Unlimited Fusion-Energy Station Concept based on Li Recovery from Seawater toward Zero-Carbon Grid : Required Conditions based on JA DEMO

Objectives

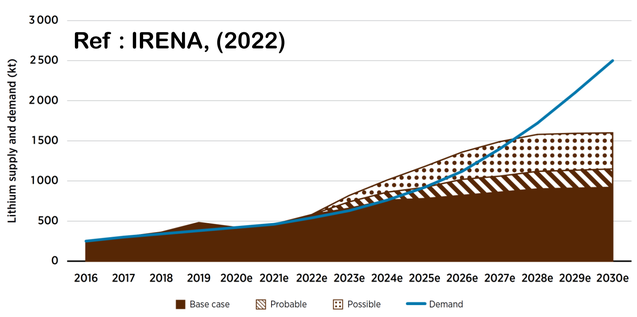
- Concept of Unlimited Fusion-Energy STAtion concept (U-FESTA) is proposed for the sustainable net-zero carbon grid, considering lithium (Li) recovery from seawater.
- Required conditions of U-FESTA is analyzed based on JA DEMO.
- Operation method of U-FESTA is also proposed for the net-zero carbon grid under the condition of large renewables installation.

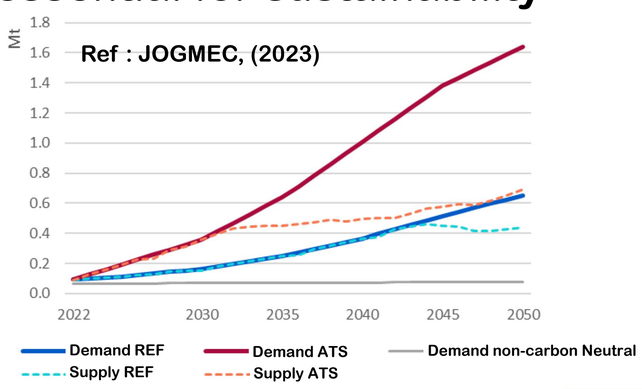
Summary

- The concept of U-FESTA is developed based on seawater-based Li, and its material flow is investigated based on the concept of JA DEMO.
- Required conditions among Li recovery efficiency, seawater intake, ^{6}Li enrichment of breeding material, blanket replacement period are investigated.
- Plant operation method of U-FESTA for Duck-Curve is established.

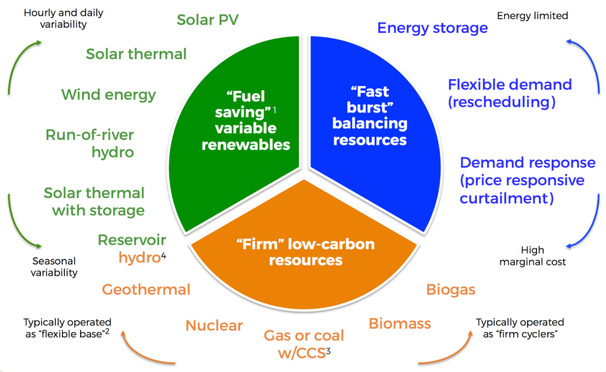
World Energy Situation for Fusion Energy Development toward Net-zero Carbon World

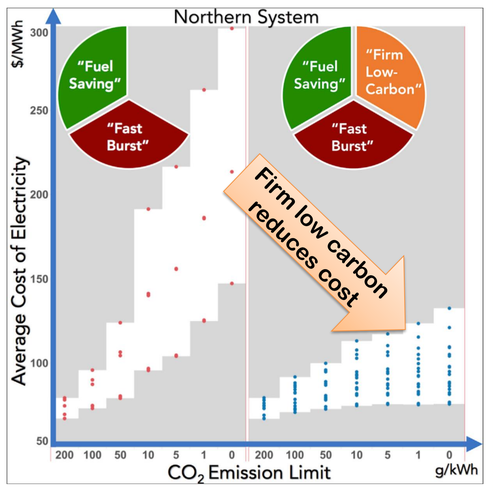
- ✓ Lithium (Li) shortage from mines is foreseen clearly from 2030-2045
- ✓ Li shortage denies D-T Fusion-Energy sustainability
- ✓ Li recovery from seawater is essential for sustainability





- ✓ Firm low carbon energy resources contribute to keep the total grid cost low.
- ✓ Fusion-Energy should be a Firm low carbon resource.



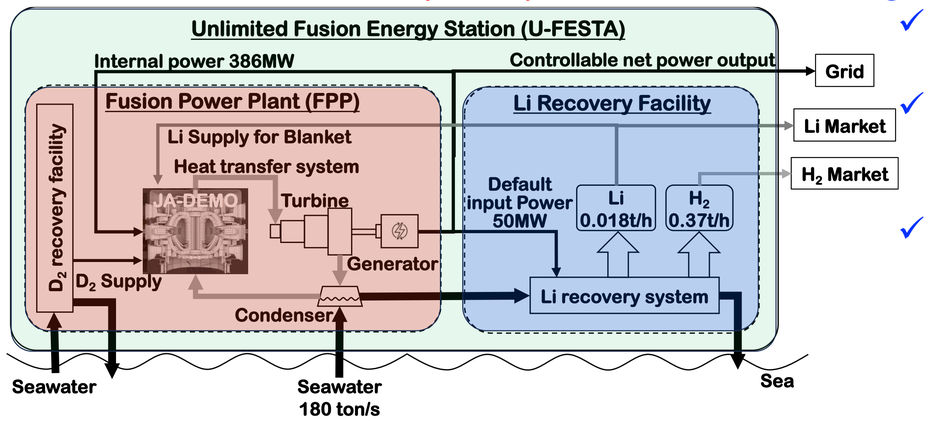


Ref : N.A.Sepulveda, Joule 2 (2018)

An U-FESTA Concept for Sustainable and Firm Low-Carbon Energy Resource

U-FESTA comprises Fusion Power Plant (FPP) and Li recovery facility from seawater

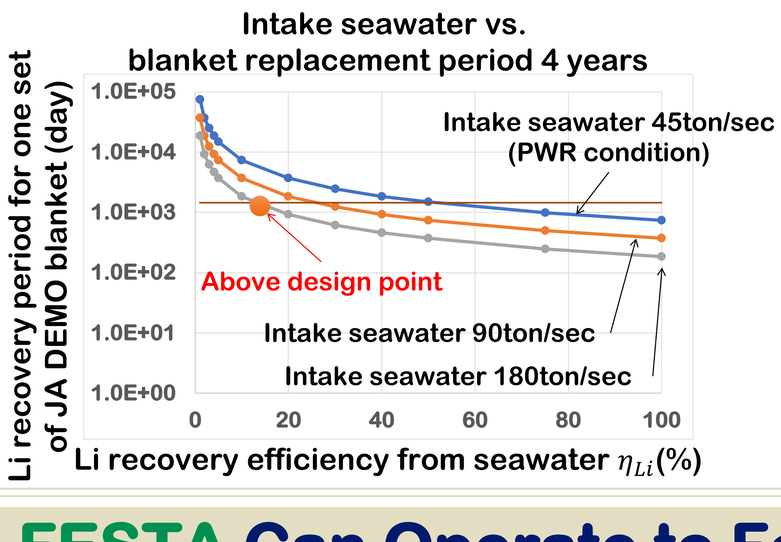
- ✓ JA DEMO is assumed as a model FPP, and Helical/Stellarator, Inertial Fusion with various blanket are also applicable for FPP.
- ✓ Steady state operation is preferable, pulsed operation is also acceptable.
- ✓ Total breeding material 389 ton of blanket (^{6}Li enrichment 90%) has to be recovered from seawater in case of JA DEMO.
- ✓ Reuse and recycle of breeding material of blanket is not considered in this report.

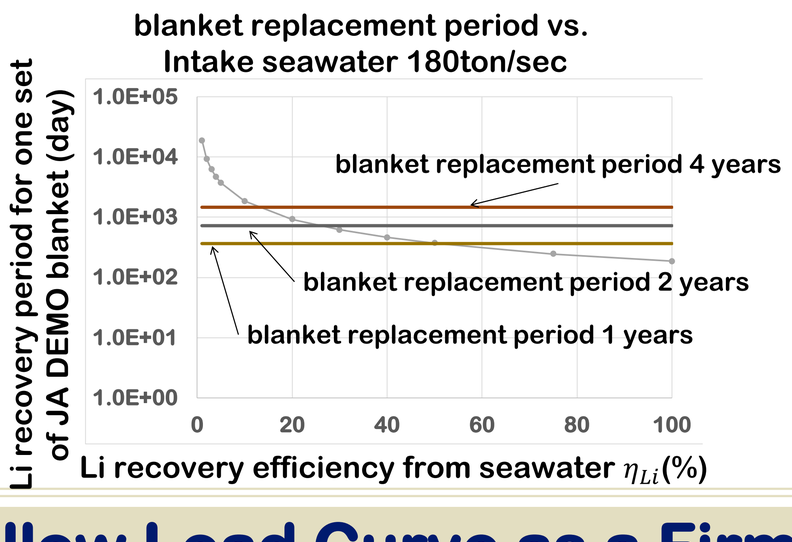


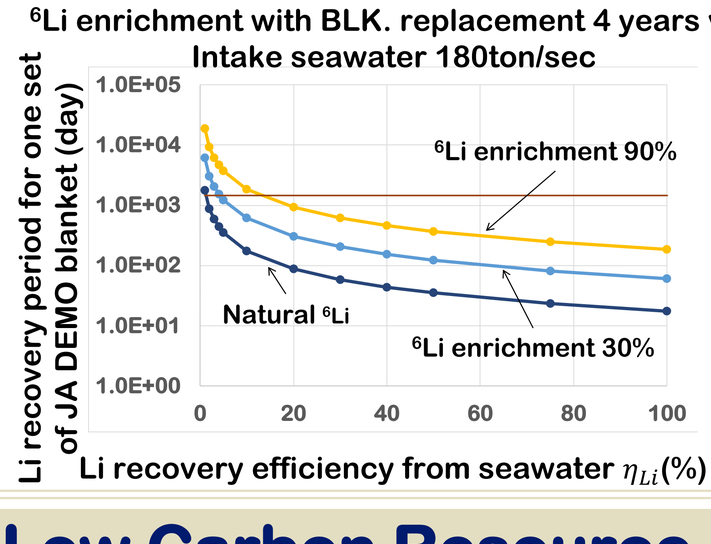
- ✓ Motivation is to apply huge intake seawater in FPP to Li recovery
- ✓ LiSMIC is a primay candidate of Li recovery & ^{6}Li enrichment with hydrogen by-products, which can be supplied in H_2 market.
- ✓ LiSMIC Li recovery efficiency achived 94% for alkaline solution, 8.3% for electrolytic solution of used Li-ion battery, 0.19% for brine water, respectively Ref : T. Hoshino, Desalination 359, (2015)
  K. Morita et al., Desalination 543, (2022).
  K. Morita et al., Fusion Eng. Des. 190, (2023)

Requirement of seawater Li recovery efficiency for U-FESTA in JA DEMO case

Li recovery efficiency η_{Li} is defined by Li concentration in seawater before(C_{Li}^{b})/after(C_{Li}^{a}) recovery process : $\eta_{Li} = (1 - C_{Li}^{a}/C_{Li}^{b}) \times 100$ (%)



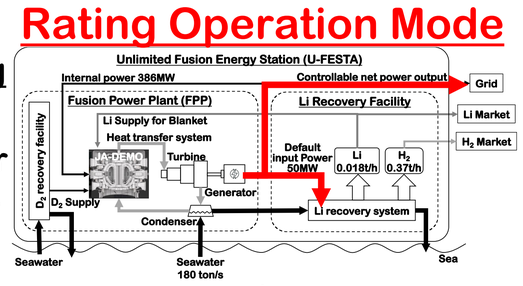




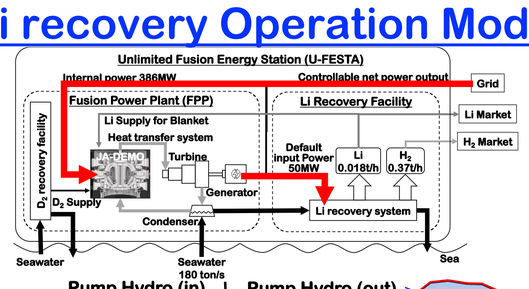
U-FESTA Can Operate to Follow Load Curve as a Firm Low Carbon Resource

- Net output power of the U-FESTA can be controlled from -386 to 254 MWe by changing the input power of Li-recovery facility.
- Li-Recovery Operation Mode : When the solar power over-generates electricity during mid-day, U-FESTA receives electricity of up to 386 MWe and produces Li and hydrogen.
- Power Operation Mode : When the solar power decreases during evenings, U-FESTA can increase the net output power up to the max. of 254 MWe.
- U-FESTA can manage Duck-Curve of the grid issue caused by renewable energy (mainly PV).

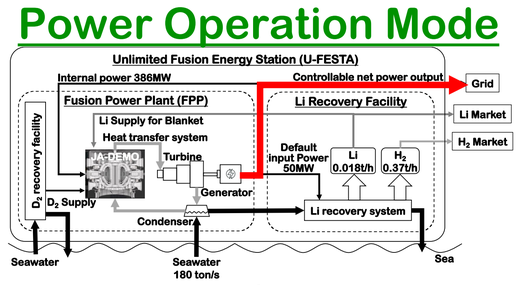
Rating Operation Mode

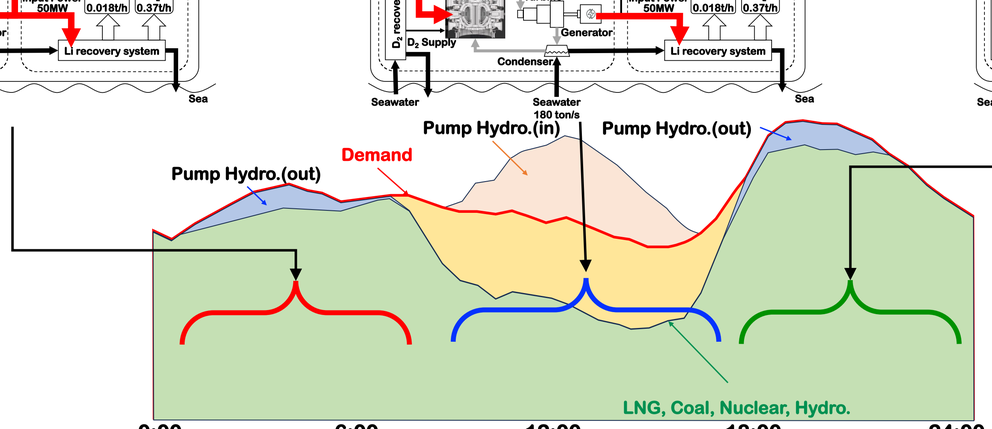


Li recovery Operation Mode



Power Operation Mode





Load Curve : Kyushu Electric Power Company (4th May, 2016)

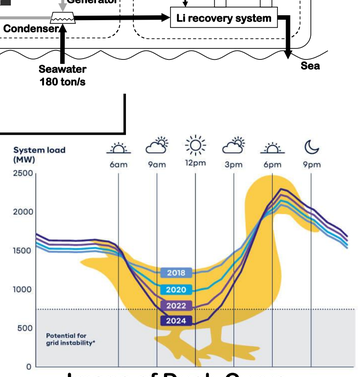


Image of Duck-Curve

Ref. : https://www.synergy.net.au/Blog/2021/10/Everything-you-need-to-know-about-the-Duck-Curve