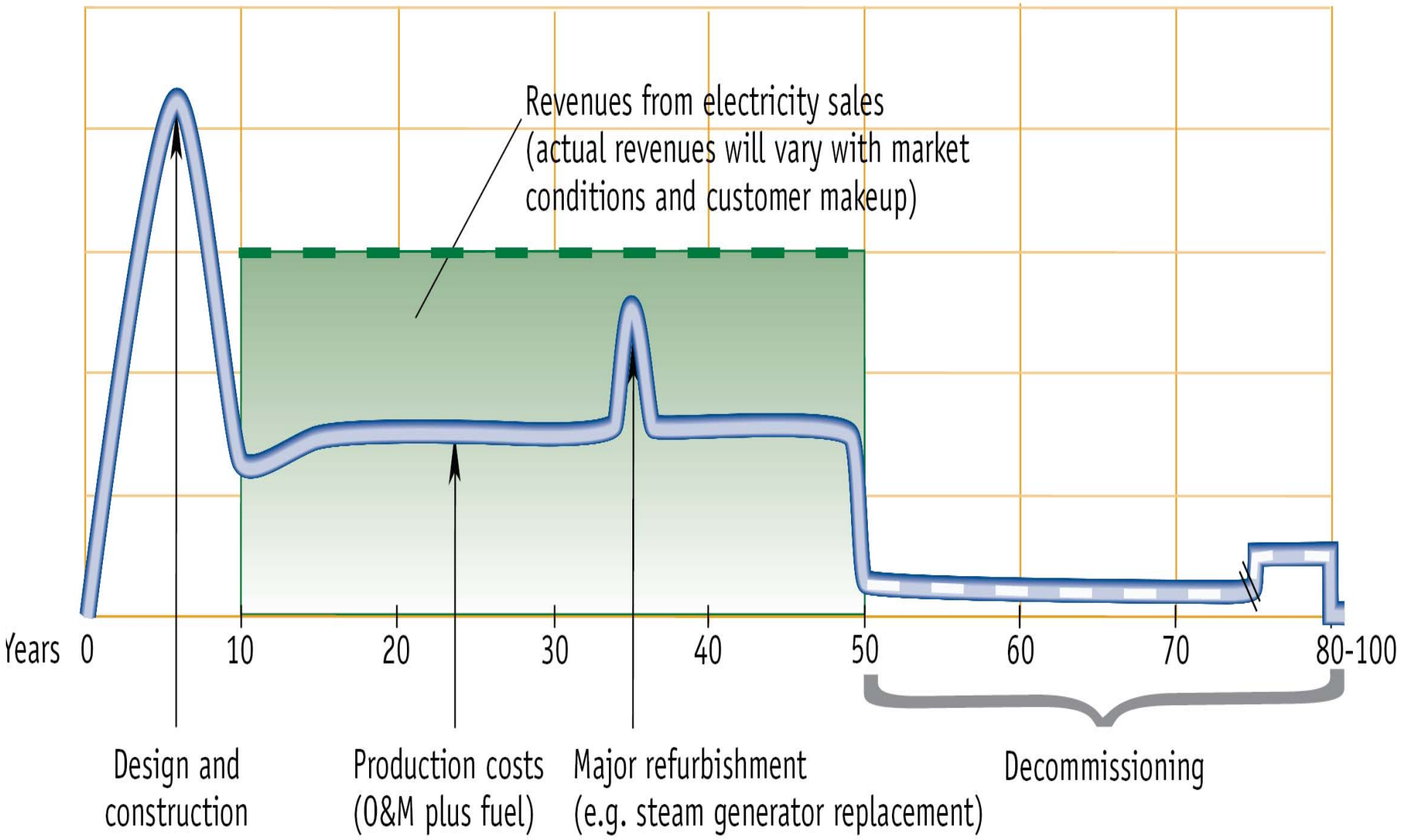
NPP LIFE CYCLE CASH FLOW



CONSTRUCTION / COMMISSIONNING & OPERATION

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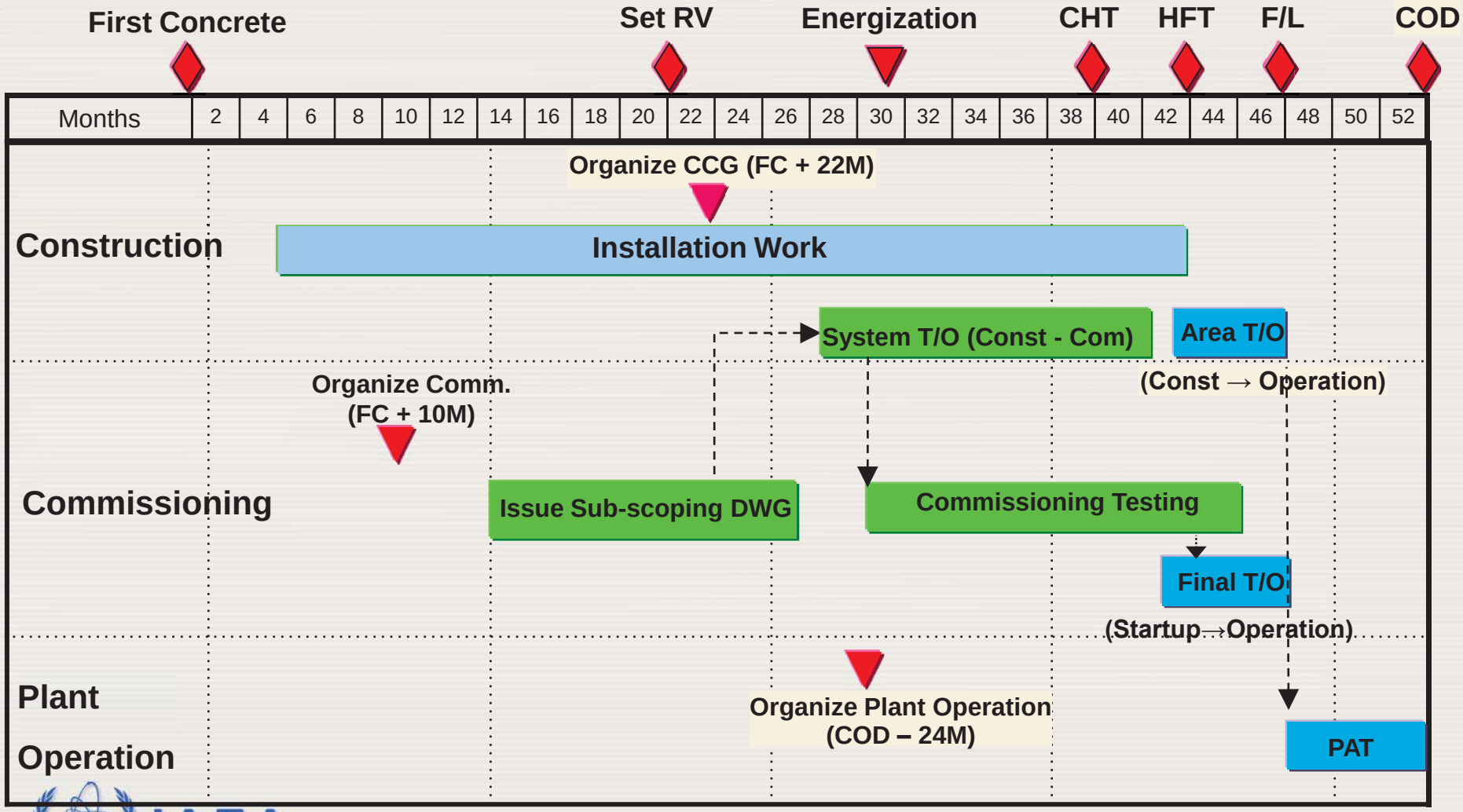
Construction Completion Schedule

❖ Typical Process



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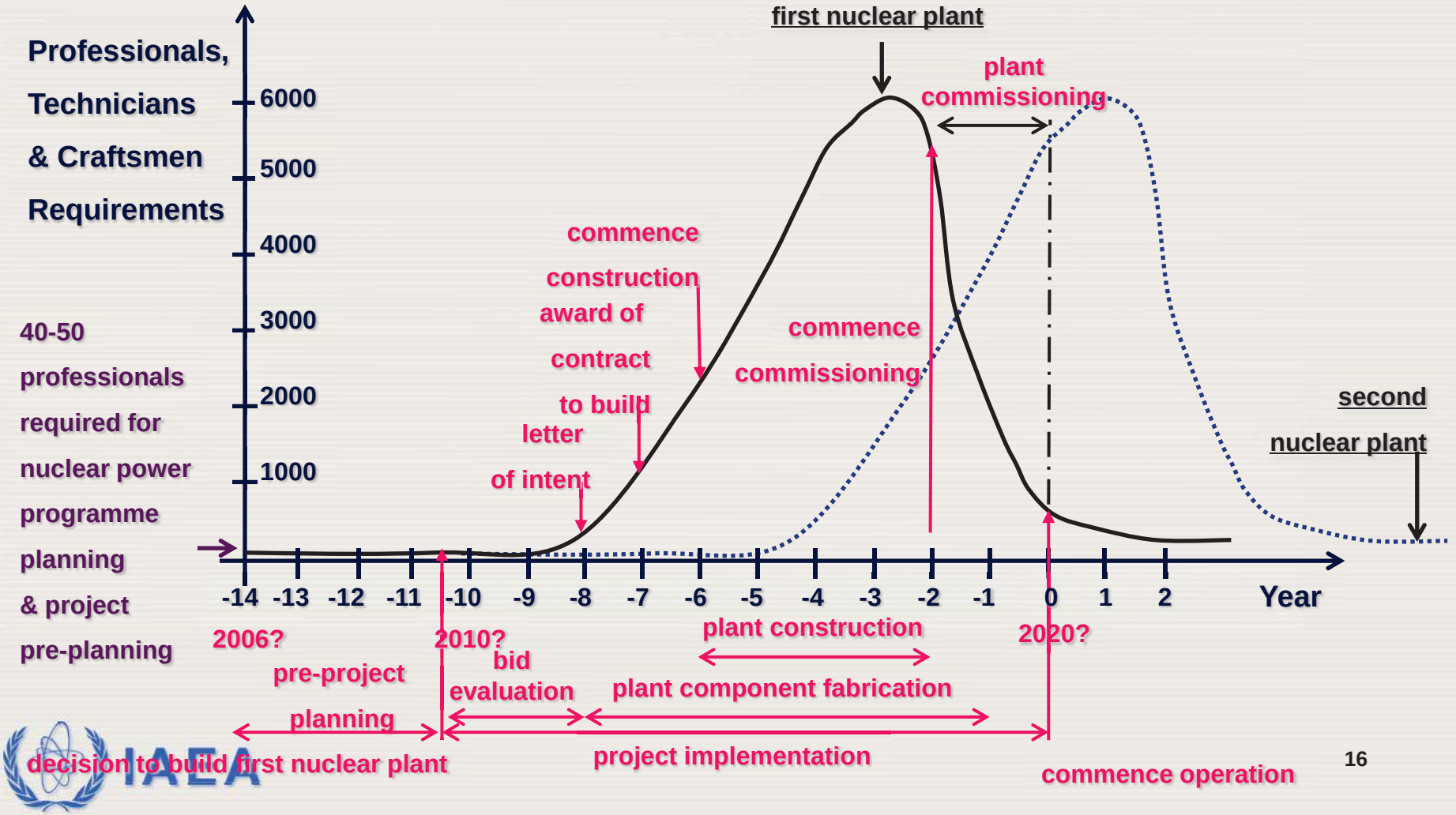
TYPICAL MANPOWER LOADING CURVE FOR NUCLEAR POWER PROJECT



CONSTRUCTION

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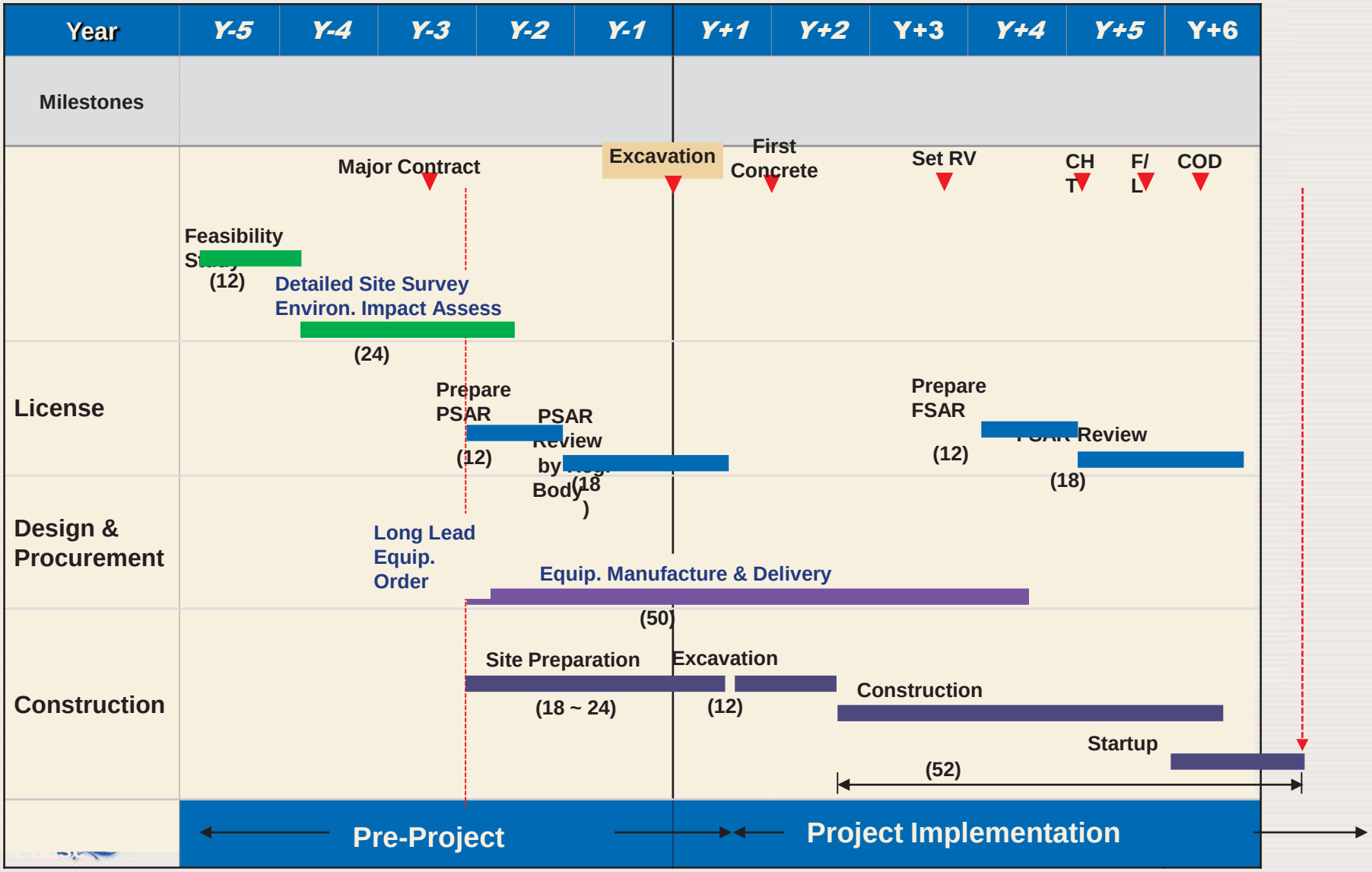
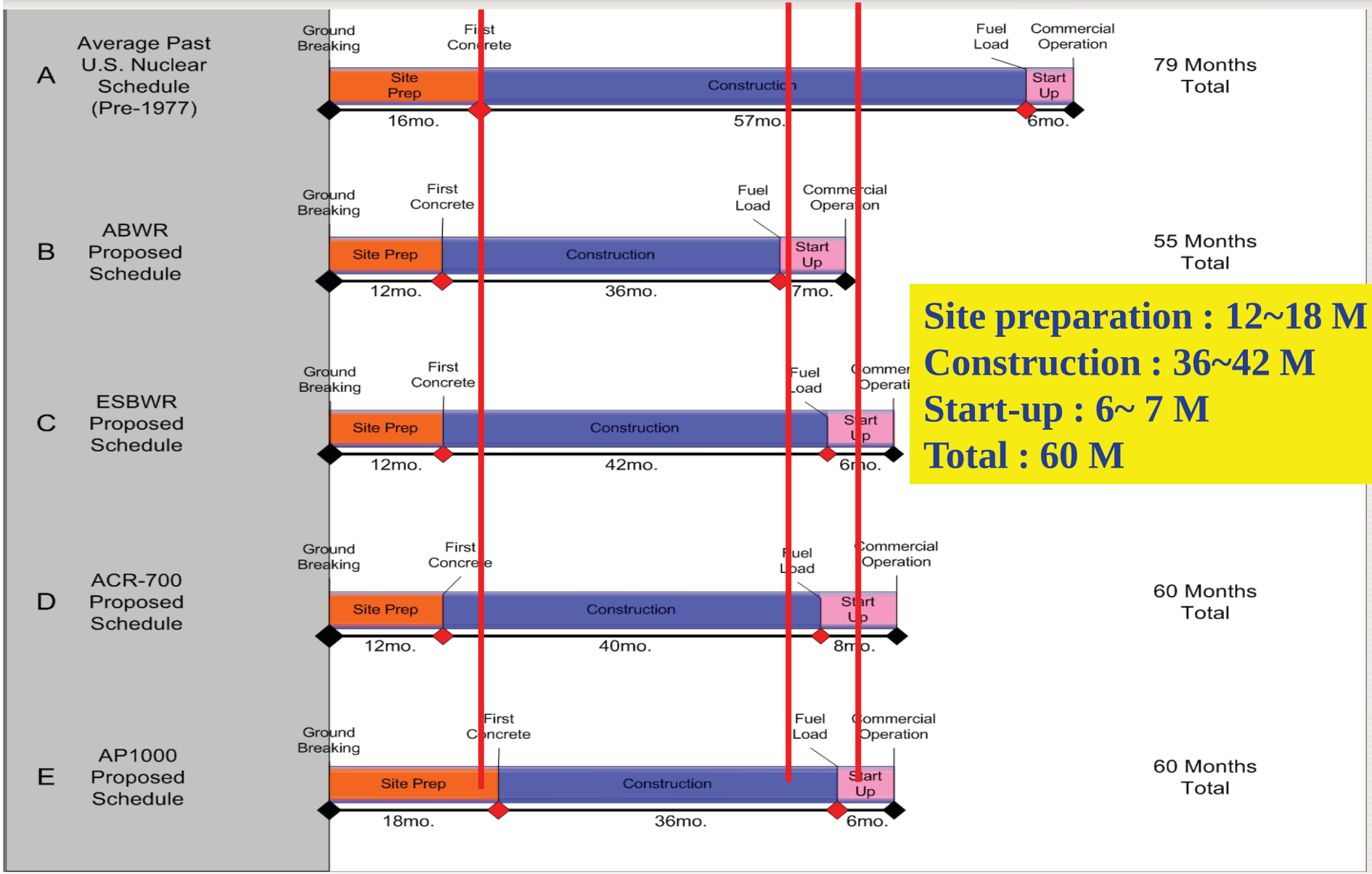
NP PROJECT SCHEDULE : CONSTRUCTION

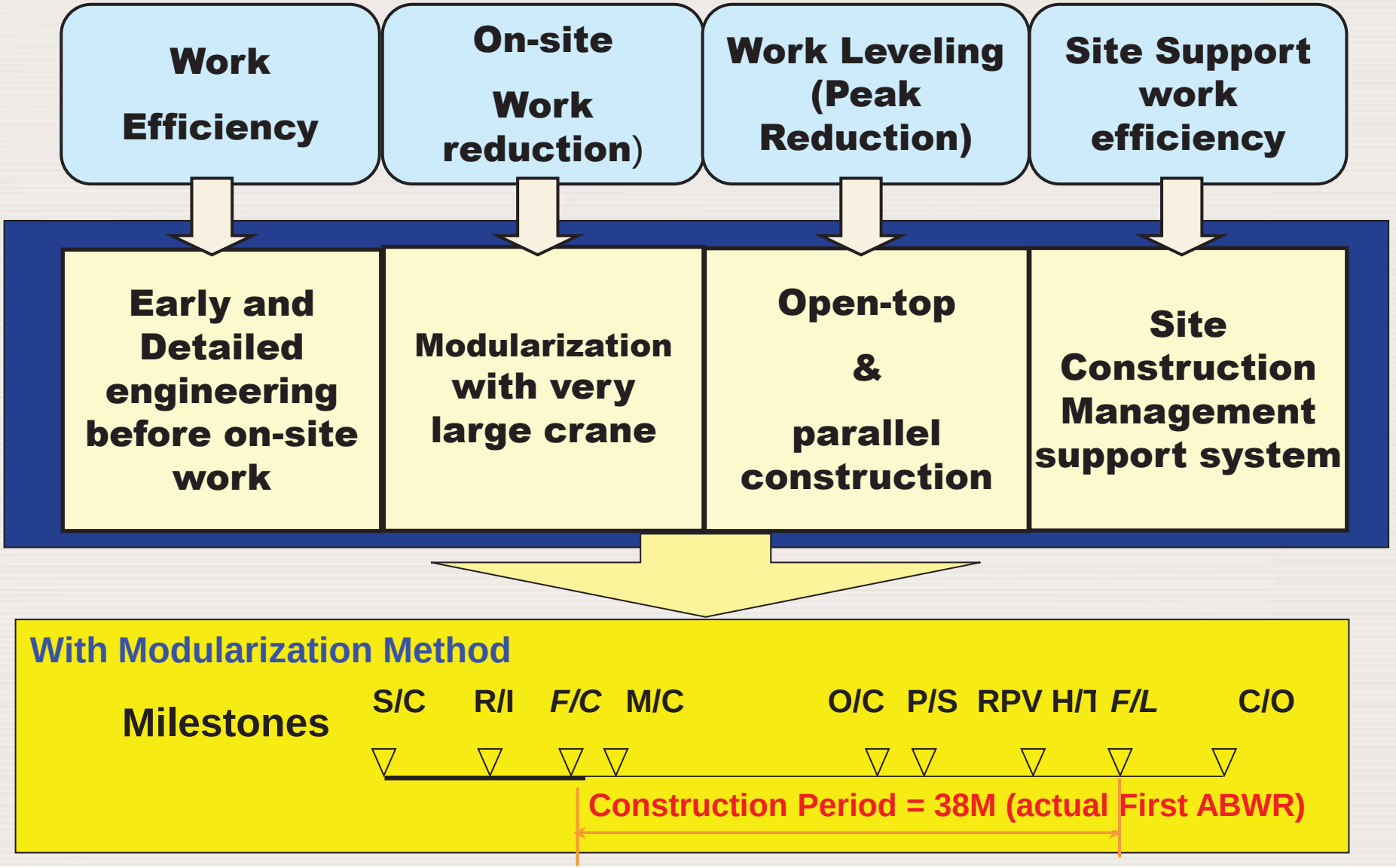


CONSTRUCTION SCHEDULE GEN III+



Site preparation : 12~18 M
Construction : 36~42 M
Start-up : 6~ 7 M
Total : 60 M

Strategies for Shortening Const. period



CONSTRUCTION METHODS

- Open Top Installation
- Modularization
- Advanced Welding Techniques
- Steel Plate Reinforced Concrete Structures
- All Weather Construction & Round the Clock Work
- Concrete Composition Technologies
- Excavation Techniques
- Cable Installation
- Area Completion Schedule Management
- Application of Computer Systems for Information Management and Control

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Open Top Installation & Very Heavy Lift Crane

Open Top Installation & Very Heavy Lift Crane

- **Advantages**

- Full exploitation of open-top construction is expected to reduce total construction time
- Reduce job-hours at jobsite

- **Disadvantages**

- The cost of heavy lift equipment and the facilities necessary for the prefabrication of modular components.
- VHL could be one of long-lead items which may take between 1 and 2 years including design and manufacturing;
- VHL crane requires larger footprint close to the major buildings - Planning for crane placement and movement is a crucial step in open-top installation
- Requires proper protection of Bulk Commodities

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On-site Work Reduction

- Modularization Method -

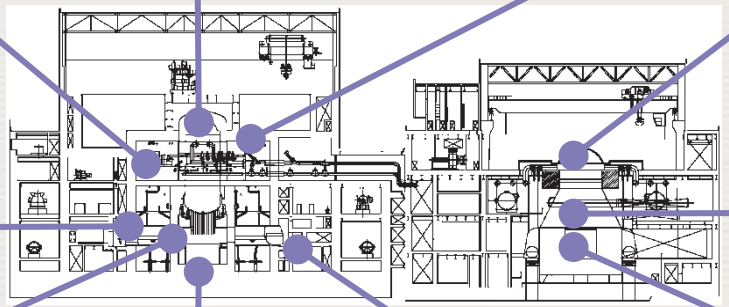
Upper Drywell Module

RPV

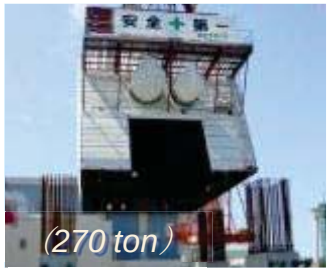
RCCV Top Slab

Stator

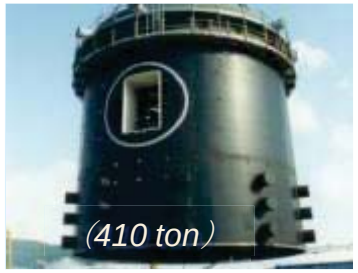
RCCV Lower Liner Module



Upper Condenser Module



RPV Pedestal Module



Base Mat Module

HPU Module

Lower Condenser Unit

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At Tarapur (India), construction of a gas insulated switch gear was completed with 50% saving in time as compared to conventional way of construction.

Modularization

- Prefabrication and pre-assembly of modules prior to installation
- Advantages:
  - Reduce site congestion
  - Allows work in parallel
  - Capability for mass production of modules for several units, with the associated benefit of reducing production time and labor requirements
  - Provision of a controlled environment for module production: easy availability of materials & components
  - Manufacturing of modules before the site becomes available
- Careful consideration of the following:
  - Necessary to complete the design of the plant before module fabrication
  - Increased Engineering for Modules
  - Construction of factories for module fabrication
  - Necessity of earlier outlay of funds for engineering, materials and components before module fabrication
  - Increase Temporary Support Structure / Lifting and Rigging Requirements - expensive custom-made heavy lift cranes
  - Transportation costs
  - Infrastructure and skills requirements

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Advanced Welding Techniques

- Quality welding is crucial and time consuming
- Advanced Techniques
  - Metal Arc Welding,
  - Gas Tungsten Arc Welding
  - Submerged Arc Welding
- Automatic welding equipment is very effective
  - Maintaining high quality
  - Improving the working environment in narrow spaces.

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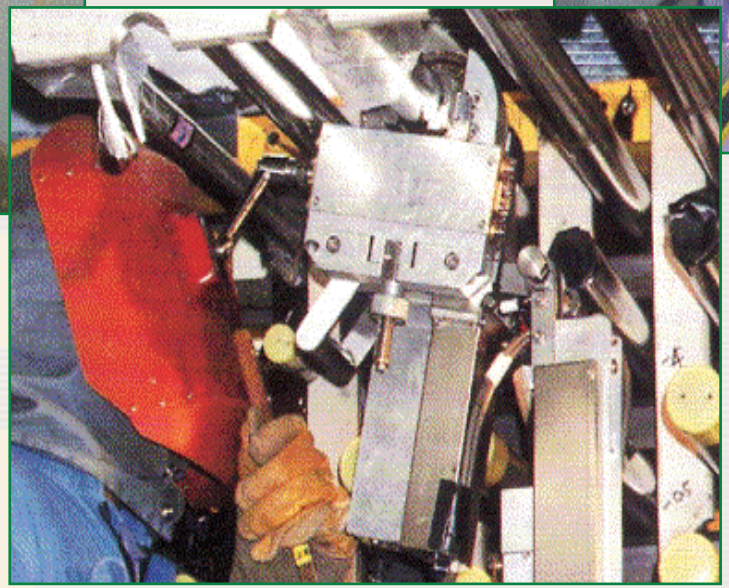
Automatic Welding Machine

Automatic Welding Machine for RCCV Liner



Automatic Welding for Small Bore Piping (CRD piping)

Automatic Welding for Large Bore Piping

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Concrete Composition Technologies

- Advanced concretes developed to improve strength, workability, and corrosion resistance.
- Examples
  - Self-compacting concrete
  - High performance concrete
  - Reactive powder concrete.

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Steel Plate Reinforced Concrete Structures

- Conventionally reinforced concrete is fabricated in place using reinforcing bars with external forms to frame the structure
  - This conventional technique requires considerable time
- For floors/walls of various buildings, including pipe runs, penetrations, etc
  - Reduced amount of reinforced bars and construction man-hours
  - Potential for huge composite modules with mechanical/electrical commodities

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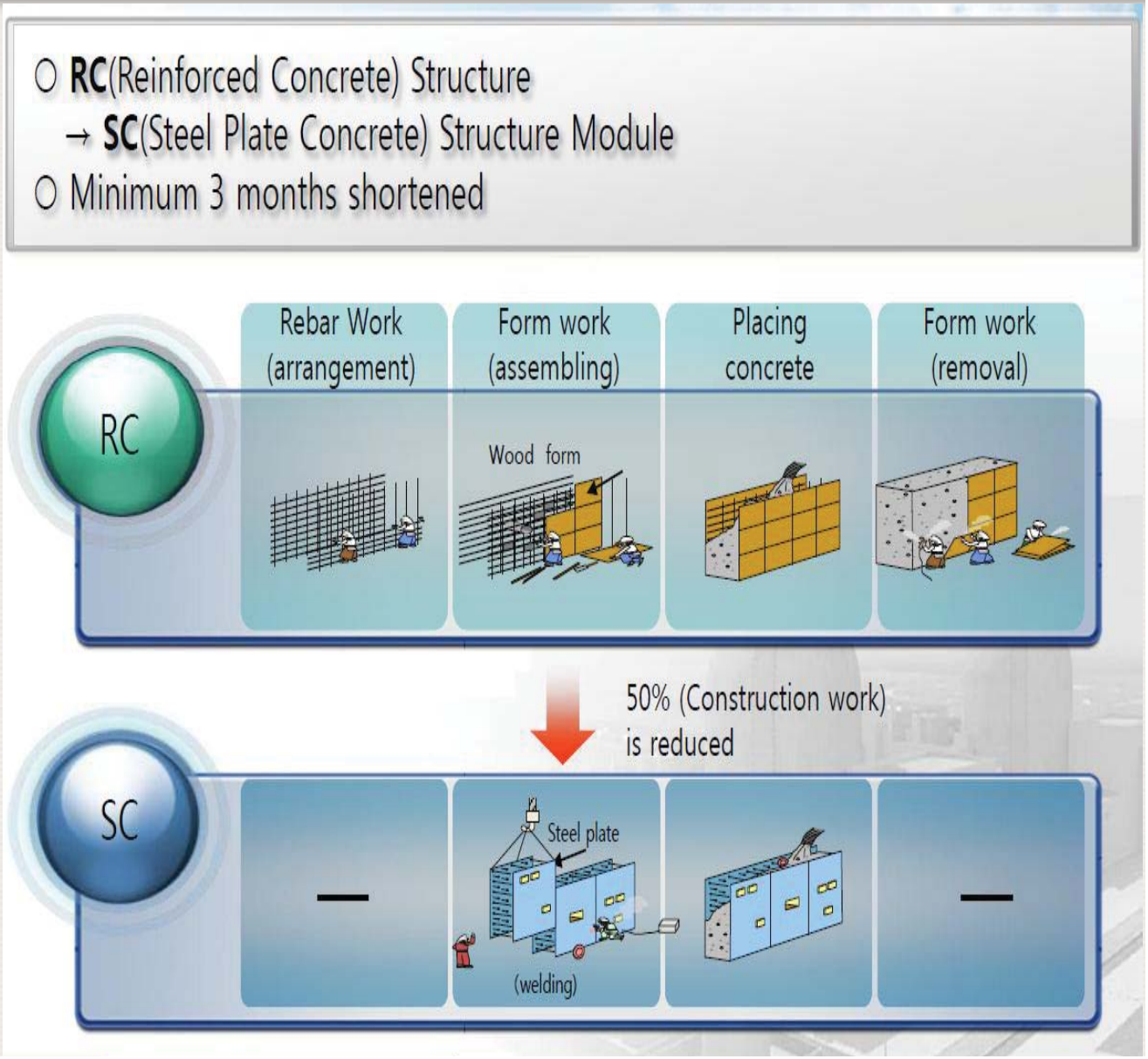
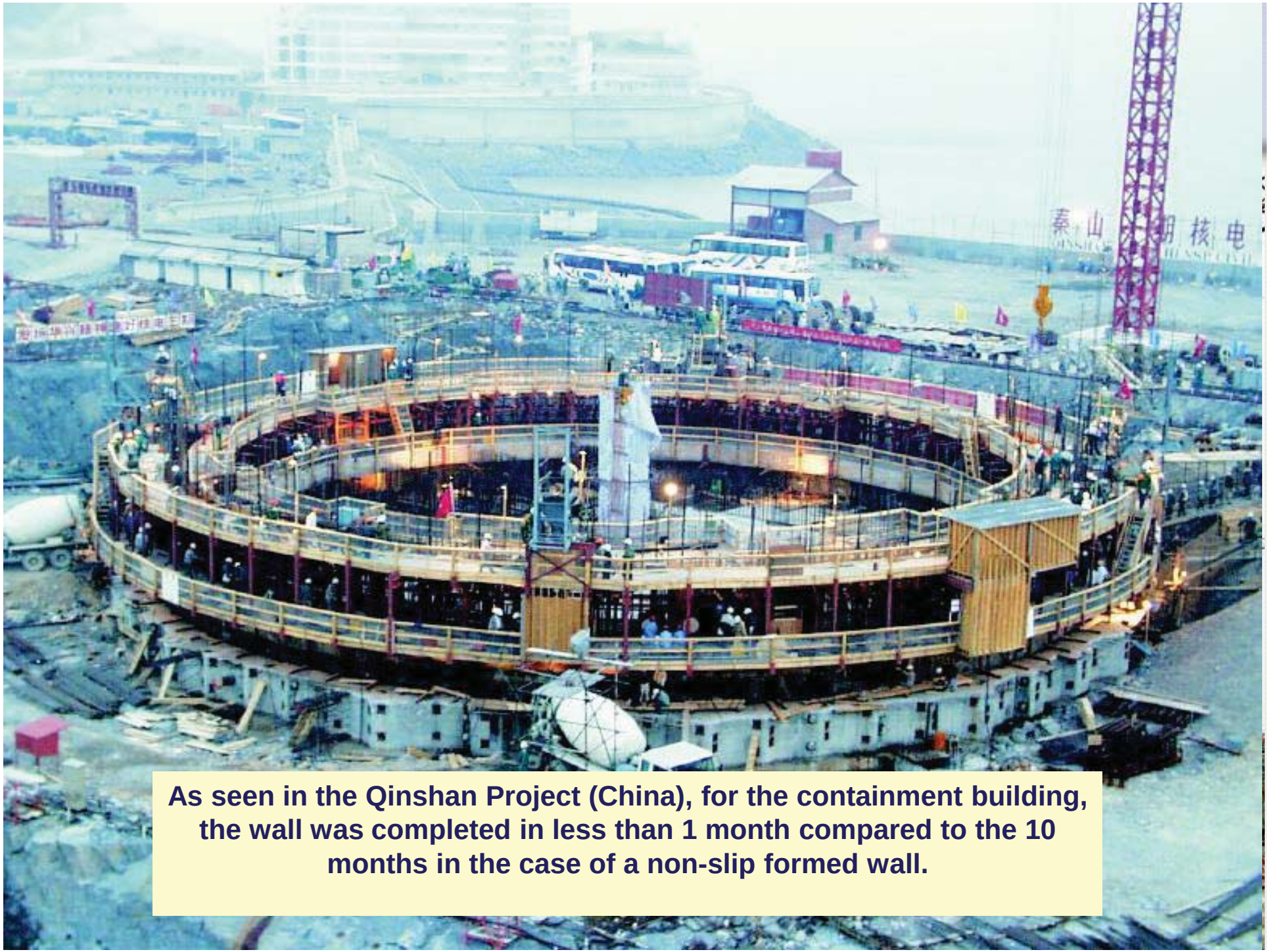
Steel Plate Reinforced Concrete Structures

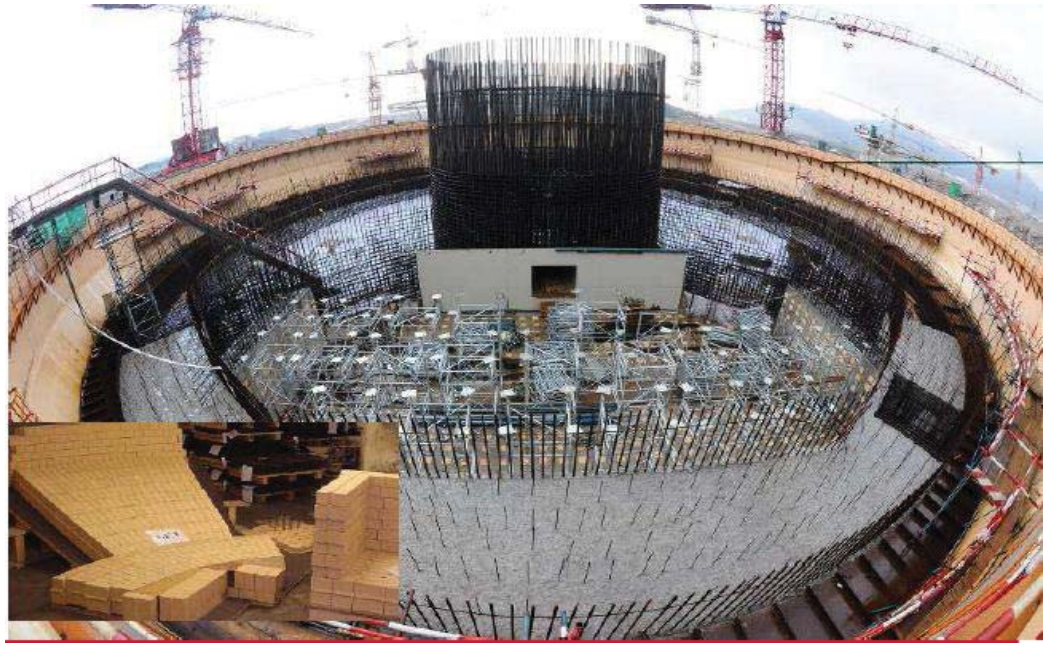
- Significant reduction of on-site works

- SC wall construction is twice as fast as RC wall





As seen in the Qinshan Project (China), for the containment building, the wall was completed in less than 1 month compared to the 10 months in the case of a non-slip formed wall.

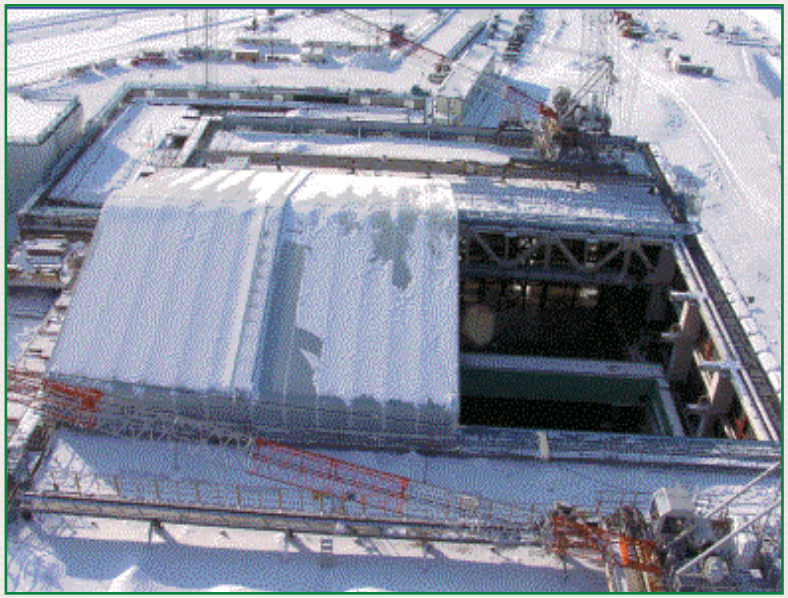



ZOOMLION
中联华兴

Four Season Construction

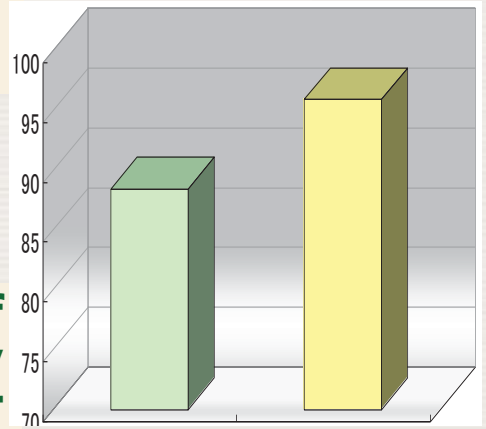
All-Weather Construction Method

Buildings with the All-Weather Structure (Steel and Temporary cover)



Movable Temporary Roof

Improvement of Work Productivity during winter



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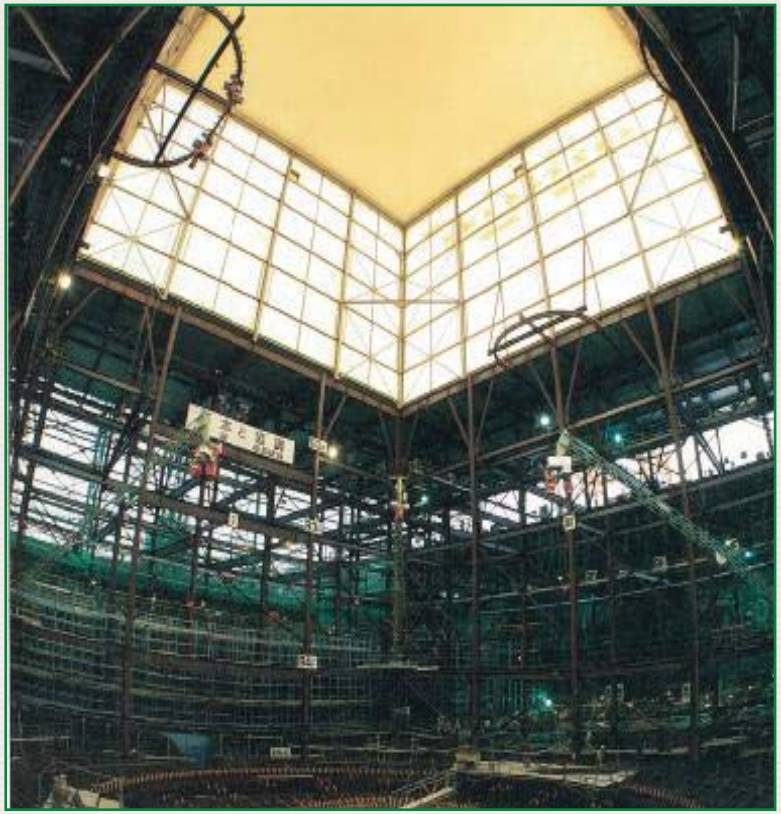
Four Season Construction

All-Weather Construction Method



Inside of All-weather structure (Reactor Building)

Installation of Condenser module using Overhead crane equipped in All-weather Turbine Building

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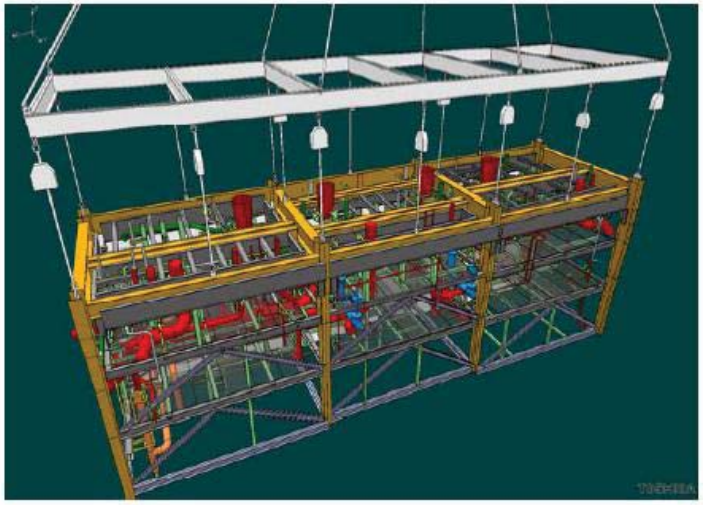
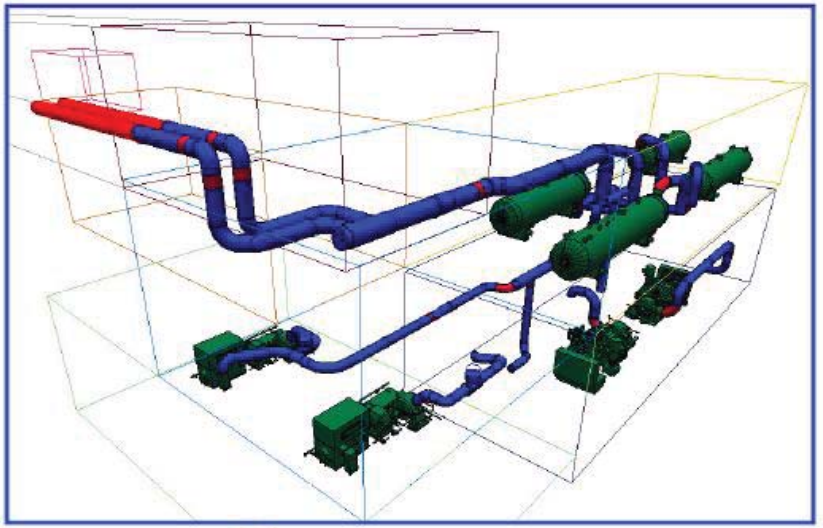
Construction Planning with 3D model

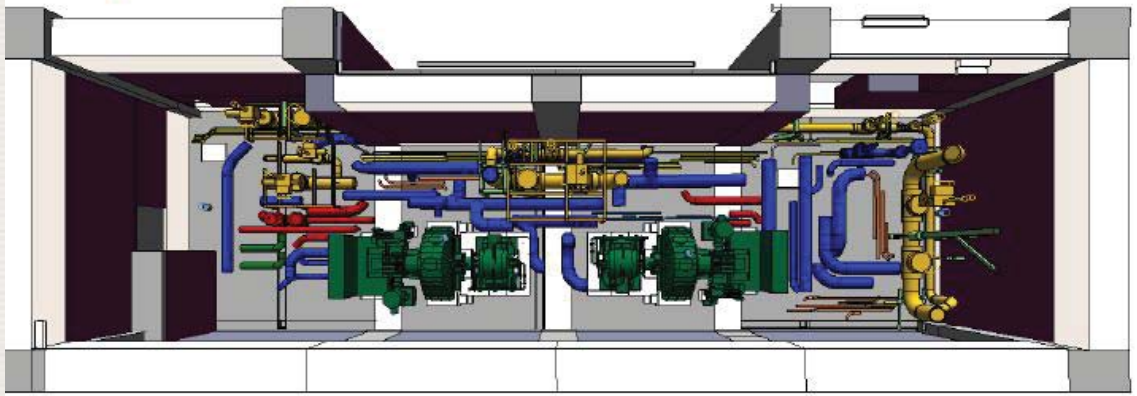
Module



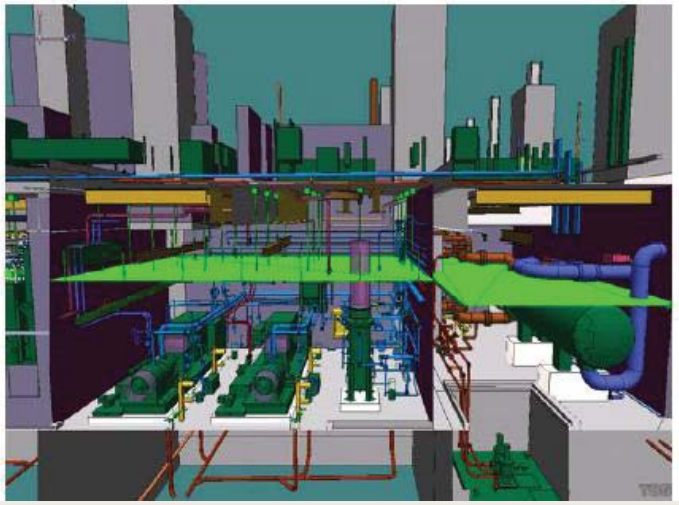
Pipe Spool



Open-top



Temporary



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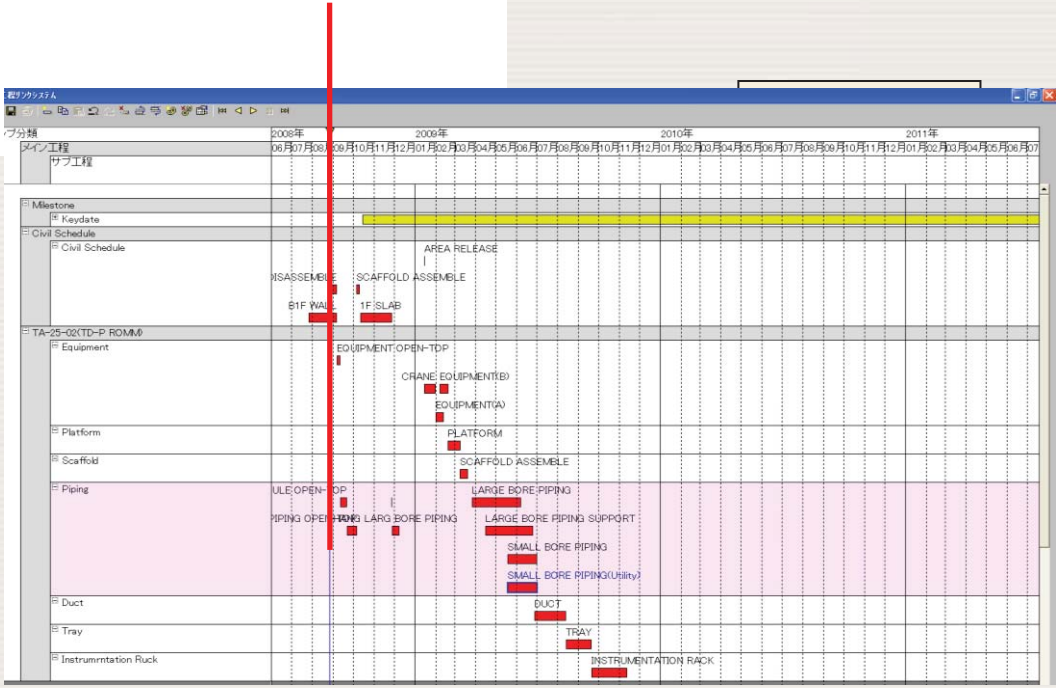
Construction Schedule with 6D

3D-model linked with Schedule



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COMMISSIONING

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Key Events for Commissioning Test

- Initial Energization
- Utilities Production
- CHT(Cold Hydro Test)
- SHT(Secondary Hydro Test)
- SIT(Structure Integrity Test)
- ILRT(Integrated Leak Rate Test)
- HFT(Hot Functional Test)
- Fuel Loading
- PAT(Power Ascension Test)
- Plant Performance Test

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CAPACITY BUILDING OWNER / OPERATOR

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Activity	Lead responsibility		
	Turnkey	Split package	Multiple package
Pre-project activities	U	U	U
Project management	MC	AE or U	U + AE
Project engineering	MC	AE + SS	U or AE
Quality assurance	MC + U	AE + SS + U	U + AE
Procurement	MC	AE + SS	U or AE
Application for license	U	U	U
Licensing	RA	RA	RA
Safeguards, physical protection	U	U	U
Manufacturing	MC	SS + EM	EM
Site preparation	U or MC	U or AE	U or AE
Erection	MC	AE + SS	U or AE
Equipment installation	MC	AE + SS	U or AE
Commissioning	MC	AE + U	U or AE
Plant operation and maintenance	U	U	U
Fuel procurement	U	U	U
Fuel fabrication	FS	FS	FS
Waste management	U	U	U

AE=Architect-engineer
FS=Fuel supplier
MC=Main contractor
EM=Equipment manufacturer
RA=Regulatory authority
SS=System supplier
U=Utility

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Each Phase of An NPP's Life Cycle Is Unique, and Requires A Different Staffing Model

- The NPP Life Cycle can be divided into eight phases:
  1. Plant Design Selection
  2. Site Selection
  3. Plant Licensing
  4. Construction
  5. Start Up/Testing
  6. Commercial Operations
  7. Shut Down/Safe Store
  8. Decommissioning
- Each life cycle phase should be examined at the level of job functions required during that time window

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STAFING REQUIREMENT

- National/local regulatory staffing environment
  - Oversight regulations
  - Reporting requirements
  - Licensing approach and frequency
- Site size and design/layout of facilities
  - Total site footprint
  - Location and relationship of buildings and infrastructure systems
- Plant design
  - NSSS type
  - Safety systems
  - Design capacity
- Plant equipment layout
  - Equipment accessibility
  - Size and locations of laydown space

Many Staffing Functions Have Multiple Drivers That Must All Be taken Into Consideration For New Nuclear Plants

- Each staffing function may have more than one site, plant, or organizational driver
- This table summarizes the complexities of staffing requirements when five major drivers are considered
  - Plant Design
  - Site Layout
  - Regulatory Requirements
  - Outsourcing Options
  - Ability to Centralize
- Careful labor planning can save significant costs over the plant's lifecycle

Area	Function	Plant Design	Site Layout	Regulatory Requirement	Outsourcing	Centralization
Operations	Applied Radiation Protection	X		X	X	X
	ALARA/Radiological Engineering	X				
	Chemistry	X				
	Decontamination/Radwaste Processing	X				
	Environmental		X			
	Fire Protection	X	X			
	Operations	X	X	X		
	Operations Support	X	X			
	Radiation Protection Support			X	X	X
Engineering	Computer Engineering	X	X	X		X
	Design/Drafting	X	X			
	Modifications Engineering	X	X			
	Nuclear Fuels	X	X			
	Plant Engineering	X	X			
	Procurement Engineering					
	Project Management				X	X
	Reactor Engineering	X	X	X		
	Technical Engineering	X	X		X	X
Maintenance	Facilities Maintenance		X		X	X
	Maintenance/Construction	X	X			
	Maintenance/Construction Support	X	X			
	Outage Management	X	X			
	Quality Control/Non-Destructive Examination					
	Safety/Health	X		X		X
	Scheduling	X				
Regulatory	Emergency Preparedness	X	X			
	Licensing	X				
	Nuclear Safety Review					
	Quality Assurance					
	Security	X	X			
Site Support	Budget/Accounting			X		X
	Communications					
	Contracts					
	Document Control/Records					
	Human Resources					
	Information Management				X	X
	Management			X		
	Management Support					
	Materials Management	X			X	X
	Purchasing				X	X
	Training		X	X		X
	Warehouse	X	X		X	X

OPERATION

ENGINEERING

MAINTENANCE

REGULATORY

SITE SUPPORT

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An Organizational Approach Will Also Be Required To Optimize Effectiveness of The Staff In Each Phase

- Once staffing requirements have been derived for each phase of the NPP's life cycle, an organizational structure/design will be required for each

- Four organizational principles should be applied:

  1. Balance layers of management and spans of control
  2. Align related and supporting functions
  3. Outsource functions that are:
     - Not required to be on-site/on-location, or
     - Not mission critical for operation, or to meet regulatory requirements
  4. Centralize functions with a parent company, where possible, due to the parent company or an alliance member having other power generation facilities

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TO AVOID

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NON SUCCESFULL NP PROGRAMMES

Zwentendorf NPP, Austria

(1978)

KEDO 1&2

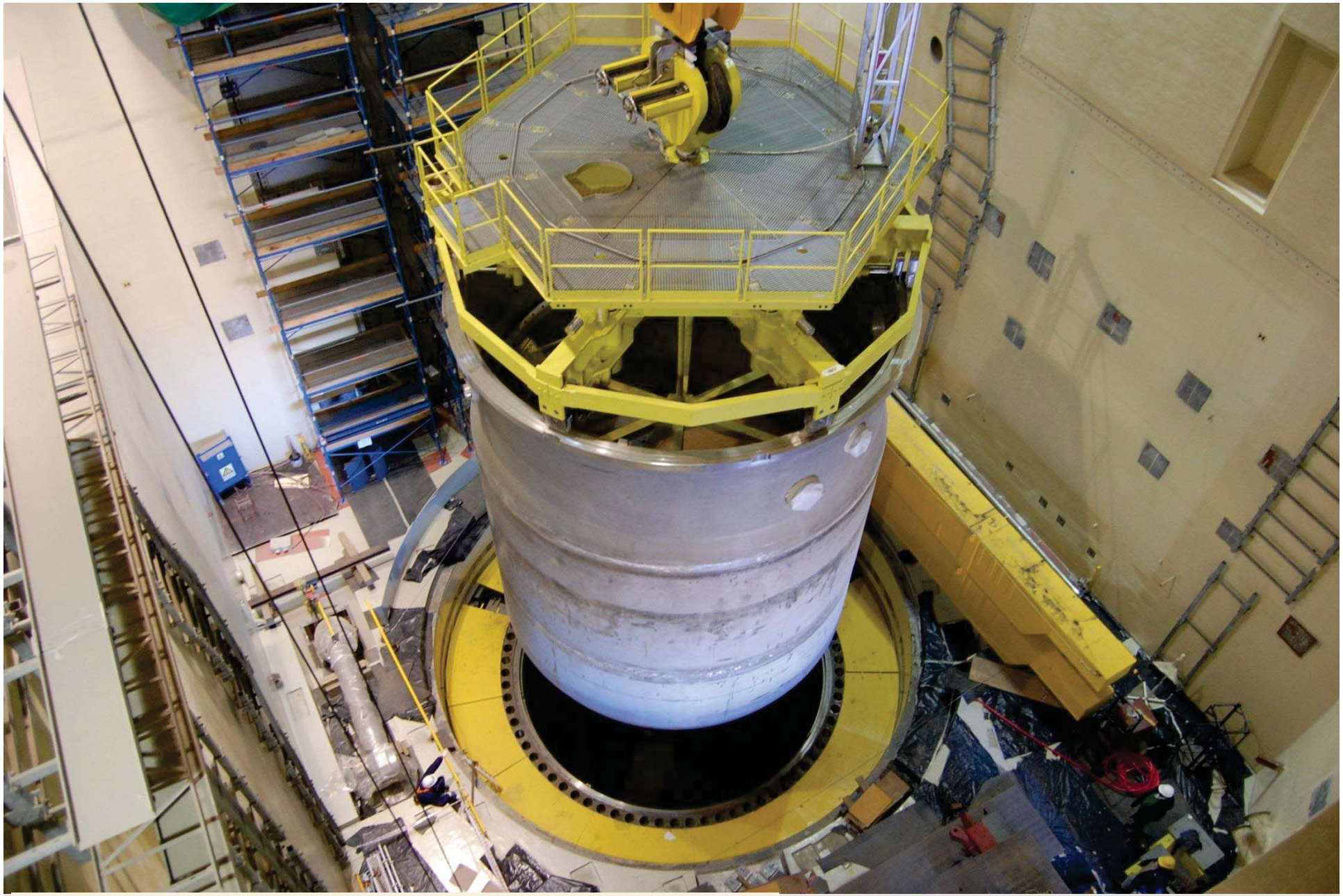
Batan NPP in Philippines

(1976) Completed but never fuelled

Preservation Of Stored Components

Angra 3 NPP in Brazil

Cernavoda NPP, Romania
Right: Unit 1 /2 (in operation), Unit 3 (in preservation)
Left: Unit 4 and 5 (in preservation)



Atucha II NPP – Argentine (1980)

Installation of Moderator Tank, June 2009

CONCLUSION

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SUMMARY & CONCLUSION

- 61 plants under construction & FUKUSHIMA accident
  - give many **different signals for the future**
- Future will have many **different options**
- Each country will adopt **different strategies**
  - Energy **independence** would be a key driver
  - **Localization** will play a major role
  - Many suppliers aiming for big portions of market
  - Using small plants !

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CONCLUSION

- Selection of these construction methods should be done in the conceptual stage
- Requires early investment in factories and shops
- Shortage of specialized skills and equipment may be a problem for some countries to implement the advanced methods
- Early Investment in the education of the contractors and fabricators must be prioritized
- There is no “one size fits all” - what works for Country X may not work for Country Y

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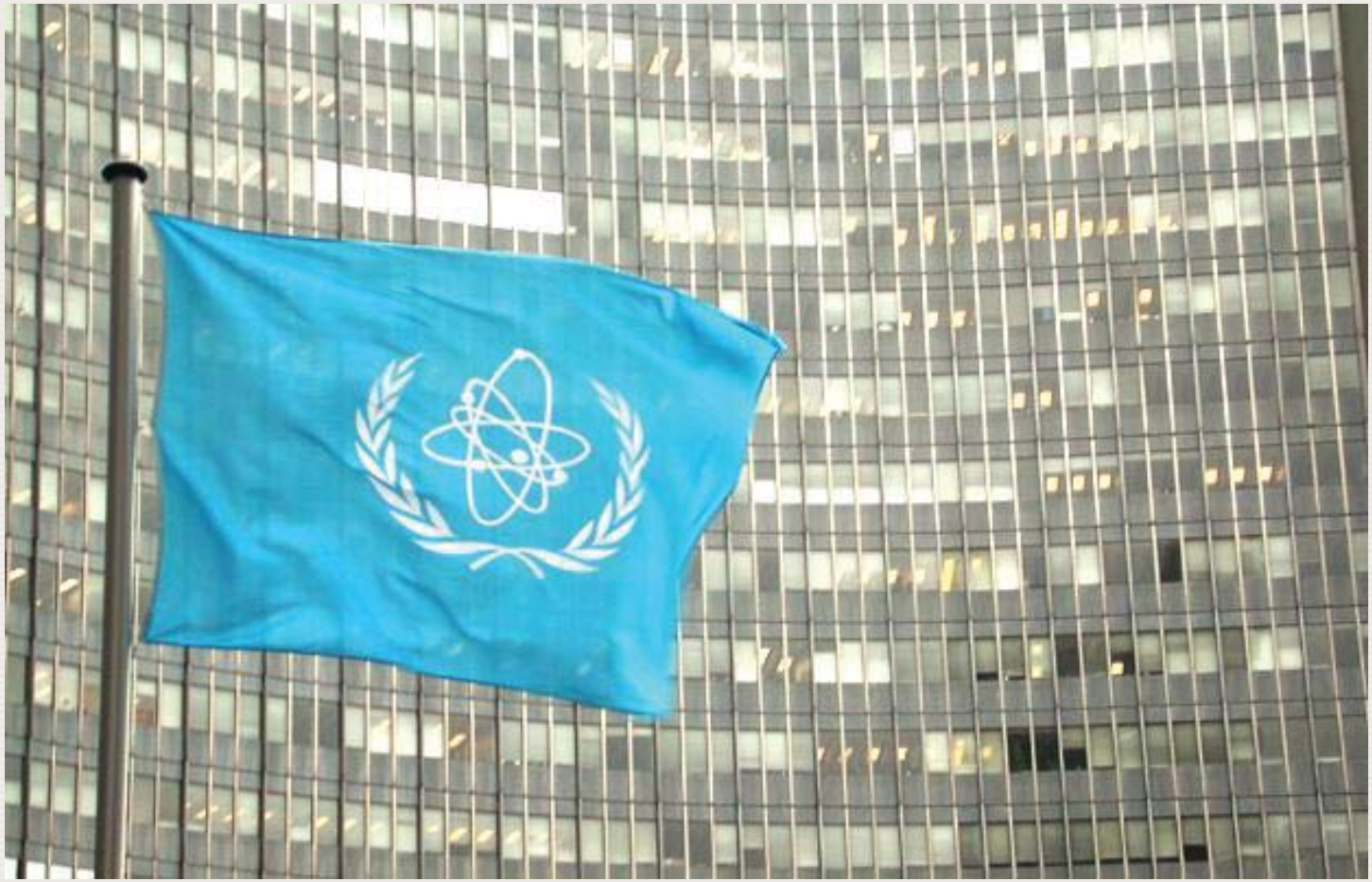

…atoms for peace.

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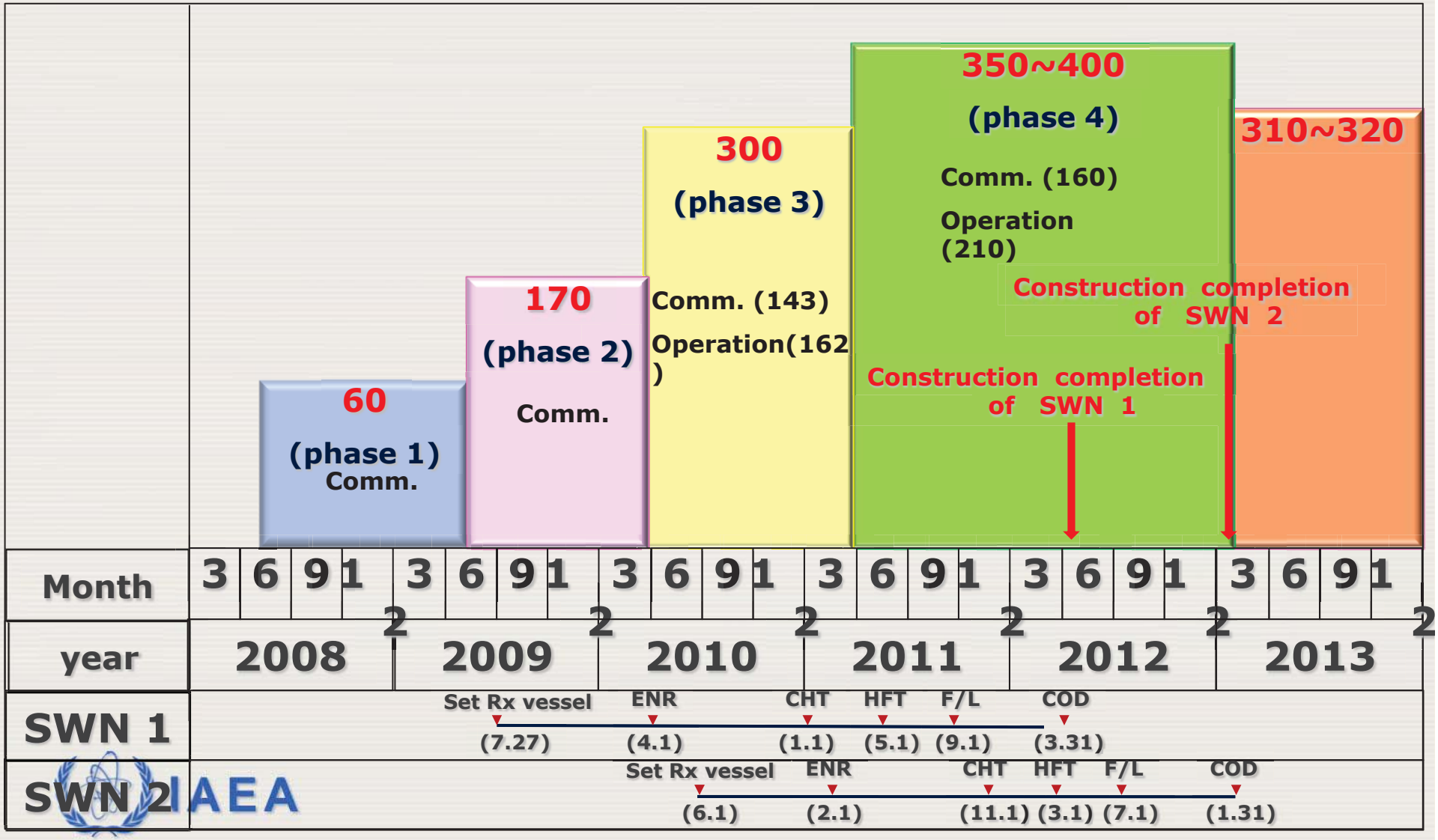
Commissioning Manpower Control



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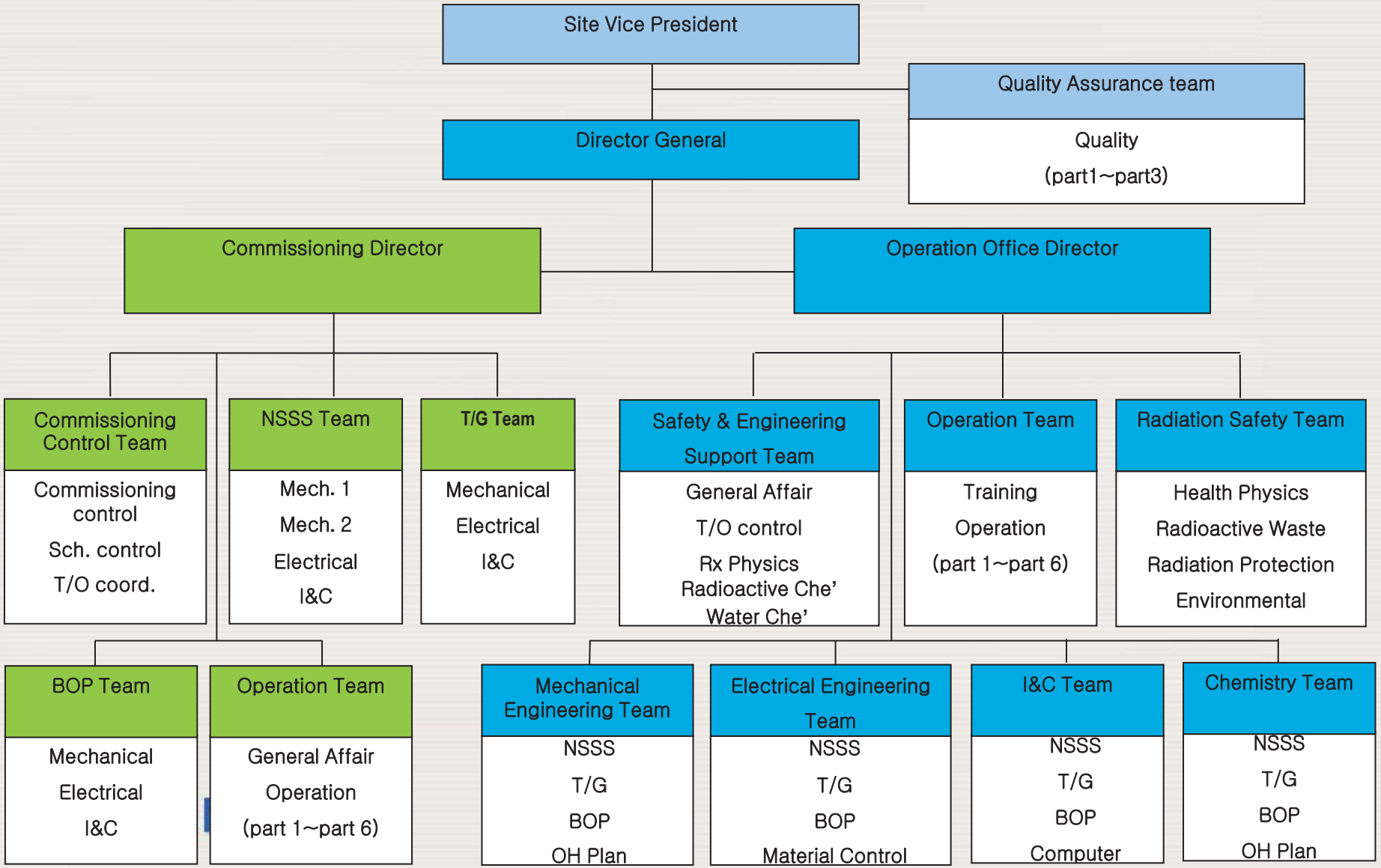
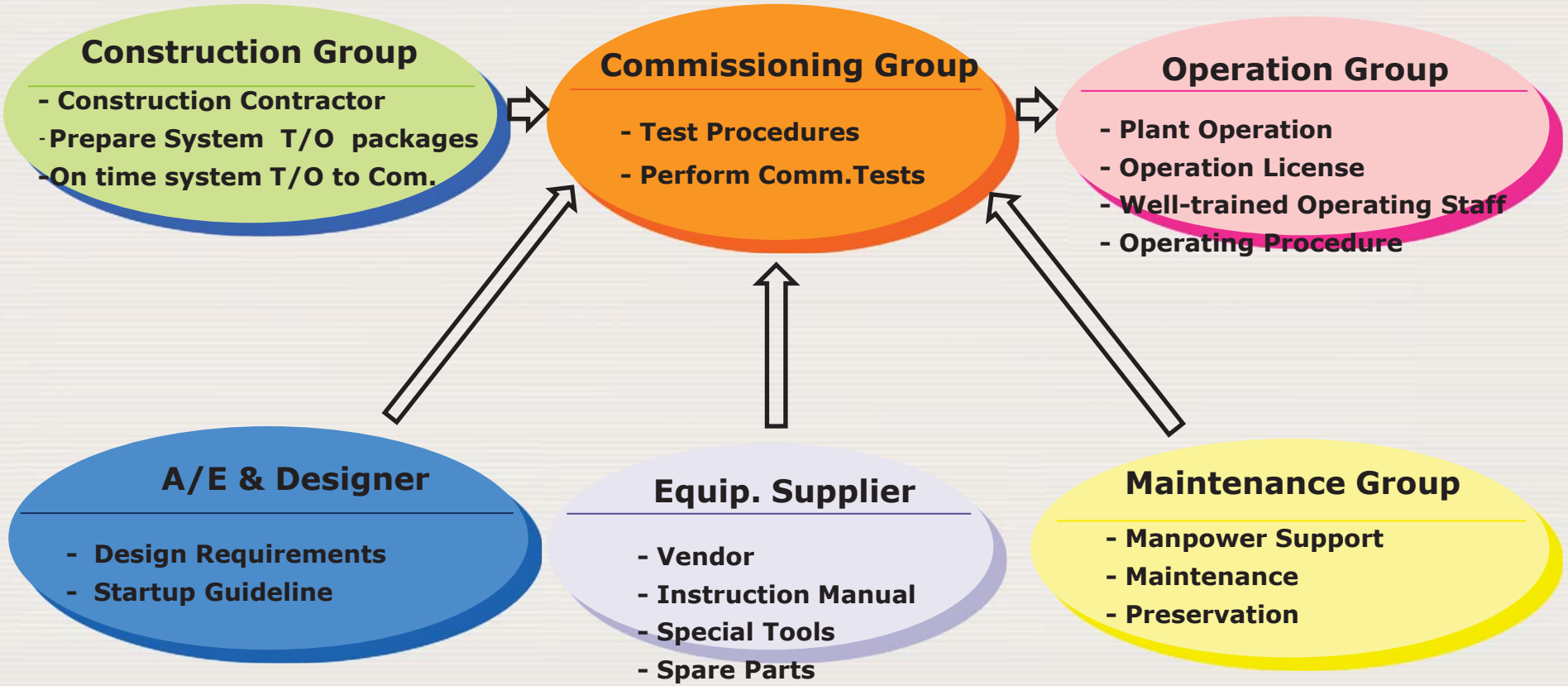
Commissioning organization



Structure of Commissioning Support



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