IAEA
International Atomic Energy Agency
Atoms for Peace and Development

Global Environmental Issues and the Role of IAEA

20 March 2024

Bumsoo Han, Radiation Chemist
Division of Physical and Chemical Sciences
Department of Nuclear Sciences and Applications
International Atomic Energy Agency (IAEA)

Polluted Environmental behind Development

Radiation Technology for Pollution Control

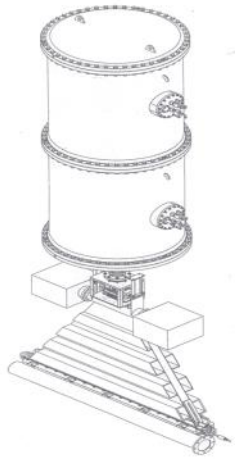
Flue Gas Purification

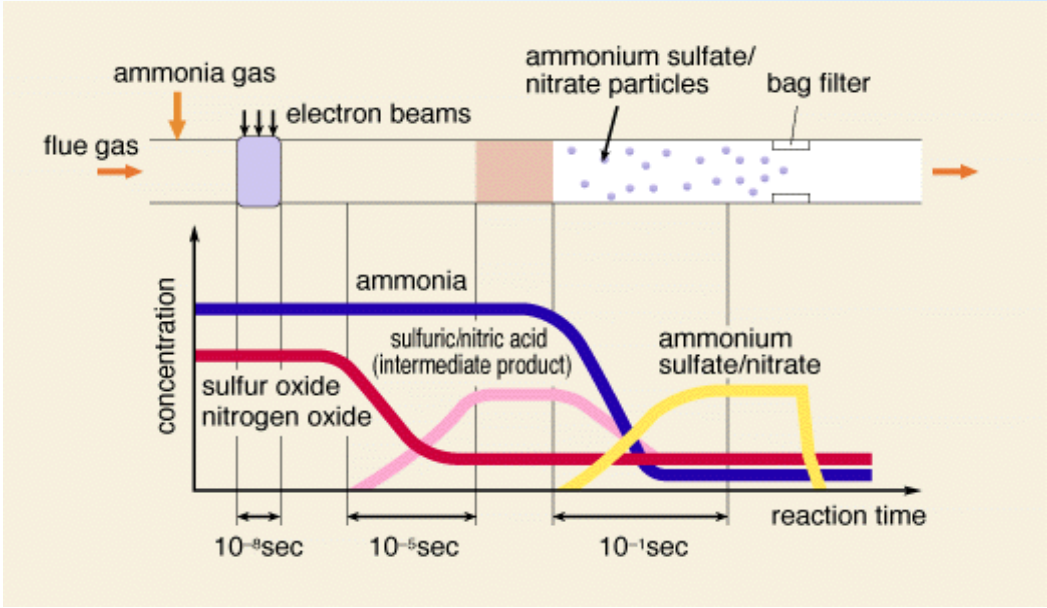
Wastewater Treatment

Sludge Hygienization

Flue Gas Treatment with Electron Beam

Flue gas Purification





SO_2 → H_2SO_4 → (NH_3) → $(NH4)_2SO_4$

NO_X → HNO_3 → (NH_3) → NH_4NO_3

HCl → NH_4Cl

Dioxin → Decomposed

Industrial Plant in Pomorzany, Poland

Flue gas Purification

Pomorzany, Poland (IAEA/EPS/INCT)	1999
Flow gas flow (coal-fired)	270,000Nm^3/h(130MW)
Flue gas temperature	130-150℃
SO2/NOx Conc.	1000~1500/400~600mg/Nm^3
SO2/NOx Removal Eff.	90%/70%
By-product production	200~300kg/h
NH3 consumption	100~150kg/h
Electron beam accelerator	800keV/4×300mA
Total power consumption	1MW

EB Flue Gas Treatment Plant Installations

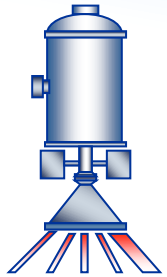
Flue gas Purification

Place	Flow rate (Nm^3/hr)	Power (MW)	Accelerator	Dose (kGy)	SO_2/NOx (ppm)
Indianapolis,USA(1984)	24,000	-	800keVX2, 160kW	30	1,000/400
Badenwerk,Germany(1985)	20,000	-	300keV, 180kW	-	500/500
Kawęczyn, Poland (1992)	20,000	-	700keV, 50kW	18.8	600/250
Nagoya, Japan (1992)	12,000	-	800 keVX3, 108kW	10.5	1,000/300
Chengdu, China (1997)	300,000	90	800keVX2, 400mA 1900kW	3	1,800/400
Pomorzany, Poland (1999)	270,000	112	800keVX4, 375mA, 1200kW	10	385/340
Nisi-Nagoya,Japan(1998)	620,000	220	800 keVX6, 500mA, 2400kW	6.7	-
Hangzhou, China (2002)	305,400	-	800keVX2, 400mA 1896kW	3	1,800/400
Beijing, China (2005)	640,000	150	1000keVX2, 500mA, 1000keV/300mA, 2850kW	-	1,900/400
Svishtov, Bulgaria (2008)	600,000	120	0.9MeV/400mAx4, 1400kW	4	1680/780

Sludge Hygienization with Ionizing Radiation

Sludge Hygienization

+. Sludge Hygienization



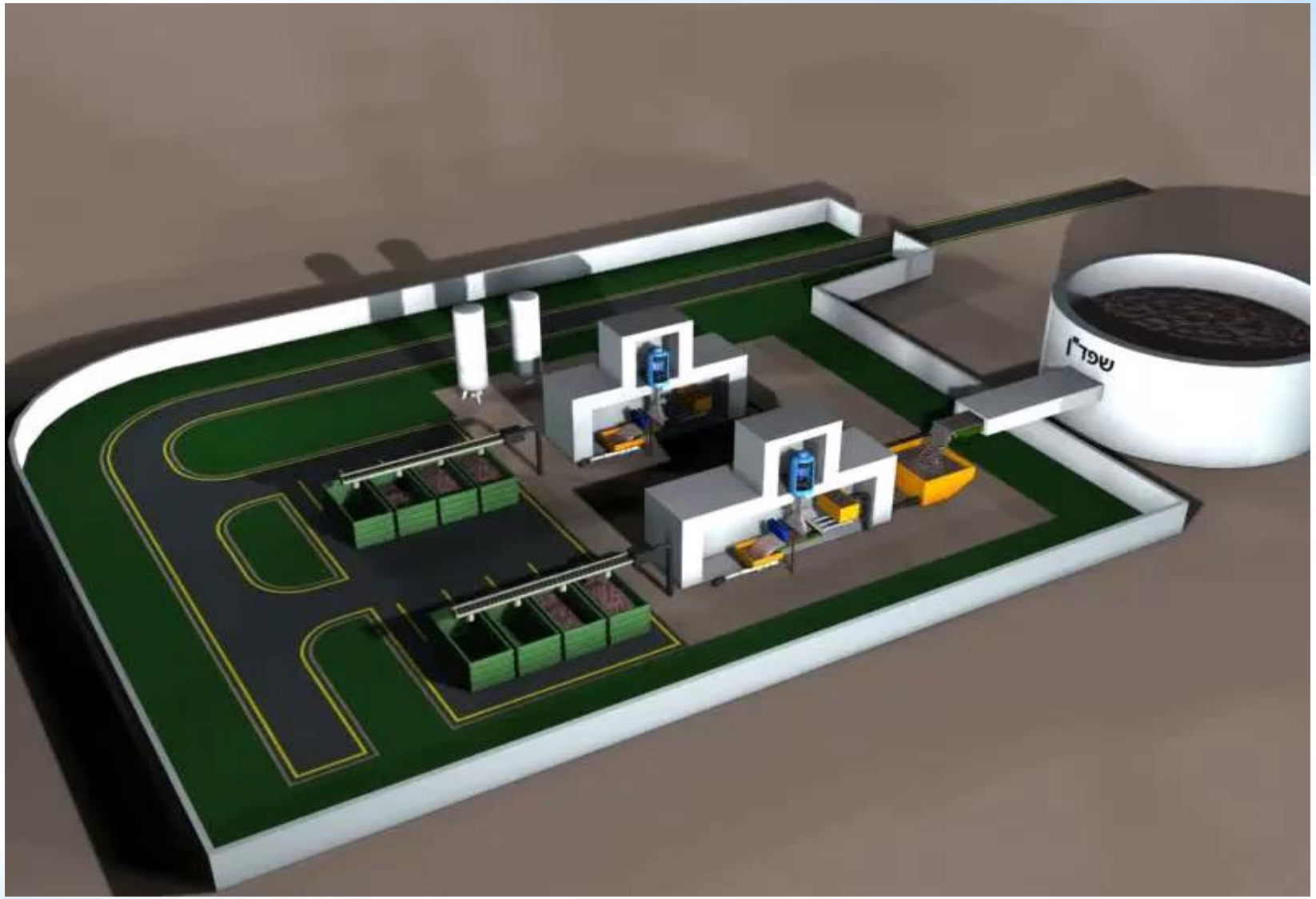
H_2O → $\bullet OH, H\bullet, e^-_{aq}, H_2, H_2O_2$

Radiation

$\bullet OH, H\bullet, e^-_{aq}$ + DNA of microorganism → Damage in DNA (no duplication)

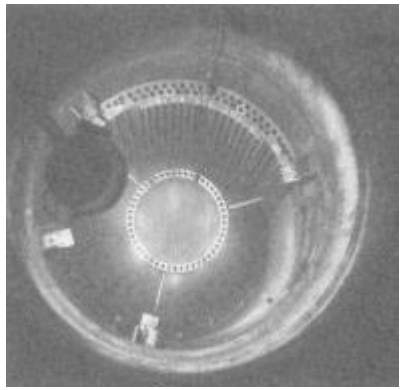
Sludge Hygienization with Ionizing Radiation

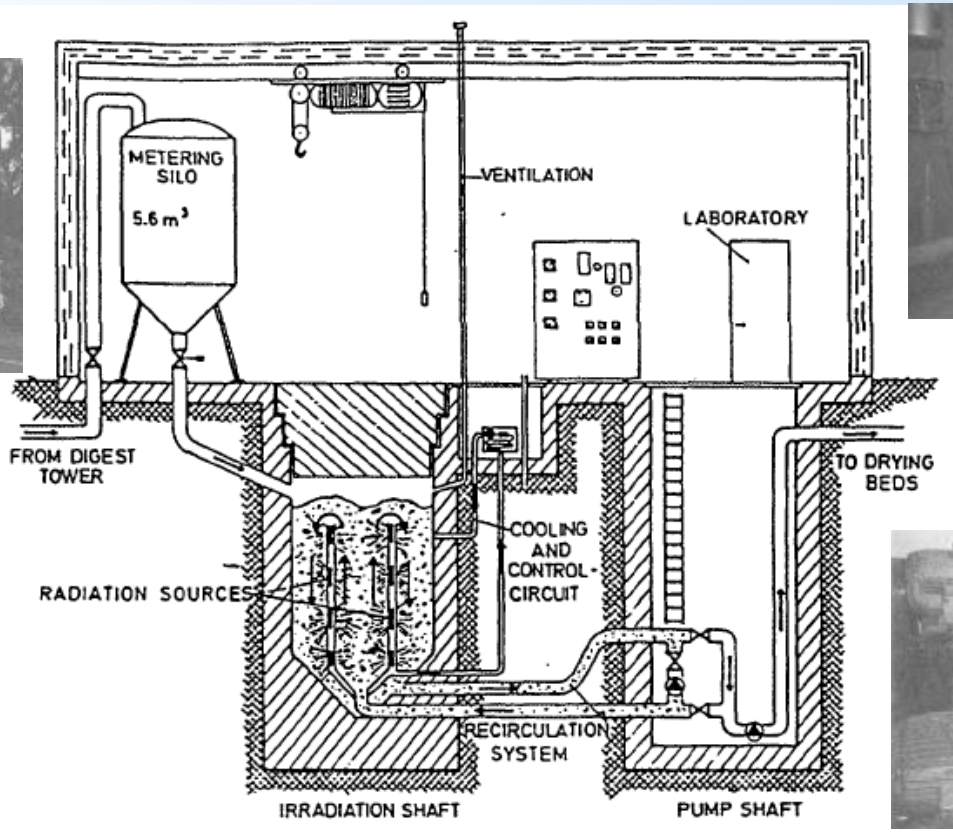
Sludge Hygienization



Sludge Hygienization Plant in Geiselbullach,Germany

Sludge Hygienization





Facilities	Irradiation Source	Irradiated material	Operation condition	Remarks
Geiselbullach, Germany (1973-1984)	Gamma-ray (Co-60, Cs-137) 0.57Mci	Liquid Sewage sludge, 145m^3/day	2-3kGy	Commercial plant

Sludge Hygienization in Ahmedabad, India

Sludge Hygienization

1st facility of 100 tons/day capacity is operational since March,2019, second under construction

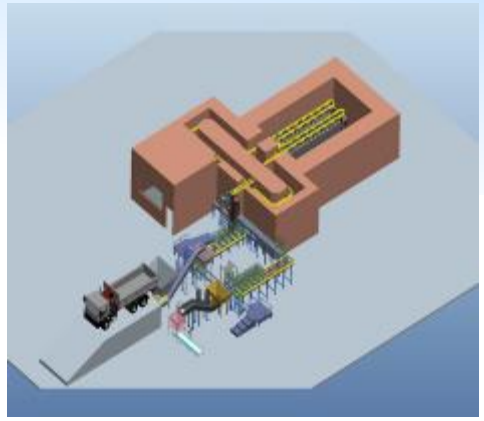
Cost of the project

$ 5.0 Millions

Project time 2.5 Years

- ❑ Converts waste sludge to Manure
- ❑ Protects health and environment
- ❑ Provides organic Carbon to soil
- ❑ Saves subsidy on Urea

Dried sludge is crushed and packed in Aluminum containers.



^{60}Co Gamma irradiation dose of 10 kGY is given in the plant

Spraying with Bio NPK using external facility

Treated sludge to farmers (manure)

Wastewater Treatment with Ionizing Radiation

Wastewater Treatment

Main purpose of wastewater treatment

-. Removal of harmful impurities (COD, BOD, S/S etc.)

-. Removal of color, odor etc.

-. Removal of T-N, T-P

Radiation Technology

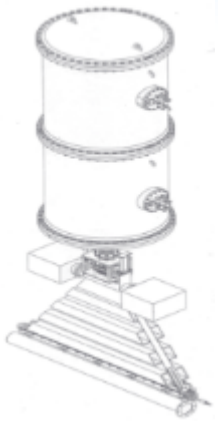
-. Disinfection of microorganisms (Pathogenic organisms etc.)

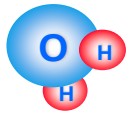
-. Destruction of residual chemicals, such as POPs, endocrine disrupters, Pesticides, and Pharmaceutical residues.

-. to discharge to river, or to re-use in industries or irrigation

Wastewater Treatment with Ionizing Radiation

Wastewater Treatment





Water Molecule

e_{aq}
OH*
H*
H_2O_2

Active Radicals

Harmful Organic in Waste-water

Complete Decomposition → H_2O, CO_2

Partial Decomposition

Suspended Solid

Monomer to Polymerization

→ Coagulation

Removal of Toxic Group → Bio-Treatment

Removal of Color, Odor

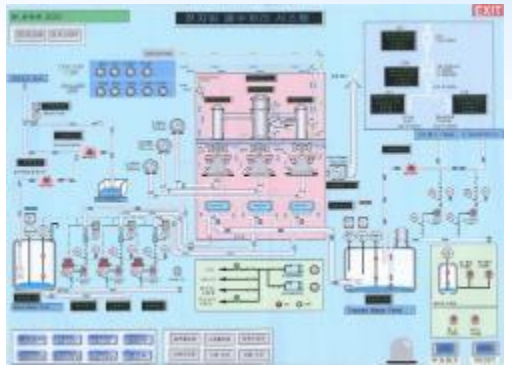
-. Removal of harmful impurities (COD, BOD, S/S etc.)
-. Removal of colour, odour etc.
-. Disinfection of microorganisms (Coli-form & pathogenic organisms)
-. Destruction of endocrine disrupter and synthetic chemicals

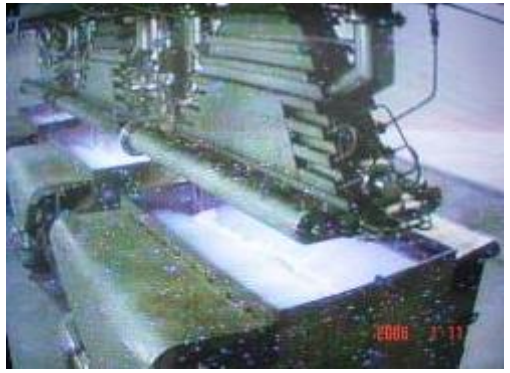
Wastewater Treatment with Ionizing Radiation

Wastewater Treatment

Textile Dyeing Wastewater Treatment Plant in Korea

Wastewater Treatment





Full-scale application of electron beam wastewater treatment plant for 10,000 m^3/d of textile dyeing wastewater with 1 MeV, 400 kW accelerator.

Textile Dyeing Wastewater Plant in China

Wastewater Treatment

IAEA support Wastewater Treatment through TC projects

CPR1008: Treating Industrial Wastewater with Electron Beam Accelerator and Biological Treatment Methods (2012-2015)

Industrial plant (30 000 m^3/d) for textile dyeing wastewater constructed in China

How can this technology become more active?

Wastewater Treatment

1. Public Acceptance

2. Regulatory works from Authorities

3. Engineering Problems ? (Research to Business)
   -. Electron Energy : Penetration in water and sludge
   -. Beam Power : Productivity
   -. Reliability
   -. Respond to Emergency

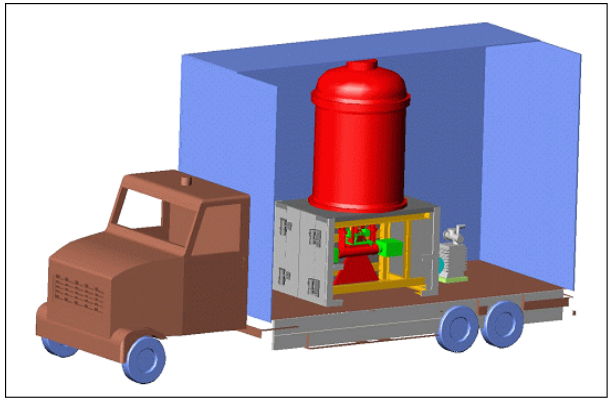
4. Economics
   -. Competitions with conventional technology
   -. Reduce doses by combining with other methods
   -. Laboratory to Commercial Plant

Laboratory to Commercial Plant via Mobile EB

Lab. Scale Experiments
(1~50m³/day)

Lab. Scale Experiments
(1~10,000Nm³/h)

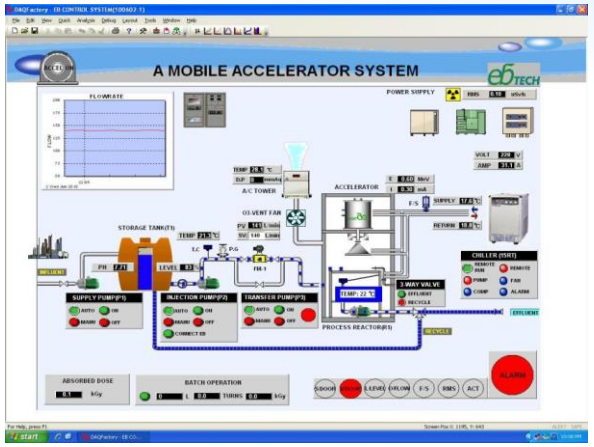
Pilot scale
Experiments
(500~1,000m³/day)



Industrial scale Wastewater Plant
(10,000m³/day)

Industrial scale EBFGT Plant
(~600,000Nm³/h)

Laboratory to Commercial Plant via Mobile EB

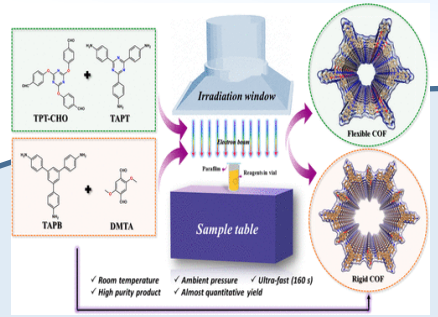


Wastewater treatment with Mobile e-beam in Korea

Mobile e-beam in Flue gas Purification from oil-refinery in Saudi Arabia

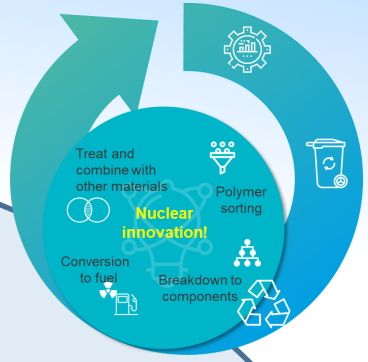
Transportable Electron Beam in IAEA

Flue gas Purification



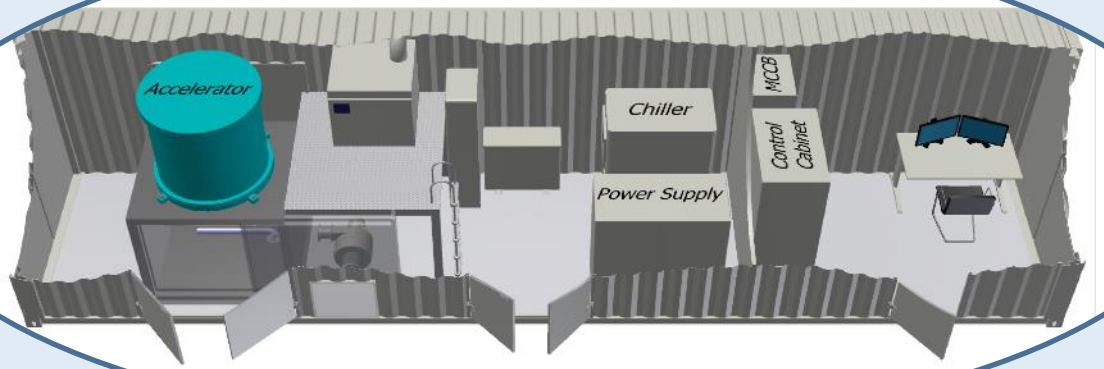
Research

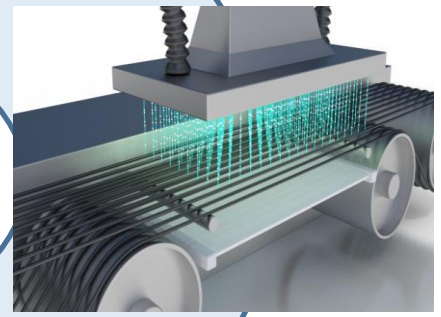
Education & Training



Plastic Recycling

Wastewater Treatment





Cable cross linking

Sludge Hygienization

Hazardous chemicals

Contaminated environment

Film/sheet treatment

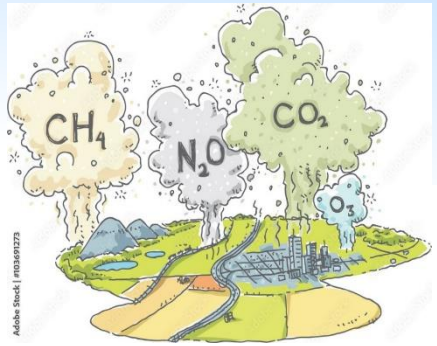
Radiation Technology for Pollution Control

Flue Gas Purification

Wastewater Treatment

Sludge Hygienization

Plastic Recycling



Removal of GHG

Completed CRPs and moved to TC projects, Publication under preparation

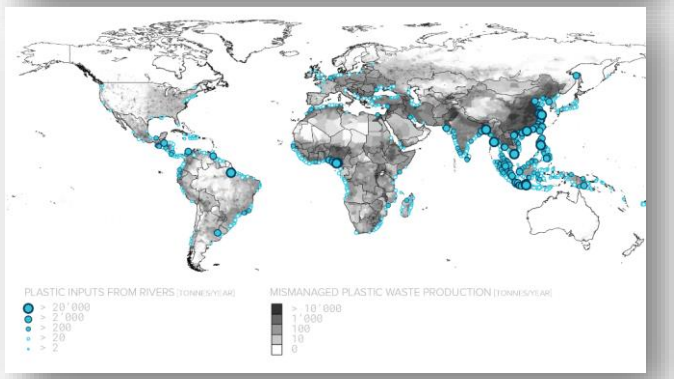
CRPs (F23036, F22081)

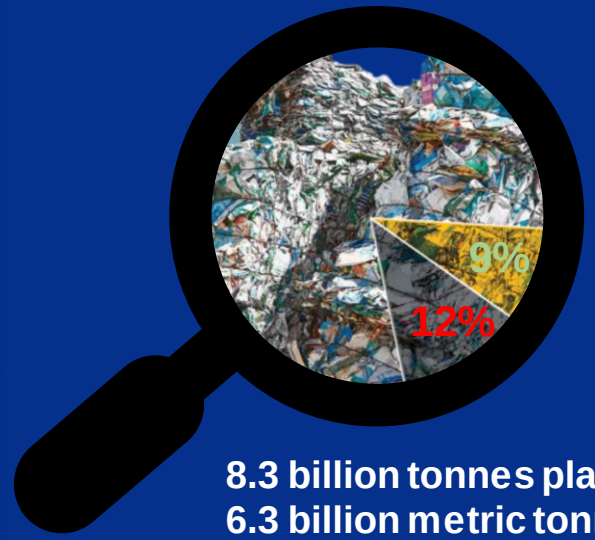
New CRP (F22080)

Plastic Waste Recycling with Ionizing Radiation

Plastic Recycling

FACTS…What do we know?





What happens to all the plastic waste?

- 8.3 billion tonnes plastic have been produced
- 6.3 billion metric tonnes now plastic waste
- 9% plastic waste recycled
- 12% plastic waste incinerated
- 60% in landfills or environment
- >150 million metric tonnes reached the oceans

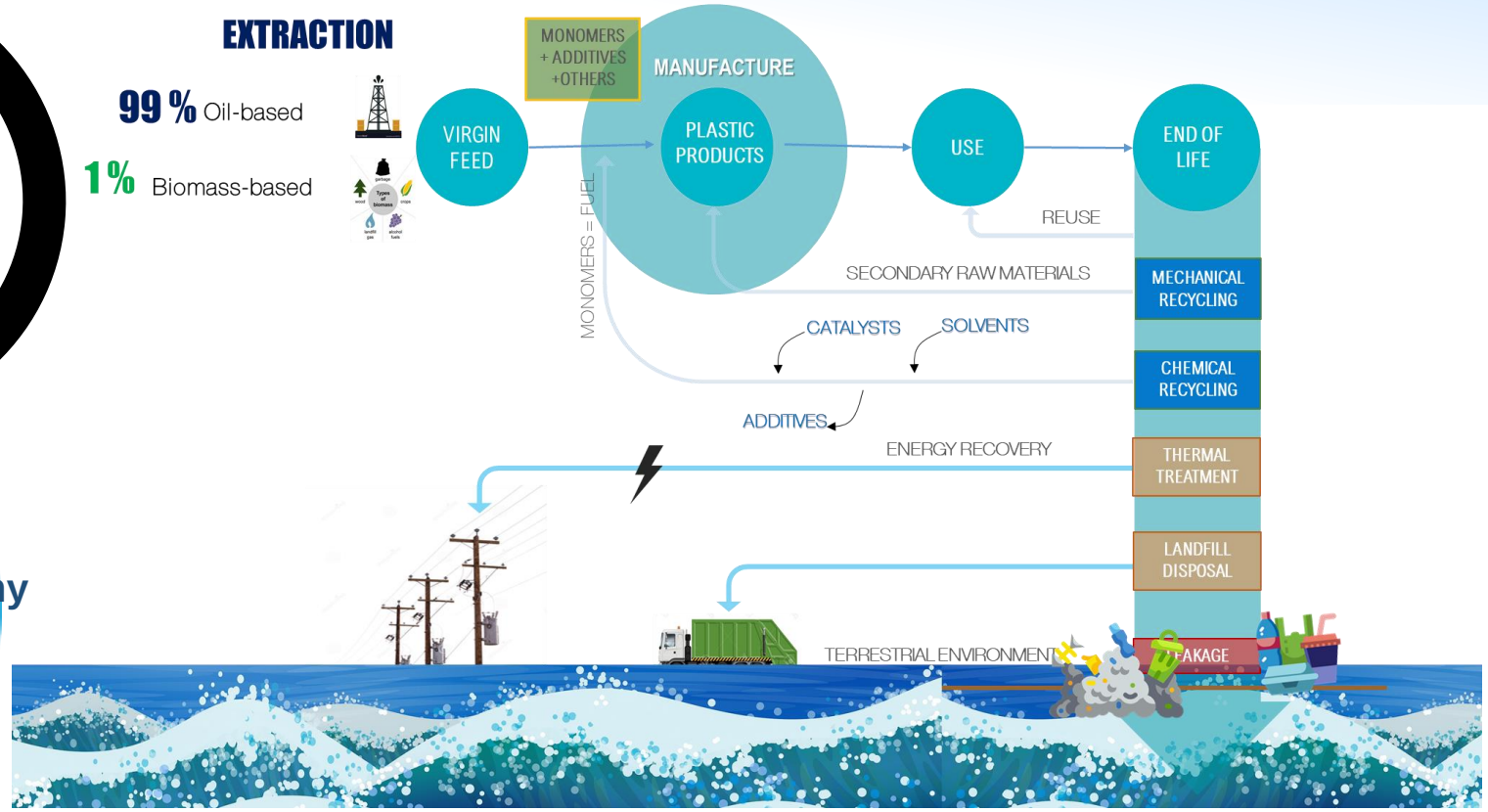
https://theoceancleanup.com/updates/quantifying-global-plastic-inputs-from-rivers-into-oceans/ (2019)

Plastic Waste Recycling with Ionizing Radiation

Plastic Recycling

Plastic value chain

Circular economy approach



Adaptation UNEP-CHW-PWPWG.1-INF-4.English (1)

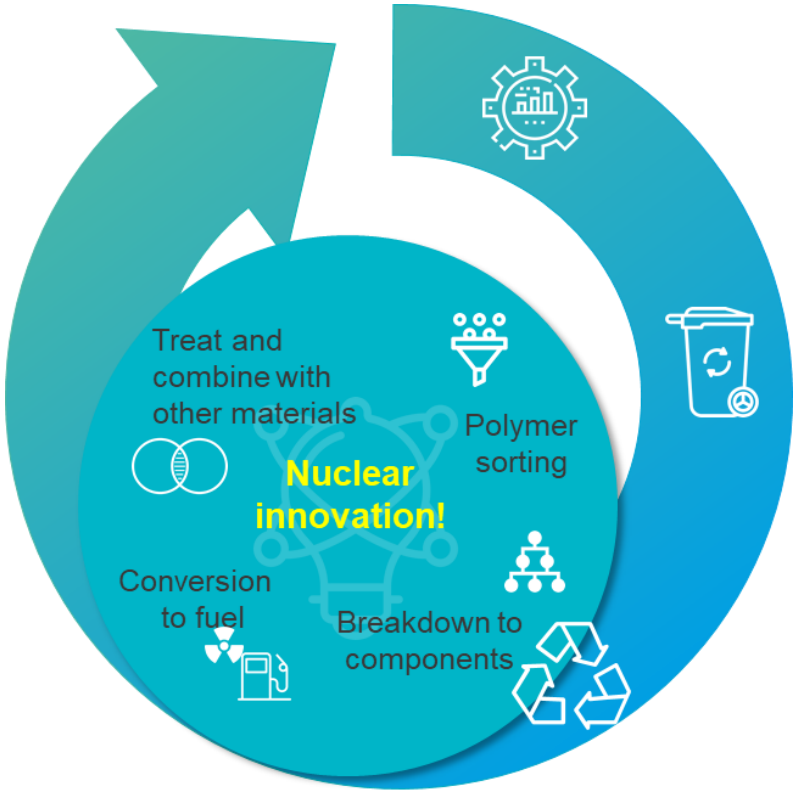
Plastic Waste Recycling with Ionizing Radiation

Plastic Recycling

Value Chain: From linear to circular economy

Plastic Waste Recycling with Ionizing Radiation

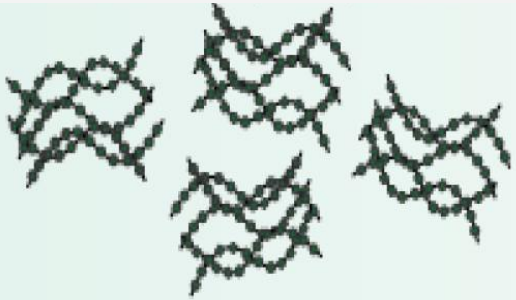
Plastic Recycling



www.iaea.org/nutec-plastics

Sort pelletized plastic waste according to polymer type for recycling via irradiation

Breakdown plastic polymers for generating new plastic products

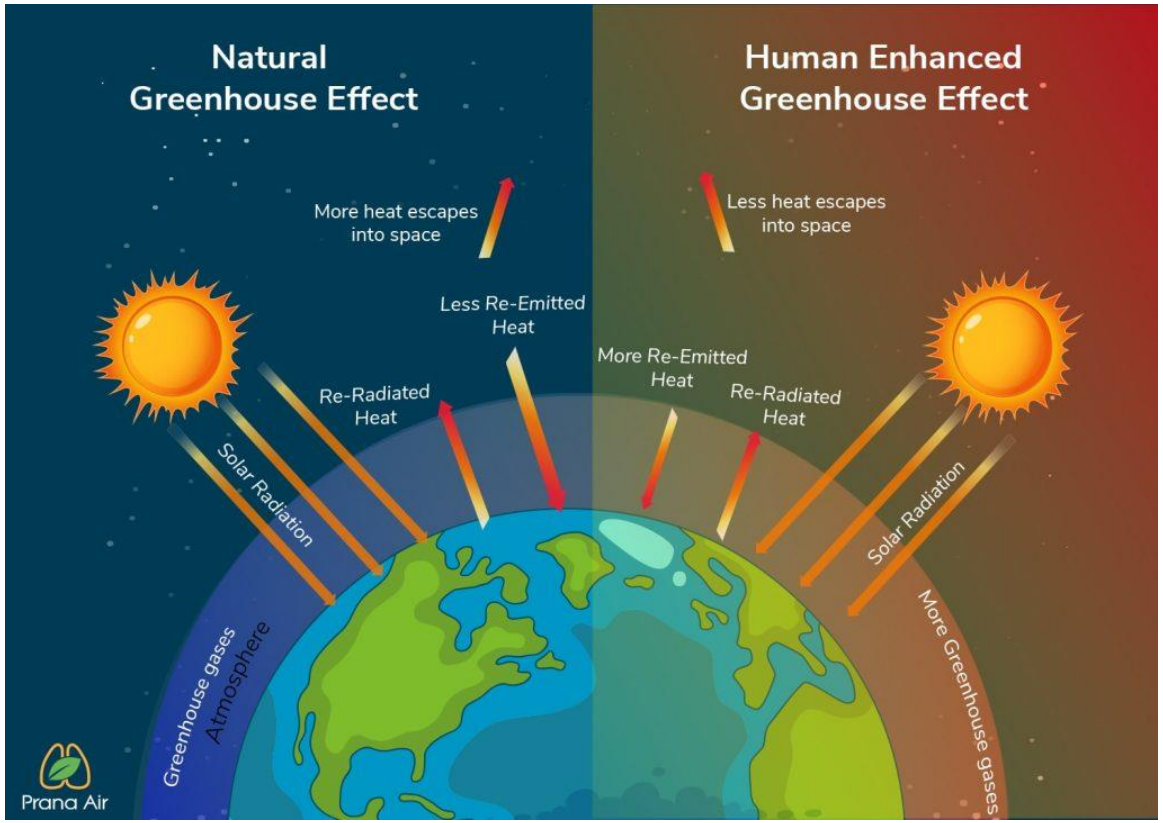


Convert plastic into fuel and feedstocks through radiolysis (irradiation & chemical recycling)

Treat plastic to make composite materials with tailored properties

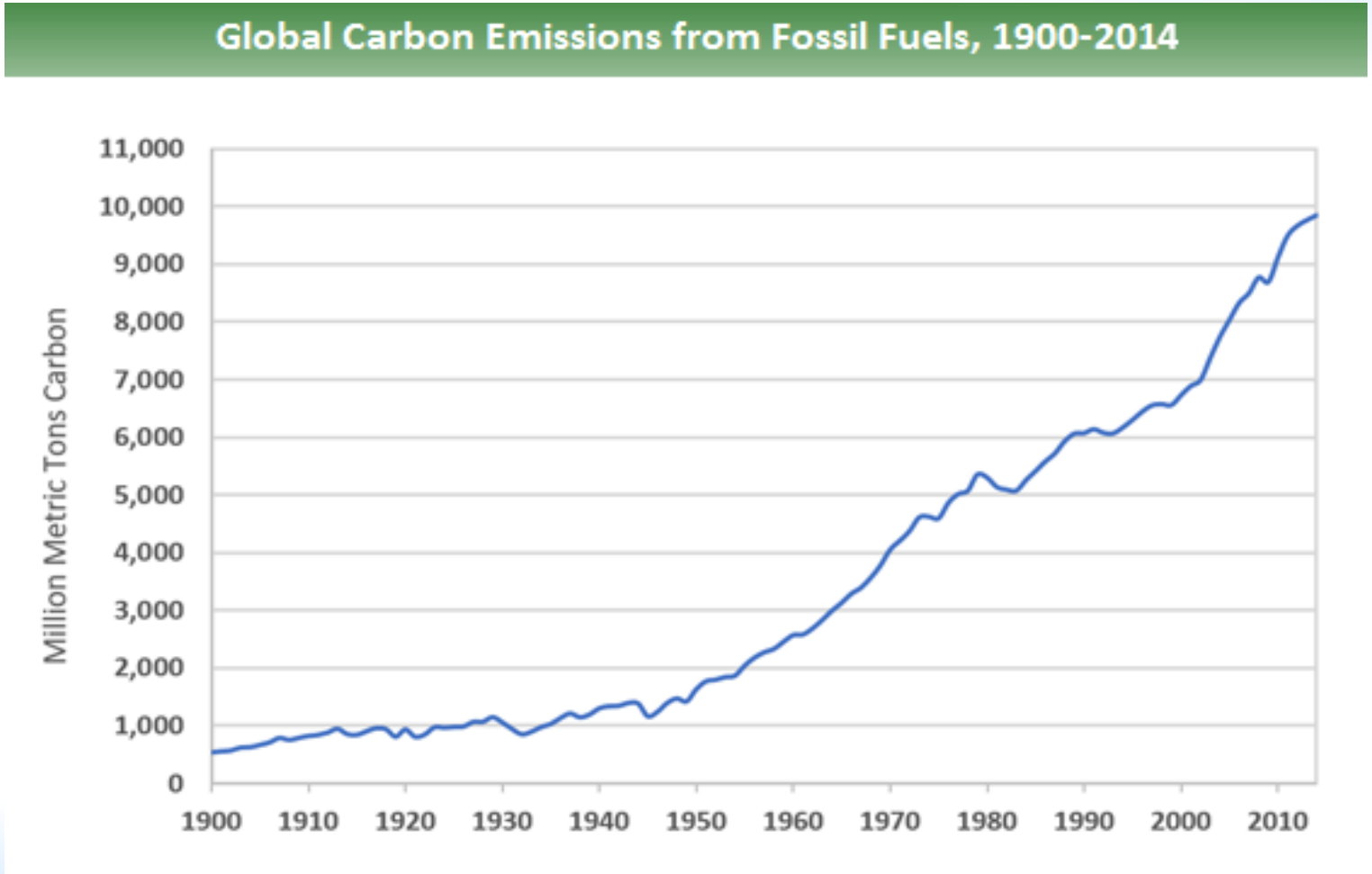
Greenhouse Gases and Global Warming

- Greenhouse gases: the gases in the atmosphere that raise the surface temperature of planet Earth.
- Typically, carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and fluorinated gases
- Human activities since the beginning of the Industrial Revolution have increased atmospheric methane concentrations by over 150% and carbon dioxide by over 50%.



Greenhouse Gases and Global Warming

- Global carbon emissions from fossil fuels have significantly increased since 1900.



Boden, T.A., Marland, G., and Andres, R.J. (2017). Global, Regional, and National Fossil-Fuel CO2Emissions. Carbon Dioxide Information Analysis Centre, Oak Ridge National Laboratory, U.S. Department of Energy, Oak Ridge, Tenn., U.S.A.

Global Emissions by Economic Sector

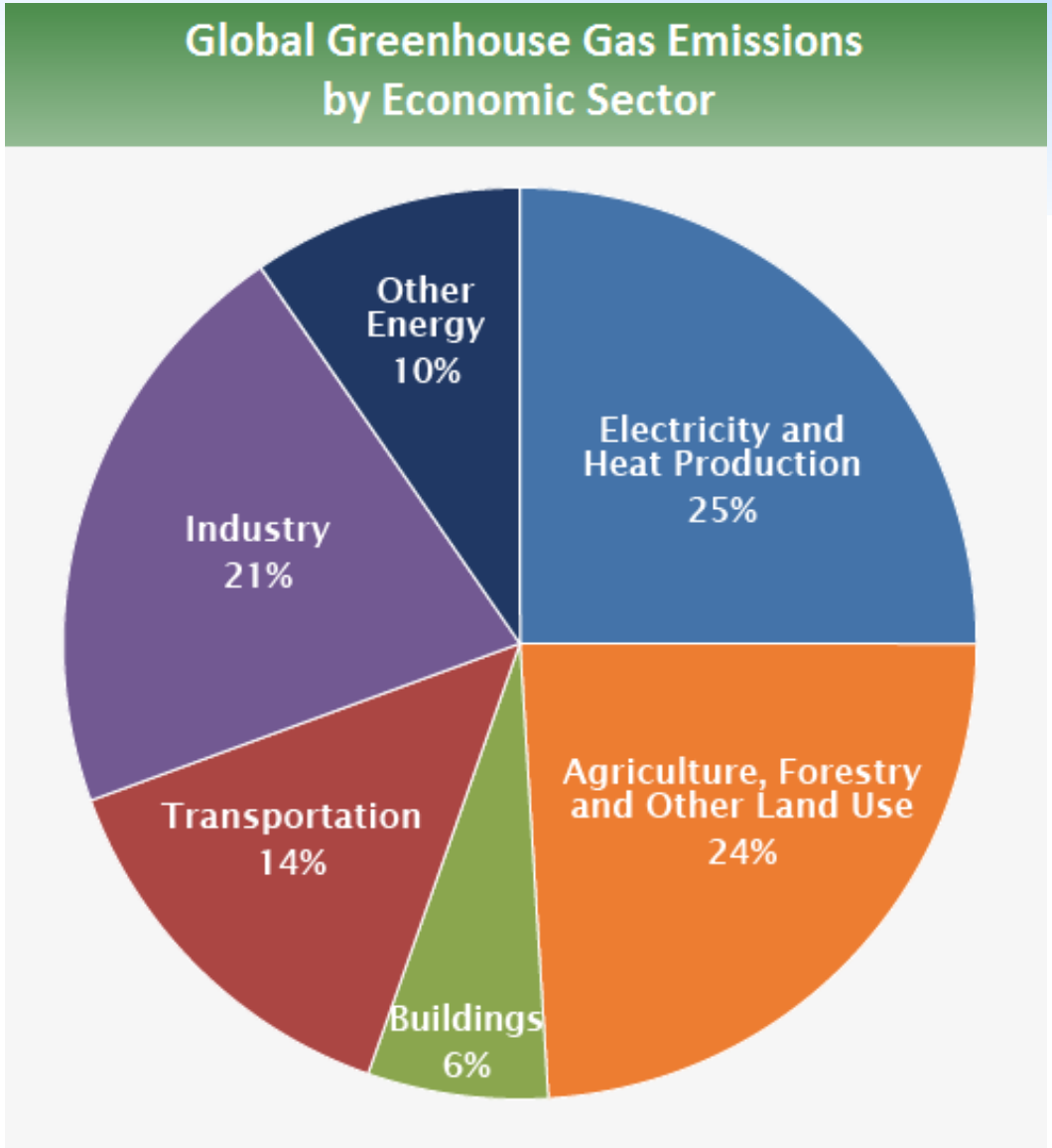
Electricity and Heat Production : The burning of coal, natural gas, and oil for electricity and heat is the largest single source.

Industry : fossil fuels burned on site at facilities for energy, emissions from chemical, metallurgical, and mineral transformation processes

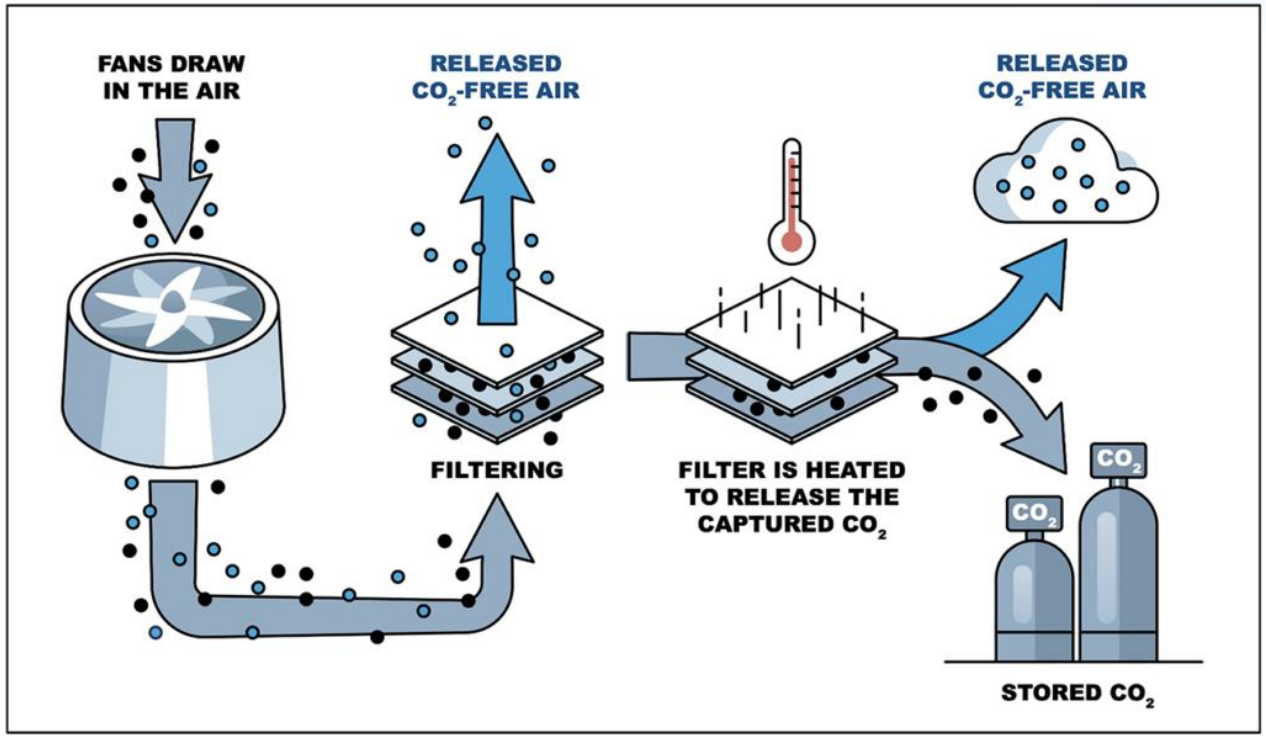
Agriculture, Forestry, and Other Land Use : cultivation of crops and livestock and deforestation.

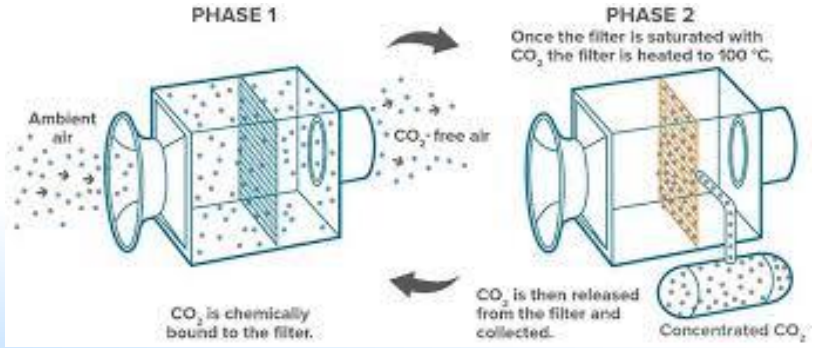
Transportation : fossil fuels burned for road, rail, air, and marine transportation.

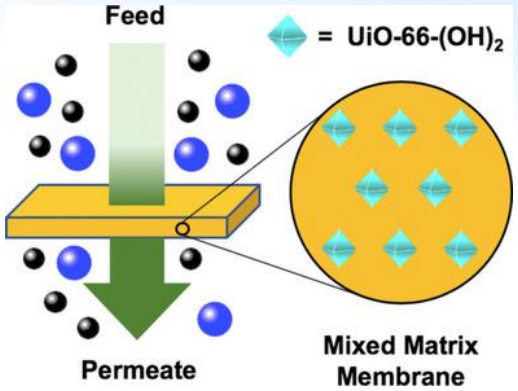
Buildings : onsite energy generation and burning fuels for heat in buildings or cooking

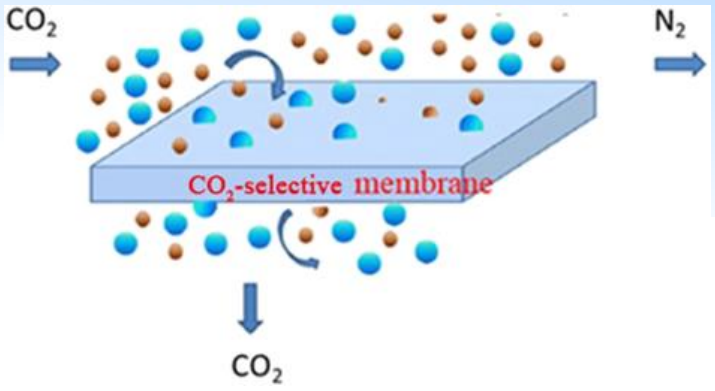


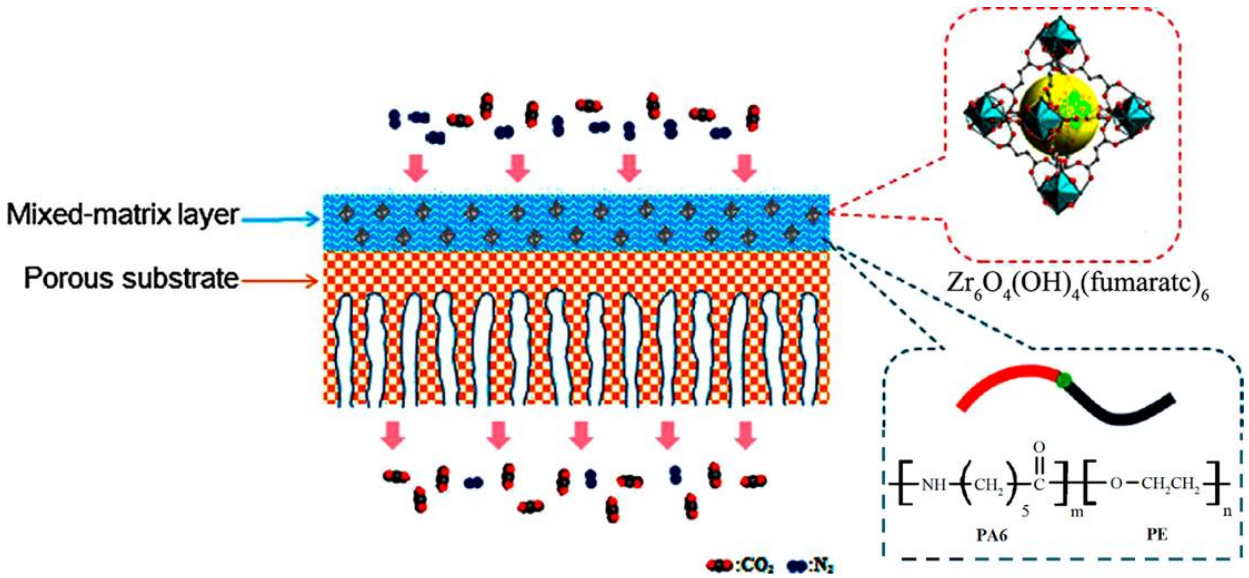
Materials for Carbon Capture and Utilization (CCU)











International Atomic Energy Agency (IAEA)

Set up as the world´s "Atoms for Peace“ organization in 1957

In 1953, Dwight Eisenhower, the President of the United States, called for the establishment of an international atomic energy agency

178 Member States

IAEA promotes safe, secure and peaceful nuclear technologies.

International Atomic Energy Agency (IAEA)

Headquarters Vienna

International Atomic Energy Agency
Vienna International Centre
PO Box 100
1400 Vienna, Austria
Tel: (+43-1) 2600-0
Fax: (+43-1) 2600-7
Email: Official Mail
Website: www.iaea.org

Liaison Office New York

IAEA Office at the United Nations

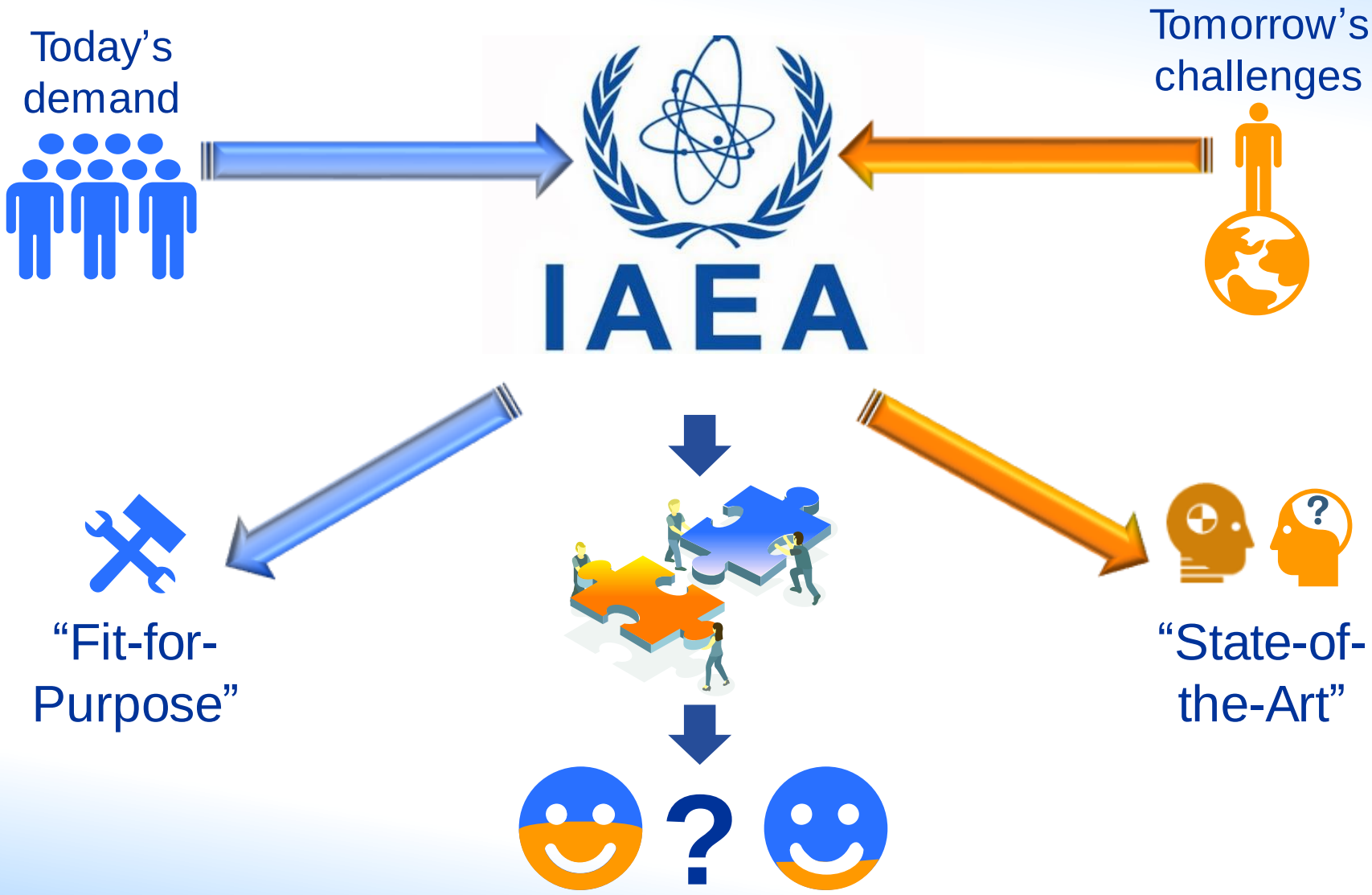
1 United Nations Plaza, Room DC-1-1155
New York, NY 10017 USA
Tel: (001) 212-963-6010 or 6011; Fax: (001) 917-367-4046
Email: iaeany@un.org

Liaison Office Geneva

IAEA Office in Geneva
United Nations, Room B 426
Palais des Nations, CH-1211 Geneva 10, Switzerland
Tel: (+41-22) 917-3620
Fax: (+41-22) 917-0066
Email: iaeage@unog.ch

- 2300 professional and support staff
- Headquarters in Vienna
- 2 scientific laboratories and research centres
- Liaison offices in New York and Geneva

Science, Technology and Innovation



How do we work?

Regular Budget Programme (TD)

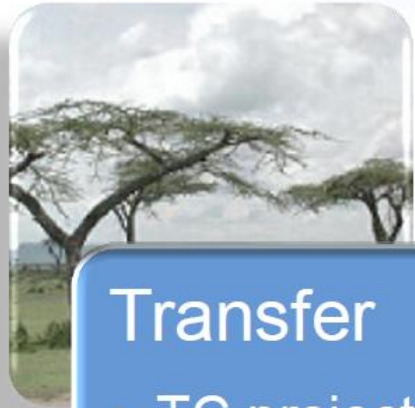
Technical Cooperation Programme

R&D

- NA Labs
- CRPs
- CCs

Validation

- CRPs
- Pilot projects

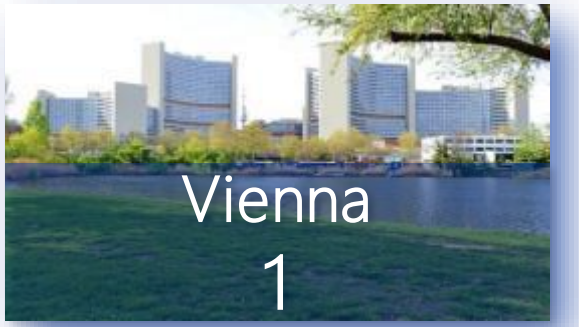


Transfer

- TC projects
- Education & training

IF TRUE THEN

12 unique laboratories



Water Resources

Food & Agriculture

Human Health

Nuclear Science

Environment

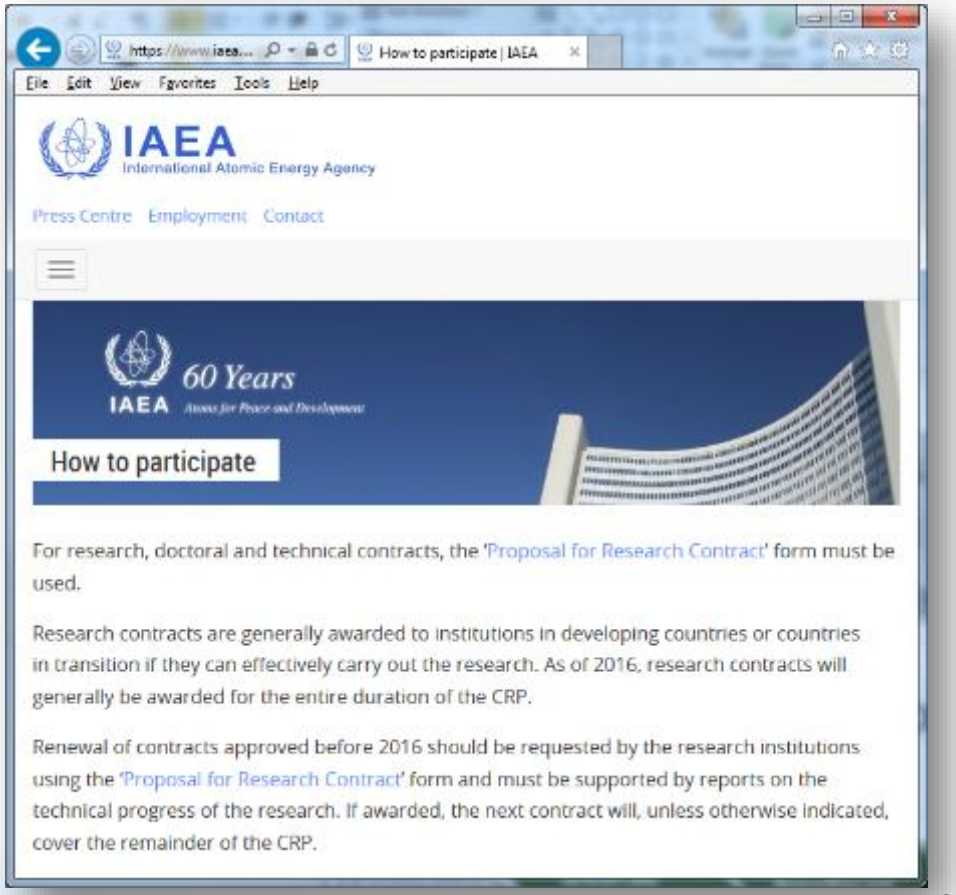
Marine Environment

Coordinated Research Projects in IAEA

- **Objective**:
  Solving technical issues of common interest in the peaceful use of nuclear technology by coordinating research networks in developing and developed countries

- **Composition**:
  10-15 scientists in Member States;
  €5,000 - 8,000 per scientist per year

- **Duration**:
  3-5 years



Coordinated Research Projects in IAEA

124 active CRPs

1710 contracts & agreements

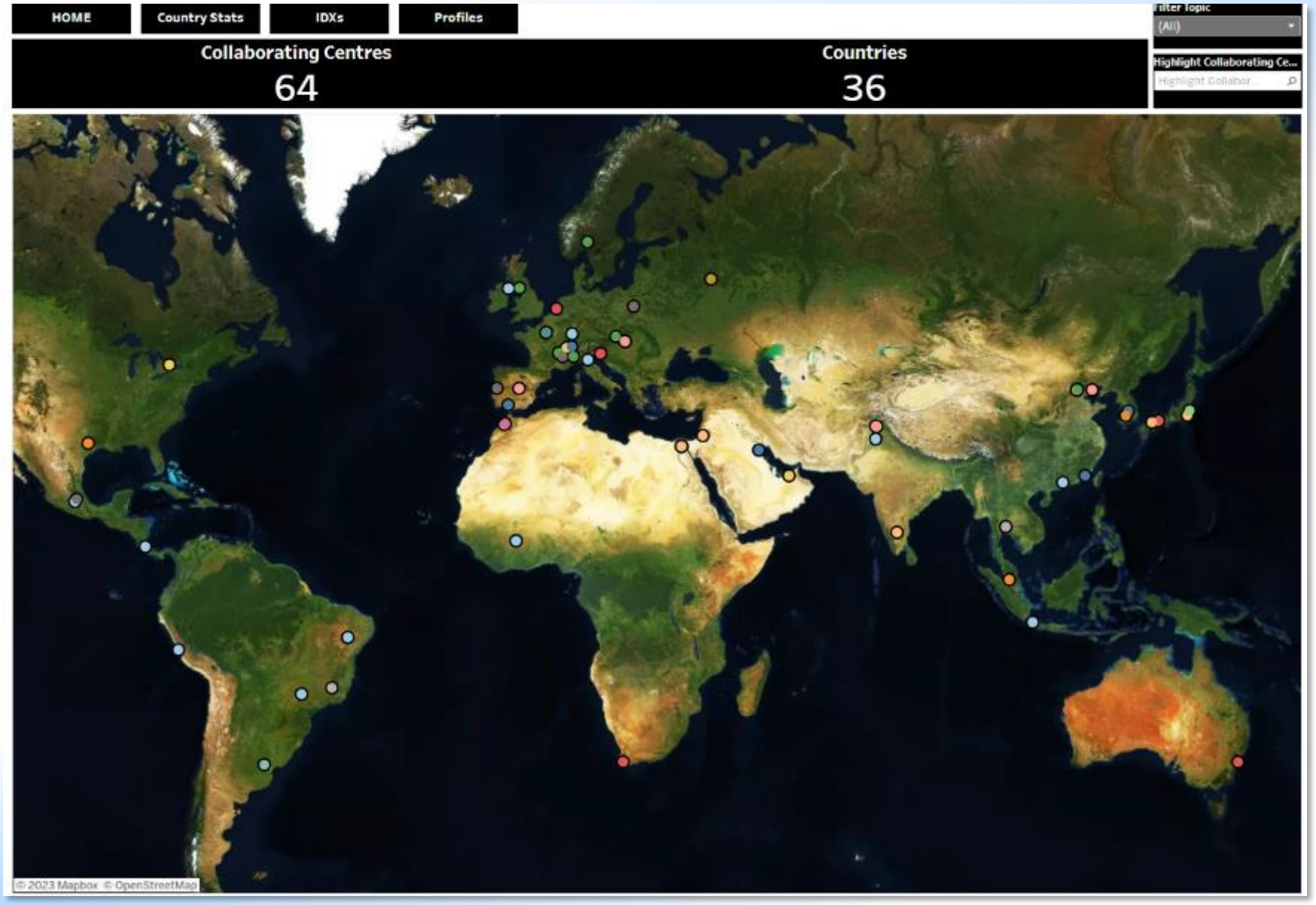
31 Research Coordination Meetings (majority virtual)

Over 100 Member States

7.0 million in 2020

NACA, 2021 data

IAEA Collaborating Centres



How do we work?

Regular Budget Programme (TD)

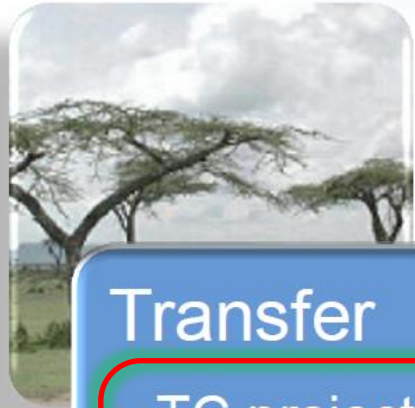
Technical Cooperation Programme

R&D

- NA Labs
- CRPs
- CCs

Validation

- CRPs
- Pilot projects



Transfer

- TC projects
- Education & training

IF TRUE THEN

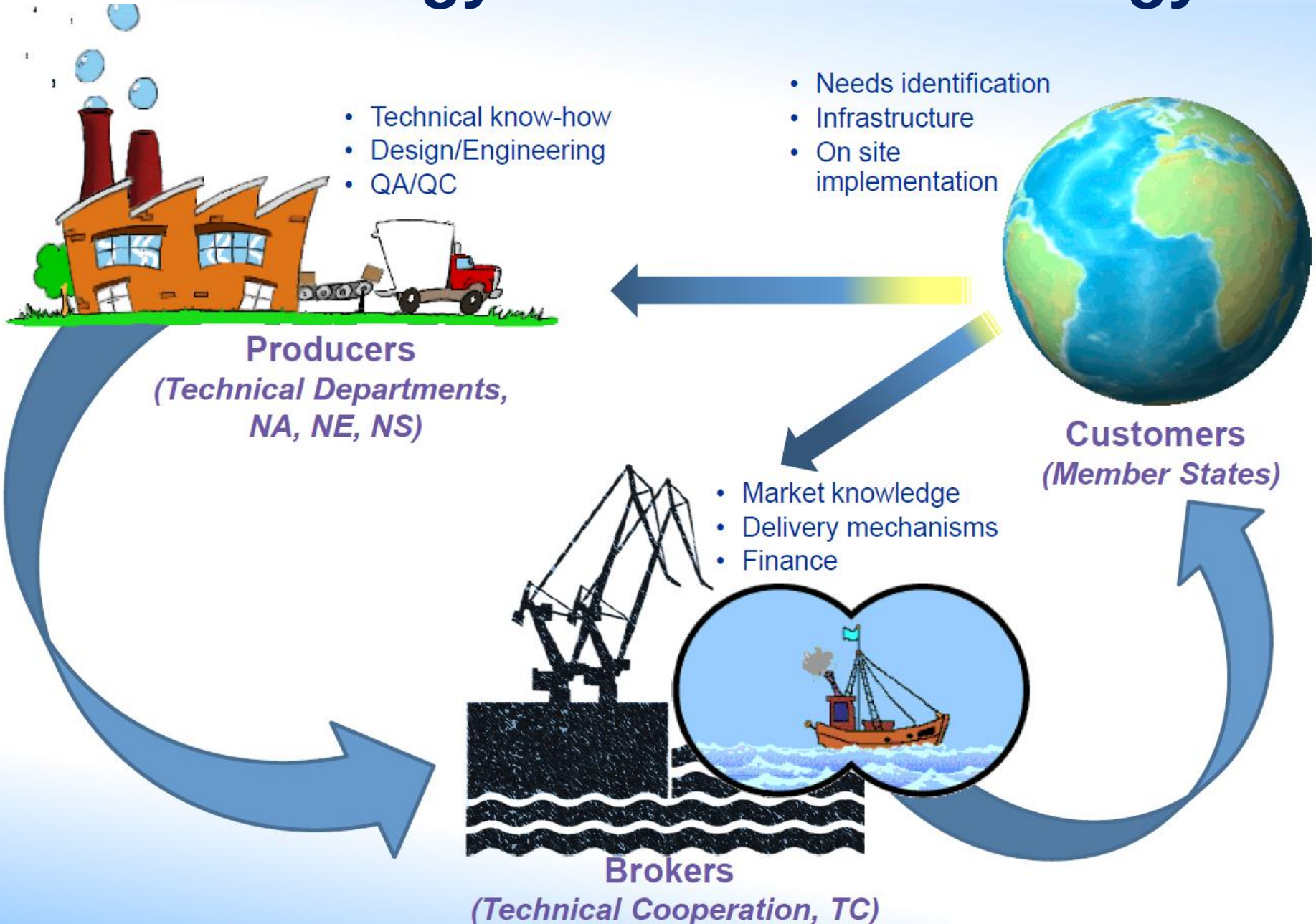
IAEA Technical Cooperation Programme

- The technical cooperation (TC) programme is the IAEA's main vehicle for delivering services from across the house to Member States
- The Department of Technical Cooperation is responsible for managing the TC programme.
- The technical Departments are responsible for the technical integrity of the programme

TC programme is guided by:

- IAEA Statute (1956)
- The Technical Cooperation Strategy (est. 1997, rev. 2002)
- Agency's Medium Term Strategy (2018-2023)
- General Conference Resolution
- Decisions of Governing Bodies
- Revised Supplementary Agreement
- INF/CIRC 267 (Guiding Principles & General Operating Rules)

Technology Transfer: An Analogy



IAEA support Wastewater Treatment through TC projects

Wastewater Treatment

Related TC projects on water treatment

- RAS/1/023 -Developing and Upscaling of Radiation Grafted Materials for Water Treatment (2018 -2021)

Objective: To make technologies affordable to small and medium scale industries in order to mitigate industrial waste water pollution. Radiation grafted materials have to be easily available for emergency purposes, especially in cases of calamities. One of the possible alternatives would be the use of radiation grafted materials which can highly adsorb these contaminants.

- BRA/1/035 Establishing a Mobile Unit with an Electron Beam Accelerator to Treat Industrial Effluents for Reuse Purposes (2016 -2019)

Objective: To enlarge the national capacity to treat industrial effluents using electron beam accelerators, the mobile unit treating effluents on site from 1m^3/h up to 1000m^3/day, will provide an effective facility between a laboratory-scale plant to a large-scale plant with the objective to demonstrate the efficacy and transfer the technology.

IAEA

Global Water Analysis Laboratory (GloWAL) Network

Fulfil basic human needs

ATOMS4CLIMATE