OVERVIEW of KO FUSION PROGRAM

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National Fusion Research Institute
Outline

- Introduction
- Legal Framework of Program
- Status of KSTAR and ITER
- Collaboration & Outreach
- Summary
Energy Deficiency of Korea

Self-sustenance of Energy ('04)

Finland: 1% Oil, 10% Coal, 99% Gas
UK: 100% Oil, 40% Coal, 99% Gas
France: 2% Oil, 4% Coal, 3% Gas
Germany: 4% Oil, 4% Coal, 68% Gas
USA: 99% Oil, 36% Coal, 100% Gas
Japan: 1% Oil, 0% Coal, 4% Gas
Korea: 0% Oil, 0% Coal, 0% Gas

Finland
UK
France
Germany
USA
Japan
Korea

Oil
Coal
Gas
Motivation

- **Needs for a Long-term plan for the change of Energy Technology paradigm**
  - Needs for Innovative Technology for Low-Carbon Energy System due to Climate Change
  - Provision for the National Energy Security for draining Natural Resources, Cost Increase, and Geopolitics issues
  - Trends of International Technology Cooperation due to Sourcing Demands of Energy

- **Provisions for building an Innovative National Energy Technology System and commercialization of the Fusion Energy**
  - Conversion of Fusion Energy Technology R&D for DEMO in 2030s and First Commercial Power Plant in 2040s
  - Needs for the National Long-term Strategy in accordance with Completion of KSTAR and Joining ITER Project
To establish a long-term and sustainable legal framework for fusion energy development phases

To promote industries and institutes which participating the fusion energy development by supports and benefit

The first country in the world prepared a legal foundation in fusion energy development

History of the FEDPL

• 1995. 12 : National Fusion R&D Master Plan
• 2007. 3 : Fusion Energy Development Promotion Law
• 2007. 4 : Ratification of ITER Implementation Agreement and entrusted to IAEA
• 2007. 8 : Framework Plan of Fusion Energy Development
### Phase-1 Strategies & Practical Items

<table>
<thead>
<tr>
<th><strong>Strategies</strong></th>
<th><strong>Practical Items</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Strategy 1</strong></td>
<td>1-1 Improvement of the Performance of KSTAR for Stable Operation &amp; Securing the Source Technology</td>
</tr>
<tr>
<td>Establishment of Fusion Energy Core Research System</td>
<td>1-2 Vitalizing to Gain a Core Technologies of the ITER</td>
</tr>
<tr>
<td></td>
<td>1-3 Expanding and Systemizing the R&amp;Ds in Reactor Engineering</td>
</tr>
<tr>
<td></td>
<td>1-4 Establishing the Development Strategy for Korean Fusion Power Plant</td>
</tr>
<tr>
<td><strong>Strategy 2</strong></td>
<td>2-1 Expanding the Research Infrastructure &amp; Basic Research Capabilities</td>
</tr>
<tr>
<td>Accelerating the Research &amp; Promotion</td>
<td>2-2 Building an Information Control and Management System for Fusion R&amp;D</td>
</tr>
<tr>
<td></td>
<td>2-3 Concentrating on Human Resources Development &amp; Training</td>
</tr>
<tr>
<td><strong>Strategy 3</strong></td>
<td>3-1 Completing the plan for participating ITER construction</td>
</tr>
<tr>
<td>Substantial Int’l Cooperation Activities</td>
<td>3-2 Fostering Joint Research &amp; International Cooperation</td>
</tr>
<tr>
<td><strong>Strategy 4</strong></td>
<td>4-1 Strengthening Support for Commercializing the Spin-off Technologies</td>
</tr>
<tr>
<td>Industrializing Spin-off Technology &amp; Having Validity</td>
<td>4-2 Having a Validity from Public with Securing the Fusion Energy Safety</td>
</tr>
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<td>4-3 Suggesting the Socio-Economic validity for Public Support</td>
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</table>
Policy and Decision Making System

**Government**

- Ministry of Education, Science & Tech. (Supervisory)
  - Ministry of Knowledge and Economy
  - Ministry of Foreign Affairs & Trade
  - Ministry of Planning & Finance
  - National Assembly Budget Office
  - Office for Government Policy Coordination

**Framework Plan Development (5yr)**

**Annual Execution Plan**

**Fusion Energy Research Council**

**Public & Private Organization**

- **Fusion R&D Institute**
  - Independent institute foundation
  - Fusion technology training center

- **Academic Sector**
  - University
  - Annex institute

- **Research Institutes**
  - Fusion related institutes
  - Private institutes

- **Industries**
  - ITER-contract industry
  - Electric power industry
  - Spin-off related industry

**International Collaboration Institute**

- ITER contracted LAB & Industry
- Other foreign LAB & Industry

- **ITER-IO**

- **ITER Korea Domestic Agency**
Vision of NFRI

Vision
World-class Research Institute Leading the R&Ds in Nuclear Fusion Reflecting the Energy-sustenance and the Climate Change

Mission
R&Ds for Core Sciences and Technologies to achieve self-sustenance of Fusion Power Plant Technologies
R&Ds for Spin-off Technologies of Fusion Science

KSTAR
Researches and Operation

ITER DA and Procurements

R&Ds for Fusion Nuclear Technologies

R&Ds for Spin-off Technologies
World Class Institute (WCI)

- Closely integrated approach of theory, simulation, and experiment in one project
- Strong support from KSTAR with new diagnostics, long-pulse operation capability, dedicated operation time
- Establishment and involvement of global collaboration network
Integrated theory, modeling, analysis, and validation program through
- International collaboration with world-leading research groups
- Exploitation of KSTAR device, supercomputing facility in KISTI
Status of KSTAR Facility
**KSTAR Mission & Progress**

**Mission:**

- to develop a steady-state-capable advanced superconducting tokamak
- to establish the scientific and technological base for an attractive fusion reactor as a future energy source

<table>
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<tr>
<th>Year</th>
<th>Event</th>
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</thead>
<tbody>
<tr>
<td>'95.12</td>
<td>KSTAR Project Approval</td>
</tr>
<tr>
<td>'98.8</td>
<td>Conceptual Design &amp; Basic R&amp;D Completed</td>
</tr>
<tr>
<td>'02.05</td>
<td>Engineering Design Completed</td>
</tr>
<tr>
<td>'07.8</td>
<td>Machine Construction Completed</td>
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<tr>
<td>'08.6</td>
<td>First Plasma Operation</td>
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</tbody>
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KSTAR & heating devices

Major Radius, $R_0 = 1.8\ m$
Minor Radius, $a = 0.5\ m$
Plasma Current, $I_P = 2\ MA$
Elongation, $\kappa = 2.0$
Triangularity, $\delta = 0.8$
Toroidal Field, $B_0 = 3.5\ T$
Pulse Length = 300 s

Start-up ECH
(0.5 MW, 2 s, 84 GHz)

ICRF
(2 MW, 300 s, 30-60 MHz)

NBI-1 (2010–2014)
(8 MW, 300 s)

LHCD
(2011 – 2016)
(2 MW, 300 s, 5 GHz)

NBI-2 (2017 – 2020)
(6 MW, 300 s)

ECCD (2011 – 2015)
(3 MW, 300s, 170GHz)
(launcher development with PPPL)

Helium transfer line

Cryostat pumping duct

VV pumping duct

Co

Helium distribution box

Helium transfer

25 deg

CNT (under consideration)
Future Plan

Operation Phase I
2008 ~ 2012

SC Tokamak operation

- Superconducting tokamak operation
- First plasma & inductive current ramp (2 MA)
- Plasma shaping & heating (DN & SN, H-mode)

Operation Phase II
2013 ~ 2017

Long-pulse operation

- Steady-state operation & ITER pilot device roles (300 s+)
- Plasma heating & non-inductive current drive
- Instability control in H-mode and AT-mode

Operation Phase III
2018 ~ 2022

High performance operation

- Advanced scenario for DEMO beyond ITER
- High-beta and high bootstrap current scenario
- Extreme operation of the superconducting tokamak

Phase IV
2023 ~

DEMO test bed

- DEMO Engineering
- DEMO simulator
- Reactor material test

First Plasma (‘08)
Current & Position control (‘09)
Divertor plasma (‘10)
H-mode operation (‘11)
Fast stabilization (‘12)
ITER Building Arrangement

39 Buildings, 180 hectares
10 years of construction
20 years of operation

Tokamak Hall
Power Supply
Present HQ Building
Permanent Office Buildings
To Aix
Parkings
The “ITER Korea” Role is performing and executing all activities with respect to the ITER Project with full responsibilities as the Domestic Agency of the Republic of Korea.

- Designing, Manufacturing and Delivering on time IO procurement packages in accordance with the IO required Technical Specification.
KO In-kind Contribution to ITER

1. TF Conductor
   - Total Value (kIUA): 215.0
   - KO Allocation: 21.18%
   - KO Contribution (kIUA): 43.39

2. Vacuum Vessel Main Body
   - Total Value (kIUA): 124.2
   - KO Allocation: 21.1%
   - KO Contribution (kIUA): 26.2

3. Vacuum Vessel Port
   - Total Value (kIUA): 78.5
   - KO Allocation: 73.5%
   - KO Contribution (kIUA): 57.7

4. Blanket First Wall
   - Total Value (kIUA): 87.0
   - KO Allocation: 10.48%
   - KO Contribution (kIUA): 9.12

5. Blanket Shield Block
   - Total Value (kIUA): 58.0
   - KO Allocation: 10.48%
   - KO Contribution (kIUA): 6.08

6. Assembly Tools
   - Total Value (kIUA): 22.0
   - KO Allocation: 100%
   - KO Contribution (kIUA): 22.0

7. Thermal Shield
   - Total Value (kIUA): 26.8
   - KO Allocation: 100%
   - KO Contribution (kIUA): 26.8

8. Tritium SDS
   - Total Value (kIUA): 14.5
   - KO Allocation: 88%
   - KO Contribution (kIUA): 12.76

9. AC/DC Converters
   - Total Value (kIUA): 82.2
   - KO Allocation: 38%
   - KO Contribution (kIUA): 31.24

10. Diagnostics
    - Total Value (kIUA): 137.5
    - KO Allocation: 3.54%
    - KO Contribution (kIUA): 4.8755

※ Total KO in-kind contribution: 241.34 kIUA (342.70 M€)Leading ItemsTokamak MainAncillary

Korea Domestic Agency
**Objectives:**
- Supply of 20.18% of TF conductor to ITER (Critical Path Items)
  * 19 of 760m and 8 of 415m TF Conductors for KO-DA

**Current works**
- Procurement Arrangement signed between KO-DA and ITER Organization on 7th May 2008
- Contract Awards for TF conductor (28t) and cabling at the beginning of 2009
Objectives:
- 20% of VV main body and 73.5% of VV ports contribution to ITER (Lead Items)
  * 2 Sectors Main Body, 17 Sets of Equatorial Ports and 9 Sets of Lower Ports including lower penetration, Sealing flange, VV supports and NB liners

Current works
- PA for VVM and Ports signed in Nov. 2008
- Call for tender for main bodies ports launched in Sept. 2009.
- Contract award was done in March 2010.
  - KO is waiting Final 3-D and 2-D drawings approved by ANB
- First (No.6) and last sector (No. 1) deliveries from KO-DA will be by March and Nov. 2014 respectively.
  - First and last port deliveries to main vessel factory, Nov. 2012 and Nov. 2013 respectively
Objectives:
- In-kind contribution to ITER Diagnostics: 3.5%

Procurement Systems
- A-1. Upper Port Plug (U18) 1 SET
- B-1. VUV Imaging Spectrometer (U18) 1 SET
- B-2. VUV Survey Spectrometer (E11) 5 SET
- B-3. Divertor VUV Spectrometer 1 SET
- C-1. Neutron Activation System-Foil (U11,18,E7,17,D12,18) 16 SET

Current works
- Port Plug Engineering
  Manufacturability study
  EM and Thermo-hydraulic analysis
- VUV Spectrometer Development
  Spectrometer system & relay optics design
  Prototype system design and fabrication
- Neutron Activation System
  In-vessel transfer lines design: interface issues
- PA: Nov. 2010, Fabrication by 2018
Collaboration & Outreach
KSTAR as a Collaboratory

User groups and foreign scientists in the second campaign

- Improved clarity and accessibility helps building a collaborative environment
  Experts from more than ten domestic institutes attended in the major steps in the second campaign.

- Forty-seven foreign scientists visited KSTAR during the second campaign including remote-participation

Foreign scientists participated in the various states during the 2nd campaign from US (GA, PPPL), Japan (NIFS, JAEA), Russia (KI), EU (CEA), ITER-IO

Domestic experts assessing the experimental results of the 2nd campaign
Global Leader in Fusion Reactor Development

- Basic Research
- Scientific Research
- Design
- Construction
- Operation
- De-activation

International

Construction and Operation of ITER
- Fusion power > 500MW
- Q > 10
- t > 400 sec

Korea

- Basic Research
- KSTAR Construction
- KSTAR Operation
- ITER Participation
- K-DEMO

Timeline:
- 1960
- 1980
- 2000
- 2020
- 2040
Role Sharing

- **KSTAR**
- **ITER**
- **DEMO**
- **KO Fusion Reactor**

**NFRI, KAERI**
Other Domestic Institutes
Design, Construction, Operation and R&D

Domestic Univ.
Foreign Collaborators
Human Resource Development, Basic R&D

Industries
Industrial Plasma Application

Fusion Energy Development Promotion Plan (2007.8)
Fusion Energy Development Promotion Law (2007.3)

Fusion Energy Development Promotion Plan (2007.3)
Fusion Energy Development Promotion Law (2007.3)

Collaboration Framework for KSTAR

International Collaboration

- Plasma Heating (KAERI)
- Plasma Transport (KAIST)
- Edge Plasma (HYU)
- Diagnostic & SSO (POSTECH)
- Reactor Engineering (SNU)

Domestic Collaboration

- ITER Pilot R&D
- KSTAR Co-Exp.
- Fusion Simulation

Fusion R&D Collaboration

World Class Institute (WCI) Program

- WCI Th/Sim.
- WCI Exp1
- WCI Exp2

World Leading Experts (International)

- WLE

Matching Funds & Collaboration

ITER Members

Non-ITER
Five Core Institutes Appointed

Plasma Core Research Center (POSTECH)
- Diagnostics
- Control
- Heating & CD

Fusion Engineering Research Center (SNU)
- Magnet Technology
- Blanket & Neutronic Material

Transport Research Center (KAIST)
- Transport MHD

Plasma Edge Research Center (HYU)
- Divertor
- PFC
- Edge Diagnostics

Ion Heating Center (KAERI)
- NBI, ICRH
KSTAR as an international research device with various collaboration programs

- Technical development & training with advanced tokamak technology
- World-wide fusion research center as an ITER pilot device

EU/ITER
- IVCC technical design
- D-T neutronics
- NBI
- Safety & risk management for ITER
- Steady-state technology
- PFC cooling
- LHCD
- Cryogenics
- Divertor for steady-state operation

RUSSIA
- SC coil design
- SC tokamak commissioning
- Hard X-ray diagnostics
- SC tokamak startup
- Machine safety

JAPAN
- NBI development
- Bolometry diagnostics
- Thomson laser system
- ITER-like 170GHz gyrotron
- Motor generator
- ECH technology
- Cryogenics
- Diagnostics

USA
- Plasma control system
- ECCD launcher R&D, LHCD
- AT-simulation, stability analysis
- Visible Filterscope
- Thomson, MSE/CER/BES R&D
- High-speed plasma control
- Control coil PS
- Long-pulse ECH / ECCD, ICRH
- Remote operation R&D
- Integrated AT-mode simulation
- Fusion Grid
- NBI diagnostics (MSE/CER/BES)
- MIR / ECEI
- Operation extent R&D

INDIA
- Heating device
- SC device operation
- Diagnostics

CHINA
- Diagnostics
- SC & control coil PS
- SC device operation
- Bilateral Workshop

Non-ITER
- MHD Studies (Australia)
- Fast Particle Study
- Diagnostics
KO fusion program is consisted of three main bodies: Basic Science Program, KSTAR Program and ITER Program.

Government supports the whole program by an integrated and centralized long-term plan and a supporting law was legislated.

Young scientists training through the basic science program, quality scientific researches through KSTAR program and contribution to the world fusion community through ITER program are the main focus of the current KO fusion program.

Domestic and International collaboration are the essence of the KO fusion program and are positively supported by the KO government.
The 23rd IAEA Fusion Energy Conference

- Date: October 10 ~ 16, 2010
- Place: Daejeon Convention Center
  Daejeon City, Republic of Korea
- Organized by IAEA and
  Hosted by Ministry of Education,
  Science & Technology through
  National Fusion Research Institute
- Pre-conference (Oct. 7~9, 2010)
  International Green Forum,
  International Youth Conference,
  Green Festival, and
  Cultural Experience

You can meet the cutting edge of Fusion Technology
Thank you for your Attention !!