Safety Classification of a Fusion DEMO

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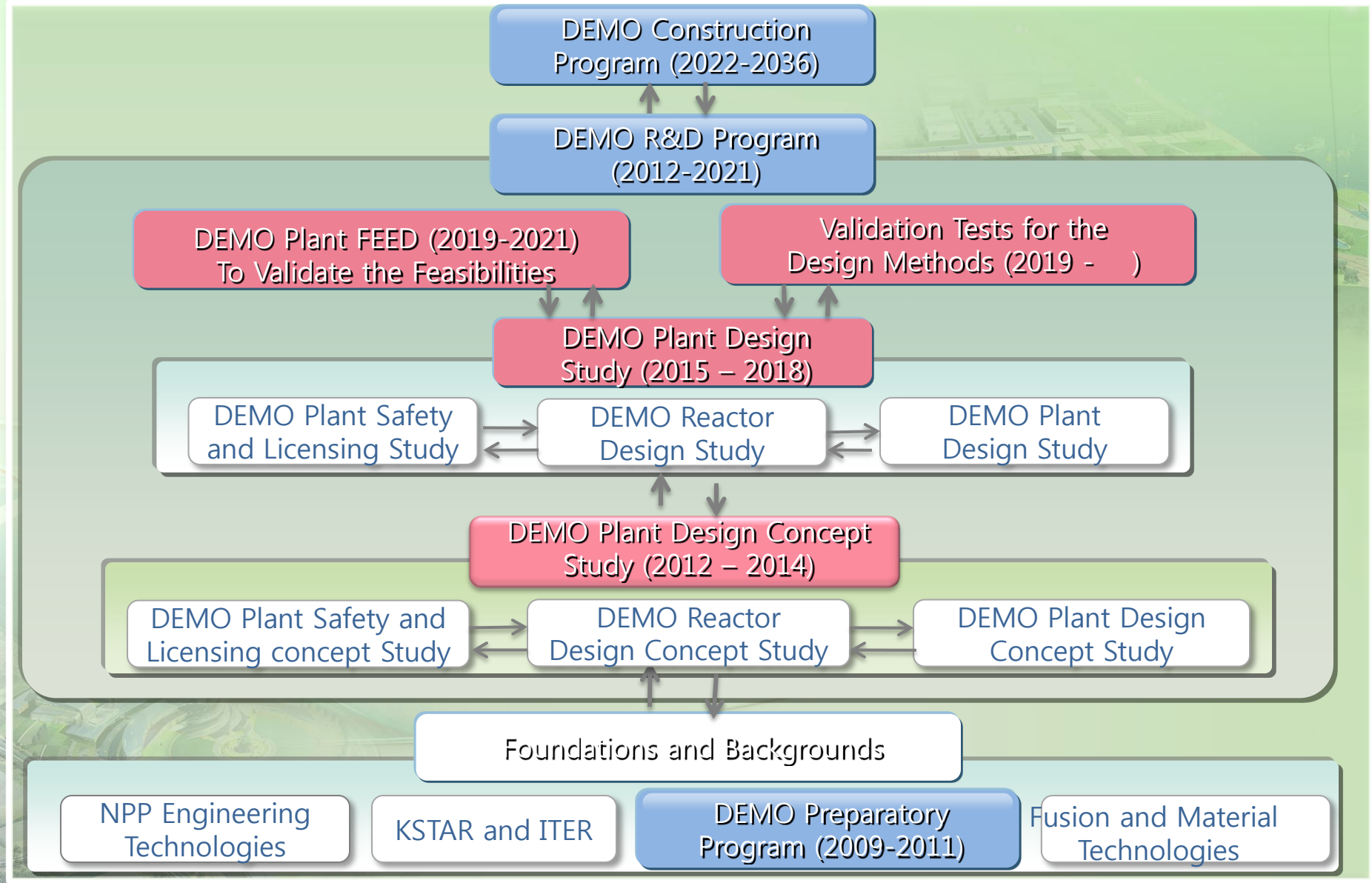
CONTENTS

Overview of the DEMO program of Korea

Phased Programs



Implementation Plans / DEMO R&D Sub-Program (I)

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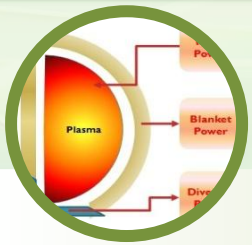
Scope of Works

- Develop Technologies for the Design, Fabrication and Construction of DEMO Systems and Components
- Complete DEMO FEED and Prove Economic and Technical Feasibilities;
- Construct the Validation Test Facilities and Validate the Design Methods

Timelines



2014

- Define DEMO Design Concept
- Front-end DEMO R&D Activities

2018

- DEMO Reactor System Design Study
- DEMO Plant System Design Study

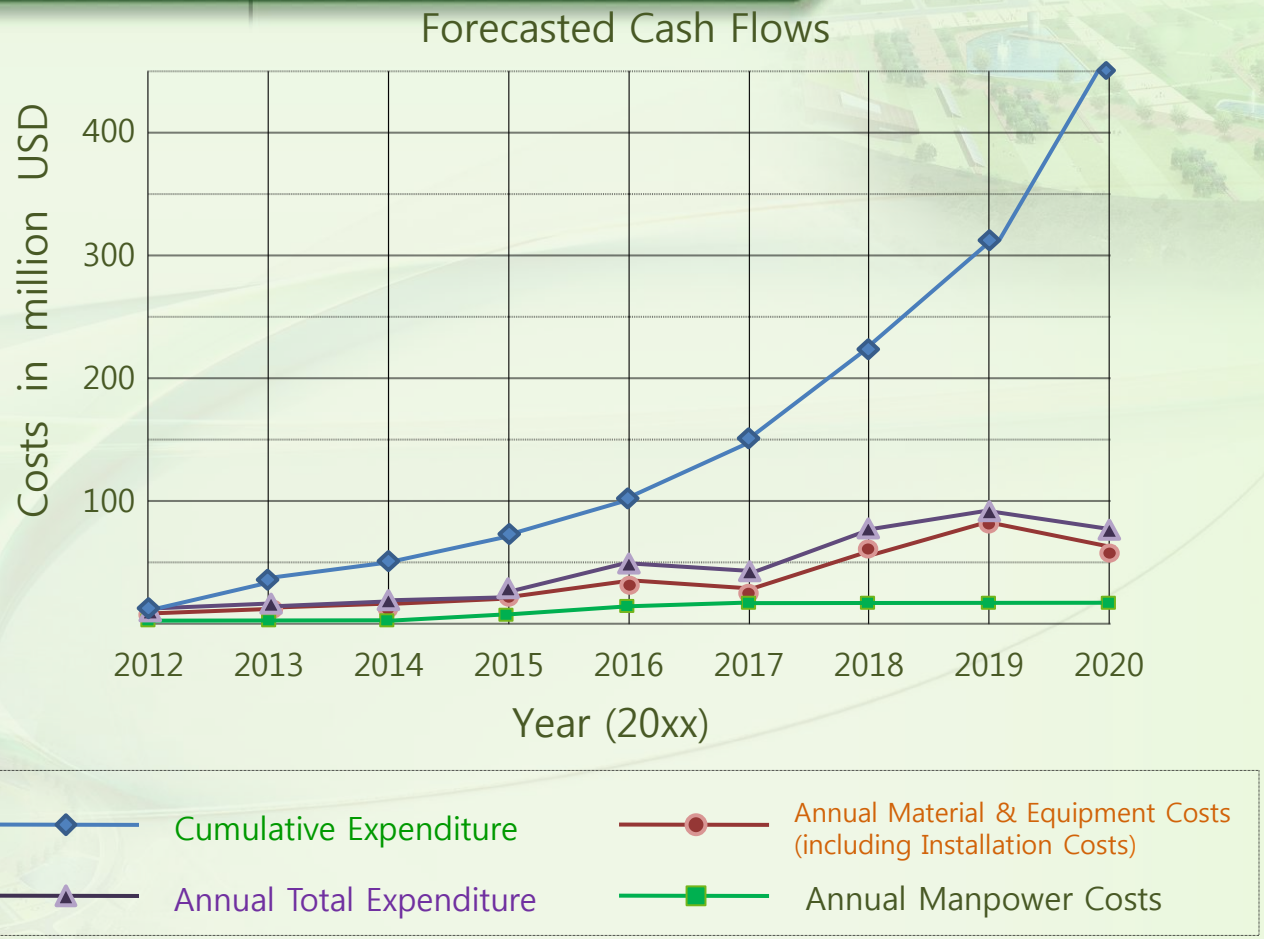
2021

- DEMO FEED & Prove Feasibilities
- Site Selection

Start DEMO Design

Resource Forecasts

- 420 at the Peak, 2,200 Man-years NFRI Staff
- 450 million USD Total Capital Investment



New Campus and Validation Test Facilities Plan

Scope of Works

- Design and Construct the Fusion DEMO Plant;
- Test Materials, Components and Systems;
- Demonstrate Power Generation (1st Phase)

※ Performance and Economic Feasibility (2nd Phase, after 2036)

Timelines (1st Phase DEMO)

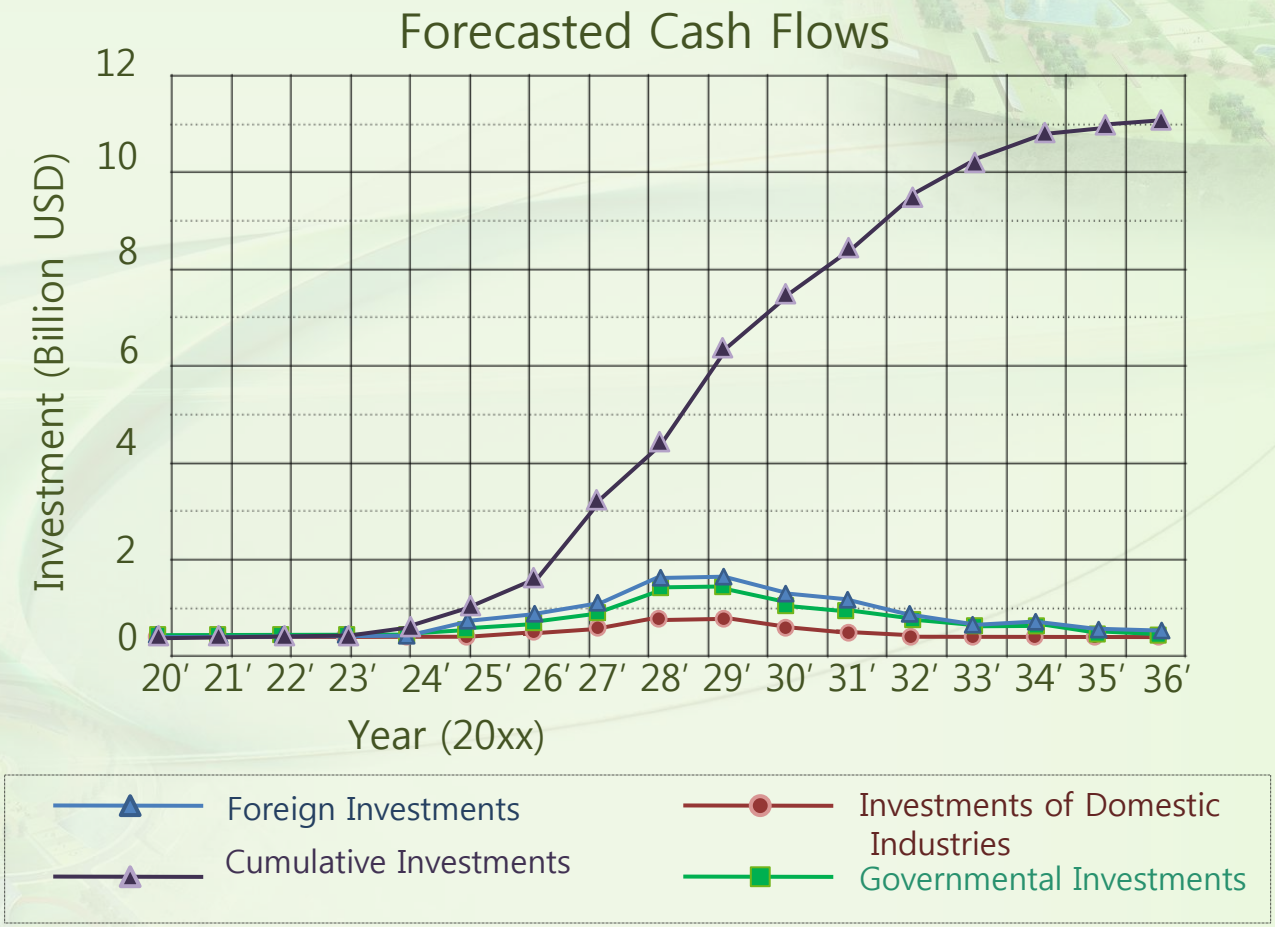
'2022	'2024	'2025	'2029	'2033	'2035	'2036
Construction Permit	Start Excavation	Select the Materials	Start Installation of Major Components	Start Commissioning	Start Operation	First Electric Power Generation

The 2nd Phase DEMO

- Select a New Set of the DEMO Materials (2030)
- Complete the Design Improvements (2033)
- Second Stage DEMO Construction Permit (2037)
- Improve the DEMO Plant (2038)

Resource Forecasts

- 4.5 to 11 billion USD with an order of magnitude method
- 600 at the peak and 3,600 man-years NFRI staff



A Hypothetical View of Fusion DEMO Plant

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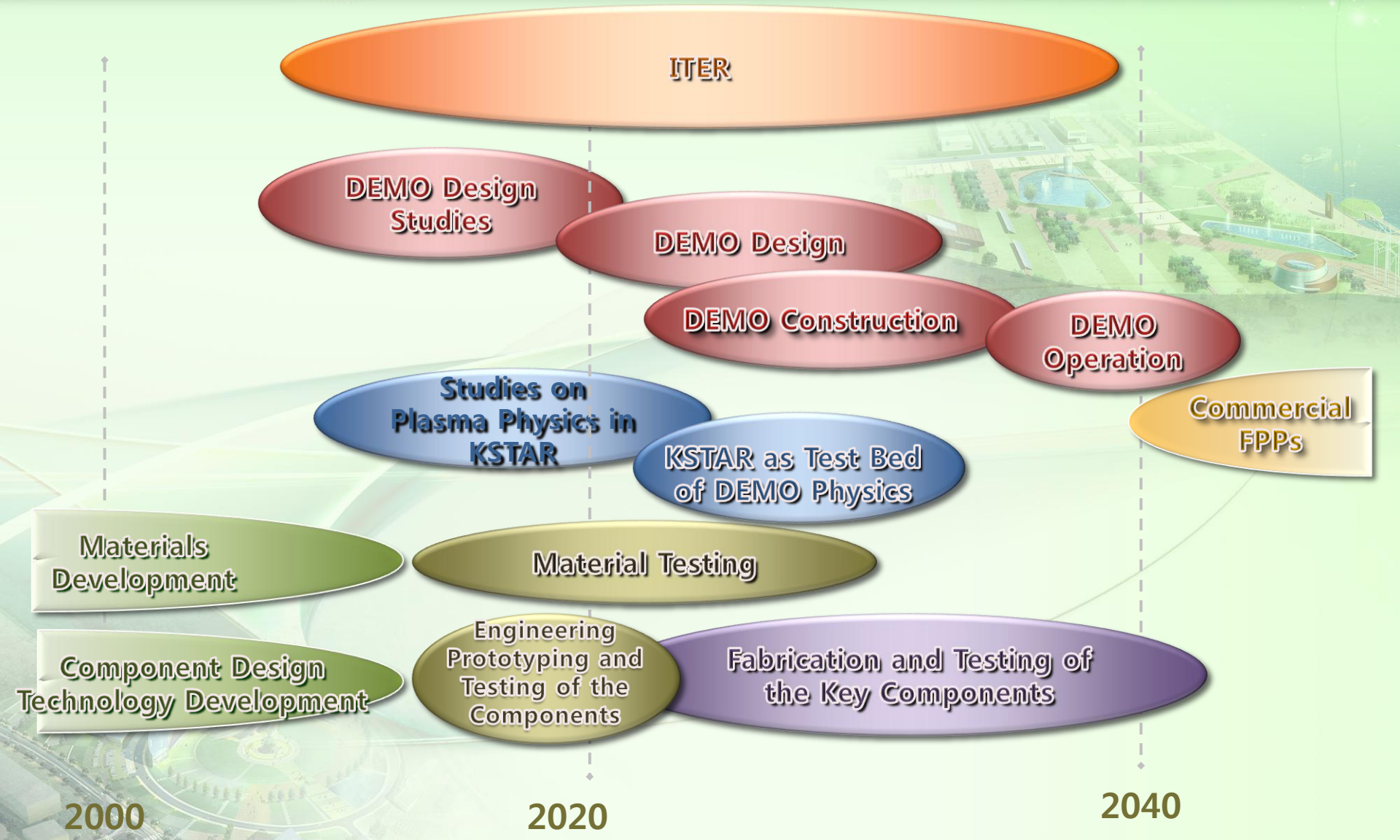
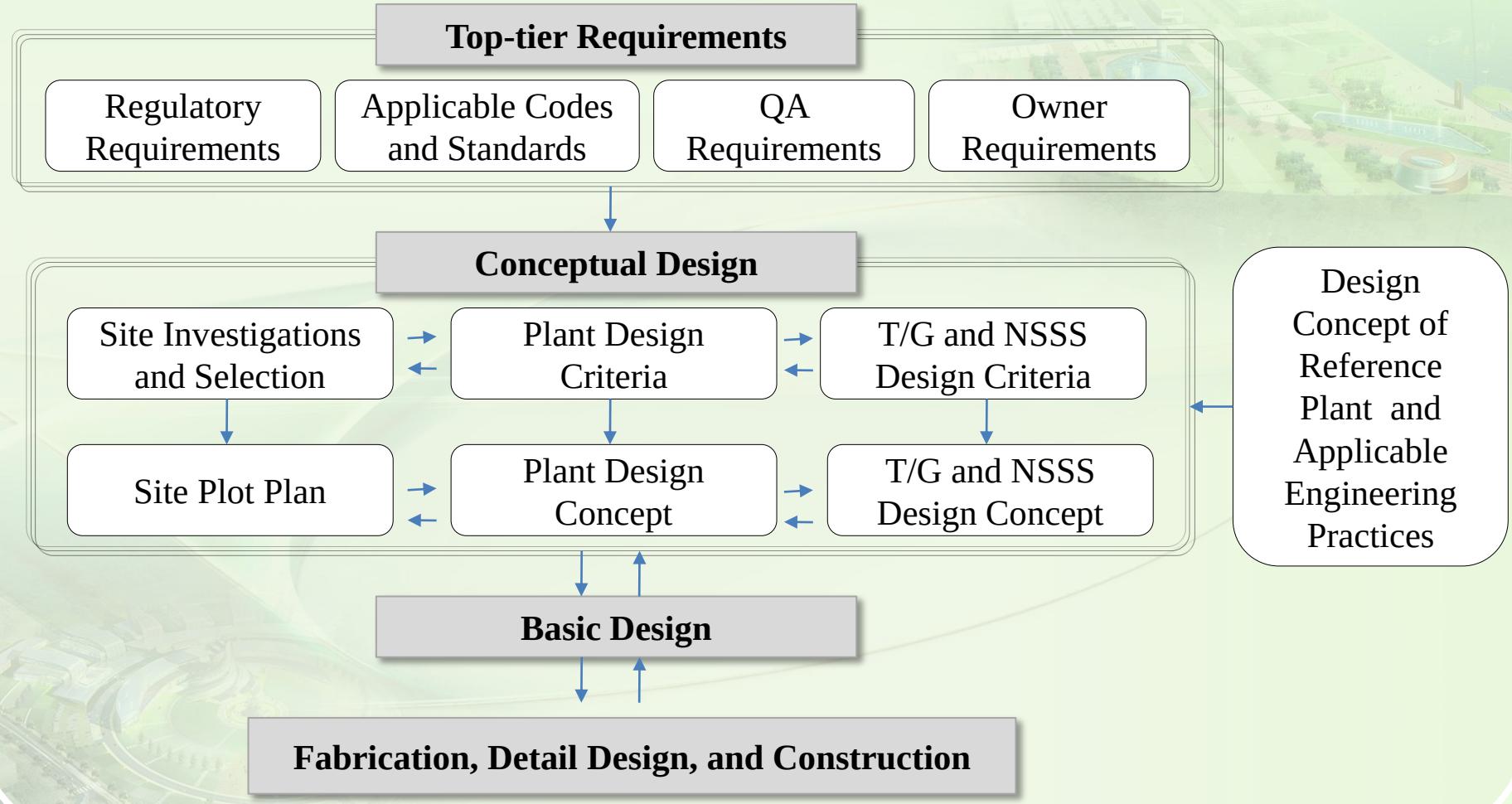
Ⅰ. Background

- Processes for Developing DEMO
- IAW vs. Properly
- Compulsory Top-tier Requirements

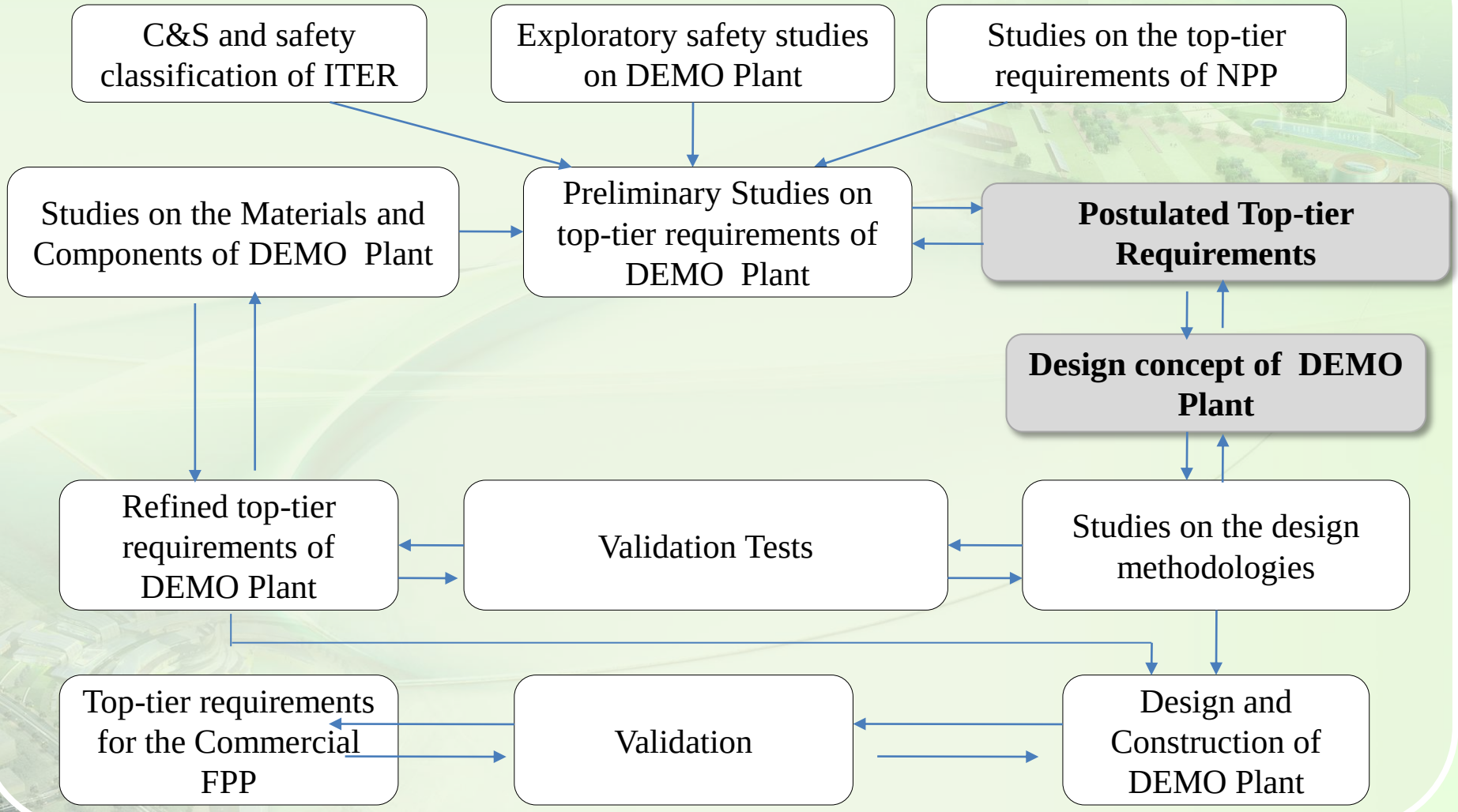
Processes for Developing DEMO (1)



Typical Processes of NPP



Proposed Processes for DEMO



Properly vs. IAW

With C&S	Without C&S
Design sth IAW C&S applicable	Properly design sth
Select the material IAW C&S applicable	Properly select the material
Fabricate sth IAW C&S applicable	Properly fabricate sth
Test IAW C&S applicable	Properly test sth
Install sth IAW C&S applicable	Properly install sth
Commission sth IAW C&S applicable	Properly commission sth
Operate and inspect sth IAW C&S applicable	Properly operate and inspect sth

Compulsory Top-tier Requirements

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- Impossible to convert sth to C&S,
  Impossible to design and build sth.

- Impossible to translate sth into a law (laws)
  Impossible to license sth.
- Including GDC (General Design Criteria),
  Classification Criteria,
  and QA Requirements
  (Also have Cost Implications)

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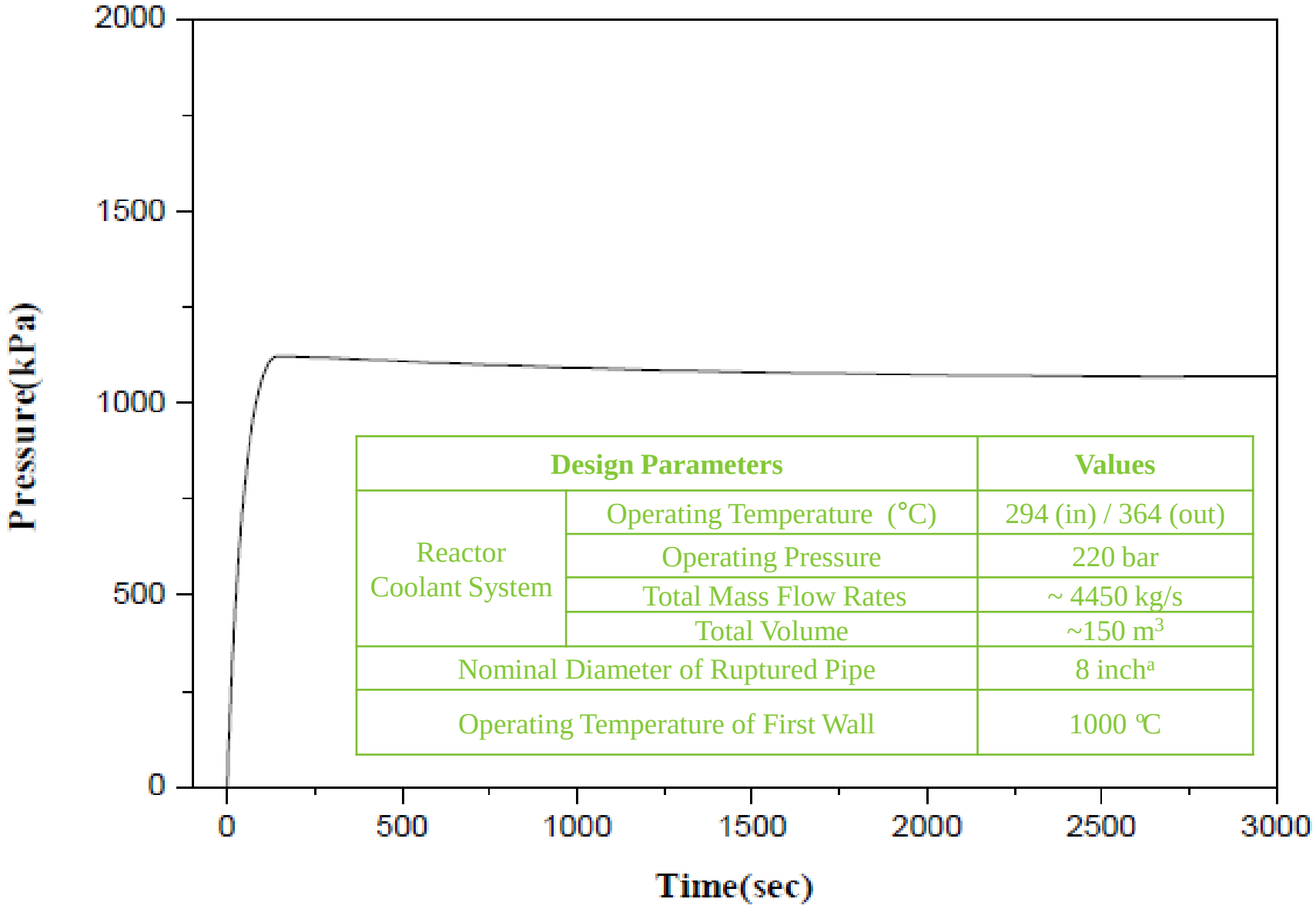
II. Exploratory Safety Studies

- Pressure Build-up after an In-vessel LOCA
- Radiation Releases after Postulated Events

Pressure Build-up after an In-vessel LOCA



Design Parameters		Values
Reactor Coolant System	Operating Temperature (℃)	294 (in) / 364 (out)
	Operating Pressure	220 bar
	Total Mass Flow Rates	~ 4450 kg/s
	Total Volume	~150 m^3
Nominal Diameter of Ruptured Pipe		8 inch[a]
Operating Temperature of First Wall		1000 ℃

Radiation Releases after Postulated Accidents

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- A breach of VV or tritium piping systems;
- A typical NPP site is postulated;
- Total release of 1kg of tritium at the height 10m, wind velocity of 6.4km/h, and under the most unstable atmospheric condition;
- The radiation dose in disintegration rate is 37 TBq.

Distance (Km)	Dose Rate in mSv
0.8	240
1.6	150
3.2	100
16.0	80
24.0	46
48.0	7

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III. Safety Classification of NPP

- Criteria of the Boundaries of SSCs
- Criteria of Radiation Releases
- Classification of SSCs of NPP

Criteria of the Boundaries of SSCs (1)

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- Quality Group, Safety Class, Seismic Category, IEEE Electrical Class;
- Quality Group A = Safety Class 1 = Seismic Category I = SSCs (Structures, Systems, and Components) in the Reactor-Coolant-Pressure-Boundary (RCPB);
- Quality Group B = Safety Class 2 = Seismic Category I = SSCs in the Reactor Containment Boundary (RCB);
- Quality Group C = Safety Class 3 = Seismic Category I = SSCs of the Other Safety Functions

Criteria of Radiation Releases

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- Quality Group, Safety Class, Seismic Category, IEEE Electrical Class;
- Quality Group A = ditto =SSCs (Structures, Systems, and Components) in the Reactor-Coolant-Pressure-Boundary (RCPB);
- Quality Group B = ditto = No US Regulations

※ ESPN N2 = SSCs of which a failure could lead to the radiation release of exceeding 3.7GBq (ESPN of France)

- Quality Group C = ditto = SSCs of which a failure could lead to the radiation release of exceeding 50mSv (RG 1.26 of US).

※ ESPN N3 = exceeding 370 MBq

Classification of SCCs of NPP

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Classification Category	Classification Criteria andApplicable C&S
Safety Class of ANS (American Nuclear Society) and ASME for Fluid systems, Pressure Vessels, Piping, Pumps and Valves	Safety Class 1: - The components specified in the left column and systems of the Reactor Coolant Pressure Boundary; - ASME Section III Sub-section NB Safety Class 2: - The components and systems of Reactor Containment Boundary; - ASME Section III Sub-section NC Safety Class 3: - The components and fluid systems performing safety functions during normal operations or after a postulated events but not classified as Safety Class 1 and 2; - ASME Section III Sub-section ND Non-Nuclear Safety Class: - Systems and components not performing safety functions; - For vessels, ASME Section VIII; - For piping and valves, ASME B31.1 - For pump, best engineering practices
Quality Group for for the Systems, Pressure Vessels, Piping, Pumps andValves	Quality Group A: Safety Class 1 systems and components Quality Group B: Safety Class 2 systems and components Quality Group C: Safety Class 3 systems and components Quality Group D [a]: Non-Nuclear Safety Related systems and components
Safety Designation for SSCs and Systems [b]	Safety Related: SSCs and systems performing safety functions during normal operations or after a postulated events Non-Safety Related: SSCs and systems not classified as Safety Related
Seismic Category for SSCs [b]	Seismic Category I: SSCs of which Quality Group is A, B, or C and Portions of the fire fighting systems that shall remain functional in the event of a safe-shutdown earth quake Seismic Category II: SSCs remain integrity in the event of an operational base earth quake Non-Seismic: SSCs other than Seismic Category 1 and 2
Classification for the electrical, and instrumentation & control components	IEEE Electrical Class 1E: Electrical systems and components performing safety functions IEEE Non-Class 1E: Electrical systems and components other than Class 1E

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Ⅳ. Classification for DEMO Plant

- Classification Criteria Proposed
- Classification of SSCs of DEMO Plant

Classification Criteria Proposed

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- Quality Group, Safety Class, Seismic Category, IEEE Electrical Class;
- Quality Group A = Safety Class 1 = No SSCs due to the Inherent-Passive-Safety of the Fusion Reactor;
- Quality Group B = Safety Class 2 = SSCs of which a failure could lead to the radiation release of exceeding 3.7GBq;
- Quality Group C = Safety Class 3 = SSCs of which a failure could lead to the radiation release of exceeding 50mSv or 370 MBq;
- Seismic Category I and IEEE Electrical Class 1E for the Safety Related SSCs.

Classification of SCCs of DEMO Plant

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SSCs	Proposed Classification Criteria
Systems and Components of VVPB including the Tritium Systems	Quality Group B, Seismic Category I
Systems and Components of RCB	Quality Group B, Seismic Category I
SSCs of VVPB	Safety Related, Seismic Category I
Engineered Safety Features (Fluid systems)	Quality Group B, Seismic Category I
Safety Related Electrical and I&C Systems and Components	Class 1E, Seismic Category I
BOP Safety-Related Systems and Components	Quality Group C, Seismic Category I
BOP Safety-Related Structures	Safety Related, Seismic Category I
In Vessel Components	Quality Group B, Seismic Category I

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V. The Other Requirements

- Applicability of GDC and QA of NPP to DEMO
- Review on the Applicability of GDC

Applicability of QA and GDC of NPP to DEMO

- For the Front-end Design Studies of DEMO , QA ‘As They Are’;
- GDC ‘With Some Modifications’ based on Postulations and Assumptions.

Reviews on the Applicability of GDC (1)

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General Design Criteria	Applicability
1 Quality Standards and Records	Use As Is
2 Design Based for Protection Against Natural Phenomena	
3 Fire protection	
4 Environmental and dynamic effects design bases	
5 Sharing of structures, systems, and components	Not Applicable
10. Reactor design	Need Modification
11 Reactor inherent protection	Not Applicable
12 Suppression of reactor power oscillations	Need Modification
13 Instrumentation and control	
14 Reactor coolant pressure boundary	
15 Reactor coolant system design	
16 Containment design	Use As Is
17 Electric power systems	
18 Inspection and testing of electric power systems	
19 Control room	
III. Protection and Reactivity Control System (GDC 20 through GDC 29)	Not Applicable
30 Quality of reactor coolant pressure boundary	Need Modification
31 Fracture prevention of reactor coolant pressure boundary	Need Modification
32 Inspection of reactor coolant pressure boundary	Need Modification
33 Reactor coolant makeup	Use As Is

Reviews on the Applicability of GDC (2)

General Design Criteria	Applicability
GDC 34 through 40	Not Applicable
41 Containment atmosphere cleanup	Use As Is
42 Inspection of containment atmosphere cleanup systems	Not Required for the Studies of the Design Concept of DEMO
43 Testing of containment atmosphere cleanup systems	
44 Cooling water	
45 Inspection of cooling water system	
46 Testing of cooling water system	
50 Containment design basis	Need Modification
51 Fracture prevention of containment pressure boundary	Not Required for the Studies of the Design Concept of DEMO
52 Capability for containment leakage rate testing	
53 Provisions for containment testing and inspection	
54 Piping systems penetrating containment	Use As Is
55 Reactor coolant pressure boundary penetrating containment	Need Modification
56 Primary containment isolation	Need Modification
57 Closed system isolation valves	Need Modification
60 Control of releases of radioactive materials to the environment	Use As Is
61 Fuel storage and handling and radioactivity control	
62 Prevention of criticality in fuel storage and handling	
63 Monitoring fuel and waste storage	
64 Monitoring radioactivity releases	

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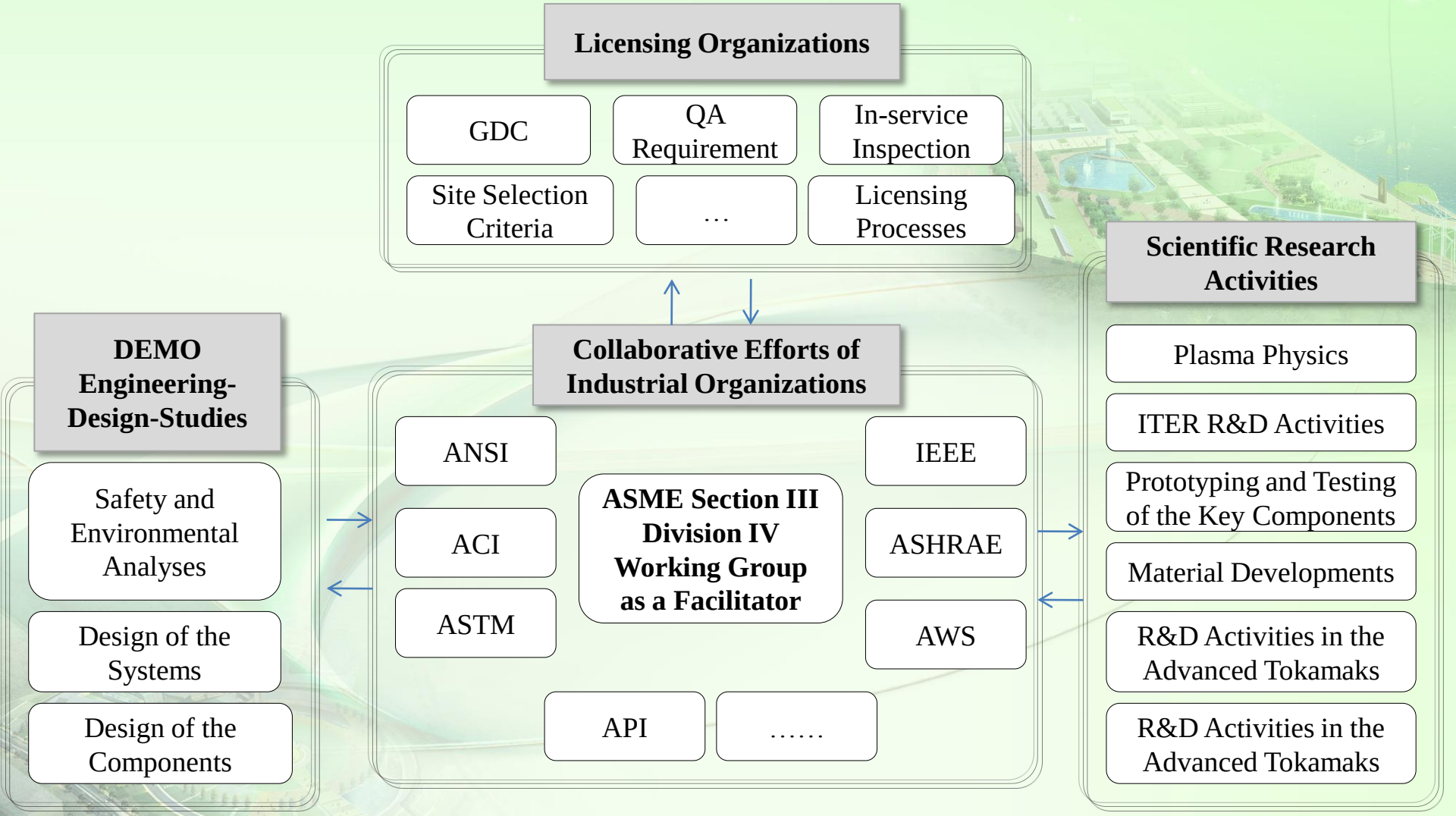
VI. Conclusion

Conclusion (1)

- Developing the Top-tier Requirements Are Urgent for the DEMO Design Studies;
- Collaborative Efforts ASME Section III, Division IV Working Group as a Facilitator Could Be a Practical Way to Go;
- This Approach may expedite involvement of industries as well.

Conclusion (2)



National Fusion Research Institute realizes
Green Korea getting joined with human beings,
environment and technology

Thank You

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