Technology Development Programme

Fusion Fuel Cycle
2025

Technology dashboards for review

FUSION FOR ENERGY

EUROfusion

Introductory notes

What is this document?

This is an intermediate document in the mapping process aiming at providing the technology dashboards to the participants for review.
The document contains the post processed data following the workshop for each technology covered.

What is expected from participants?

If you have the time and interest, please review the technologies of interest to you. Let us know if you feel the data needs to be modified (missing or incorrect information).
We are particularly interested in your feedback on:

- TRL
- Test facilities
- Entities involved (public and private)
- TDAs

A list of technologies is provided on page 3 to facilitate your navigation in the file. The description of the TRL scale is provided in Appendix for reference.

How to provide feedback?

Send an email to matthias.dremel or marc.simon on the domain f4e.europa.eu.
You may either annotate this file directly or list your comments in the body of the email.

What do I need to know about the dashboards?

What you receive here is a prototype. We are still working on the priority score and spider diagram so please do not pay too much attention to this yet.
We are also working on the importance graph (nice to have vs essential and resolved vs unresolved).
The test facilities and actors listed must be based in the EU, UK or Switzerland. For test facilities, we have accepted to list those which are operated by companies based in the EU, UK and Switzerland even if they are outside those territories.

List of technologies

Fueling and storage

- Centrifugal acceleration for solid injection
- Diagnostic System for pellet injection
- Extruder
- Gas-gun acceleration mechanism for solid injection
- Inertial Fusion Target Filling
- Inertial Fusion Target Injection
- Inertial Fusion Target Storage
- Inertial Fusion Target tracking
- Modelling and Software Developments
- Pellet Cutter
- Pellet injectors for divertor cooling gas
- Pellet Punchers
- Storage of hydrogen isotopes

Membranes and Packing

- Column packings
- Combined Electrolysis and Catalytic Exchange (CECE)
- Cryogenic distillation to separate D and T from plasma exhaust
- Electrolyser
- Equilibrators
- Cryogenic distillation for isotope separation
- Liquid Phase Catalytic Exchange (LPCE)
- Membrane Absorption
- Packed Beds
- Pd-Ag Membranes
- Quantum sieving
- Temperature/Pressure Swing Adsorption (TSA)
- Vapor Phase Catalytic Exchange (VPCE)
- Water distillation

Pumping

- Continuous Cryogenic Diffusion Pump / Snail Pump
- Cryogenic Adsorption pumps
- Cryogenic turbo molecular pumps
- Cryogenic Viscous Compressor (CVC)
- Liquid Ring pumps
- Liquid metal diffusion pump
- Metal bellow pumps
- Metal foil pump
- Non-Evaporable Getter (NEG) pumps
- Turbo molecular pumps
- Oil diffusion pumps with tritium compatible oils
- Piston pumps
- Proton conductor pump
- Root pumps
- Screw pumps
- Scroll pumps
- Temperature Staged cryogenic condensation and adsorption pumps

Tritium Management

- Coating technologies for permeation barriers
- Cryogenic Temperature Sensor
- Instruments to measure hydrogen isotope concentrations
- Magnetic Sector Leak Detector (MSLD)
- Material characterisation for permeation
- Material development for permeation
- Non-destructive Tritium detection in solids
- Wearable tritium detector
- Process simulation benchmarking
- Tritium accountancy
- Tritium detectors for gas
- Tritium detectors for water

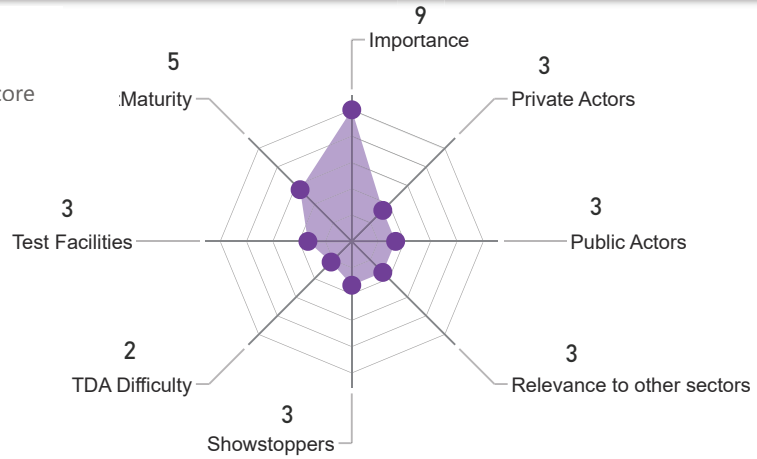
FUELING AND STORAGE

- Centrifugal acceleration for solid injection
- Diagnostic System for pellet injection
- Extruder
- Gas-gun acceleration mechanism for solid injection
- Inertial Fusion Target Filling
- Inertial Fusion Target Injection
- Inertial Fusion Target Storage
- Inertial Fusion Target tracking
- Modelling and Software Developments
- Pellet Cutter
- Pellet injectors for divertor cooling gas
- Pellet Punchers
- Storage of hydrogen isotopes

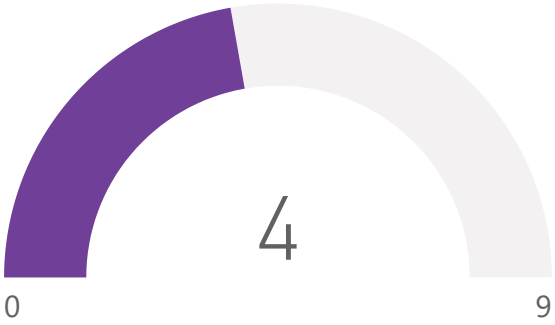
Fuel Cycle › Fuelling and storage

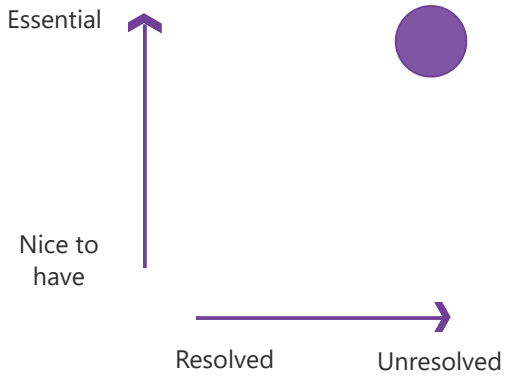
Centrifugal acceleration for solid injection

31
Priority Score



TRL





Other Applications

Space launchers

Alternatives

Gas gun

Showstoppers list

Interface with the pellet source
Reliability
Tritium application/compatibility

Tech Characteristics

Existing Test Facilities	Additional Test Facility Needed
IPP DIPAK-PET (KIT under construction) UNITY 2 (Under construction)	Test reliability and repeatability Demonstrate integrability with continuous extruder

European Entities Involved

Public	Private
IPP (Garching) KIT (Karlsruhe) HUN-REN (Budapest)	Sener (Spain) Kyoto Fusioneering (Germany)

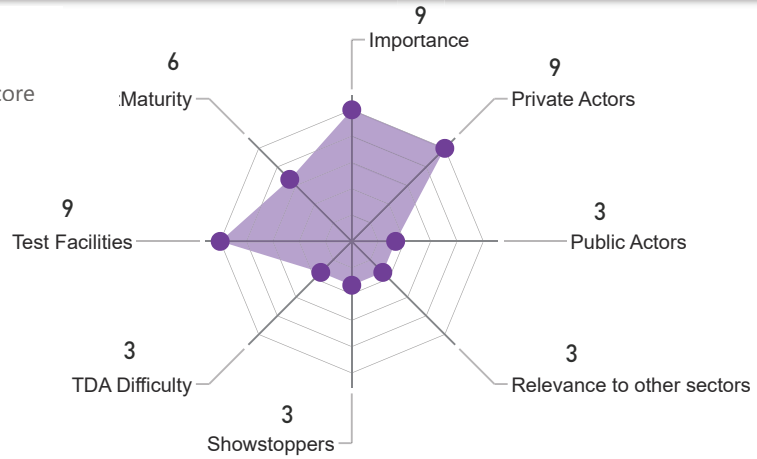
TDA Information

TDA Name	Characteristics	Priority	Funded
Build prototype centrifugal accelerator for test facility	>80%, 6 months to 2 years, >1M	High	Partially
Develop test facility for HD testing of pellet acceleration	>80%, >2 years, >1M	High	No
Improve the long term reliability of the main bearing	>80%, 6 months to 2 years, <250k	Medium	No

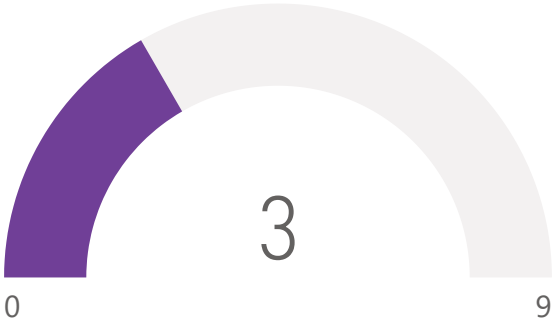
Fuel Cycle › Fuelling and storage

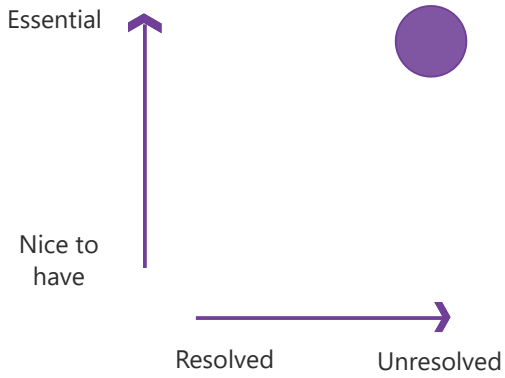
Diagnostic System for pellet injection

45
Priority Score



TRL





Other Applications	Alternatives	Showstoppers list
Optical monitoring	Plasma diagnostics Mirnov coils	Line of sight in the case of optical diagnostic Reliability under radiated environment

Tech Characteristics

Existing Test Facilities	Additional Test Facility Needed
DIPAK-PET (KIT under construction)	Functional test on real pellets

European Entities Involved	
Public	Private
Hun-REN (Budapest) IPP (Garching)	

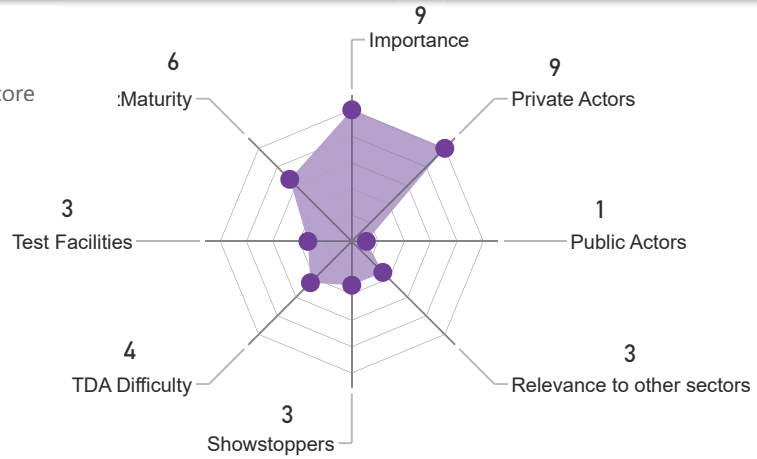
TDA Information

TDA Name	Characteristics	Priority	Funded
Define technologies to detect if pellets entered the highly confined plasma	>80%, <6 months, <250k	Medium	No
Optical diagnostic to measure successful arrival of pellets into the vessel	<40%, >2 years, >1M	Medium	No

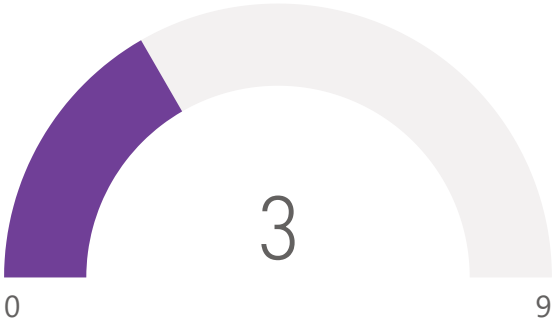
Fuel Cycle › Fuelling and storage

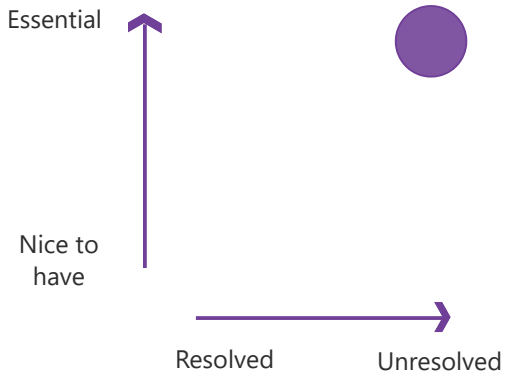
Extruder

38
Priority Score



TRL





Other Applications	Alternatives	Showstoppers list
Laser Targets, Neutron Spallation Sources	Maybe cryogenic liquid injection	Reliability with tritium application

Tech Characteristics

Existing Test Facilities	Additional Test Facility Needed
HUN-REN (Budapest) CEA France (Grenoble) KIT (Karlsruhe) IPP (Garching) Unity 2 (Canada)	D-T validation

European Entities Involved

Public	Private
IPP Ciemat HUN-REN CEA IPP	

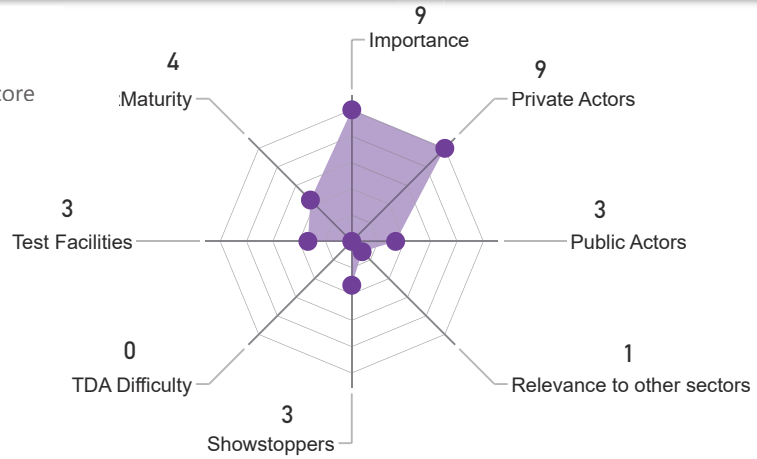
TDA Information

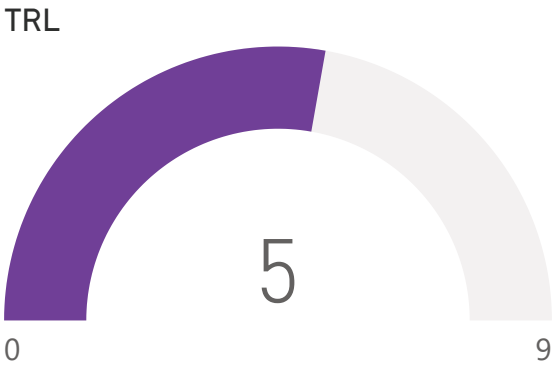
TDA Name	Characteristics	Priority	Funded
Design, build and test prototype pellet extruder	40 to 80%, 6 months to 2 years, 250k to 1M	High	Partially
Obtain mechanical properties of H isotopes ice	<40%, 6 months to 2 years, >1M	High	No

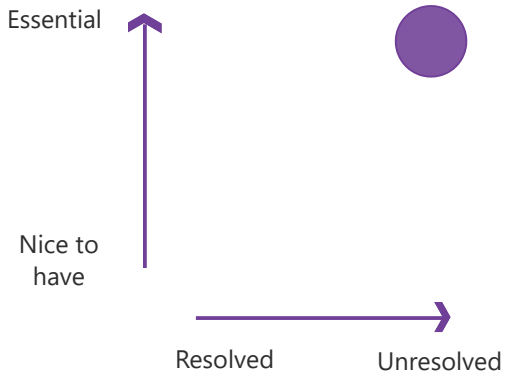
Fuel Cycle › Fuelling and storage

Gas-gun acceleration mechanism for solid injection

32
Priority Score







Other Applications
Military Propulsion technologies

Alternatives
Centrifugal Accelerators, Mechanical Puncher.

Showstoppers list
Gas load can be a strong burden on the fuel cycle Damage to pellets Tritium compatibility

Tech Characteristics

Existing Test Facilities	Additional Test Facility Needed
DIPAK-PET (KIT under construction) UNITY 2 (Canada under construction)	Functional test

European Entities Involved

Public	Private
KIT (Karlsuhe) CIEMAT (Madrid) IPP (Garching) CEA (Grenoble)	

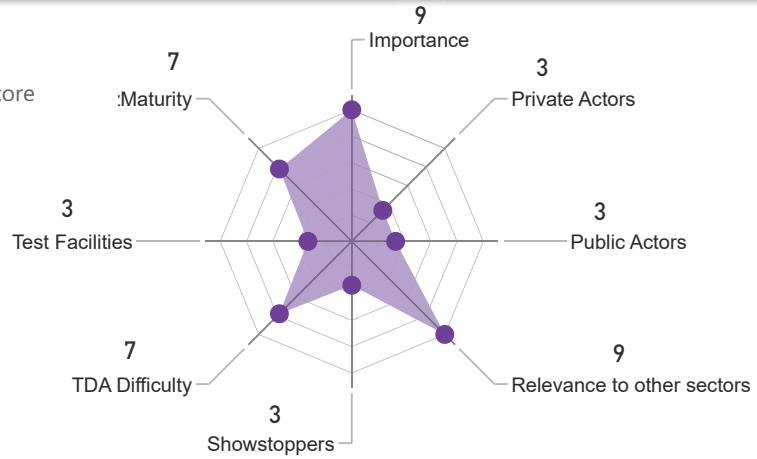
TDA Information

TDA Name	Characteristics	Priority	Funded
Build tritium compatible prototype and develop test facility	>80%, >2 years, >1M	Low	Partially

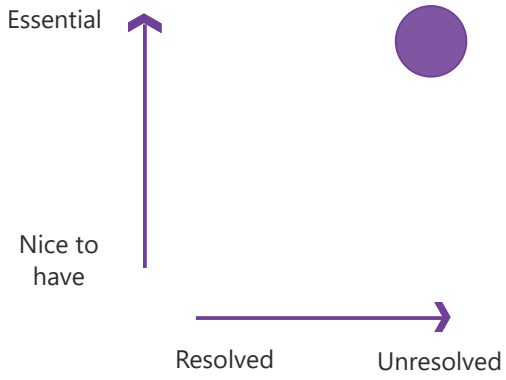
Fuel Cycle › Fuelling and storage

Inertial Fusion Target Filling

44
Priority Score



TRL



Other Applications

Alternatives

Showstoppers list

Time to fill

Tech Characteristics

Existing Test Facilities	Additional Test Facility Needed
CEA (Bordeaux and Dijon) IFE Targetry Hub (Darmstad under development)	Demonstrate feasibility of fast and repetitive filling

European Entities Involved

Public	Private
CEA (Bordeaux Dijon) Fraunhofer IAF (Darmstadt)	Focused Energy (Germany)

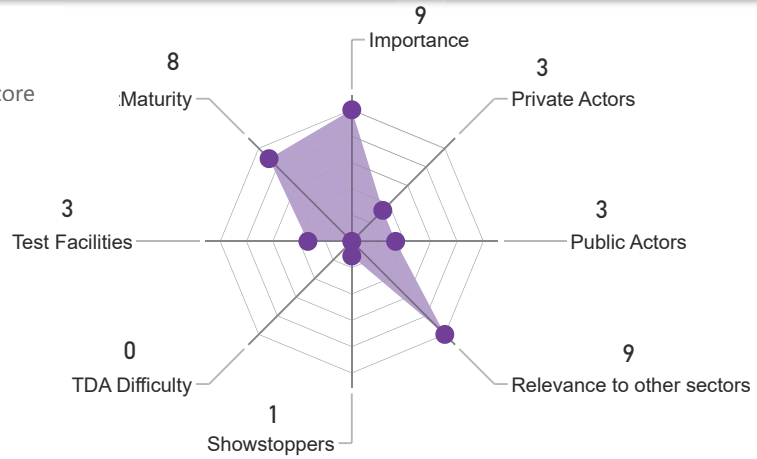
TDA Information

TDA Name	Characteristics	Priority	Funded
Process definition (capillary vs permeation)	<40%, 6 months to 2 years, <250k	High	Partially

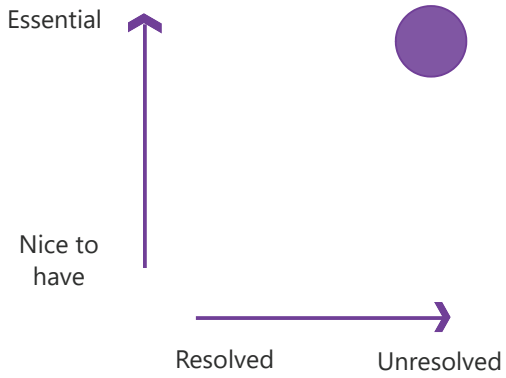
Fuel Cycle › Fuelling and storage

Inertial Fusion Target Injection

36
Priority Score



TRL



Other Applications

Alternatives

Showstoppers list

Precision and localization of target,
High repetition rate,
Shape precision and durability of the pellets,
Synchronization between driver and pellet injector

Tech Characteristics

Existing Test Facilities	Additional Test Facility Needed
CEA (Grenoble) ELI (Prague)	Repeatability, precision and localization of the pellet.

European Entities Involved

Public	Private
CEA (Grenoble) ELI (Prague)	Focused Energy (Germany)

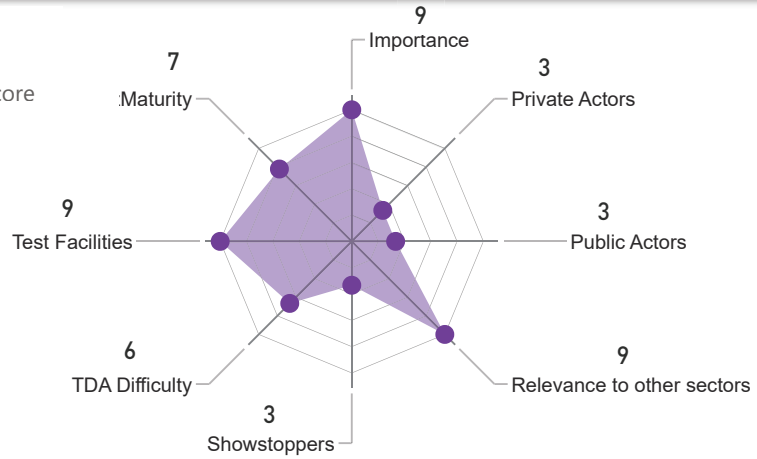
TDA Information

TDA Name	Characteristics	Priority	Funded
Build and test a prototype injector	>80%, >2 years, >1M	High	No

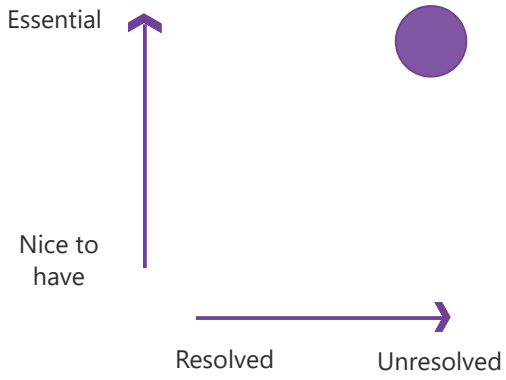
Fuel Cycle › Fuelling and storage

Inertial Fusion Target Storage

49
Priority Score



TRL



Other Applications

Alternatives

Showstoppers list

Tech Characteristics

Existing Test Facilities	Additional Test Facility Needed
	Validate storage and handling functionality

European Entities Involved

Public	Private
CEA (France)	Focused Energy (Germany)

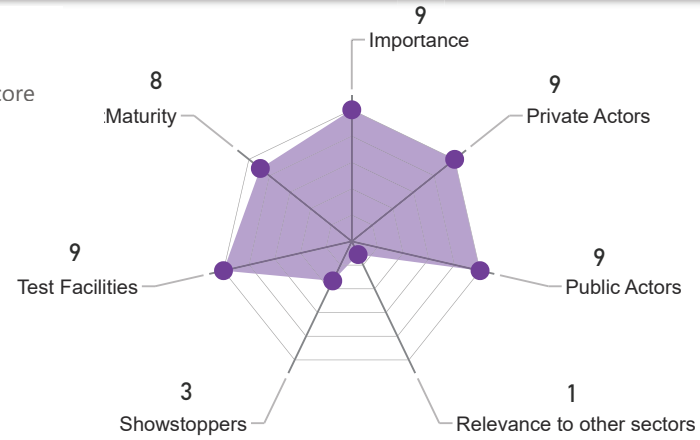
TDA Information

TDA Name	Characteristics	Priority	Funded
Define specification as well as possible storage and handling technologies	>80%, <6 months, <250k	Medium	No

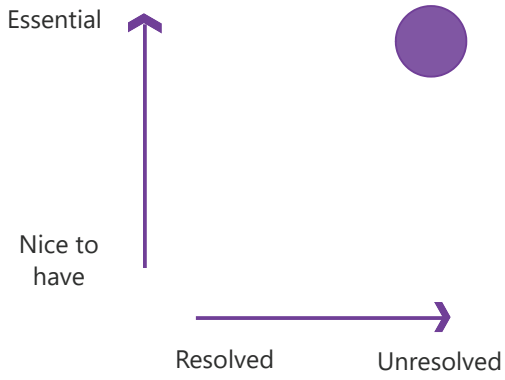
Fuel Cycle › Fuelling and storage

Inertial Fusion Target tracking

48
Priority Score



TRL



Other Applications	Alternatives	Showstoppers list
Military/defense Metrology		

Tech Characteristics

Existing Test Facilities	Additional Test Facility Needed

European Entities Involved	
Public	Private

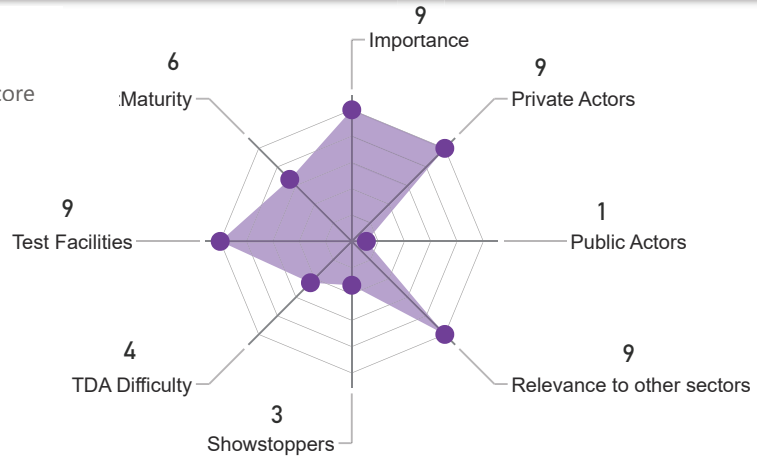
TDA Information

TDA Name	Characteristics	Priority	Funded

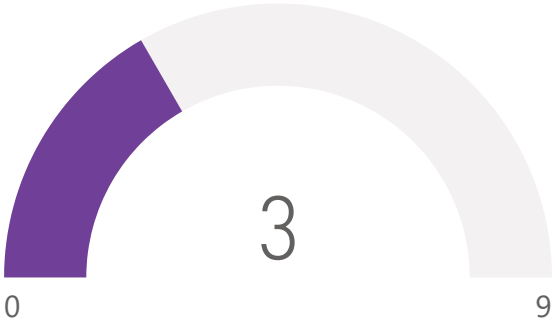
Fuel Cycle › Fuelling and storage

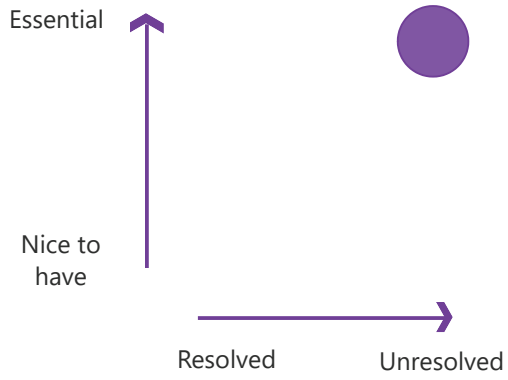
Modelling and Software Developments

50
Priority Score



TRL





Other Applications

Alternatives

Experiments

Showstoppers list

Validation of codes
Unknown properties of HDT ice

Tech Characteristics

Existing Test Facilities	Additional Test Facility Needed

European Entities Involved

Public	Private
CEA (Cadarache & Grenoble), HUN-REN (Budapest), IPP (Garching), KIT (Karlsruhe), ENEA (Frascati)	

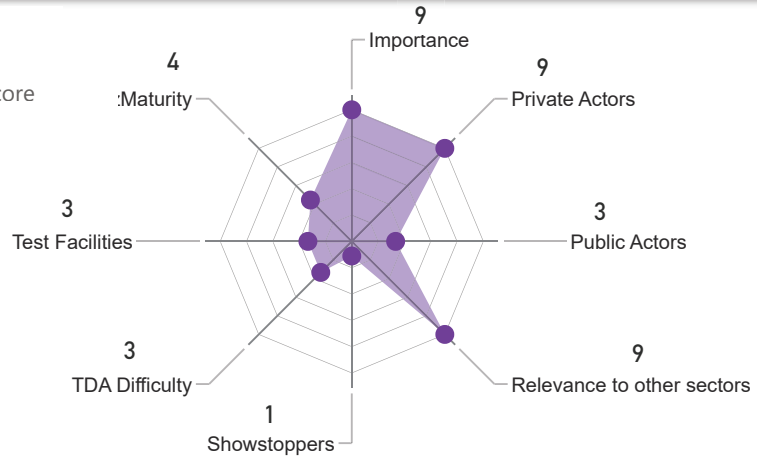
TDA Information

TDA Name	Characteristics	Priority	Funded
Mechanical model for behaviour of the pellets in the guide tube	>80%, <6 months, <250k	Medium	No
Mechanical model for pellet behaviour during acceleration	>80%, <6 months, <250k	Medium	No
Modelling of heating of targets through gas friction during inertial fusion injection	>80%, 6 months to 2 years, <250k	High	No
Modelling of the centrifugal acceleration process	>80%, <6 months, <250k	Medium	No
Process and thermal model of the extrusion process	>80%, <6 months, <250k	High	No
Test facility to characterize the mechanical properties of the various species of pellets	40 to 80%, >2 years, >1M	High	No

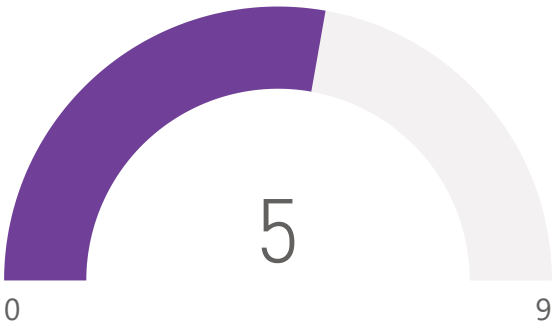
Fuel Cycle › Fuelling and storage

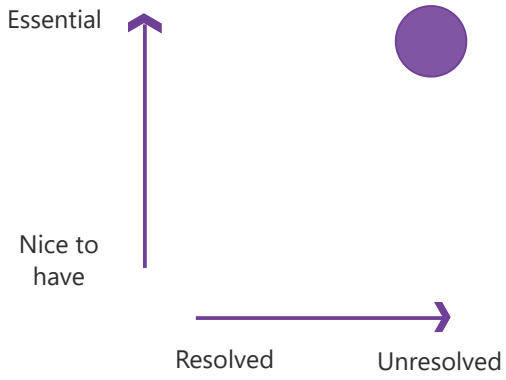
Pellet Cutter

41
Priority Score



TRL





Other Applications

Alternatives

Showstoppers list

Reliability for tritium application,
Unknown properties of DT/T ice.

Tech Characteristics

Existing Test Facilities	Additional Test Facility Needed
HU-REN (Budapest) DIPAK-PET (KIT under construction)	Test the reliability of the technology with Tritium

European Entities Involved

Public	Private
IPP (Garching) Ciemat (Madrid) HUN-REN (Budapest) CEA (Grenoble) KIT (Karlsruhe)	

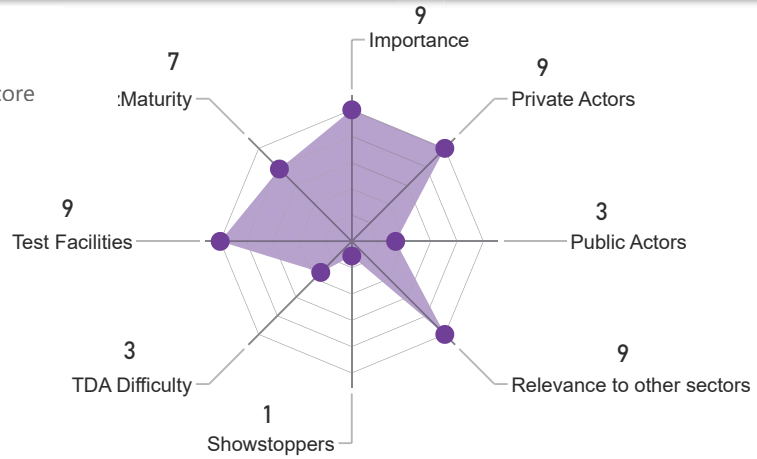
TDA Information

TDA Name	Characteristics	Priority	Funded
Build prototype and test it in a cryogenic and vacuum environment (+ Tritium as second step)	40 to 80%, 6 months to 2 years, 250k to 1M	High	No

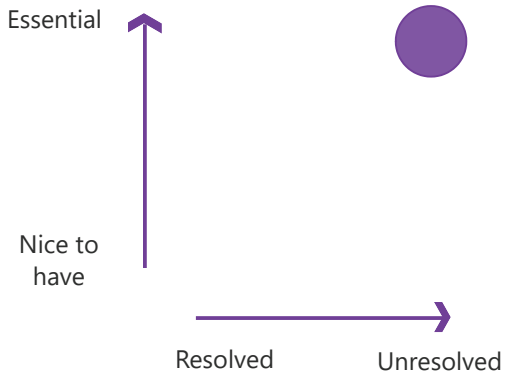
Fuel Cycle › Fuelling and storage

Pellet injectors for divertor cooling gas

50
Priority Score



TRL



Other Applications

Alternatives

Gas injection

Showstoppers list

Contamination,
Access to the divertor,
Better understanding of divertor physics to qualify need

Tech Characteristics

Existing Test Facilities	Additional Test Facility Needed
DTT (no tritium)	Access to magnetic confinement machine to test the function

European Entities Involved

Public	Private
KIT	

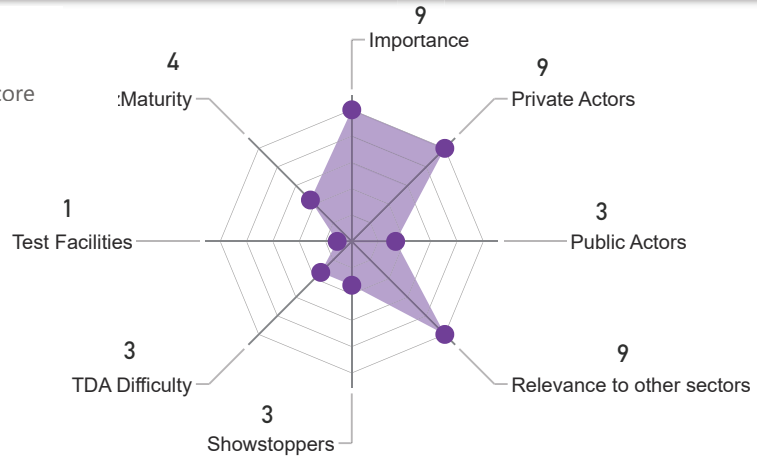
TDA Information

TDA Name	Characteristics	Priority	Funded
Comparative study pellet injection vs gas injection for divertor detachment control	>80%, <6 months, <250k	Medium	No

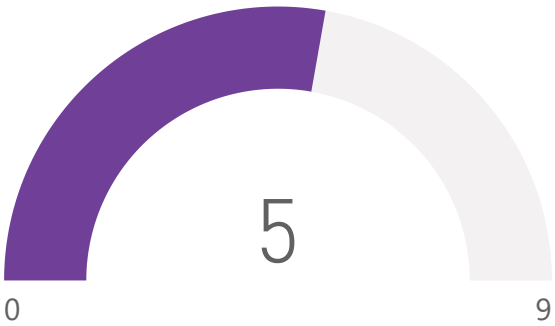
Fuel Cycle › Fuelling and storage

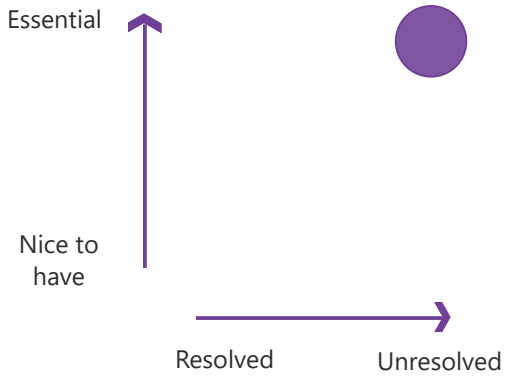
Pellet Punchers

41
Priority Score



TRL





Other Applications	Alternatives	Showstoppers list
	Gas gun	

Tech Characteristics

Existing Test Facilities	Additional Test Facility Needed
HUN-REN (Budapest)	

European Entities Involved

Public	Private
Hun-REN (Budapest) IPP (Garching)	

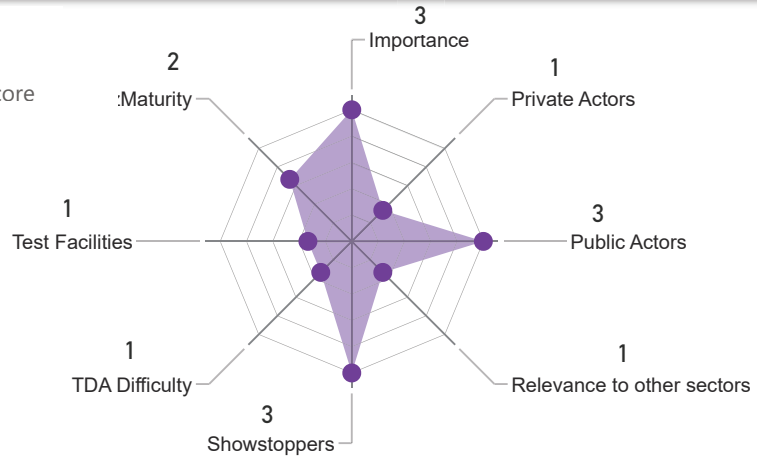
TDA Information

TDA Name	Characteristics	Priority	Funded
Develop a vacuum-compatible electromagnetic actuator	40 to 80%, 6 months to 2 years, 250k to 1M	Medium	No

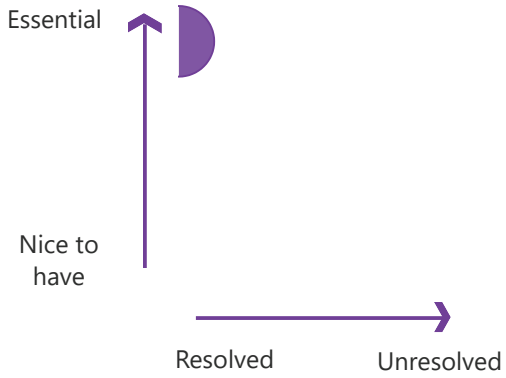
Fuel Cycle › Fuelling and storage

Storage of hydrogen isotopes

15
Priority Score



TRL



Other Applications	Alternatives
Bulk H storage, Hydrogen generation	

Showstoppers list
Nuclear licensing (for depleted Uranium)

Tech Characteristics

Existing Test Facilities	Additional Test Facility Needed
TLK (Karlsruhe), H3aT (Culham under construction) Unity 2 (Canada under construction)	

European Entities Involved	
Public	Private
	Monteiro, Alsymex, Kyoto Fusioneering, SAES, Urenco, Orano

TDA Information

TDA Name	Characteristics	Priority	Funded
Design, build and test prototype ZrCo transport container	>80%, 6 months to 2 years, 250k to 1M	High	No

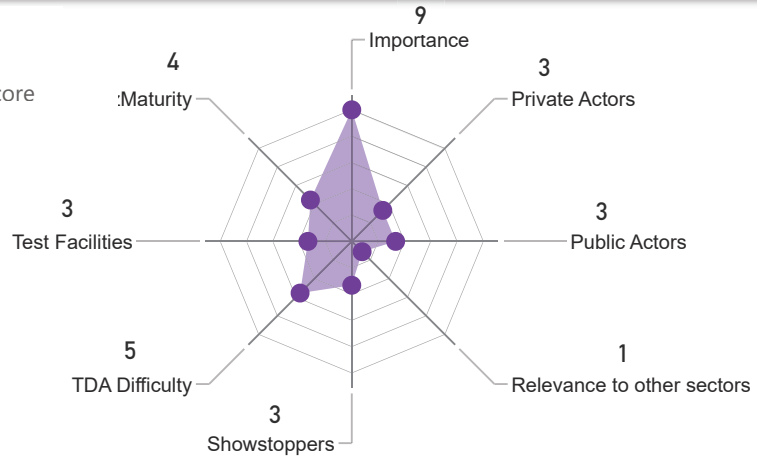
MEMBRANES AND PACKING

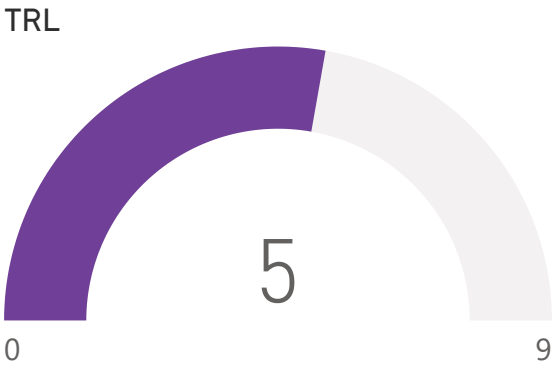
- Column packings
- Combined Electrolysis and Catalytic Exchange (CECE)
- Cryogenic distillation to separate D and T from plasma exhaust
- Electrolyser
- Equilibrators
- Cryogenic distillation for isotope separation
- Liquid Phase Catalytic Exchange (LPCE)
- Membrane Absorption
- Packed Beds
- Pd-Ag Membranes
- Quantum sieving
- Temperature/Pressure Swing Adsorption (TSA)
- Vapor Phase Catalytic Exchange (VPCE)
- Water distillation

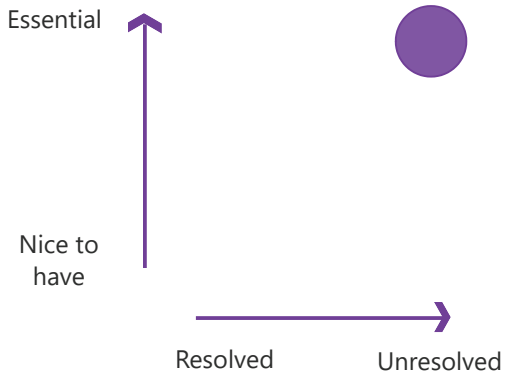
Fuel Cycle › Membranes and packing

Column packing

31
Priority Score







Other Applications
Gas separation
Fission
Water Purification
Petrochemical

Alternatives
Trays

Showstoppers list
Tritium Compatibility

Tech Characteristics

Existing Test Facilities	Additional Test Facility Needed
ICSI (Romania) KIT(Karlsruhe)	Characterise packing performance, Upscale testing

European Entities Involved

Public	Private
ICSI (Valcea) KIT/TLK (Germany) ENEA (Frascati)	Sulzer Chemtech (Switzerland), Montz (Germany).

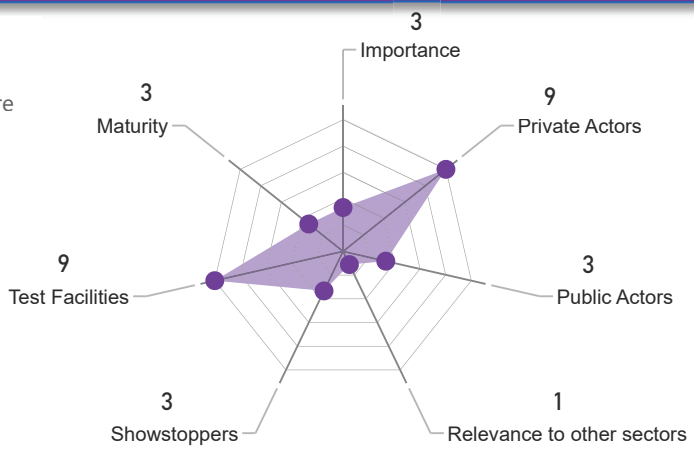
TDA Information

TDA Name	Characteristics	Priority	Funded
Multifunctional Water Distillation test facility	40 to 80%, 6 months to 2 years, 250k to 1M	High	No
Upscale Testing	<40%, >2 years, >1M	Medium	No
Wet Scrubber Optimization	40 to 80%, <6 months, <250k	Medium	No

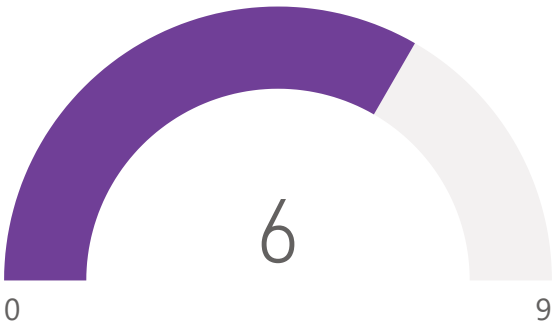
Fuel Cycle › Membranes and packing

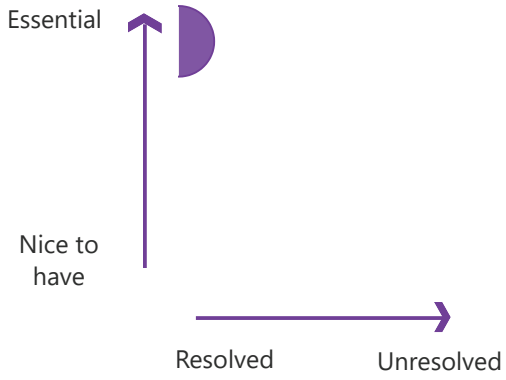
Combined Electrolysis and Catalytic Exchange (CECE)

31
Priority Score



TRL





Other Applications
Fission
Hydrogen

Alternatives
Water distillation
LPCE

Showstoppers list
Energy demand
Complexity of operation
Lifetime

Tech Characteristics

Existing Test Facilities	Additional Test Facility Needed
KIT (Karlsruhe)	

European Entities Involved

Public	Private
ENEA (Frascati)	
KIT (Karlsruhe)	

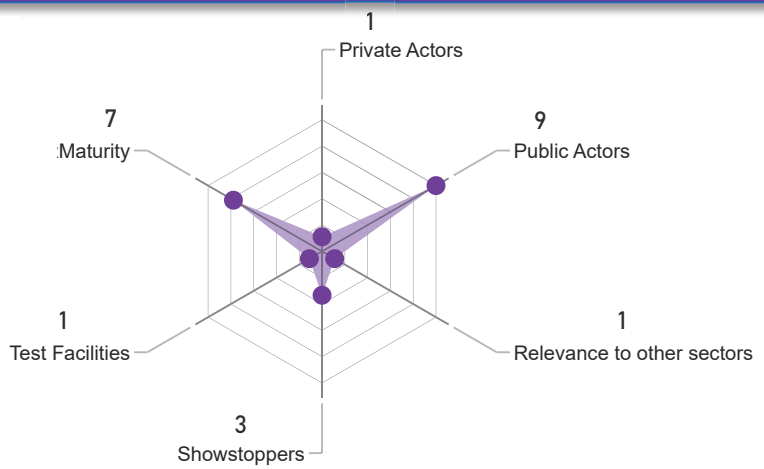
TDA Information

TDA Name	Characteristics	Priority	Funded

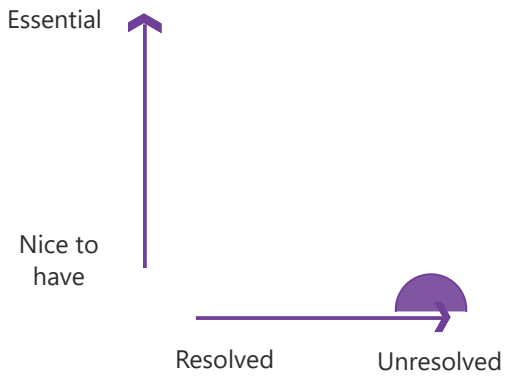
Fuel Cycle › Membranes and packing

Cryogenic distillation to separate D and T from plasma exhaust

22
Priority Score



TRL



Other Applications

Gas separation/purification
medical industry
chemical and steel manufacturing
electronics

Alternatives

Cryo Pumps, Snail Pumps, Membranes, Wet Scrubbers

Showstoppers list

Residence time
Small difference of evaporation temperatures
Development effort compared to other technologies
Uncertainty over suitability for function

Tech Characteristics

Existing Test Facilities	Additional Test Facility Needed

European Entities Involved

Public	Private
	Air Liquide (Grenoble), Linde (Pfungen), Research Instruments (Koln), Absolut System (Grenoble), Polaris (Misinto)

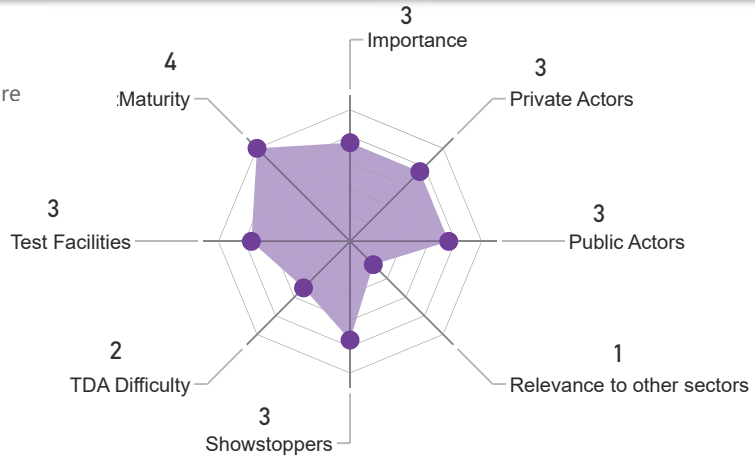
TDA Information

TDA Name	Characteristics	Priority	Funded

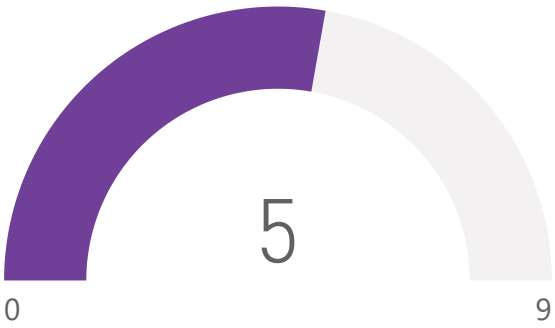
Fuel Cycle › Membranes and packing

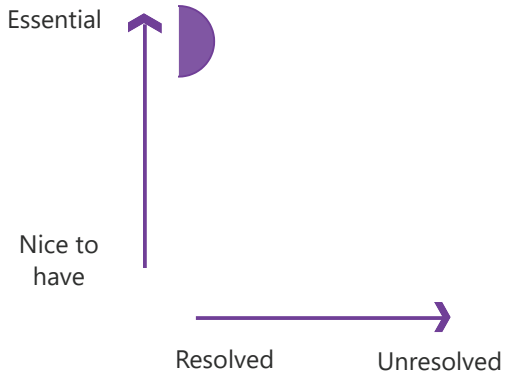
Electrolyser

22
Priority Score



TRL





Other Applications
Fission
Hydrogen

Alternatives
Water distillation plus LPCE

Showstoppers list
High energy consumption
Lifetime
Tritium compatibility

Tech Characteristics

Existing Test Facilities	Additional Test Facility Needed
ICSI (Valcea)	Tritium long term operation
H3AT (Culham under construction)	Roe collection and exchange
KIT (Karlsruhe)	
Unity 2 (Canada under construction)	

European Entities Involved

Public	Private
ICSI (Valcea)	Kyoto Fusioneering (Karlsruhe)
UKAEA (Culham)	Kraftanlagen (Heidelberg)
KIT (Karlsruhe)	Veolia Water Technologies

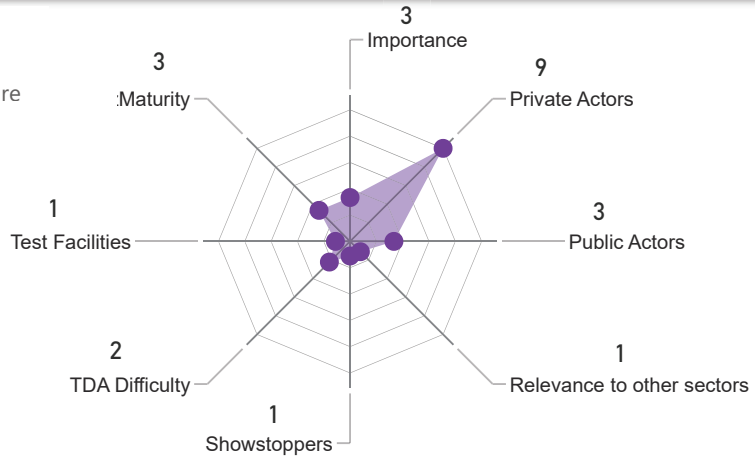
TDA Information

TDA Name	Characteristics	Priority	Funded
Test electrolyzer materials with tritium to improve lifetime and reliability.	40 to 80%, >2 years, >1M	Medium	No

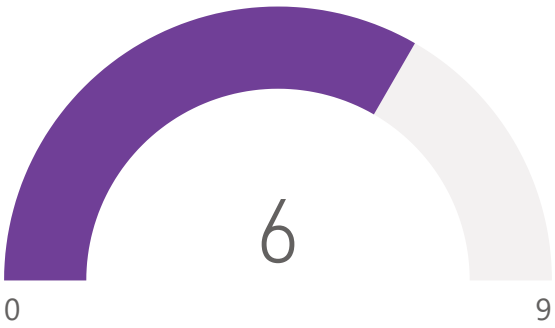
Fuel Cycle › Membranes and packing

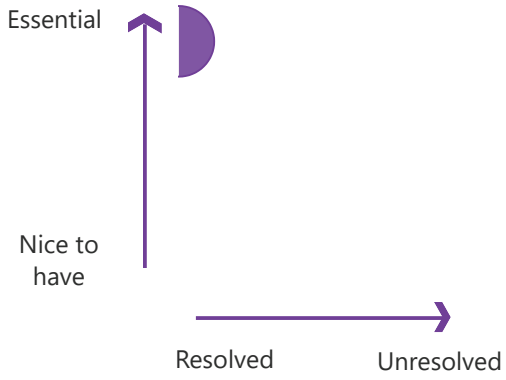
Equilibrators

23
Priority Score



TRL





Other Applications	Alternatives	Showstoppers list
Chemical Plants	Packing Distillation	Catalyst Performance, Availability of Testing Equipment

Tech Characteristics

Existing Test Facilities	Additional Test Facility Needed

European Entities Involved	
Public	Private
KIT (Karlsruhe) ICSI (Valcea)	

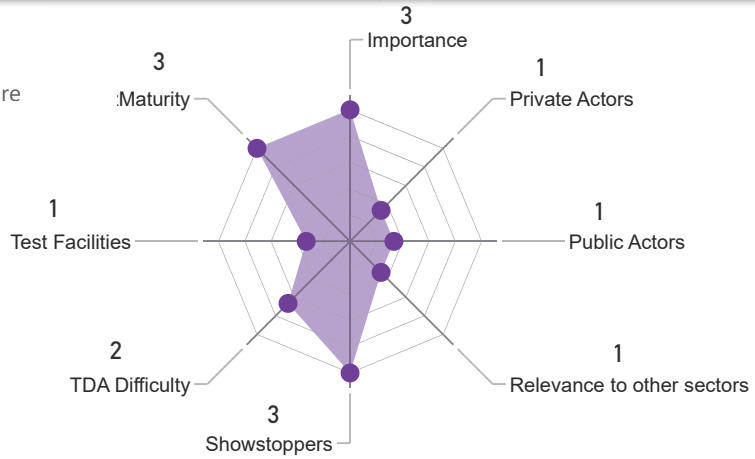
TDA Information

TDA Name	Characteristics	Priority	Funded
R&D and testing of new catalyst solutions for equilibrators	40 to 80%, 6 months to 2 years, <250k	Medium	No

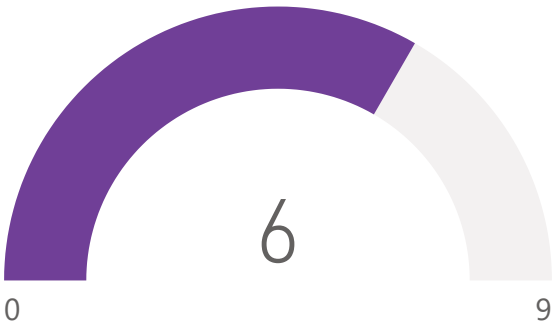
Fuel Cycle › Membranes and packing

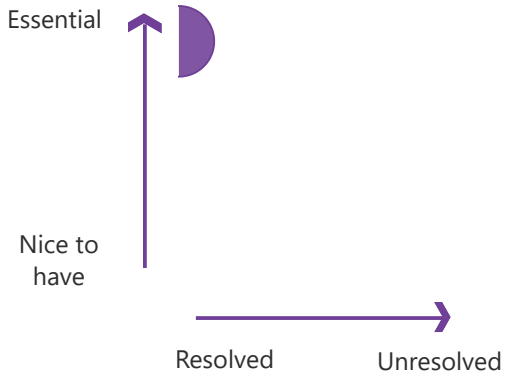
Cryogenic distillation for isotope separation

15
Priority Score



TRL





Other Applications
Fission
Gas separation
Medical industry
Chemical and steel manufacturing
Electronics.

Alternatives
TSA
PSA
Membranes

Showstoppers list
Large Inventory
Energy consumption

Tech Characteristics

Existing Test Facilities	Additional Test Facility Needed
KIT TLK (Germany), ICSI (Valcea), UKAEA H3AT (Culham under construction), UKAEA AGHS (Culham)	

European Entities Involved	
Public	Private
UKAEA (Culham), KIT (Karlsruhe), ITER (Cadarache), ICSI (Valcea), ENEA (Frascati)	Air Liquide (Grenoble), Linde (Pfungen), Research Instruments (Koln), Absolut System (Grenoble), Polaris (Misinto)

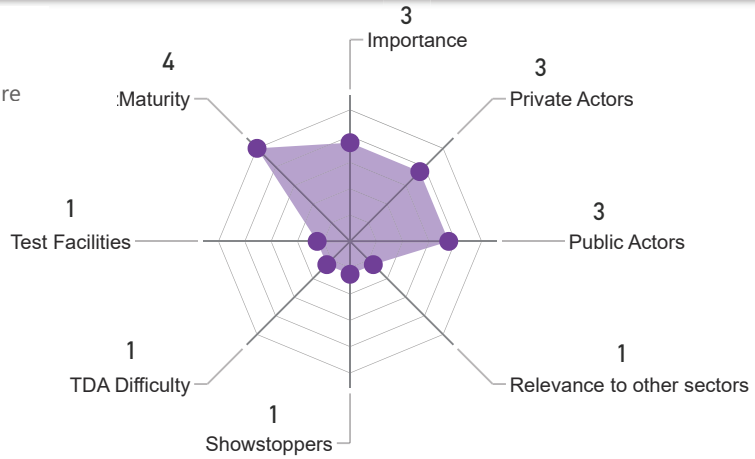
TDA Information

TDA Name	Characteristics	Priority	Funded
Development of compact heat exchangers and copper-SS joining techniques	>80%, 6 months to 2 years, 250k to 1M	Medium	No
Packing performances assessment testing	>80%, 6 months to 2 years, 250k to 1M	Low	No
Testing of the dynamic operation of multiple columns (control loops)	>80%, 6 months to 2 years, 250k to 1M	Medium	Yes

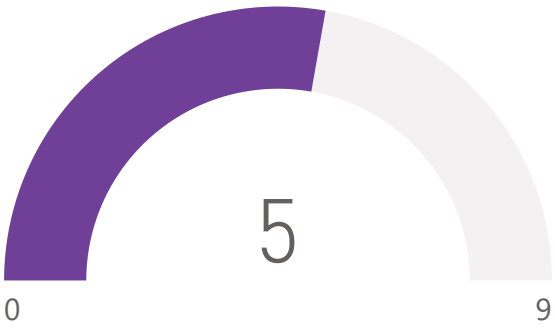
Fuel Cycle › Membranes and packing

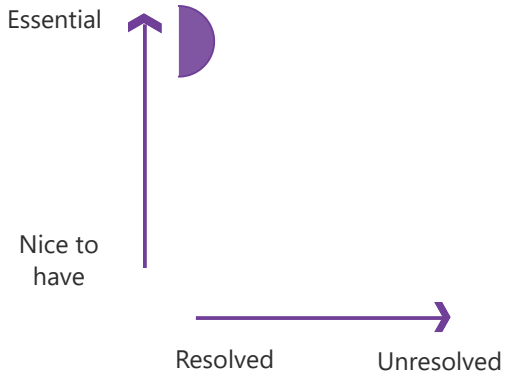
Liquid Phase Catalytic Exchange (LPCE)

17
Priority Score



TRL





Other Applications	Alternatives	Showstoppers list
Fission Reactive distillation	Water distillation, Membrane reactor	Catalyst performance, Packing characterization, Maintenance

Tech Characteristics

Existing Test Facilities	Additional Test Facility Needed
ICSI (Valcea) KIT (Karlsruhe) JET - AGHS (Culham)	

European Entities Involved

Public	Private
ICSI (Valcea) KIT (Karlsruhe) ENEA (Frascati)	VEOLIA - SPG - Eiffage

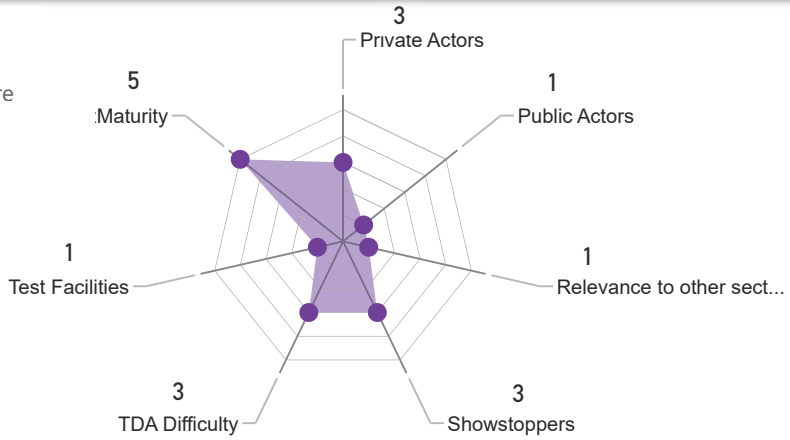
TDA Information

TDA Name	Characteristics	Priority	Funded
LPCE Catalyst development for Tritium	>80%, >2 years, >1M	Medium	Partially

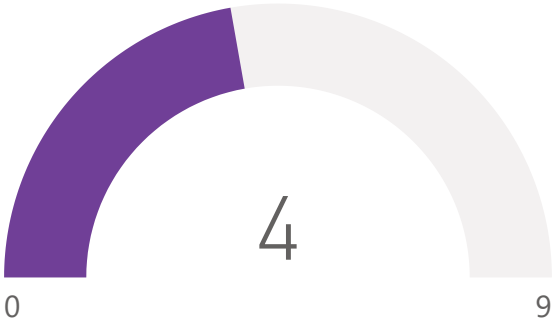
Fuel Cycle › Membranes and packing

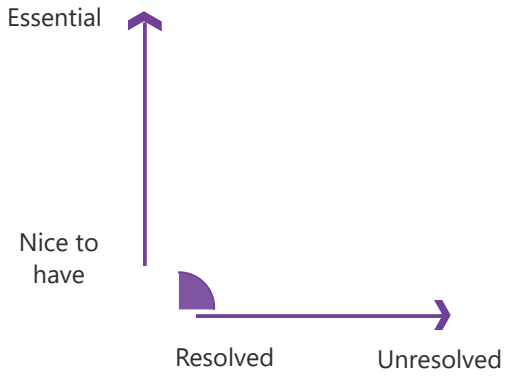
Membrane Absorption

17
Priority Score



TRL





Other Applications
Hydrogen Gas Separation

Alternatives
Packings, Cryo separation

Showstoppers list
Capacity Batch Process High Process Control and Safety demand

Tech Characteristics

Existing Test Facilities	Additional Test Facility Needed
UKAEA (Culham) University of Bath ENEA (Frascati)	Adsoption process to be characterized for fusion process

European Entities Involved

Public	Private
ENEA (Frascati), Univ of Calabria, UKAEA (Culham), University of Bath and Rochester, TNO (Netherlands)	Tecnalia

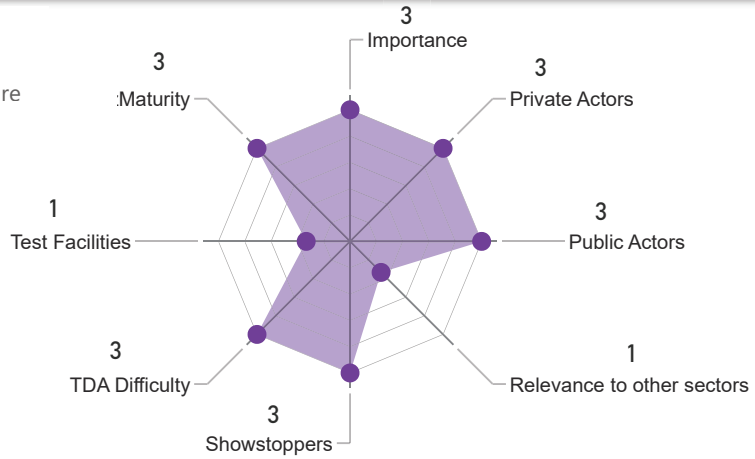
TDA Information

TDA Name	Characteristics	Priority	Funded
Charaterise adsorption for fusion process	40 to 80%, 6 months to 2 years, 250k to 1M	Low	No

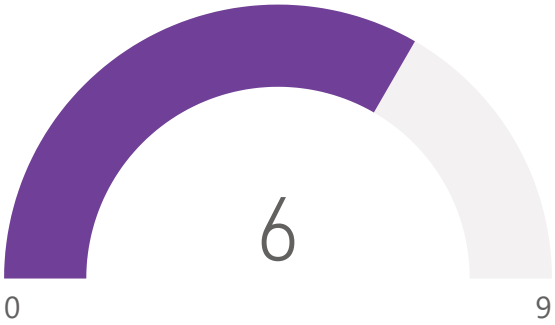
Fuel Cycle › Membranes and packing

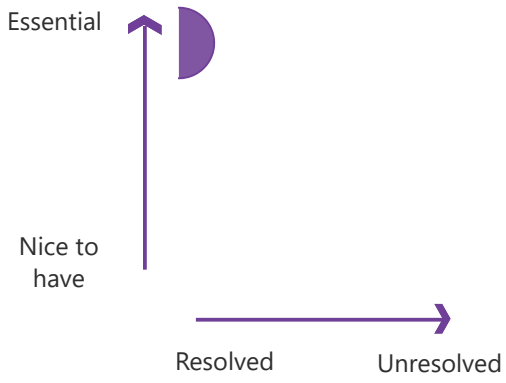
Packed Beds

20
Priority Score



TRL





Other Applications
Gas Purification
Chemical Plants
Heavy Water
Cryo
Reactors
Laboratory
Semiconductor Industry

Alternatives
Membranes
Water Distillation

Showstoppers list
Experimental facilities needed

Tech Characteristics

Existing Test Facilities	Additional Test Facility Needed
ENEA - Hydrex (Italy) Smolsys (Switzerland)	Test material in high pressure of inert gas and low partial pressure of tritium

European Entities Involved

Public	Private
ENEA (Frascati)	Sulzer Chemtech (Switzerland) Saes (Italy) Smolsys (Lucerne)

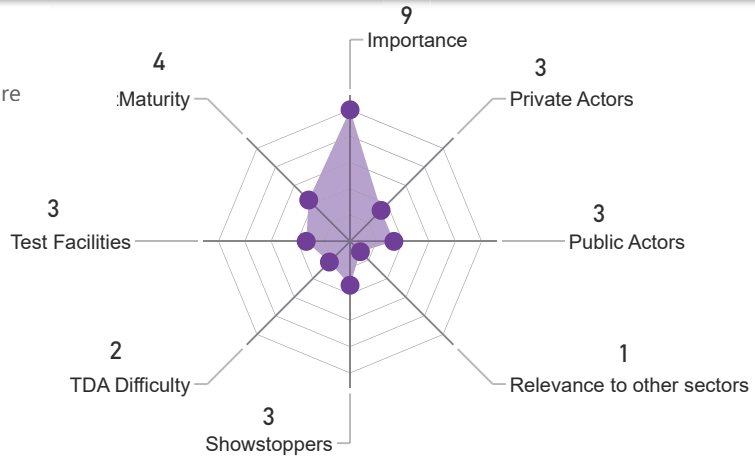
TDA Information

TDA Name	Characteristics	Priority	Funded
Digital Twin technology usage for Tritium Scale Up design	<40%, 6 months to 2 years, <250k	Medium	No
Regeneration procedure and efficiency of the Packed Bed	>80%, >2 years, 250k to 1M	Medium	No

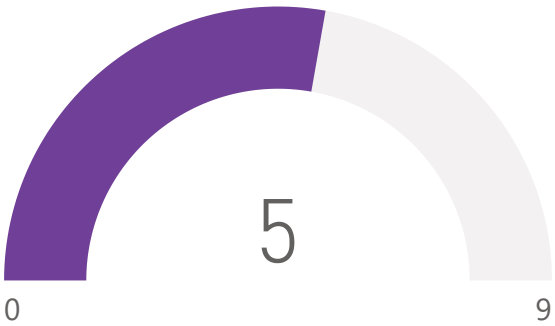
Fuel Cycle › Membranes and packing

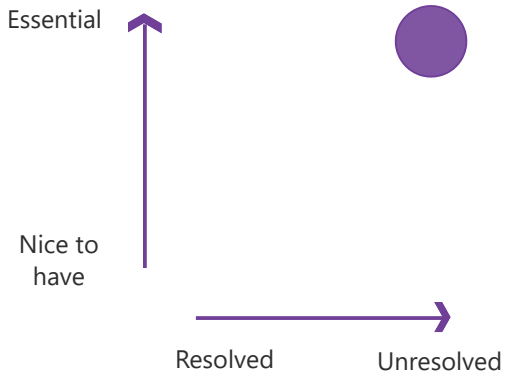
Pd-Ag Membranes

28
Priority Score



TRL





Other Applications	Alternatives	Showstoppers list
Hydrogen fuel Membrane reactors	Alternative membrane materials, Adsorption, Composite Membrane, Distillation and Catalytic Oxidation	Mechanical resistance Mechanical coupling

Tech Characteristics

Existing Test Facilities	Additional Test Facility Needed
UKAEA (Culham), University of Bath ENEA (Frascati)	Separation performance Life expectancy Poisoning

European Entities Involved

Public	Private
UKAEA (Culham) KIT (Karlsruhe) ENEA (Frascati) TNO (NL)	Tecnalia Kyoto Fusioneering

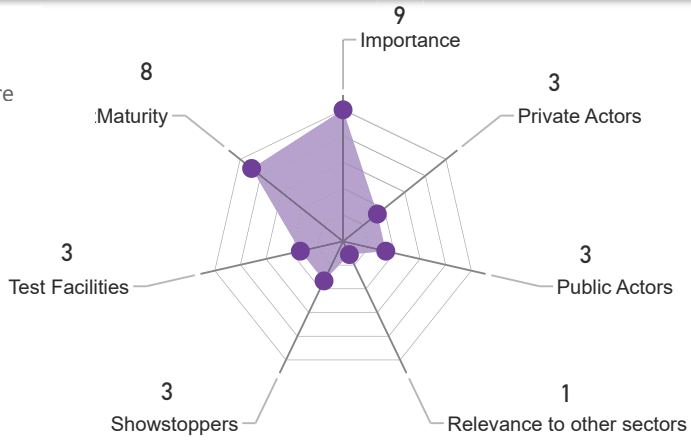
TDA Information

TDA Name	Characteristics	Priority	Funded
Development of Pd-Ag membrane reactor/catalyst (air-like)	40 to 80%, 6 months to 2 years, 250k to 1M	High	No
industrialization of membranes modules (shape, joining, compatibility with environment, etc.)	>80%, 6 months to 2 years, 250k to 1M	Medium	No

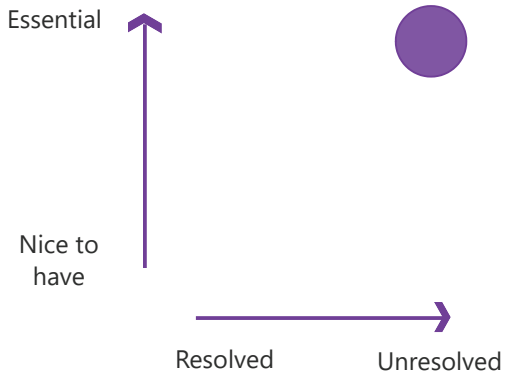
Fuel Cycle › Membranes and packing

Quantum sieving

30
Priority Score



TRL



Other Applications
Fission Gas separation

Alternatives
Cryo distillation, Pd Membranes, Metal Foil pump

Showstoppers list
Manufacturability Control

Tech Characteristics

Existing Test Facilities	Additional Test Facility Needed
Univ of Bath (UK) UKAEA NPL (London) Liverpool University (UK)	Characterise material, process control, performance, chemistry compatibility, reproducibility, scale-up

European Entities Involved

Public	Private
Univ of Bath (UK) UKAEA NPL (London) Liverpool University (UK)	Tecnalia (Spain), Atkins (UK), BIMOTECH (PL)

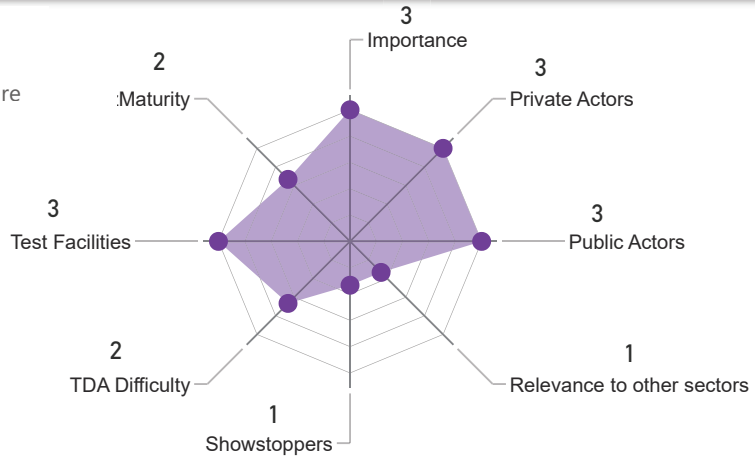
TDA Information

TDA Name	Characteristics	Priority	Funded

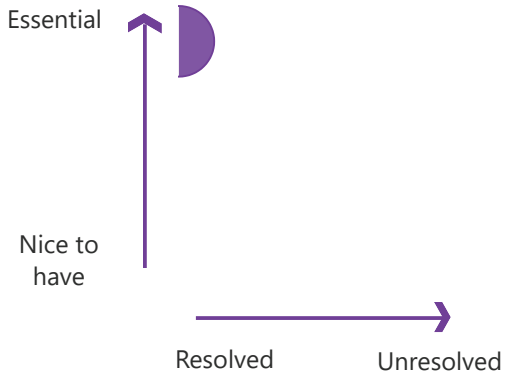
Fuel Cycle › Membranes and packing

Temperature/Pre. Swing Adsorption (TSA)

18
Priority Score



TRL



Other Applications
Hydrogen Separation
Carbon Adsorption

Alternatives
Cryo distillation, PSA, Membranes, Gas Chromatography

Showstoppers list
Capacity, Control, Efficiency, Large Inventory, Throughput, Batch, Slow performance

Tech Characteristics

Existing Test Facilities	Additional Test Facility Needed
MAIA (KIT) HESTIA (KIT) Air Liquide Innov campus	same functions as others

European Entities Involved

Public	Private
KIT (Karlsruhe) ENEA (Frascati)	Air Liquide Linde

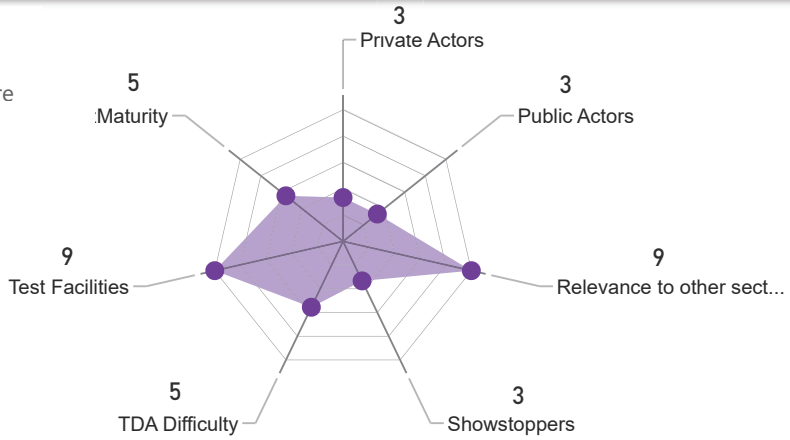
TDA Information

TDA Name	Characteristics	Priority	Funded
Characterization of adsoprtion of T by/for different materials	>80%, 6 months to 2 years, 250k to 1M	Low	No
Investigate TSA for H/DT rebalancing using existing proto to see if reqs. (e.g. throughput vs separation) can be met	40 to 80%, 6 months to 2 years, 250k to 1M	Low	No

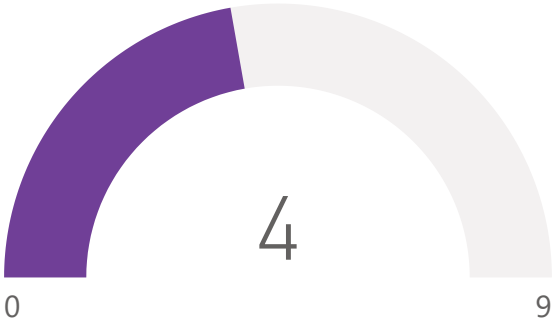
Fuel Cycle › Membranes and packing

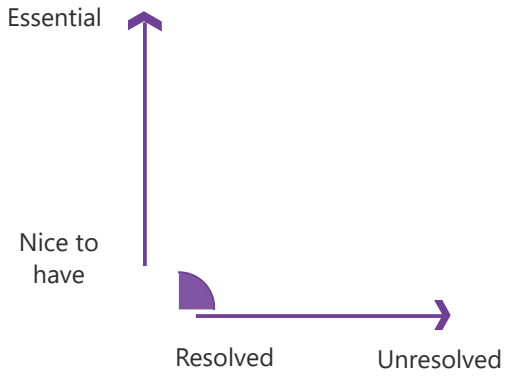
Vapor Phase Catalytic Exchange (VPCE)

37
Priority Score



TRL





Other Applications

Alternatives

LPCE, CECE, Water distillation

Showstoppers list

Catalyst and packing
Operation temperature

Tech Characteristics

Existing Test Facilities	Additional Test Facility Needed
CEA KIT UKAEA-AGS	depends on the level. Qualification program (Detritiation).

European Entities Involved

Public	Private
ENEA CEA KIT UKAEA	SPG-Eiffage

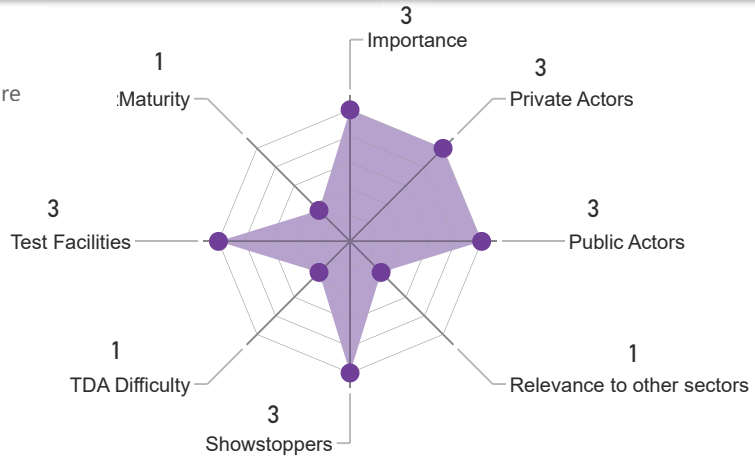
TDA Information

TDA Name	Characteristics	Priority	Funded
Air detritiation wet Scrubber development	<40%, 6 months to 2 years, 250k to 1M	Low	No

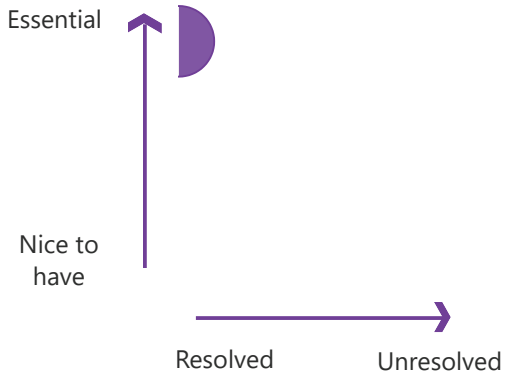
Fuel Cycle › Membranes and packing

Water distillation

18
Priority Score



TRL



Other Applications
Fission
Water purification
Desalination

Alternatives
Membranes
LPCE
CECE

Showstoppers list
Column size
Energy intensive
High inventory
Packing performance in relevant conditions

Tech Characteristics

Existing Test Facilities	Additional Test Facility Needed
ICSI (Valcea)	Packing characterization, Performance. Operability and Maintenance. Integration with other type of processes.

European Entities Involved

Public	Private
ICSI (Valcea)	SPG - Effiage
ENEA (Frascati)	Sulzer
	Koch-glitsch
	Montz
	Kraftanlagen

TDA Information

TDA Name	Characteristics	Priority	Funded
Water Distillation optimization for tritium separation	>80%, >2 years, >1M	Medium	No

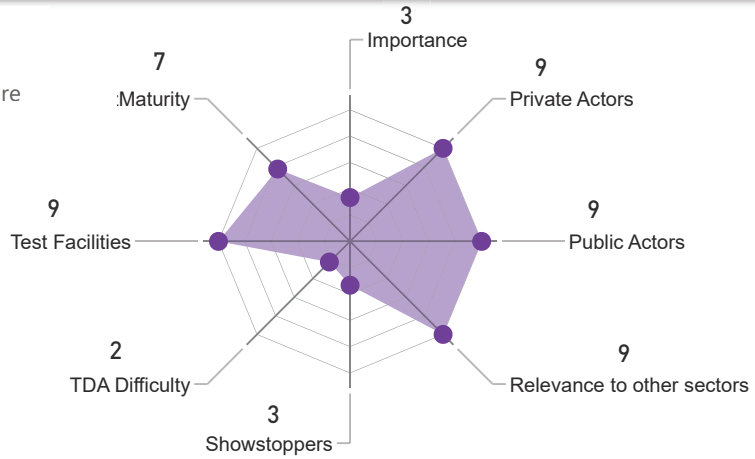
PUMPING

- Continuous Cryogenic Diffusion Pump / Snail Pump
- Cryogenic Adsorption pumps
- Cryogenic turbo molecular pumps
- Cryogenic Viscous Compressor (CVC)
- Liquid Ring pumps
- Liquid metal diffusion pump
- Metal bellow pumps
- Metal foil pump
- Non-Evaporable Getter (NEG) pumps
- Turbo molecular pumps
- Oil diffusion pumps with tritium compatible oils
- Piston pumps
- Proton conductor pump
- Root pumps
- Screw pumps
- Scroll pumps
- Temperature Staged cryogenic condensation and adsorption pumps

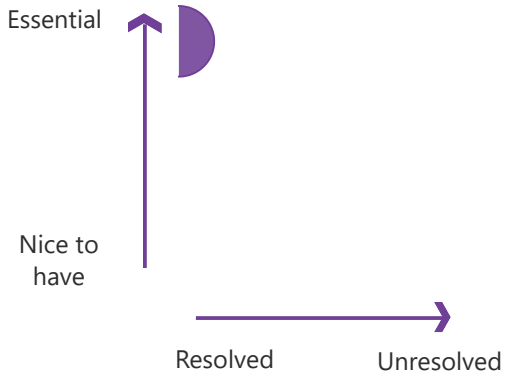
Fuel Cycle › Pumping

Continuous Cryogenic Diffusion Pump / Snail Pump

51
Priority Score



TRL



Other Applications

Alternatives

NEG
Cryomechanical or diffusion pumps

Showstoppers list

Scale-up
Moving parts reliability

Tech Characteristics

Existing Test Facilities	Additional Test Facility Needed

European Entities Involved

Public	Private

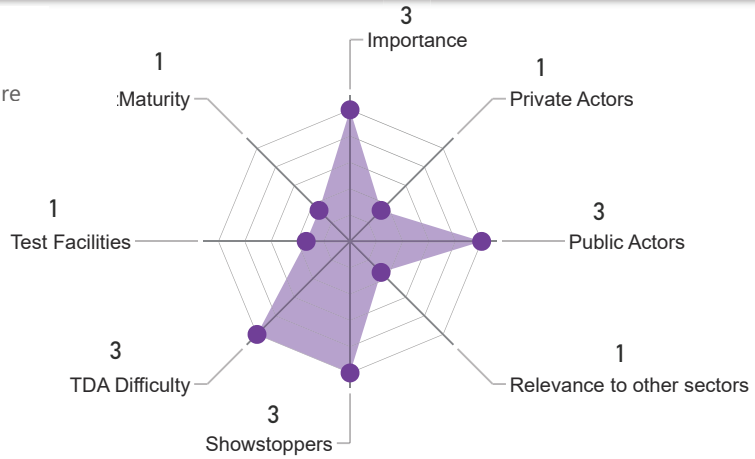
TDA Information

TDA Name	Characteristics	Priority	Funded
Develop a snail pump in Europe	<40%, >2 years, >1M	Low	No

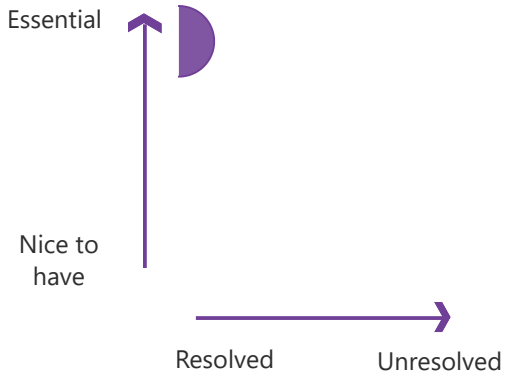
Fuel Cycle › Pumping

Cryogenic Adsorption pumps

16
Priority Score



TRL



Other Applications

Semiconductor
solar process,
Aerospace,
High energy physics

Alternatives

NEG pumps, Foil pumps,
Diffusion pumps, Cold Turbo MP,
Turbo MP

Showstoppers list

Tritium inventory and hydrogen safety
Scale up-helium cost

Tech Characteristics

Existing Test Facilities	Additional Test Facility Needed
ITER	

European Entities Involved

Public	Private
ITER KIT	Research Instruments, ALSYMEX, Kyoto Fusioneering, Absolut System, SDMS, AVS

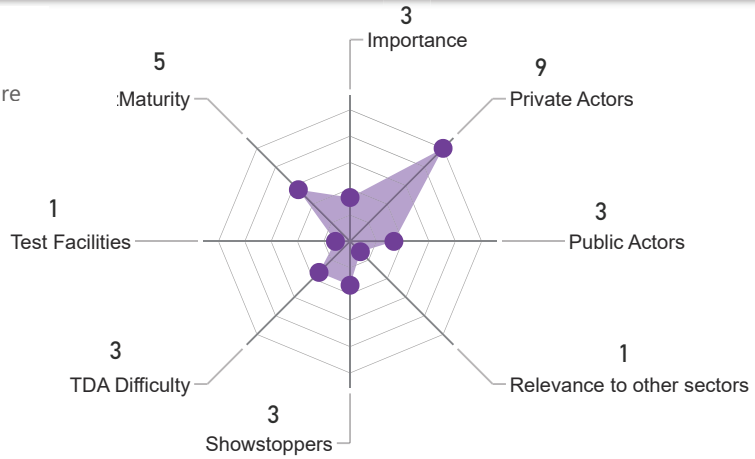
TDA Information

TDA Name	Characteristics	Priority	Funded
Develop water resistant glue for charcoal	>80%, 6 months to 2 years, <250k	Medium	No
Prototype a cryopump panel with carbon nanotube cryosorption media	<40%, 6 months to 2 years, 250k to 1M	Low	No

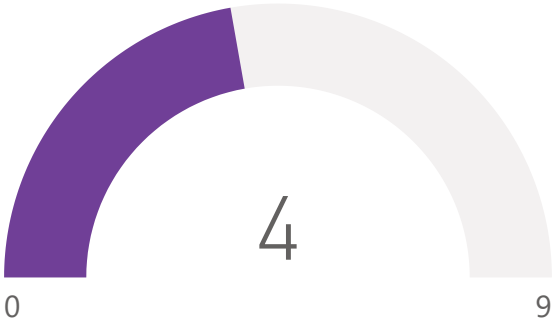
Fuel Cycle › Pumping

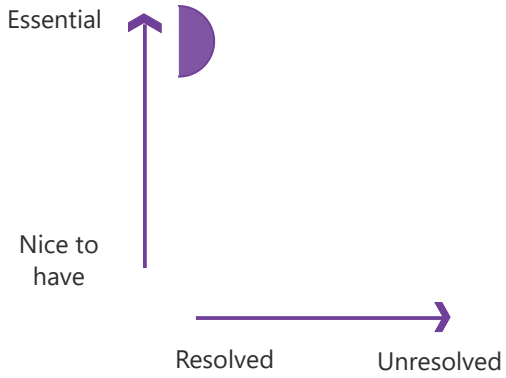
Cryogenic turbo molecular pumps

28
Priority Score



TRL





Other Applications

Semiconductors
Chemical Vapour Deposition Coating
High energy physics
space

Alternatives

TMP, Cryosorption, Diffusion pumps, NEG

Showstoppers list

Conductance loss in pre-cooler
Tritium compatible materials
Not compatible with magnetic fields & radiation environment

Tech Characteristics

Existing Test Facilities	Additional Test Facility Needed
CEA (Grenoble)	

European Entities Involved

Public	Private
ITER CEA (Grenoble)	

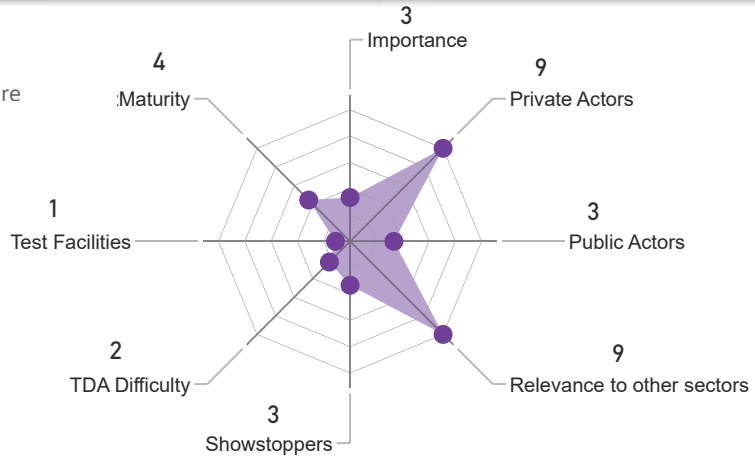
TDA Information

TDA Name	Characteristics	Priority	Funded
Academic study for TMP and cryo TMP Tokamak operation environment	>80%, <6 months, <250k	Low	No
Develop TMP with a rotor and MagLev suspension working at cryogenic temperatures	40 to 80%, 6 months to 2 years, 250k to 1M	Low	No
Development of a magnetic field compatible TMP.	40 to 80%, 6 months to 2 years, 250k to 1M	Low	No

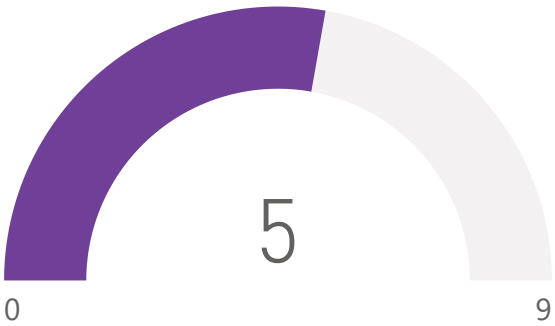
Fuel Cycle › Pumping

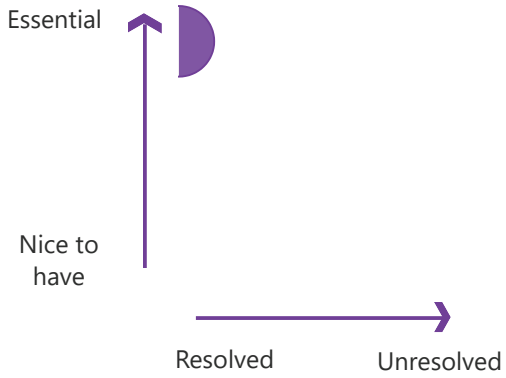
Cryogenic Viscous Compressor (CVC)

34
Priority Score



TRL





Other Applications

Alternatives

Tritium compatible, mechanical pumps
Metal foil pumps
Conventional pumps scroll, roots

Showstoppers list

Large tritium inventories
Regeneration technology
Explosion protection limits

Tech Characteristics

Existing Test Facilities	Additional Test Facility Needed
CEA (Grenoble)	

European Entities Involved

Public	Private
ITER CEA (Grenoble)	

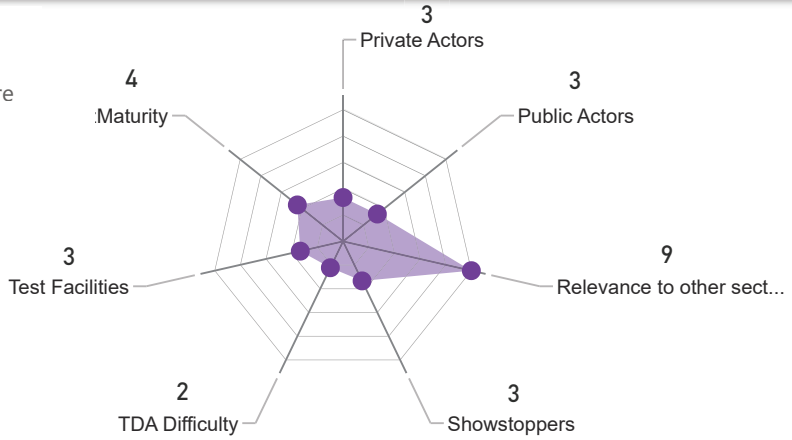
TDA Information

TDA Name	Characteristics	Priority	Funded
Investigate the use of the CVC technology in a fusion fuel cycle and define associated requirements	40 to 80%, 6 months to 2 years, <250k	Low	No

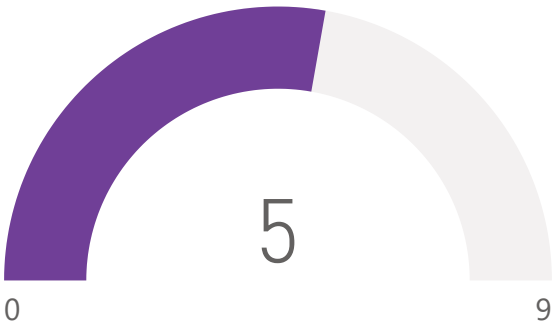
Fuel Cycle › Pumping

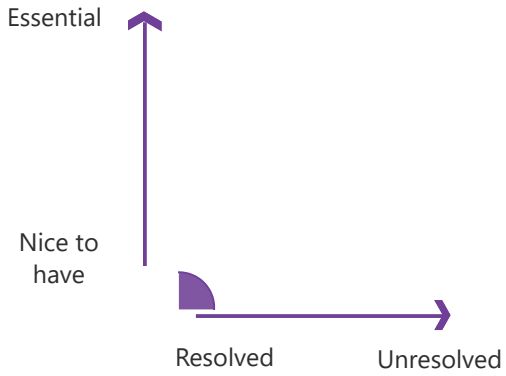
Liquid Ring pumps

27
Priority Score



TRL





Other Applications

Alternatives

Mechanical displacement pumps
CVC

Showstoppers list

Pump liquid not compatible with fusion process gases

Tech Characteristics

Existing Test Facilities	Additional Test Facility Needed
DIPAK (KIT under construction) UKAEA (Rochester) Unity-2 (Canada under construction)	Tritium test bench

European Entities Involved

Public	Private
KIT	Vakuo GmbH Nash Friatec AG Hermetic

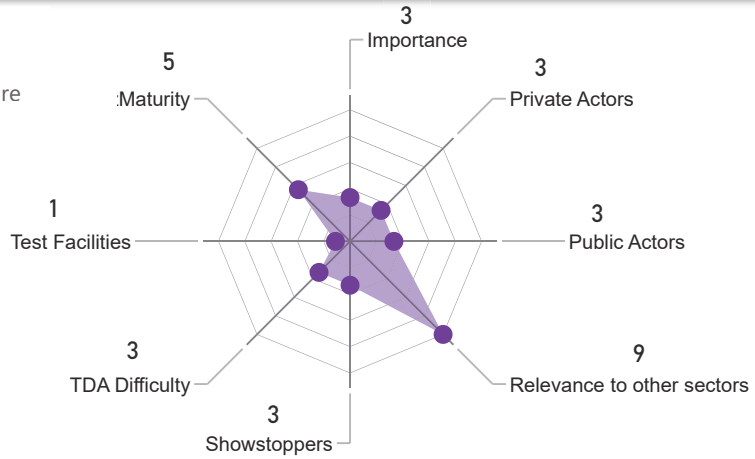
TDA Information

TDA Name	Characteristics	Priority	Funded
Find an alternative to mercury	40 to 80%, 6 months to 2 years, <250k		No
Qualify the mercury liquid ring pump to fusion requirements	>80%, 6 months to 2 years, >1M		No

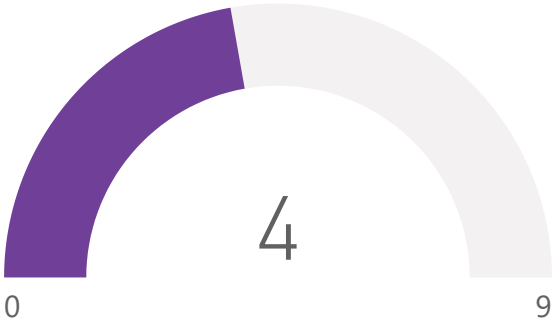
Fuel Cycle › Pumping

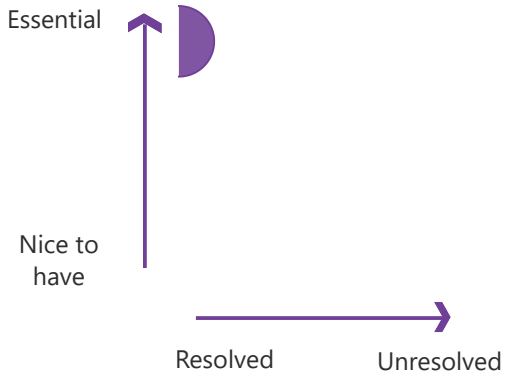
Liquid metal diffusion pump

30
Priority Score



TRL





Other Applications

Alternatives

Cryopumps, TMP, other diffusion pumps,

Showstoppers list

Mercury regulation-toxicity-contamination
Halogens getting into the tritium plant and plasma
Safety

Tech Characteristics

Existing Test Facilities	Additional Test Facility Needed
DIPAK (KIT Karlsruhe under construction)	

European Entities Involved

Public	Private
KIT (Karlsruhe)	Kyoto Fusioneering

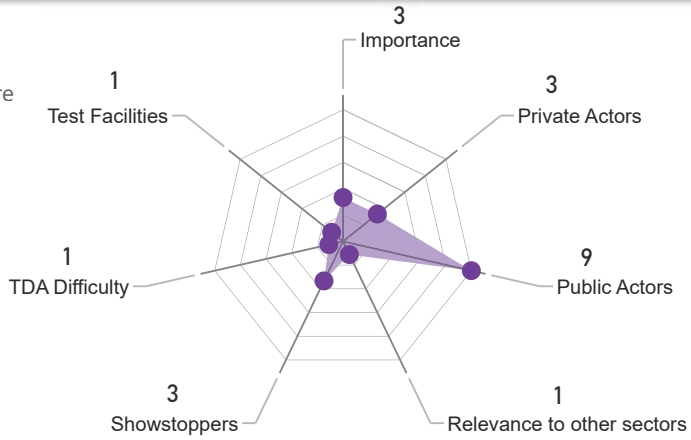
TDA Information

TDA Name	Characteristics	Priority	Fun
Demonstrate Mercury Diffusion Pump compatibility with a plasma protection systems as DMS	40 to 80%, <6 months, <250k	Low	No
Develop liquid lithium diffusion pump	40 to 80%, 6 months to 2 years, 250k to 1M	Low	Yes
Investigate mercury back flow into the torus by simulations and optimize the design	40 to 80%, 6 months to 2 years, <250k	Low	No
Performance and operation demonstration of the mercury diffusion pump in a	>80%, >2 years, >1M	Low	No

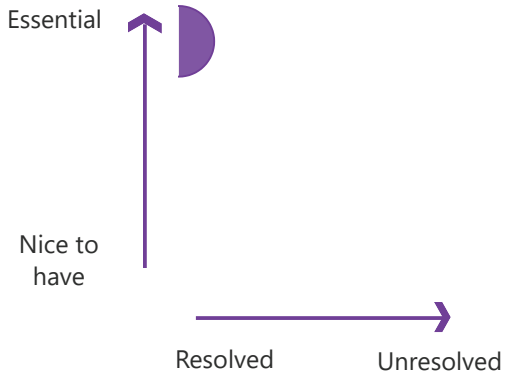
Fuel Cycle › Pumping

Metal bellow pumps

21
Priority Score



TRL



Other Applications	Alternatives	Showstoppers list
Aerospace Petrochemical		

Tech Characteristics

Existing Test Facilities	Additional Test Facility Needed	European Entities Involved	
		Public	Private
KIT - Tritium Laboratory Karlsruhe (TLK) UKAEA (Rochester) Unity-2 (Canada under construction)			

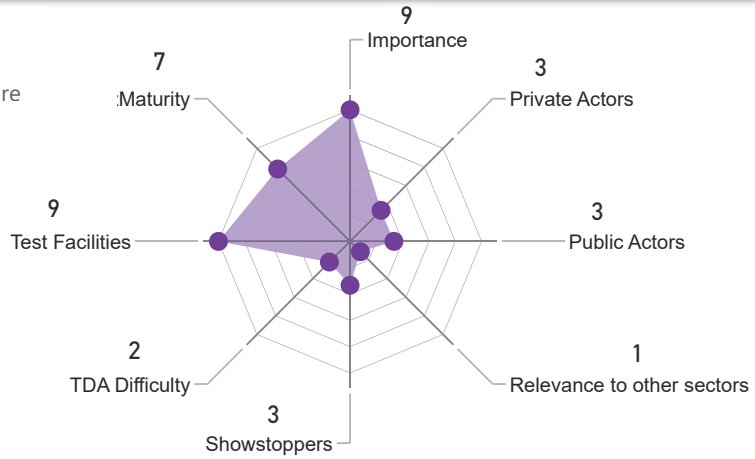
TDA Information

TDA Name	Characteristics	Priority	Funded
Certify existing internationally available pumps to European Market	>80%, 6 months to 2 years, 250k to 1M	Medium	No

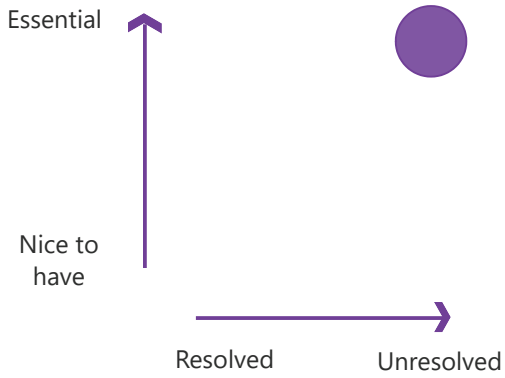
Fuel Cycle › Pumping

Metal foil pump

37
Priority Score



TRL



Other Applications

Hydrogen industry
Semiconductors

Alternatives

Proton conductor pumps,
CVC
Cryosorption pumps

Showstoppers list

Reliability and maintenance in environment
Conductance limitation for the primary pump

Tech Characteristics

Existing Test Facilities	Additional Test Facility Needed
DIPAK (KIT under construction) H3AT (UK under construction) UNITY-2 (Canada under construction).	Test performance and operation Testing with Tritium

European Entities Involved

Public	Private
KIT University of Stuttgart	Kyoto Fusioneering

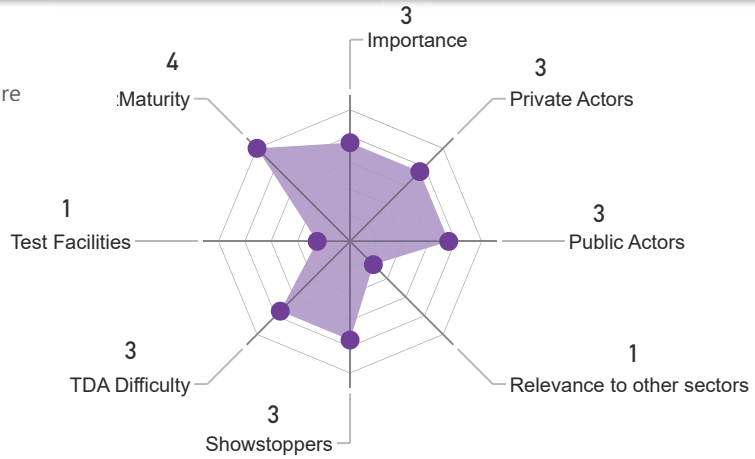
TDA Information

TDA Name	Characteristics	Priority	Funded
Develop atomic H2 production sources	40 to 80%, 6 months to 2 years, 250k to 1M	Low	No
Performance and operation qualification (1° qualification step)	40 to 80%, 6 months to 2 years, 250k to 1M	Medium	Partially
Prototype the Metal Foil Pump	>80%, >2 years, >1M	Medium	Partially
Qualification with tritium (second qualification step)	40 to 80%, 6 months to 2 years, 250k to 1M	Low	Partially

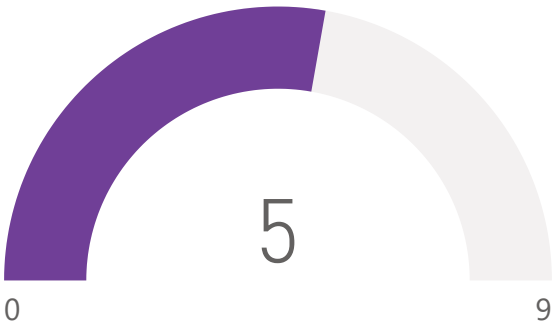
Fuel Cycle › Pumping

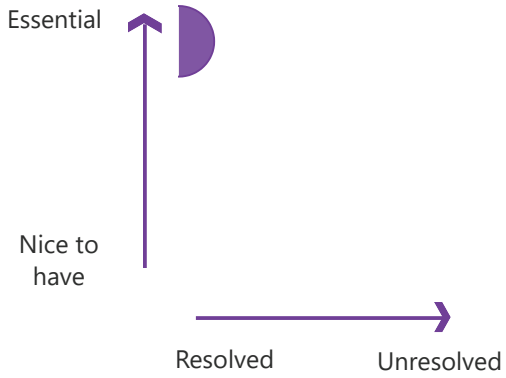
Non-Evaporable Getter (NEG) pumps

21
Priority Score



TRL





Other Applications

Accelerators
Hydrogen

Alternatives

Cryopumps, TMP, diffusion pumps, other getter pumps

Showstoppers list

No pumping of noble gases
Regeneration temperature

Tech Characteristics

Existing Test Facilities	Additional Test Facility Needed
Saes Getters (Milan) Spider (RFX Padova) DIPAK (KIT Karlsruhe)	Radiation and tritium compatibility

European Entities Involved

Public	Private
KIT RFX IPP CERN	SAES Getter

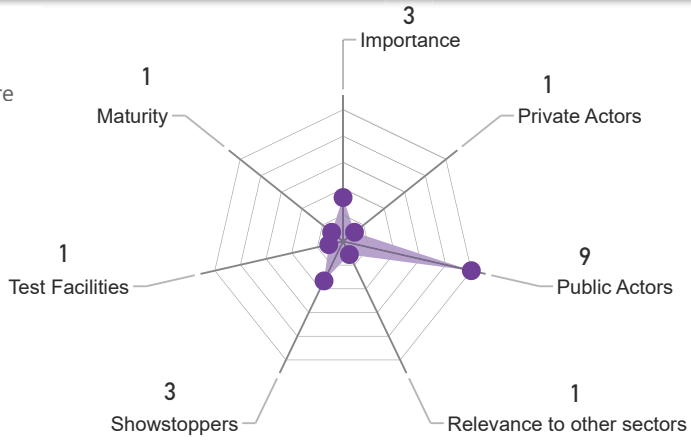
TDA Information

TDA Name	Characteristics	Priority	Funded
Getter pump material research to improve robustness	40 to 80%, 6 months to 2 years, 250k to 1M	Low	No
Getter Pump qualification for prove compatibility with radiation and tritium.	40 to 80%, 6 months to 2 years, 250k to 1M	Low	No
High Pressure Characterization of Getter Beds	>80%, >2 years, 250k to 1M	Low	No
Successfuly validate an stage pumping system by simulation/computation	40 to 80%, 6 months to 2 years, <250k	Low	No

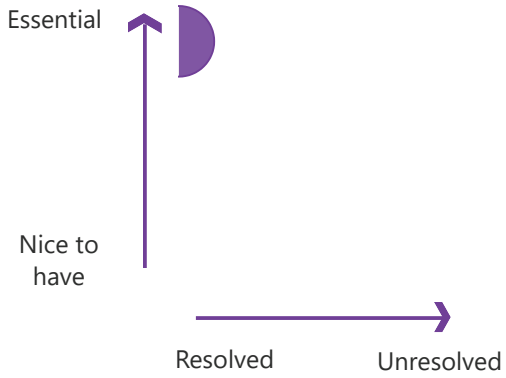
Fuel Cycle › Pumping

Turbo molecular pumps

19
Priority Score



TRL



Other Applications

Semiconductor,
Accelerator,
HV applications,
Laser,
Vacuum welding

Alternatives

Cryo TMP
Cryopumps
Diffusion
NEGs

Showstoppers list

Tritium compliance
Magnetic field compliance
Small capacity

Tech Characteristics

Existing Test Facilities	Additional Test Facility Needed

European Entities Involved	
Public	Private

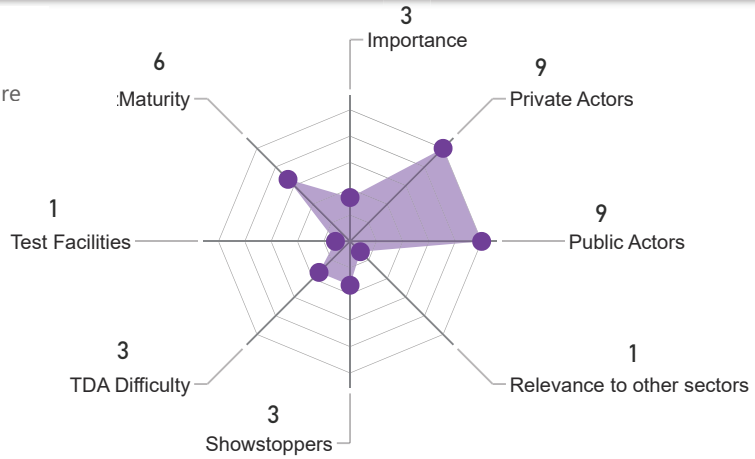
TDA Information

TDA Name	Characteristics	Priority	Funded

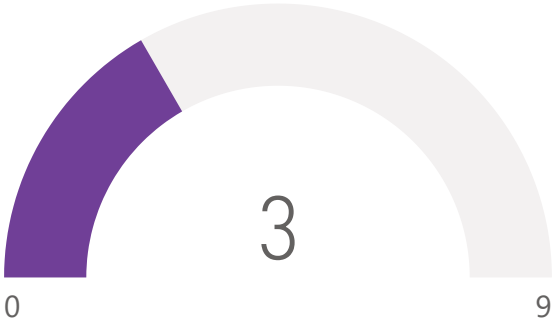
Fuel Cycle › Pumping

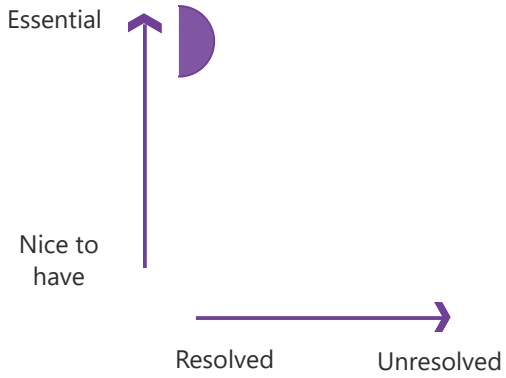
Oil diffusion pumps with tritium compatible oils

35
Priority Score



TRL





Other Applications

Petrochemicals semiconductors,

Alternatives

Cryopump, TMP, Hg diffusion, NEGs

Showstoppers list

Oil in the process
Contamination of plasma
Tritium compatibility
Degradation of oil

Tech Characteristics

Existing Test Facilities	Additional Test Facility Needed

European Entities Involved

Public	Private

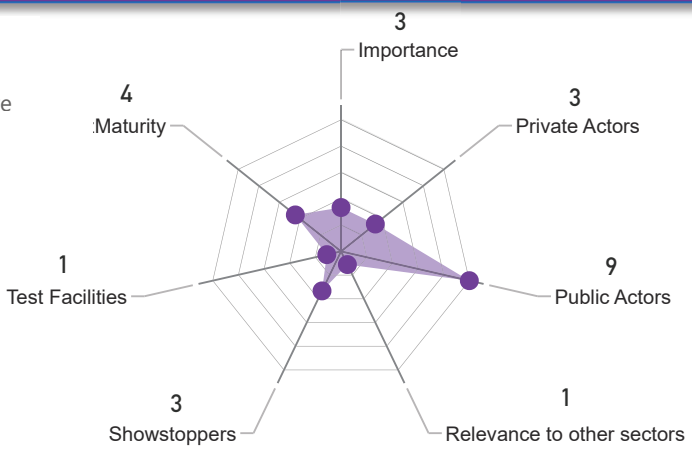
TDA Information

TDA Name	Characteristics	Priority	Funded
Design optimization to minimize oil back flow to be compatible with requirements	40 to 80%, 6 months to 2 years, <250k	Low	No
Develop oil that is tritium compatible	<40%, >2 years, 250k to 1M	Low	No

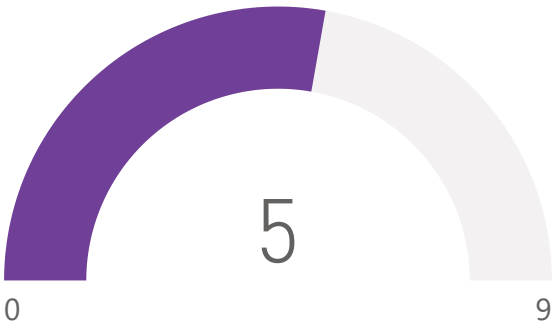
Fuel Cycle › Pumping

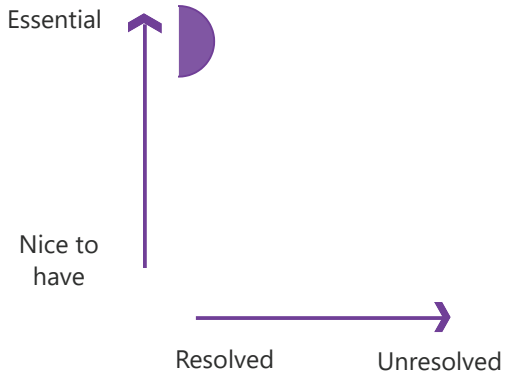
Piston pumps

24
Priority Score



TRL





Other Applications	Alternatives	Showstoppers list
Petrochemical	Mechanical displacement pumps	

Tech Characteristics

Existing Test Facilities	Additional Test Facility Needed
KIT - Tritium Laboratory Karlsruhe (TLK) UKAEA (Rochester) Unity-2 (Canada under construction)	

European Entities Involved	
Public	Private

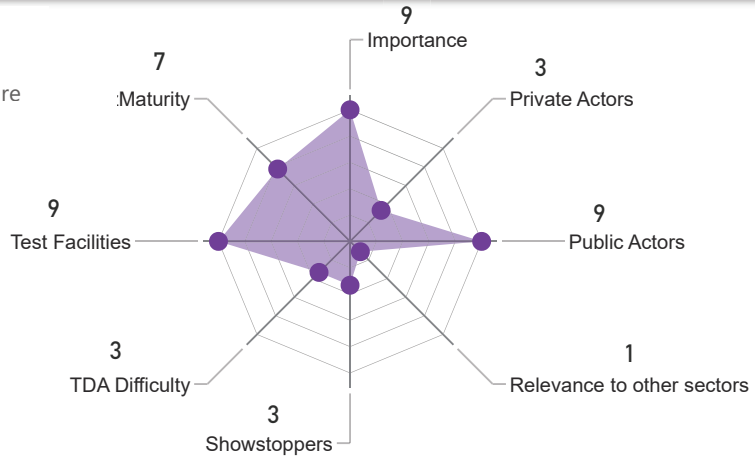
TDA Information

TDA Name	Characteristics	Priority	Funded

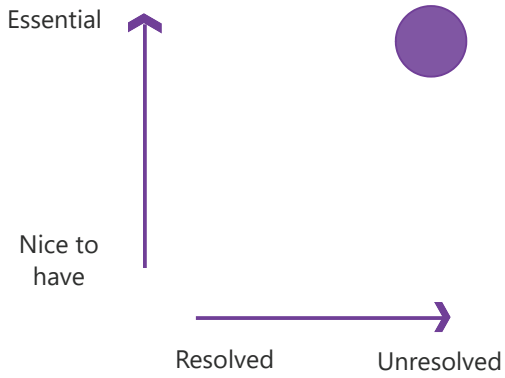
Fuel Cycle › Pumping

Proton conductor pump

44
Priority Score



TRL



Other Applications

Pure hydrogen separation, H2 purification, Petrochemical

Alternatives

Metal foil, quantum sieving

Showstoppers list

Reliability
Compatibility with operational conditions
Maintenance

Tech Characteristics

Existing Test Facilities	Additional Test Facility Needed

European Entities Involved	
Public	Private

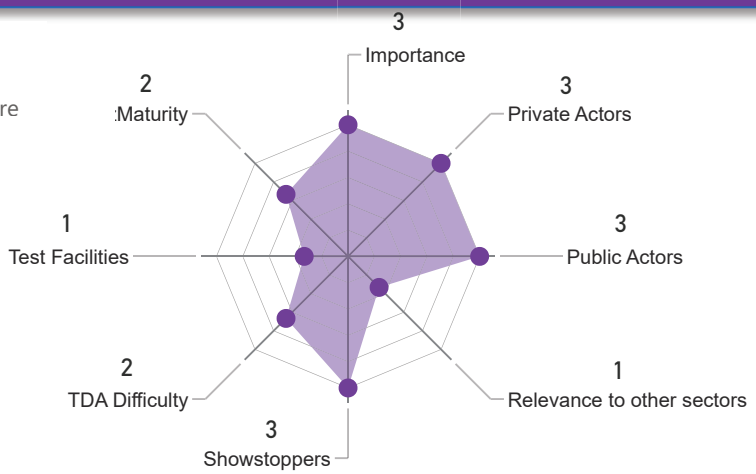
TDA Information

TDA Name	Characteristics	Priority	Funded
Assess the feasibility of a proton conductor pump for the fusion fuel cycle	>80%, <6 months, <250k	Low	No

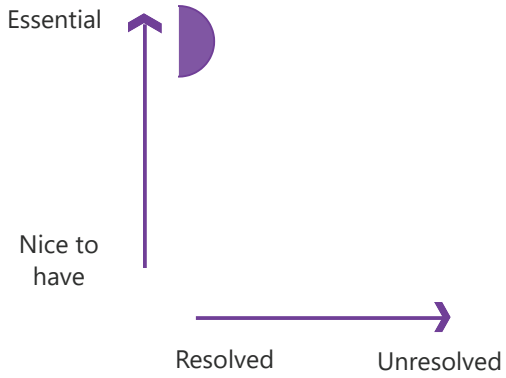
Fuel Cycle › Pumping

Root pumps

18
Priority Score



TRL



Other Applications

Accelerators
Semiconductor

Alternatives

CVC, screw

Showstoppers list

Tech Characteristics

Existing Test Facilities	Additional Test Facility Needed
KIT - Tritium Laboratory Karlsruhe (TLK) UKAEA (Culham) Unity-2 (Canada under construction)	

European Entities Involved

Public	Private
ITER	Pfeiffer Edwards Busch Vacuum solutions Leybold

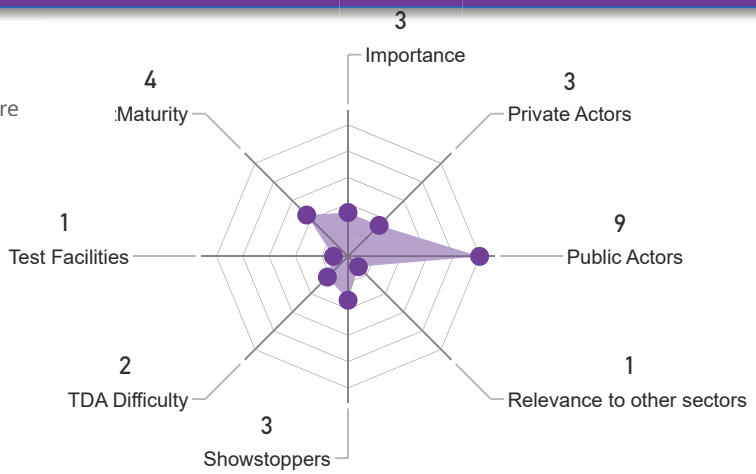
TDA Information

TDA Name	Characteristics	Priority	Funded
Determine the Roots pump tritium compatibility	>80%, 6 months to 2 years, >1M	Medium	Yes
Industrialize tritium compatible roots pumps	>80%, 6 months to 2 years, <250k	Medium	Partially

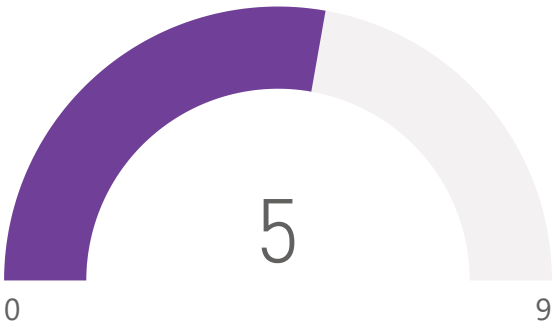
Fuel Cycle › Pumping

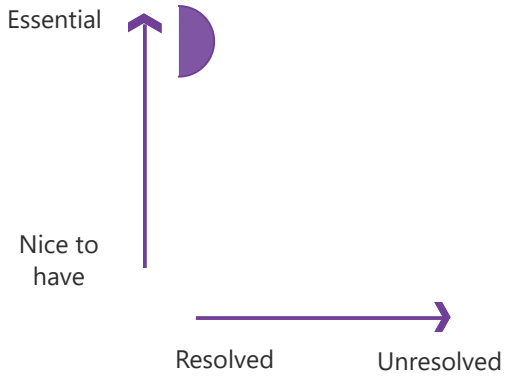
Screw pumps

26
Priority Score



TRL





Other Applications

Accelerators
Semiconductor

Alternatives

Showstoppers list

Tech Characteristics

Existing Test Facilities	Additional Test Facility Needed	European Entities Involved	
		Public	Private
KIT - Tritium Laboratory Karlsruhe (TLK) UKAEA (Culham Rochester) Unity-2 (Canada under construction)			

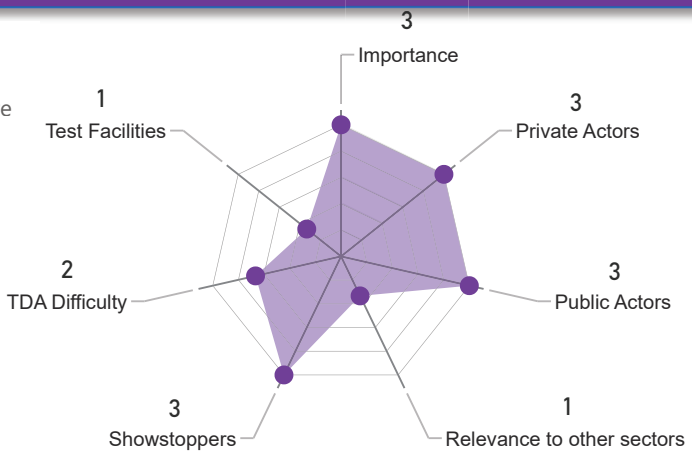
TDA Information

TDA Name	Characteristics	Priority	Funded
Develop a tritium compatible single shaft screw pump	>80%, 6 months to 2 years, >1M	Medium	No
Develop tritium compatible oil	<40%, >2 years, >1M	Low	No
Screw pump purge gas alternative	40 to 80%, 6 months to 2 years, 250k to 1M	Low	No

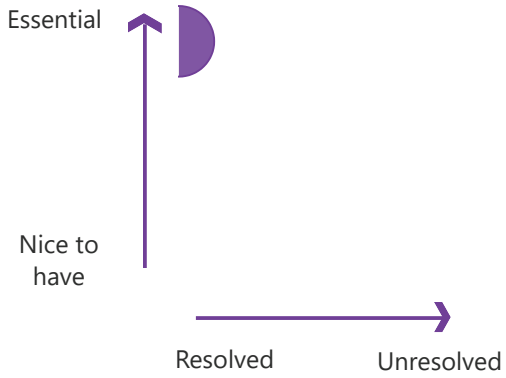
Fuel Cycle › Pumping

Scroll pumps

16
Priority Score



TRL



Other Applications

Process industry
Accelerators

Alternatives

Showstoppers list

Tech Characteristics

Existing Test Facilities	Additional Test Facility Needed	European Entities Involved	
		Public	Private
KIT - Tritium Laboratory Karlsruhe (TLK) UKAEA (Rochester) Unity-2 (Canada under construction)			EUMECA

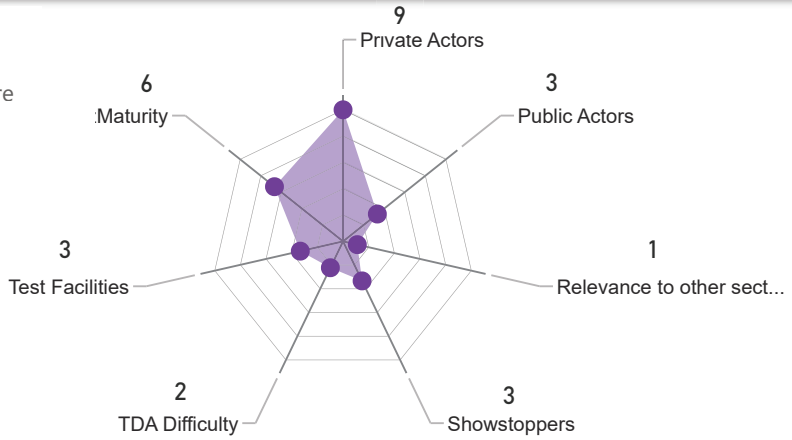
TDA Information

TDA Name	Characteristics	Priority	Funded
Develop tritium compatible tip seal to improve pumping performances	>80%, 6 months to 2 years, <250k	Low	No
Diversify the supply chain for tritium compatible scroll pump	>80%, >2 years, 250k to 1M	Medium	No

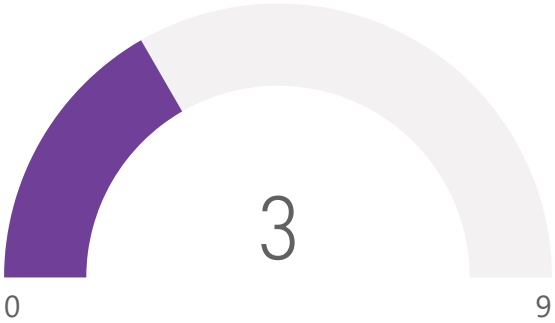
Fuel Cycle › Pumping

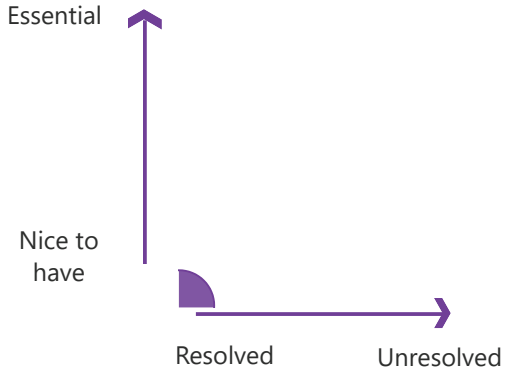
Temperature Staged cryogenic condensation and adsorption pumps

27
Priority Score



TRL





Other Applications
Hydrogen

Alternatives
TMPs, Cryosorption, NEG,Metal foil pump, proton conductor pump

Showstoppers list

Tech Characteristics

Existing Test Facilities	Additional Test Facility Needed
ITER	Investigate separation capabilities of the pumps

European Entities Involved

Public	Private
CEA (Grenoble) CERN KIT ITER	

TDA Information

TDA Name	Characteristics	Priority	Funded
Detailed study of a temperature staged cryopump	40 to 80%, 6 months to 2 years, 250k to 1M	Low	No

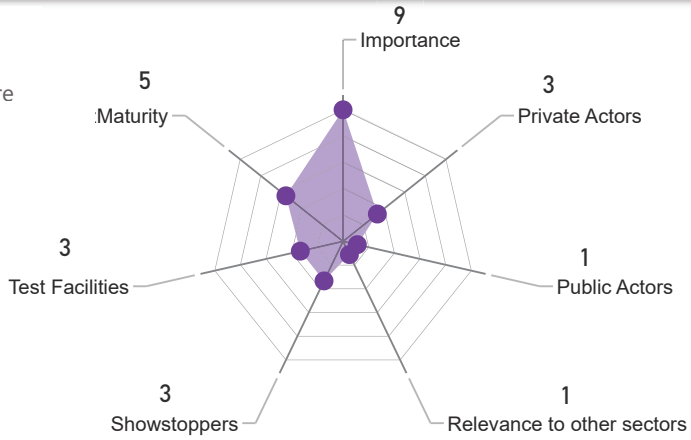
TRITIUM MANAGEMENT

- Coating technologies for permeation barriers
- Cryogenic Temperature Sensor
- Instruments to measure hydrogen isotope concentrations
- Magnetic Sector Leak Detector (MSLD)
- Material characterisation for permeation
- Material development for permeation
- Non-destructive Tritium detection in solids
- Wearable tritium detector
- Process simulation benchmarking
- Tritium accountancy
- Tritium detectors for gas
- Tritium detectors for water

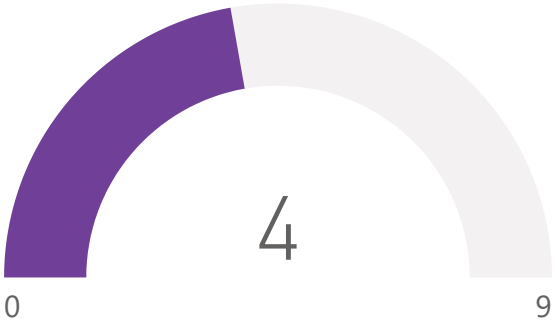
Fuel Cycle › Tritium management

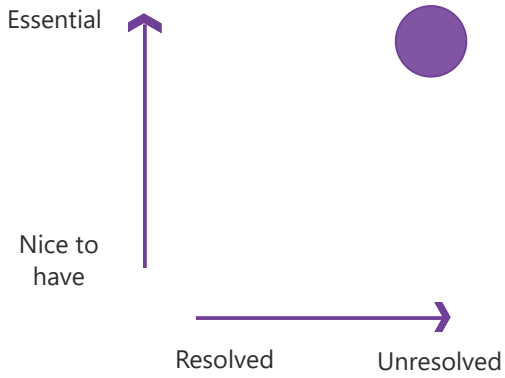
Coating technologies for permeation barriers

25
Priority Score



TRL





Other Applications

Hydrogen production
Fission

Alternatives

Base material selection
Healing under irradiation

Showstoppers list

Regulatory issues
Limited relevant permeation test facility
Complex shapes of components
Resistance to harsh environment

Tech Characteristics

Existing Test Facilities	Additional Test Facility Needed
UKAEA (Culham)	Permeation measurements

European Entities Involved

Public	Private
CEA (Grenoble) CERN University of Latvia (Riga) Fraunhofer Institute (Dresden) UKAEA (Culham) IPP (Garching)	BIMO Tech (Poland) Kyoto Fusioneering (Germany)

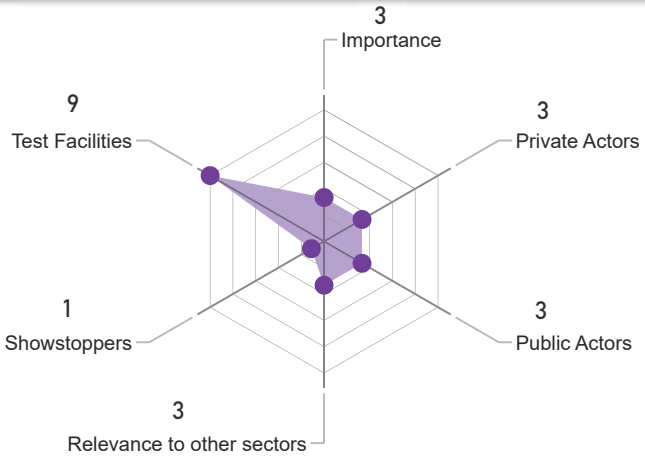
TDA Information

TDA Name	Characteristics	Priority	Funded

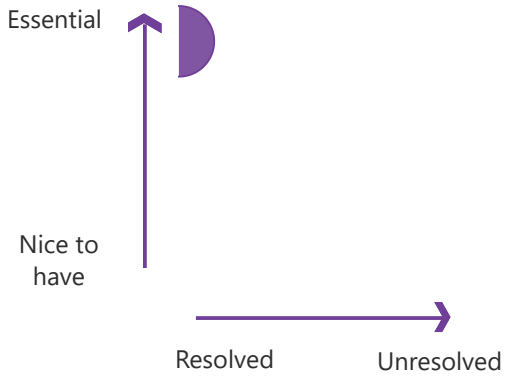
Fuel Cycle › Tritium management

Cryogenic Temperature Sensor

22
Priority Score



TRL



Other Applications	Alternatives	Showstoppers list
Accelerators	Use of room temperature systems	neutron flux, qualification

Tech Characteristics

Existing Test Facilities	Additional Test Facility Needed

European Entities Involved	
Public	Private
ITER	Fraco-Term (PL)

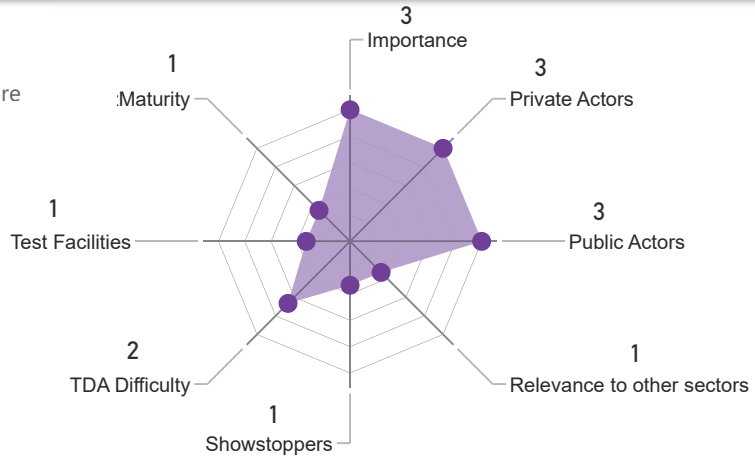
TDA Information

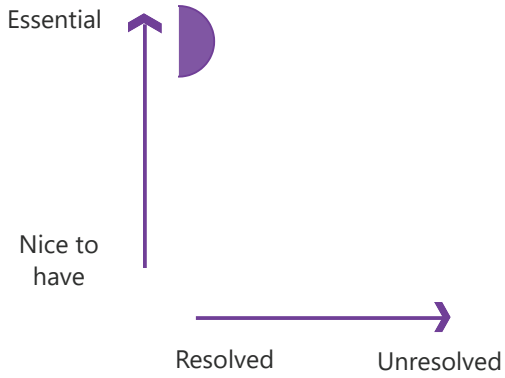
TDA Name	Characteristics	Priority	Funded
Qualify operation range of Fraco-term TVOs to 500K	, 6 months to 2 years, <250k	Low	No

Fuel Cycle › Tritium management

Instruments to measure hydrogen isotope concentrations

15
Priority Score





Other Applications

Hydrogen economy
Heavy water production
Fission

Alternatives

Raman, mass spectrometry, ion chambers, scintillation and proportional counters

Showstoppers list

Online measuring in high flows, not for fuel cycle, memory effects, SMF, Magnetic field conditions.

Tech Characteristics

Existing Test Facilities	Additional Test Facility Needed
TLK (Karlsruhe) UKAEA (Culham)	

European Entities Involved

Public	Private
CEA KIT (Karlsruhe)	SMOLSYS (Lucerne) IS Instruments Ltd (Tonbridge)

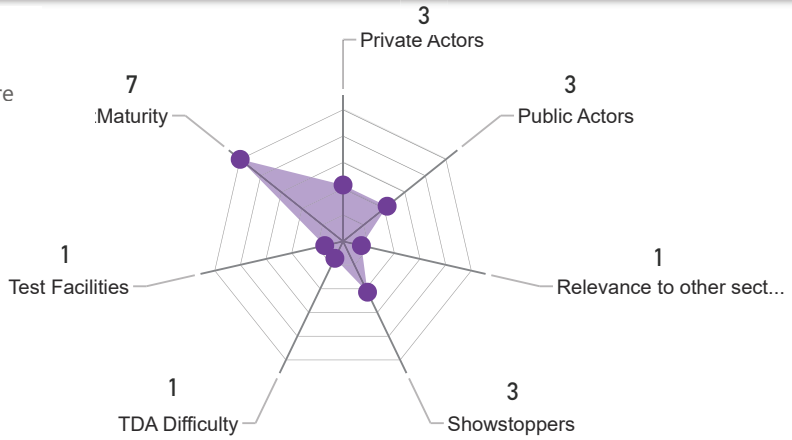
TDA Information

TDA Name	Characteristics	Priority	Funded
Improvement of response time and sensitivity for low concentration applications	40 to 80%, 6 months to 2 years, 250k to 1M	Low	No
Industrialization of Raman Spectroscopy Detector	>80%, >2 years, 250k to 1M	Medium	Partially

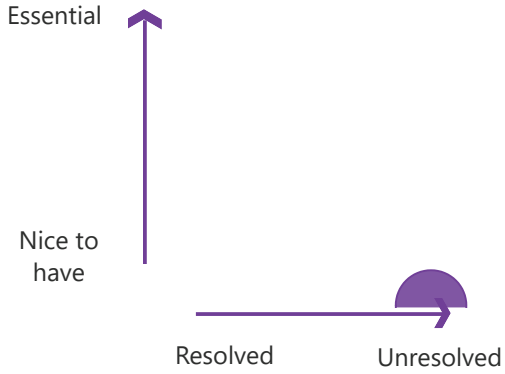
Fuel Cycle › Tritium management

Magnetic Sector Leak Detector (MSLD)

19
Priority Score



TRL



Other Applications
Defense space,

Alternatives
Time of Flight Mass Spectroscopy

Showstoppers list
Radiation compatible electronics

Tech Characteristics

Existing Test Facilities	Additional Test Facility Needed

European Entities Involved	
Public	Private
KIT CEA ITER	Pfeiffer, Edwards, Inficon, VACOM

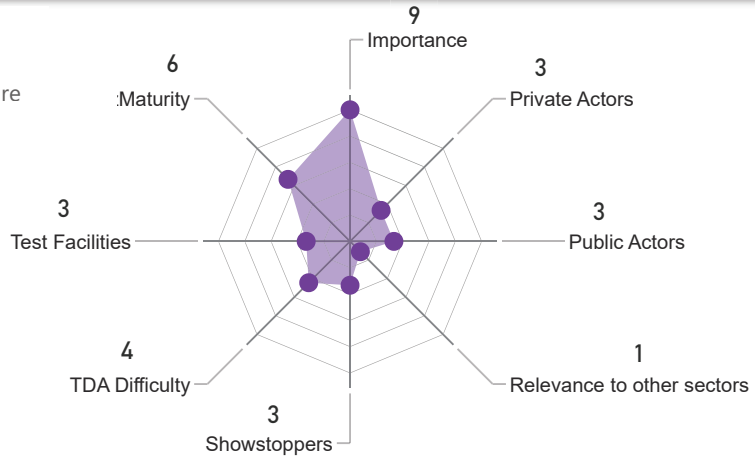
TDA Information

TDA Name	Characteristics	Priority	Funded
Develop prototype with a specialized supplier	40 to 80%, 6 months to 2 years, >1M	Medium	No

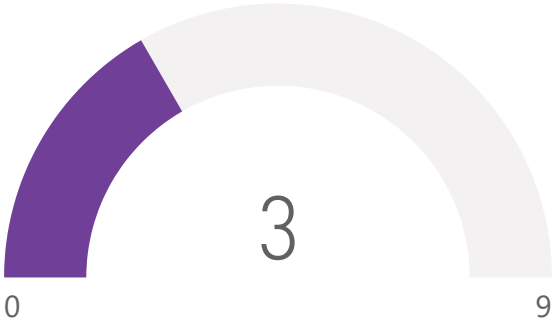
Fuel Cycle › Tritium management

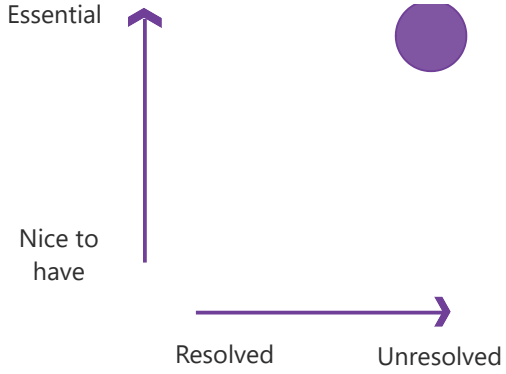
Material characterisation for permeation

32
Priority Score



TRL





Other Applications
Fission
Fast breeders
H related technologies
space
waste

Alternatives
Return on experience from operation

Showstoppers list
Lack of coordination in the field
Missing and inconsistent data
Lack of experimental facilities

Tech Characteristics

Existing Test Facilities	Additional Test Facility Needed
Max Plank UKAEA	Permeation testing

European Entities Involved

Public	Private
UKAEA (Culham) CEN-SCK (Belgium) VTT (Finland) CEA (Saclay and Cadarache)	Amentum, Tokyo Fusioneering, Orano

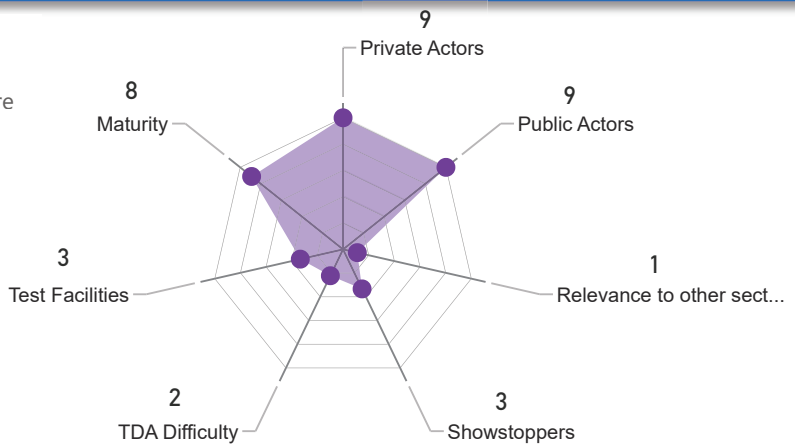
TDA Information

TDA Name	Characteristics	Priority	Funded
Amendment of material codes to cover tritium permeation (or develop specific code)	>80%, >2 years, 250k to 1M	Low	No
Consolidation of existing data in database	>80%, 6 months to 2 years, <250k	High	Partially
Create a community for permeation material testing	>80%, <6 months, <250k	High	Yes
Creation of a handbook of best practices for tritium permation	40 to 80%, 6 months to 2 years, <250k	Low	No
Creation of a reference document for testing protocols	>80%, 6 months to 2 years, <250k	High	Yes

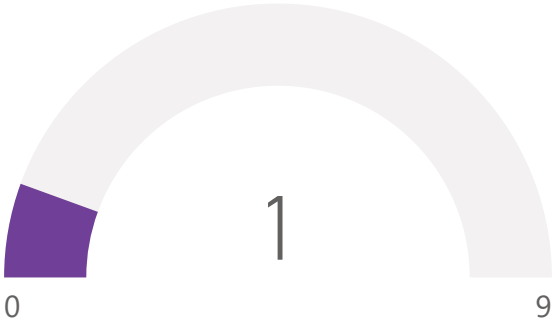
Fuel Cycle › Tritium management

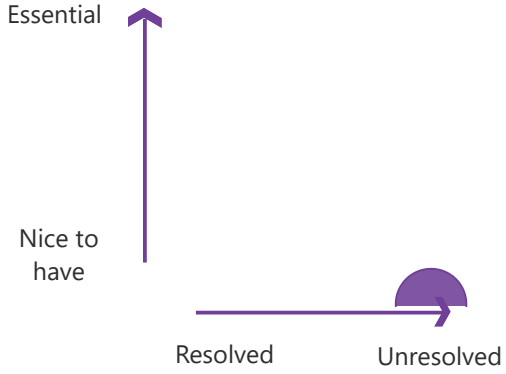
Material development for permeation

35
Priority Score



TRL





Other Applications	Alternatives	Showstoppers list
Fission Military	Coating, Use of existing materials	

Tech Characteristics

Existing Test Facilities	Additional Test Facility Needed	European Entities Involved	
		Public	Private

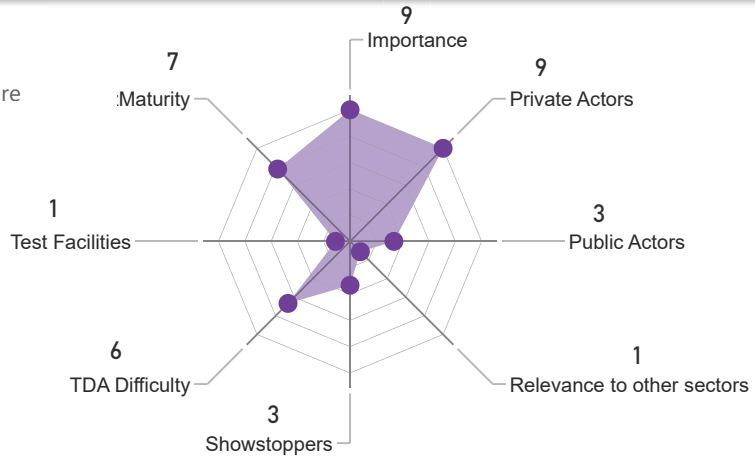
TDA Information

TDA Name	Characteristics	Priority	Funded
Develop specific material to limit permeation (eg EUROPERM)	40 to 80%, >2 years, >1M	Low	No

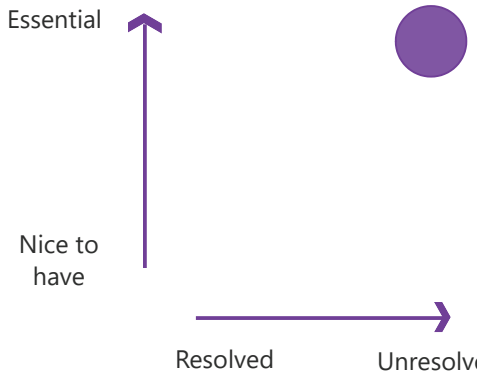
Fuel Cycle › Tritium management

Non-destructive Tritium detection in solids

39
Priority Score



TRL



Other Applications	Alternatives	Showstoppers list
Fission waste	Destructive methods	Difficulty in detecting low-energy beta particles

Tech Characteristics

Existing Test Facilities	Additional Test Facility Needed

European Entities Involved	
Public	Private
CEA (Cadarache)	

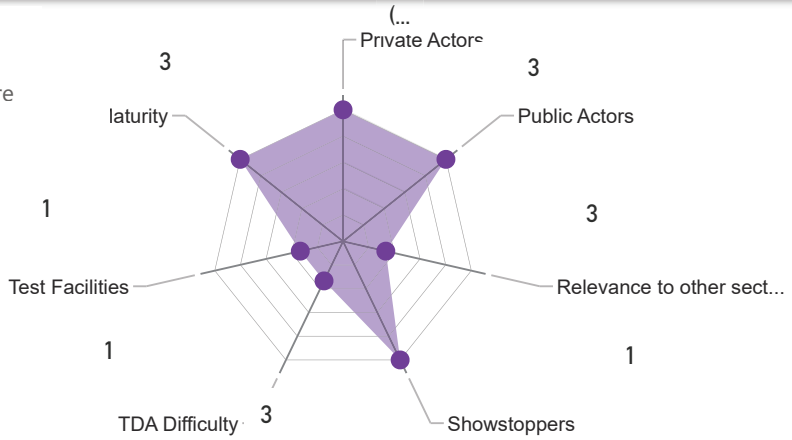
TDA Information

TDA Name	Characteristics	Priority	Funded
Carry out a literature review of possible techniques for surface measurement of tritium in solids and dust	>80%, <6 months, <250k	Medium	No

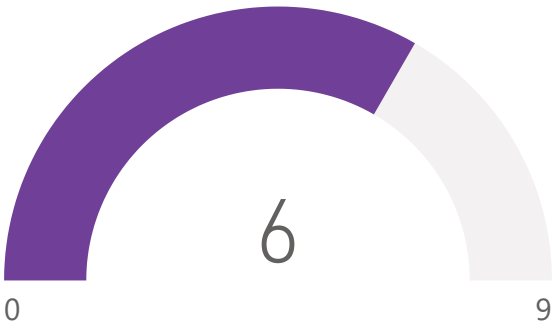
Fuel Cycle › Tritium management

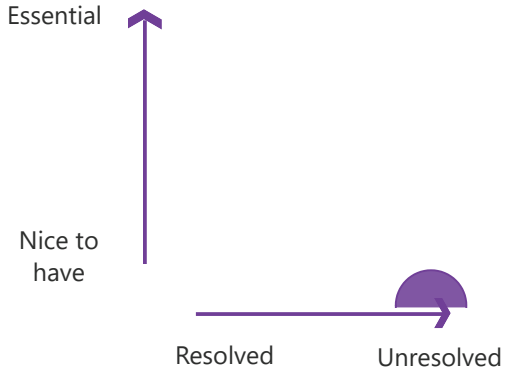
Wearable tritium detector

15
Priority Score



TRL





Other Applications	Alternatives	Showstoppers list
Fission waste	ex post analysis, room monitors	Size limitation Online-measuring

Tech Characteristics

Existing Test Facilities	Additional Test Facility Needed

European Entities Involved

Public	Private
ENEA (frascati) CIEMAT (Madrid) CEA (Cadarache)	Mirion, Tekniker, Else Nuclear

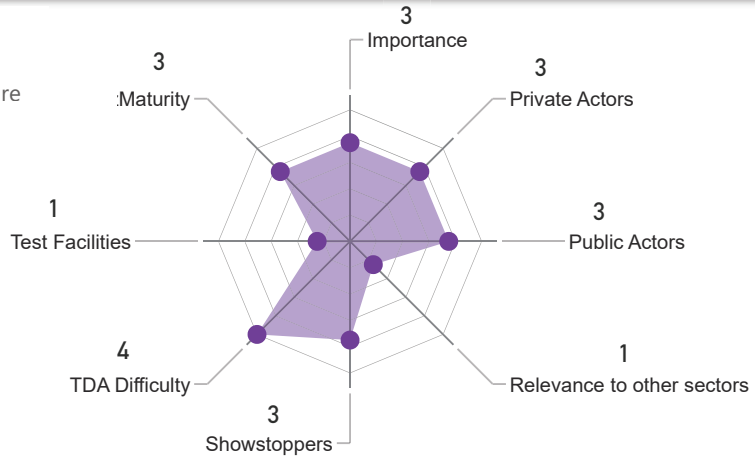
TDA Information

TDA Name	Characteristics	Priority	Funded
Develop a prototype wearable tritium detector	>80%, 6 months to 2 years, 250k to 1M	Medium	Yes

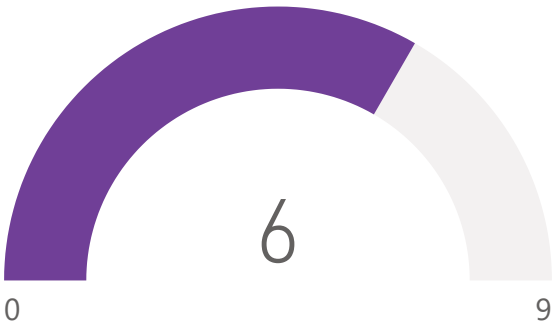
Fuel Cycle › Tritium management

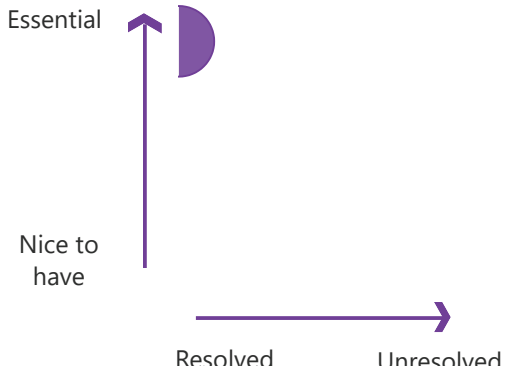
Process simulation benchmarking

21
Priority Score



TRL





Other Applications

Other tritium systems
H economy
Fission
Petrochemical

Alternatives

Showstoppers list

Lack of experimental data for validation

Tech Characteristics

Existing Test Facilities	Additional Test Facility Needed
H3AT (Culham under construction) Unity 2 (Canada under construction)	

European Entities Involved

Public	Private
ITER ENEA	ENI (Milan) RINA (Genoa) Impresarios Agrupados (Madrid) Atkins Realis Polaris (Minsito) Kraftenlagen (Heildelberg)

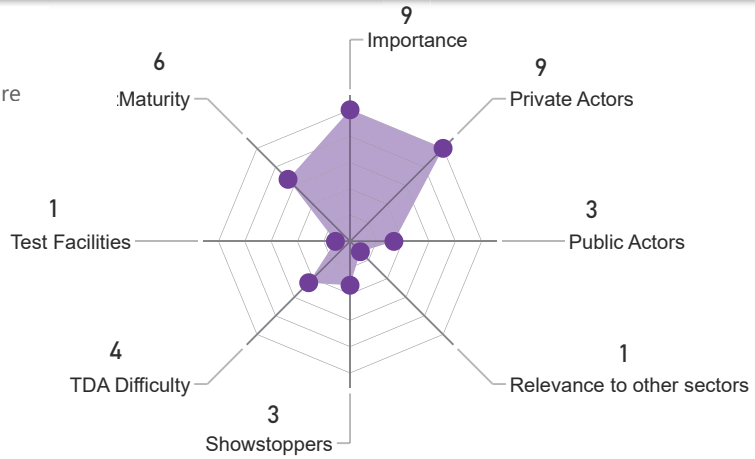
TDA Information

TDA Name	Characteristics	Priority	Funded
Create a community for tritium process simulation	>80%, <6 months, <250k	Medium	Yes
Create and populate database for H isotope properties	40 to 80%, 6 months to 2 years, 250k to 1M	Medium	No
Exchange results and data for benchmarking.	>80%, <6 months, <250k	Medium	No

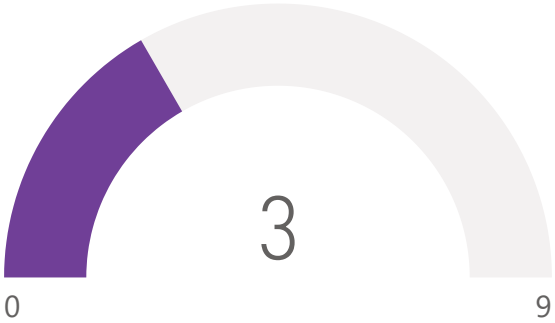
Fuel Cycle › Tritium management

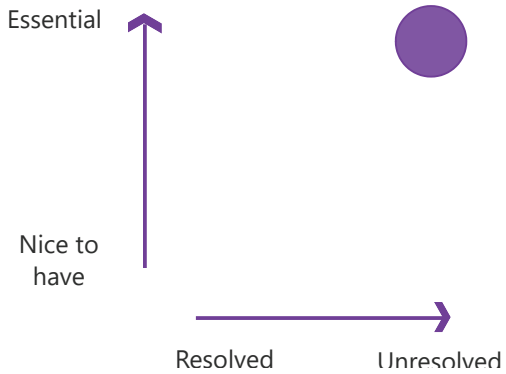
Tritium accountancy

36
Priority Score



TRL





Other Applications	Alternatives	Showstoppers list
Fission waste		Lack of tools Human errors and uncertainty Lack of experimental data

Tech Characteristics

Existing Test Facilities	Additional Test Facility Needed	European Entities Involved	
		Public	Private
		University of Manchester UKAEA ITER	

TDA Information

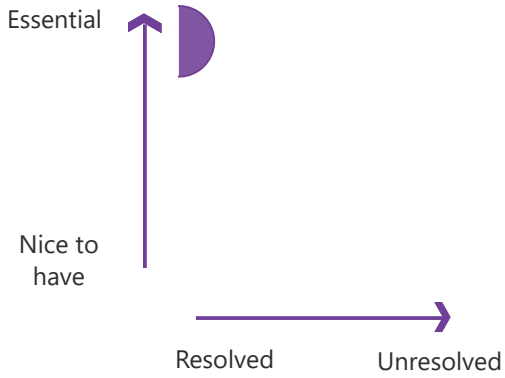
TDA Name	Characteristics	Priority	Funded
Create a community	>80%, <6 months, <250k	Medium	No
Import best practice from fission fuel accountancy and create a reference document including specificities for tritium accountancy,	>80%, 6 months to 2 years, <250k	Medium	No

Fuel Cycle › Tritium management

Tritium detectors for gas

13
Priority Score

TRL



Other Applications

Fission waste

Alternatives

Showstoppers list

Memory effects, quantitative measurements in situ, magnetic field compatibility.

Tech Characteristics

Existing Test Facilities	Additional Test Facility Needed
CEA UKAEA KIT (Karlsruhe) Cavendish (UK) ITER (Cadarache)	Magnetic field, neutron irradiation, high tritium concentration

European Entities Involved

Public	Private
CEA ENEA CIEMAT UKAEA KIT	Mirion (France), Berthold (Germany), Else Nuclear (Italy), Bertin (France)

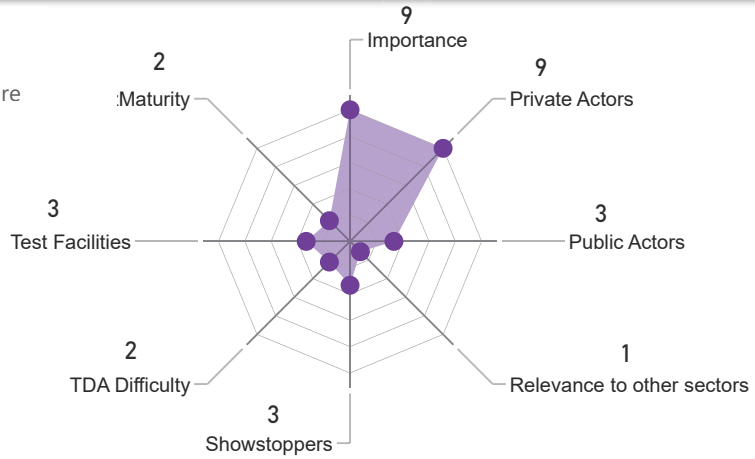
TDA Information

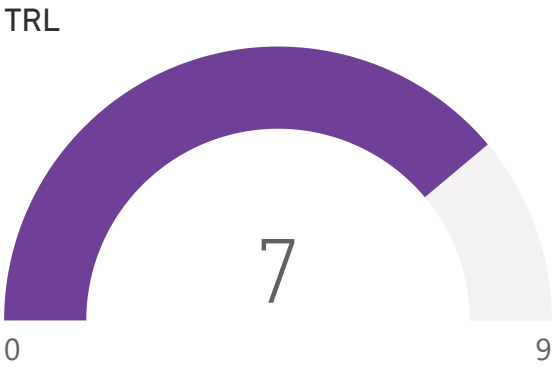
TDA Name	Characteristics	Priority	Funded
Create a tritium performance and calibration test bench (for high concentration)	>80%, 6 months to 2 years, >1M	Medium	Partially

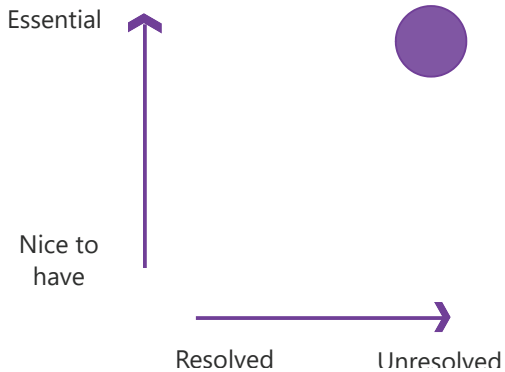
Fuel Cycle › Tritium management

Tritium detectors for water

32
Priority Score







Other Applications	Alternatives	Showstoppers list
Fission CANDU waste		Size Memory effects (especially in low level measurements)

Tech Characteristics

Existing Test Facilities	Additional Test Facility Needed	European Entities Involved	
		Public	Private
ITER	Compatibility with neutron flux, magnetic field	CEA (Cadarache)	

TDA Information

TDA Name	Characteristics	Priority	Funded
Design, build and test a European prototype detector for tritium in water	40 to 80%, 6 months to 2 years, 250k to 1M		No

Appendix 1: Technology Readiness Levels

For this workshop, a TRL scale from 1 to 9 will be used, in line with the IAEA definitions[1].
It considers the different criteria for different streams as illustrated in the table below extracted from the document in reference. By default, the "System" stream will be used. For more details, please refer to the TECDOC 2047 itself[1].

TRL	Systems	Materials	Software	Manufacturing	Instrumentation
1	Basic principles	Evidence from literature	Mathematical formulation	Process concept proposed	Understand the physics
2	Technology concept	Agreed property targets, cost & timescales	Algorithm implementation documented	Validity of concept described	Concept designed
3	Proof of concept	Materials' capability based on lab scale samples.	Prototype architectural design of important functions is documented	Experimental proof of concept completed	Lab test to prove the concept works.
4	Validation in a laboratory environment	Design curves produced.	ALPHA version with most functionalities implemented with User Manual and Design File available	Process validated in lab	Lab demonstration of highest risk components
5	Partial system validation in a relevant environment	Methods for material processing and component manufacture	BETA version with complete software functionalities, documentation, test reports and application examples available	Basic capability demonstrated using production equipment	Requiring specialist support
6	Prototype demo in a relevant environment	Validated via component and/or sub-element testing.	Product release ready for operational use	Process optimised for capability and rate using production equipment	Applied to realistic location/environment with low level of specialist support.
7	Prototype demo in an operational environment	Evaluated in development rig tests	Early adopter version qualified for a particular purpose	Economic run lengths on production parts	Successful demonstration in test.
8	Test and demonstration	Full operational test	General product ready to be applied in a real application	Significant run lengths	Demonstrated productionised system
9	Successful mission operation	Production ready material	Live product with full documentation and track record available	Demonstrated over an extended period	Service proven

[1] IAEA TECDOC 2047 Considerations of TRL for Fusion Technology Components available from: https://www-pub.iaea.org/MTCD/Publications/PDF/TE-2047web.pdf