# Development of Innovative Isotope Separation System for the Realization of Compact Fusion Fuel Cycle

Project manager

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## Summary of the project

To achieve innovative societal implementation of fusion energy by 2050, the establishment of isotope-separation technologies is indispensable. This research and development project focuses on two primary objectives: (1) developing high-efficiency technologies for removing HTO molecules—generated when tritium permeates from the reactor blanket into the primary cooling water under high-flow-rate conditions; and (2) establishing technologies for separating heavy water from freshwater, as well as extracting $^{6}$Li (the raw material for tritium production) from $^{6}$Li/$^{7}$Li mixtures, thereby enabling domestic production and stable supply of fusion fuels (deuterium and tritium).

The foundation of this effort lies in the development of adsorbents and ion-exchange materials capable of sensitively recognizing minute quantum effects that arise between isotopic molecules and ions—an endeavor that advances the frontiers of adsorption science and isotope science. Through this approach, the project aims to develop an innovative isotope-separation system by 2034.

Furthermore, the project is expected not only to accelerate progress along the mainline tokamak-reactor pathway and explore alternative fusion concepts, but also to contribute to broader societal applications such as the use of deuterium in high-value-added materials and the realization of resource-circulation systems for lithium-ion batteries.

## Milestone by 2034

This research and development component aims to create high-performance separation materials for water-isotope separation based on a materials-informatics framework. Specifically, the computational search space will be systematically expanded, while ensuring homogeneity and representativeness in feature-space sampling to enable reliable identification of candidate separation materials, followed by synthesis and development.

Furthermore, bench-scale systems will be developed for (1) tritium-water separation, (2) heavy-water separation, and (3) $^{6}$Li separation. By evaluating separation performance, stability, and operating conditions, the project will demonstrate the innovativeness of each system. Building on these results, technical guidelines for system scale-up and societal implementation will be established, paving the way toward future deployment of full-scale systems.

## Milestone by 2029

Development will be carried out for three isotope-separation systems: (1) tritium-water separation, (2) heavy-water separation, and (3) $^{6}$Li separation. As a first step, materials-informatics methods will be used to predict high-performance separation materials from both known and unexplored materials spaces for water-isotope separation.

Candidate materials identified through computational screening within the known-materials space will then be synthesized. Using these materials, the innovativeness of a tritium-water separation system based on water-distillation techniques will be demonstrated with laboratory-scale apparatus, and the fundamental data for bench-plant design will be obtained.

Laboratory-scale development and demonstration will also be conducted for the heavy-water separation system and the $^{6}$Li separation system. Based on these outcomes, design guidelines for bench-scale plants of innovative isotope-separation systems will be established, contributing to the realization of fusion-energy fuel cycles.

## Project structure

This research and development project consists of four R&D themes, which are mutually integrated to form a co-creative research and development framework—from materials development to system development (Fig. 1).

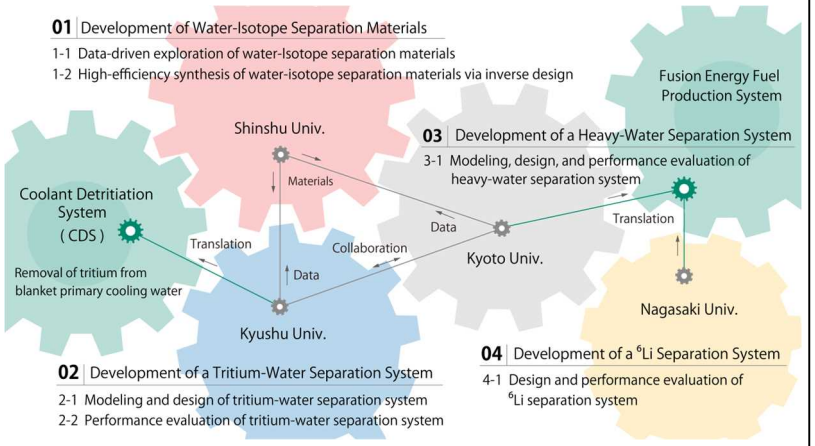


**Fig. 1. R&D Framework.**