ICARST 2017
1st International Conference on Applications of Radiation Science and Technology

Multipurpose Gamma Irradiator and Mobile Unit with an Electron Beam Accelerator Developed in Brazil

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Nuclear and Energy Research Institute (IPEN)
National Nuclear Energy Commission (CNEN)
Radiation Technology Centre
IPEN-CNEN/SP

GOVERNO DO ESTADO SÃO PAULO · ipen · CNEN Comissão Nacional de Energia Nuclear · MINISTÉRIO DA CIÊNCIA, TECNOLOGIA, INOVAÇÕES E COMUNICAÇÕES · BRASIL GOVERNO FEDERAL

Irradiation facilities in Latina America and the Caribbean

Radioactive Facilities	Latina America Caribbean	Brazil	Japan	USA	China	World
GAMMA IRRADIATORS (100 kCi - 10 MCi)	> 14	> 7	> 8	> 30	> 80	> 300
ELECTRON BEAM ACCELERATORS (100 keV - 10 MeV)	> 30	> 20	> 300	> 500	> 140	> 1600

www-naweb.iaea.org/napc/iachem/home.html

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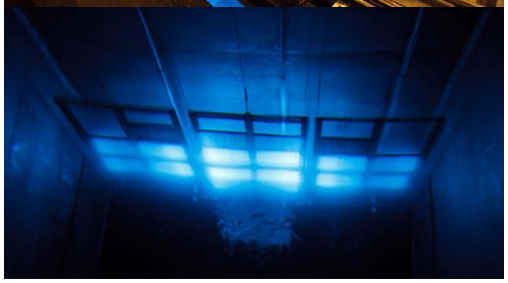
STERIGENICS-CBE

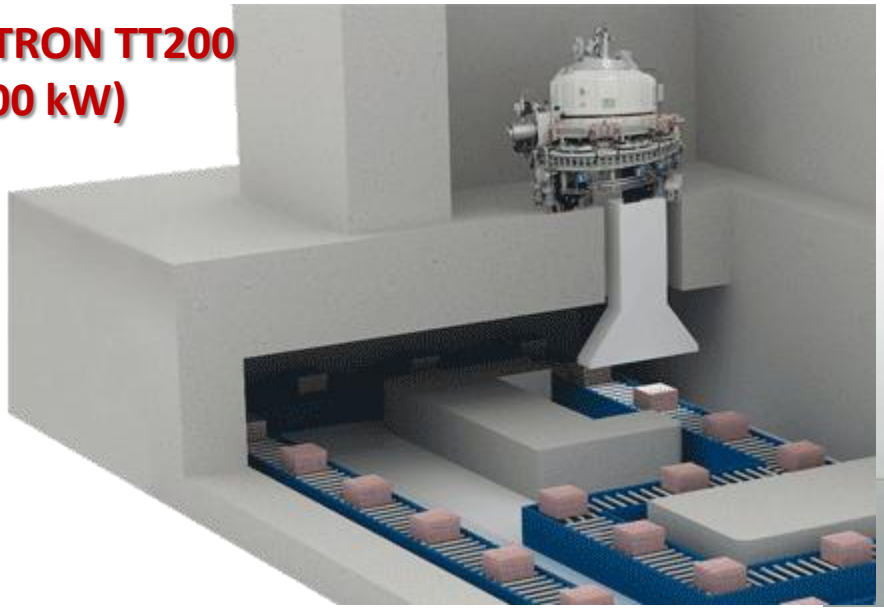
National Technology (3MCi)

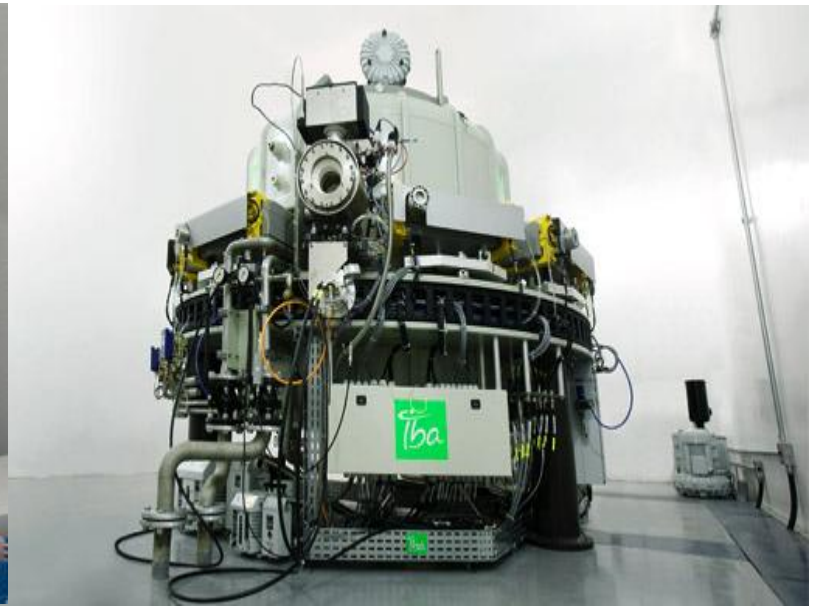
PALLET GAMMA IRRADIATOR



STERIGENICS -CBE

RHODOTRON TT200
(100 kW)



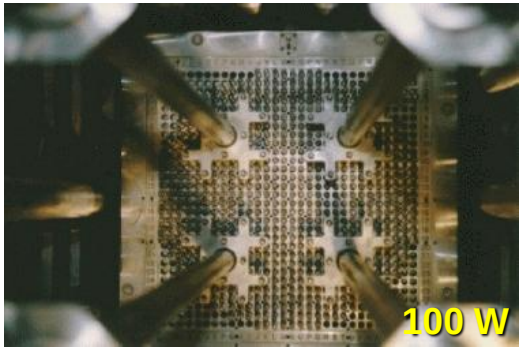


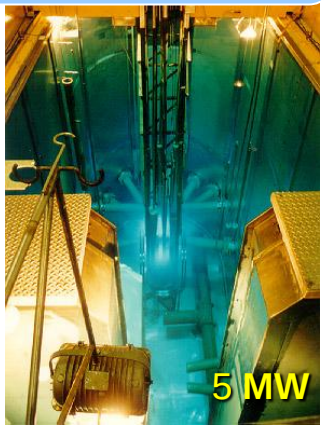
Sterilized Medical Devices: 135.000 m³/year

BRAZIL
NUCLEAR AND ENERGY RESEARCH INSTITUTE (IPEN)

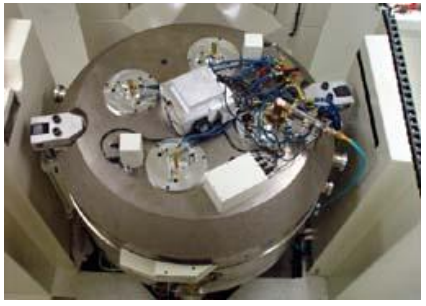
BRAZIL
NUCLEAR AND ENERGY RESEARCH INSTITUTE (IPEN)

☞ 2 RESEARCH REACTORS
- ✓ 100W and 5MW

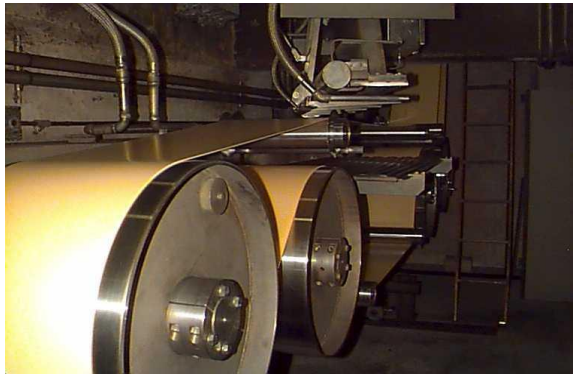




☞ 2 CYCLOTRONS
- ✓ IBA (18/9MeV and 30MeV)



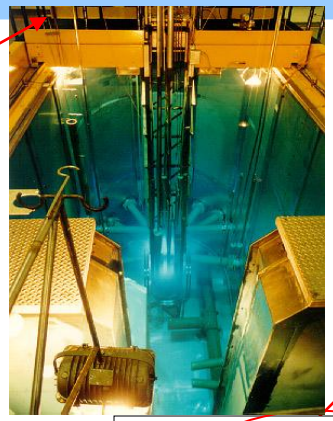
☞ 2 ELECTRON BEAM ACCELERATORS
- ✓ RDI (1.5 MeV)

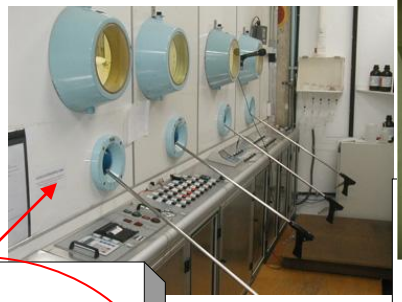


☞ 3 GAMMA IRRADIATORS
- ✓ Multipurpose (2 MCi)
- ✓ Gammacell (12 kCi)
- ✓ Panoramic (5 kCi)

BRAZIL
NUCLEAR AND ENERGY RESEARCH INSTITUTE (IPEN)

^{125}I, ^{131}I, ^{153}Sm, ^{192}Ir





RADIOISOTOPES

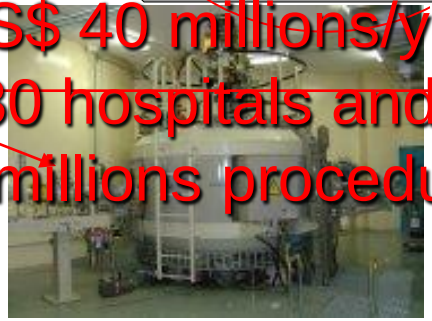
Material Test Reactors

Cyclotrons

Image Equipment

Radiopharmaceutical Products

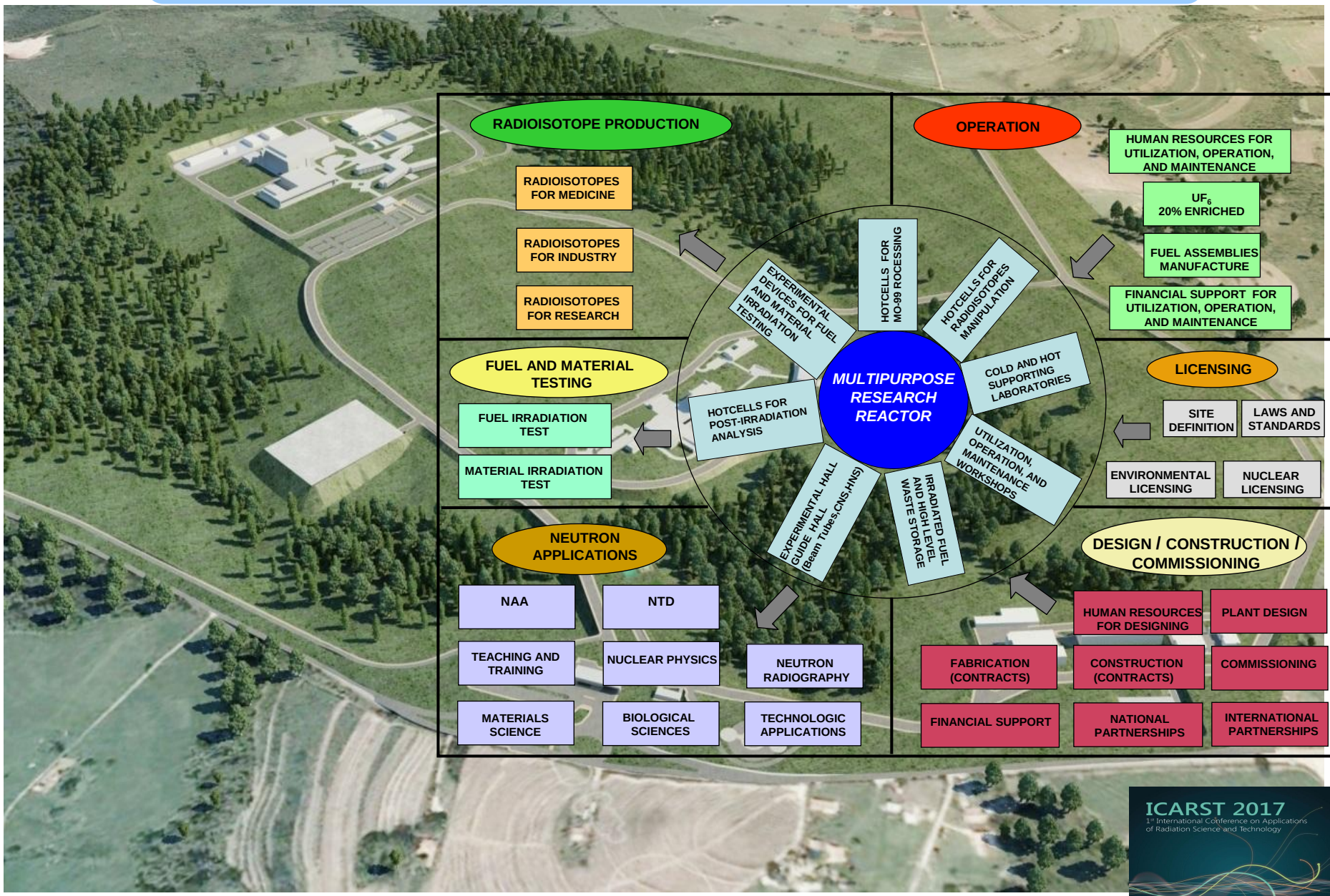
US$ 40 millions/year
430 hospitals and clinics
2 millions procedures/year



Nuclear Medicine

^{123}I, ^{18}F, ^{67}Ga, ^{201}Tl

BRAZIL
MULTIPURPOSE RESEARCH REACTOR (30MW)



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TECHNICAL COOPERATION

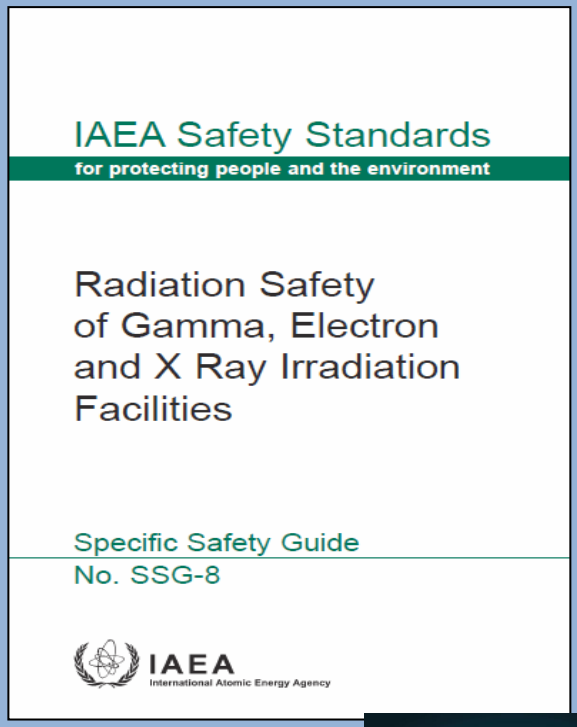
Success Story - I

Safety Design, Construction and Operation of Multipurpose Gamma Irradiator in Brazil

1. International Basic Safety Standards (BSS)
   - Protection against Ionizing Radiation
   - Safety of Radiation Sources

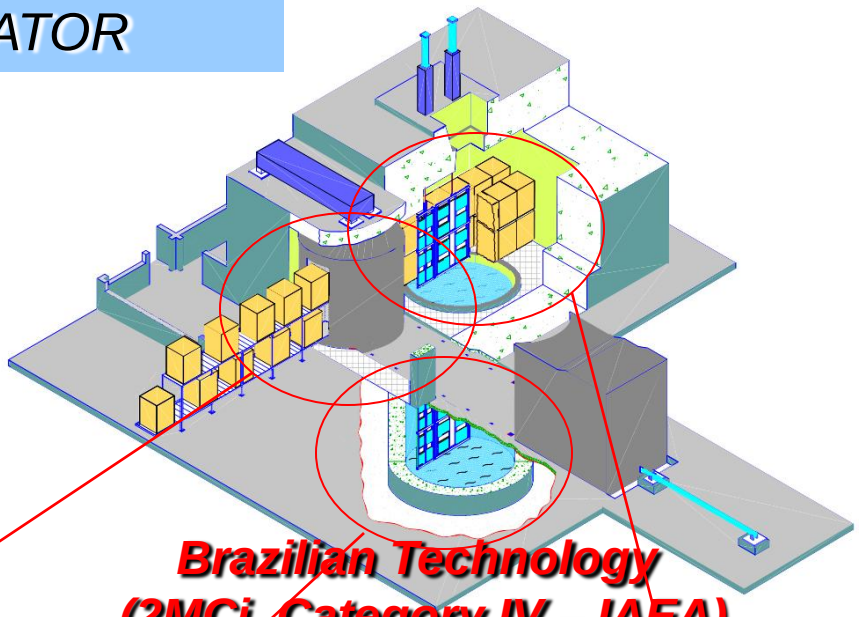
2. IAEA Safety Standards and Lessons Learned from Accidents in Industrial Irradiation Facilities

3. Safety Standards of the National Nuclear Energy Commission (CNEN) - Brazil

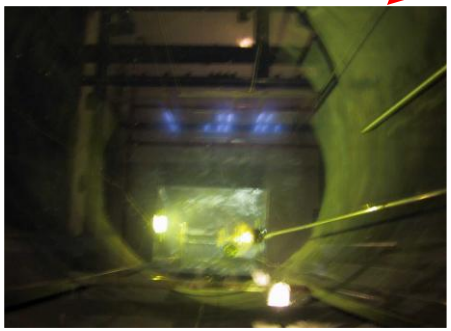


NUCLEAR AND ENERGY RESEARCH INSTITUTE (IPEN)

MULTIPURPOSE GAMMA IRRADIATOR



Brazilian Technology
(2MCi, Category IV – IAEA)



DUR / Efficiency:
1,33 / 11,6% (0,09g/cm^3)
2,08 / 36,6% (0,49g/cm^3)

MULTIPURPOSE GAMMA IRRADIATOR

Project and construction

Pool liner

Bunker

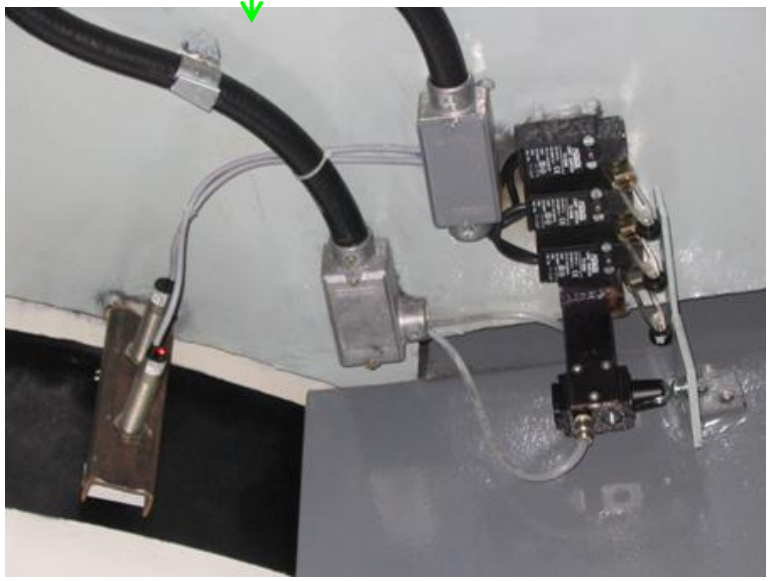
VII/VIII Modified Mercalli Scale
(wind of 331km/h)

Wearhouse

Safety interlock system

Geiger-Müller detector

Redundancy, diversity and independence systems



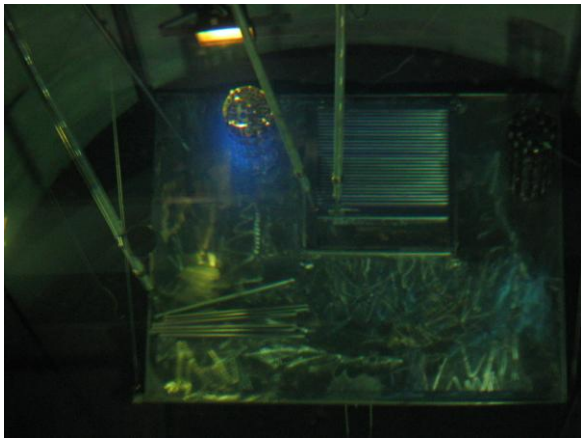
Safety interlock system

Hydraulic system (tote boxes irradiator)

Pneumatic (^{60}Co source racks) and ventilation (O_3) systems

Geiger-Müller detector and conductivity instrumentation *(< 10μSiemens/cm)*

Loading of ^{60}Co sealed sources

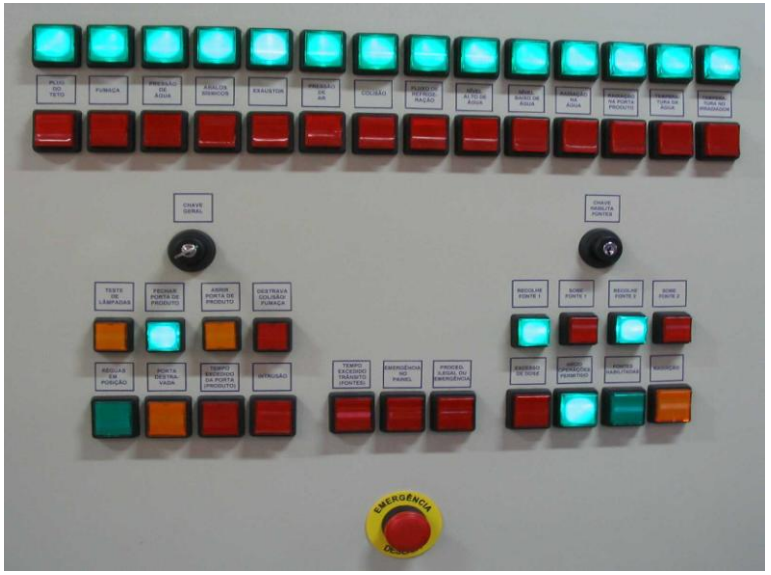


^{60}Co Sealed Sources (C-188)

Flushing Test
Activity < 5nCi (185Bq)

Type B(U) Package

Safety interlock system (control room)



Geiger-Müller detector and ionization chamber (< 2µSv/h)

Radiation detectors and seismic intrumentation

MULTIPURPOSE GAMMA IRRADIATOR

Radiosterilization - $^{99}Mo/^{99m}Tc$ Generators

- 400 generators / week
- 250, 500, 750,1000, 1250, 1500 and 2000mCi

Radiation Processing of cultural Heritage

Routine operations (semi-industrial scale)

- Disinfestation and disinfection of cultural objects (books, furniture, sculptures and paintings) > 20,000 artefacts / year






STAKEHOLDER INVOLVEMENT AND PUBLIC COMMUNICATION

- **IAEA ARCAL RLA0058** - Using Nuclear Techniques in Support of Conservation and Preservation of Cultural Heritage Objects.

Radiation technologies in daily life

https://www.youtube.com/watch?v=ePiNdzWjoWM

- **IAEA CRP / F23032** - Developing Radiation Treatment Methodologies and New Resin Formulations for Consolidation And Preservation of Archived Materials and Cultural Heritage Artefacts.

Culture meets nuclear

https://www.youtube.com/watch?v=wvid7KvPPjE

TECHNICAL COOPERATION

Success Story – II

IAEA TC BRA1035 (2016-2018)

Establishing a Mobile Unit with an Electron Beam Accelerator to Treat Industrial Effluents for Reuse Purposes in Brazil

ICARST 2017

"We need more demonstration facilities to disseminate the EB-Technology in industrial scale for environmental applications"

(B. S. Han, IAEA)

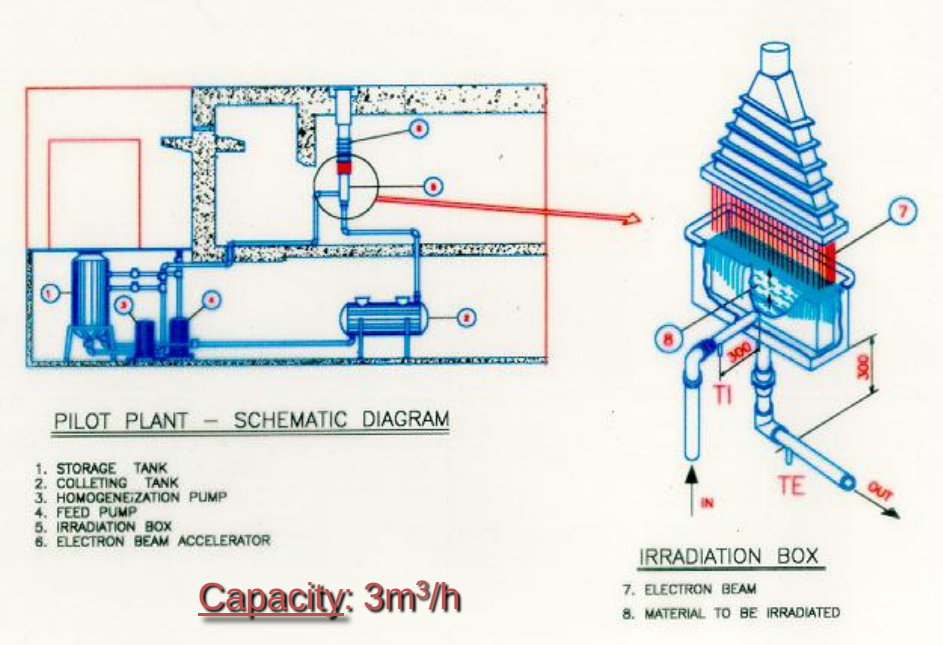
"Transportable EB systems are needed to address contaminated groundwater situations"

(S. Pillai, Texas A&M University)

"Application of Mobile EB for remediation of soil and groundwater "

(S. Yu, KAERI)

WASTEWATER TREATMENT BY ELECTRON BEAM ACCELERATOR



IAEA TC Project BRA/8/025
Electron Beam Treatment of Wastewater
(1993-1997)

IAEA's Model Project
(1995)

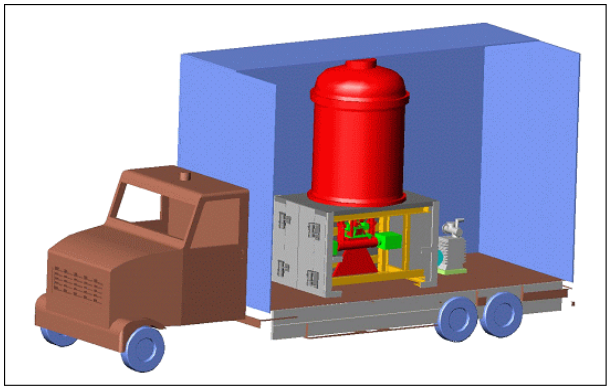
MOBILE ELECTRON ACCELERATOR – EB TECH

Laboratorial scale experiments (1~50m³/day)

Laboratorial scale experiments (1~10,000Nm³/h)

Pilot scale experiments (20~1,000m³/day)

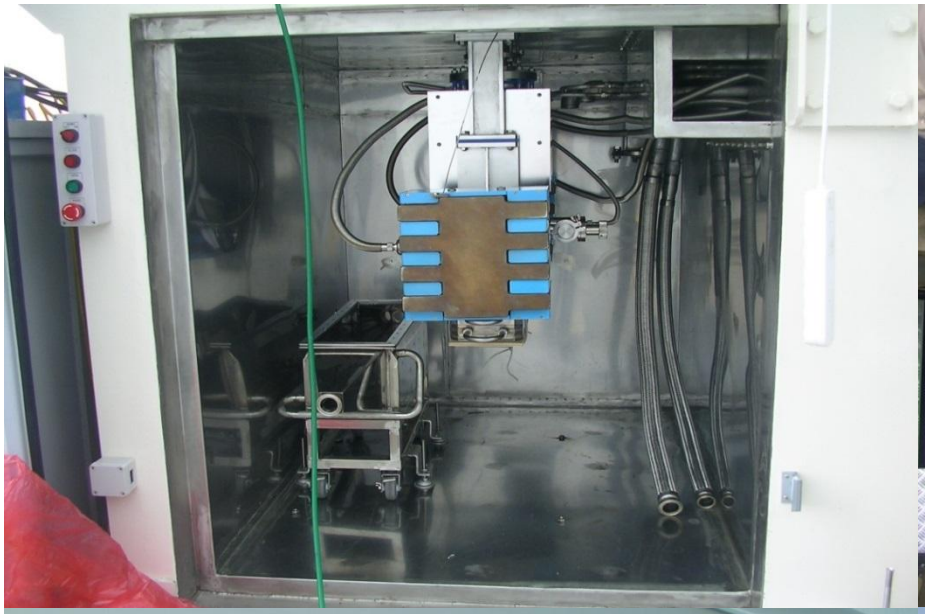
- Cost
- Space
- Operation & Maintenance, other

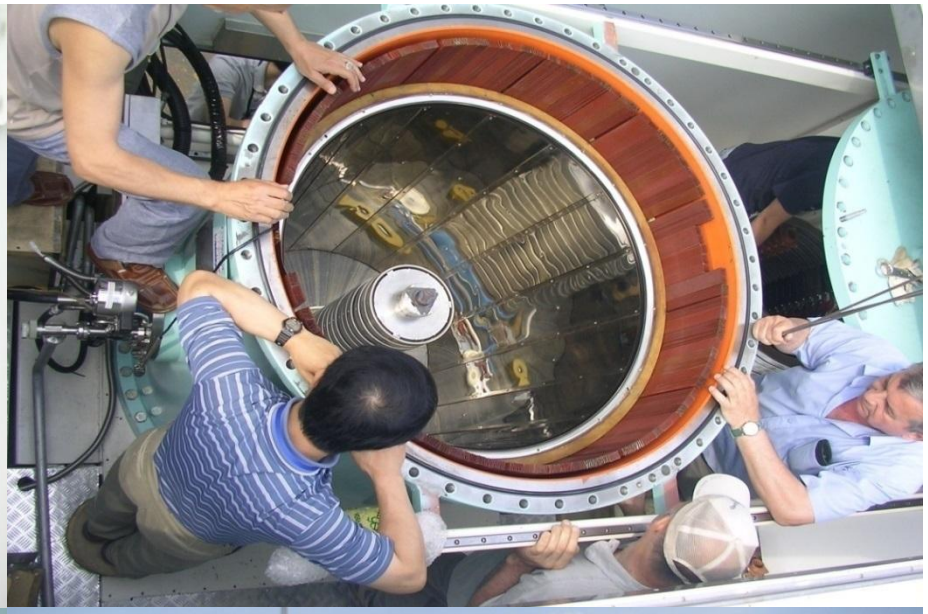


Industrial scale wastewater plant (10,000m³/day)

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

MOBILE ELECTRON ACCELERATOR – EB TECH





- Beam Energy: 0.4 ~ 0.7 MeV
- Beam Power: 20 kW
- Total weight: 40 tons

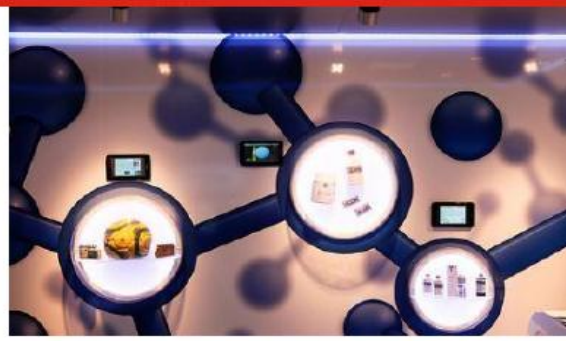
PARTNERS

TRUCKVAN

Truckvan manufactures road implements, in special aluminum vans, products and diverse solutions for special uses, equipment and Mobile Units. Its portfolio includes consolidated, high technology solutions for the healthcare, training, trading, operations, entertaining, events, defense and security industries.

SENAI SÃO PAULO

Nanoworld

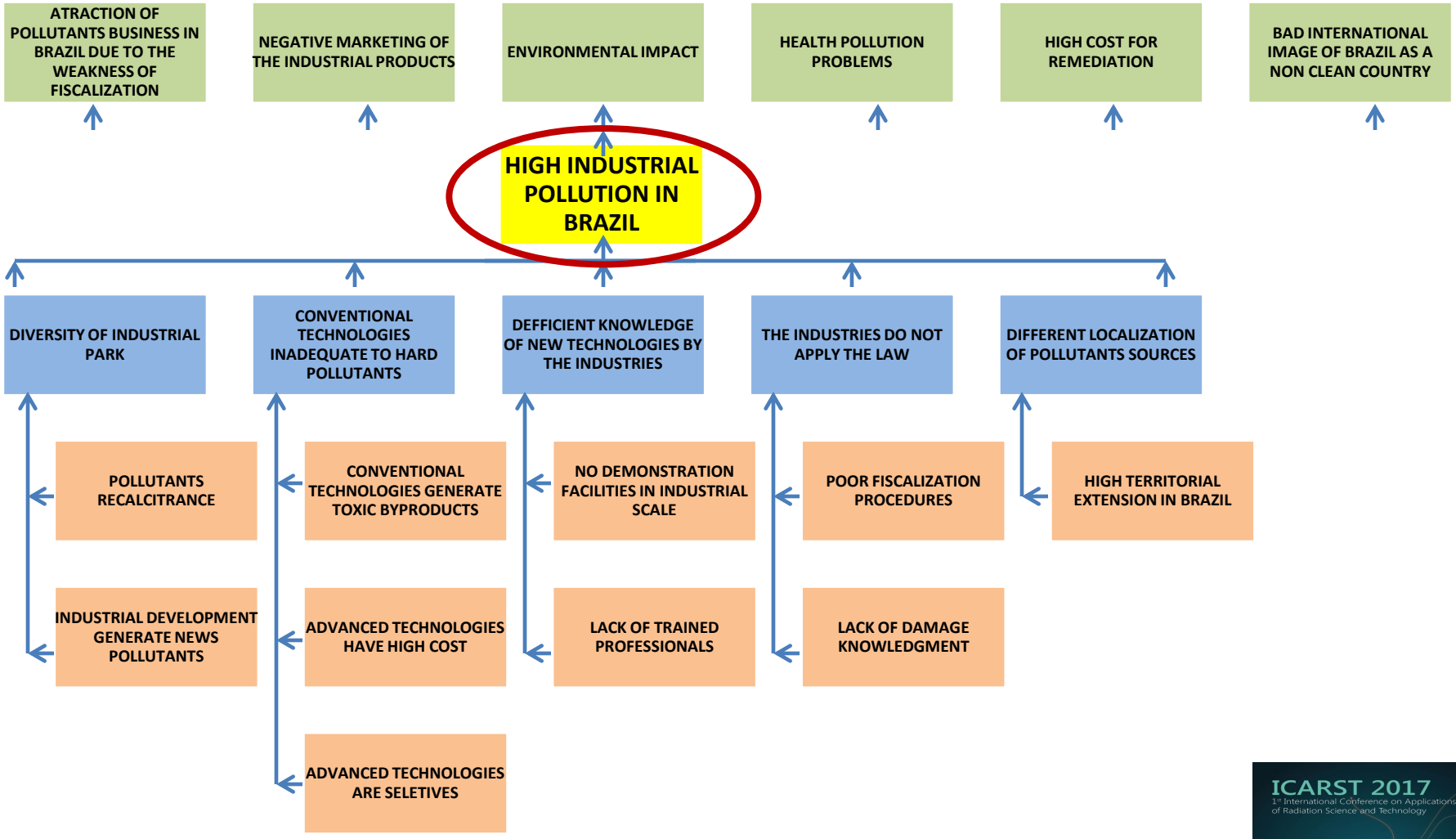


75 Mobile Units

IAEA TC BRA1035

MOBILE UNIT WITH AN ELECTRON BEAM ACCELERATOR TO TREAT INDUSTRIAL EFFLUENTS FOR REUSE PURPOSES

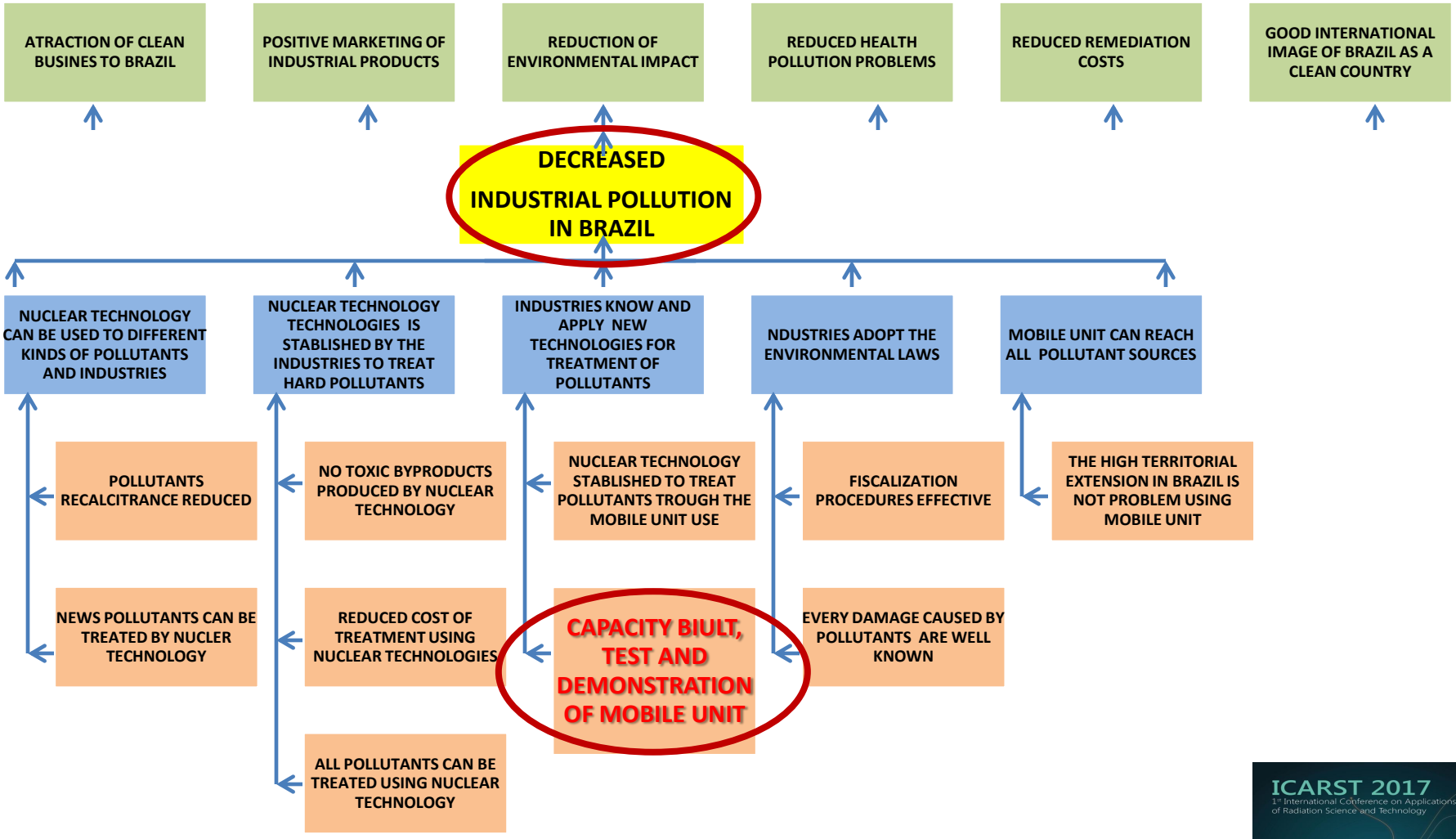
PROBLEM TREE



Source: PCMF-IAEA

IAEA TC BRA1035
MOBILE UNIT WITH AN ELECTRON BEAM ACCELERATOR TO TREAT INDUSTRIAL EFFLUENTS FOR REUSE PURPOSES

OBJECTIVE TREE



Source: PCMF-IAEA

IAEA TC BRA1035 - Funding and Project Budget

Project	2016	2017	2018	TOTAL (EUROS)
IAEA	18,800	174,300	20,000	213,100
FINEP (Brazilian Innovation Agency)	8,000	411,000	10,000	429,000
IPEN, TRUCKVAN, SENAI	-----	437,400	89,800	527,200

PROJECT IAEA TC BRA1035	Project Workplan 2016 - 2018	EUROS 1,169,300

Investors

- IAEA Technical Cooperation Fund
- Sao Paulo Research Foundation (FAPESP)
- CNPq (Ministry of Science and Technology)
- Sao Paulo Sanitation Company (SABESP)
- Energy Company PETROBRAS
- SENAI (National Service of Industrial Training)
- TRUCKVAN
- IPEN-CNEN/SP

Source: PCMF-IAEA

IAEA TC BRA1035 - PROJECT COSTS

Capital Cost (Investment)

Initial costs	Investments (US$)
Engineering design, installation and functional testing (10% of investment)	150,000
Water cooling system (chiller and piping) > 45.000 kcal/h	40,000
Shielding structure and shield door	130,000
Consumption materials (SF_6 gas, methanol, acetone, N_2 gas, O_3 filter, electrical materials, electronic, hydraulic, mechanical and pneumatic materials)	50,000
Tools, systems and equipment (multi-meter, Megger high-voltage insulation tester, air compressor)	40,000
Radiation monitoring device and survey meters	30,000
Transformer (480V/440V/380V/220V) with electric control panel	40,000
Process control, safety and interlock systems	**60,000**
Under-beam unit (irradiation device, beam catcher, pumps, piping, sensors, man/machine interface program)	80,000
Shelter and trailer (6.47 tons, maximum capacity of 24.8 tons) with side and roof structure (aluminum), monitoring system with camera, extinguisher, heater, air conditioner, cable tray, lights, inside walls with door (soundproof)	220,000
Electron Beam Accelerator (0,7MeV e 20kW) with vacuum system, foil fan, ozone ventilation fan, wiring and cabling	**570,000**
Licenses for construction and operation (National Nuclear Energy Commission – Brazil)	20,000
Skilled labor in the Radiation Technology Center and IPEN-CNEN/SP (construction and installation)	70,000
Total cost (investment)	**1,500,000**

IAEA TC BRA1035 - PROJECT COSTS

Operating costs (fixed and variable)

Operating costs (Annual)	Price (US$)
Fixed costs	
Depreciation (20 years and interest rate of 5% per year)	75,000
Bank interest (5% of total investment)	75,000
Management: insurance and fees (2% of total investment)	30,000
Subtotal	**180,000**
Variable costs	
Maintenance (3,5% of total investment)	52,500
Electricity consumption of 50kW and 333 days/year: electron accelerator = 25kW (80% efficiency) and other equipment = 25kW	48,000
Labor (3 shifts)	100,000
Subtotal	**200,500**
Total operating cost	**380,500**

IAEA TC BRA1035 - PROJECT COSTS

Treatment Costs

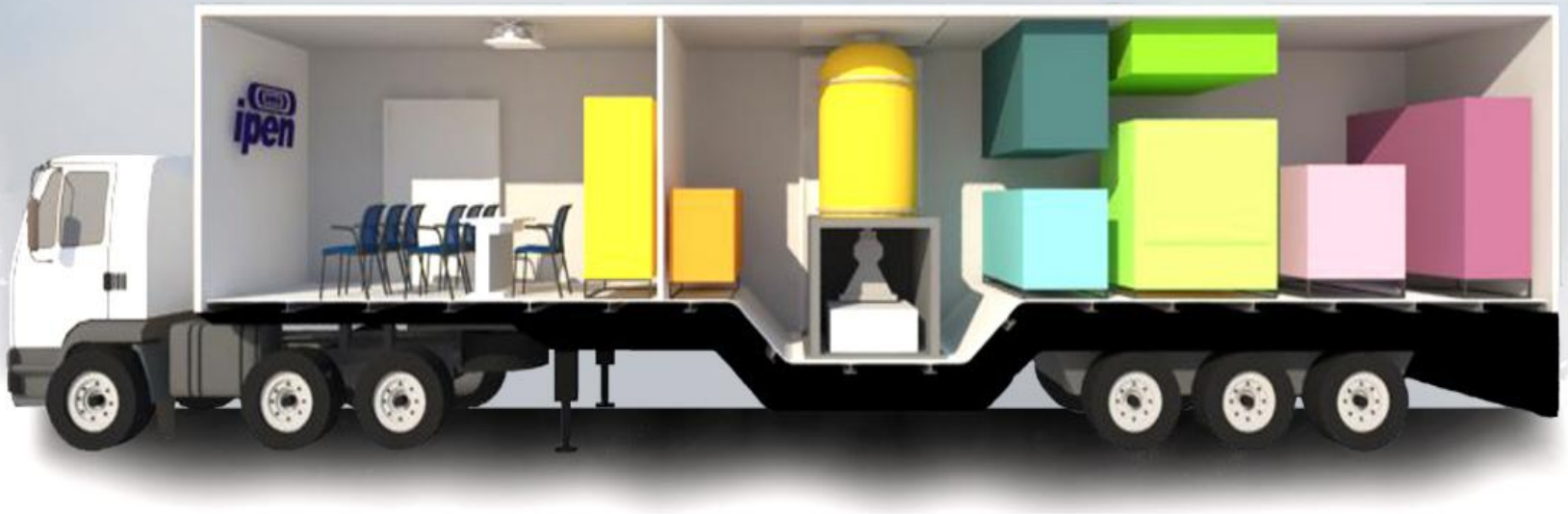
Effluent	Dose (kGy)	Amount (m^3/day)	Power (kW)	Capital cost (Million US$)	*Variable cost **(Variable and fixed costs) (Million US$)	Cost/m^3 of effluent treated (US$)
Removal of geosmine-GEO and methilisoborneol-MIB from drinking water	**1**	**1,000**	20	1.5	0.20 (0.38)	**0.60** **(1.14)**
Removal of industrial textile dyeing from wastewater	2	500	20	1.5	0.20 (0.38)	**1.20** **(2.28)**
Elimination of coliforms from raw sewage, secondary and chlorinated effluents	3	340	20	1.5	0.20 (0.38)	**1.77** **(3.36)**
Removal of organic compounds from petroleum production water	20	50	20	1.5	0.20 (0.38)	**12.0** **(22.8)**
Removal of PCB from transformers oils	50	20	20	1,5	0.20 (0.38)	**30.1** **(57.1)**

*** Variable cost only (maintenance, electricity and labor)**

**** Both variable and fixed costs (depreciation, bank interest and management)**

MOBILE UNIT WITH EB ACCELERATOR TO TREAT INDUSTRIAL EFFLUENT FOR REUSE PURPOSE

The EB Mobile Unit will enlarge the national capacity to treat industrial effluents, with the capacity to treat effluents on site from 1m³/h up to 1,000m³/day. Will provide an effective facility between a laboratory-scale plant to a large-scale plant with theobjective to demonstrate the efficacy and transfer the technology



For treatment of effluent from chemical, pharmaceutical and petroleum production, petroleum desulfurization and degradation of toxic organic compounds in wastewater for reuse

Examples of industrial effluent raw (darker) and after (clearer) treatment by EB Technology at IPEN

MOBILE UNIT WITH AN ELECTRON BEAM ACCELERATOR TO TREAT INDUSTRIAL EFFLUENT FOR REUSE PURPOSE

TECHNICAL CHARACTERISTICS

EB ACCELERATOR
0.7 MeV and 20 KW

MODULE 1
Electric Control Panel
Meeting and Class Room
Transformer Power Supply

MODULE 2
EB Accelerator
Shielding Structure
Irradiation System

MODULE 3
Transformer
Power Supply
Water Cooling System

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60 Years IAEA
INTERNATIONAL ATOMIC ENERGY AGENCY
TC PROJECT BRA1035

Finep 50 anos
FUNDING AUTHORITY FOR STUDIES AND PROJECTS OF THE BRAZILIAN FEDERAL GOVERNMENT

PARTNERS

TRUCKVAN 25 anos

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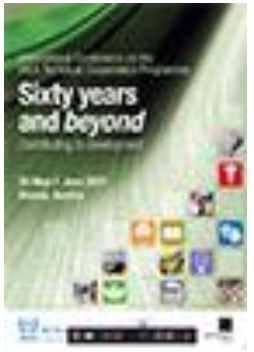
STAKEHOLDER INVOLVEMENT AND PUBLIC COMMUNICATION

- IAEA ARCAL CXLVI/RLA1013 (2016-2019) - Creating Expertise in the Use of Radiation Technology for Improving Industrial Performance, Developing New Materials and Products, and Reducing the Environmental Impact of the Industry.

International Conference on the IAEA Technical Cooperation Programme: Sixty Years and Beyond – Contributing to Development

(Vienna, Austria, 30 May - 1 June 2017)



- IAEA CRP / F23029 - Radiation Treatment of Wastewater for Reuse with Particular Focus on Wastewaters Containing Organic Pollutants.

www.iaea.org/newscenter/multimedia/photoessays/e-beam-treatment-wastewater

THANK YOU VERY MUCH FOR YOUR ATTENTION !

***Source*: Russian weather satellite Elektro-L**