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ARIES WP3 kick-off - the Industrial and Societal Applications of Particle Accelerators

New applications of low energy electron beams

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Cracow, Poland, September 13th,2017

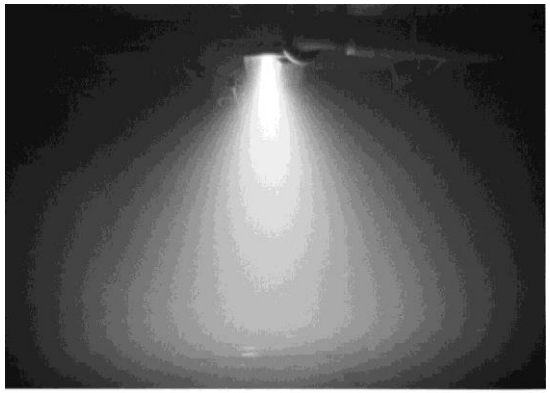
Electron beam

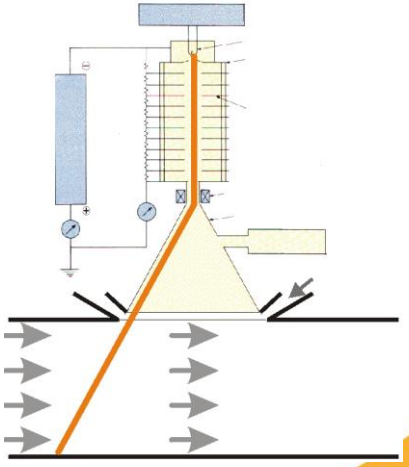
$$4.43N_2 \xrightarrow{100\ eV} 0.29N_2^* + 0.885N(^2D) + 0.295N(^2P) + 1.87N(^4S) + 2.27N_2^+ + 0.69N^+ + 2.96e^- \quad (1)$$

$$5.377O_2 \xrightarrow{100\ eV} 0.077O_2^* + 2.25O(^1D) + 2.8O(^3P) + 0.18\,O^* + 2.07O_2^+ + 1.23O^+ + 3.3e^- \quad (2)$$

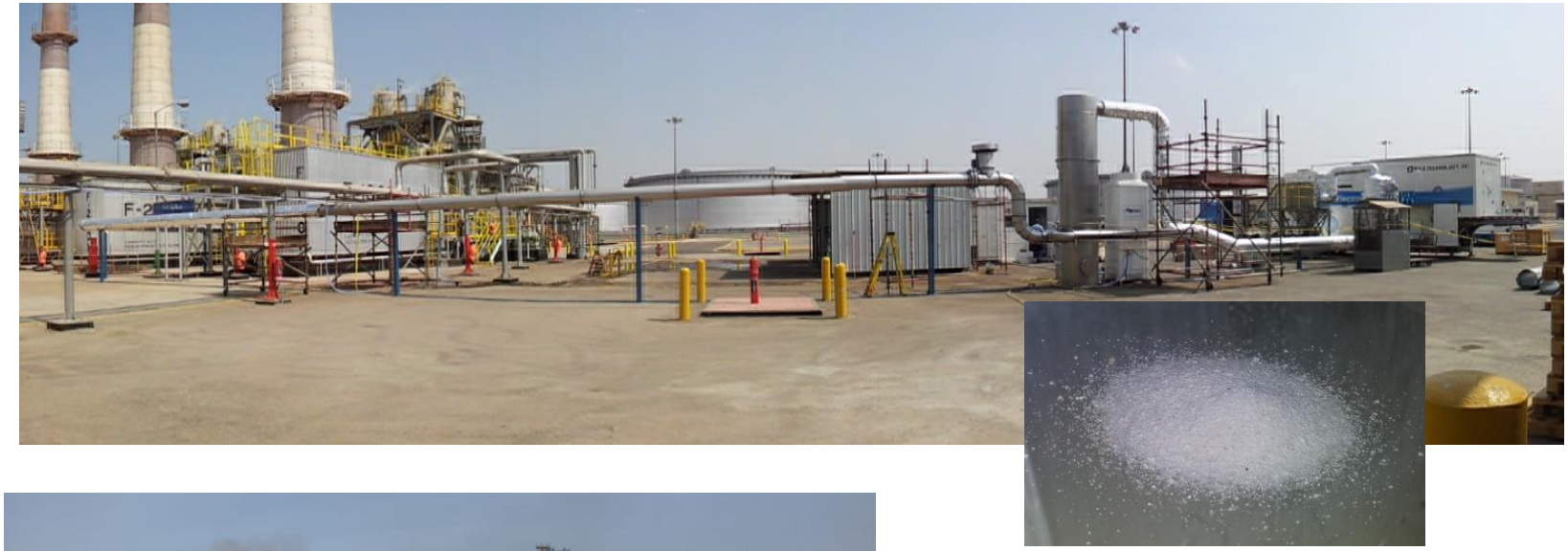
$$7.33H_2O \xrightarrow{100\ eV} 0.51H_2 + 0.46O(^3P) + 4.25OH + 4.15H + 1.99H_2O^+ + 0.01H_2^+ + 0.57OH^+ + 0.67H^+ + 0.06O^+ + 3.3e^- \quad (3)$$

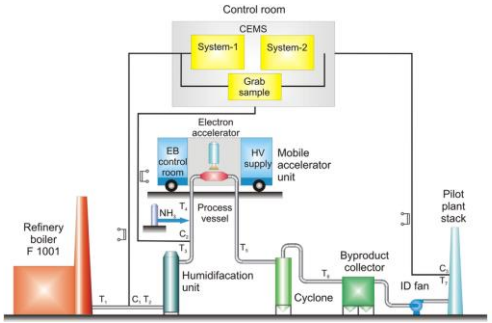
$$7.54CO_2 \xrightarrow{100\ eV} 4.72CO + 5.16O(^3P) + 2.24CO_2^+ + 0.51CO^+ + 0.07C^+ + 0.21O^+ + 3.03e^- \quad (4)$$





EBFGT at ARAMCO, Jeddah, AS - gudron



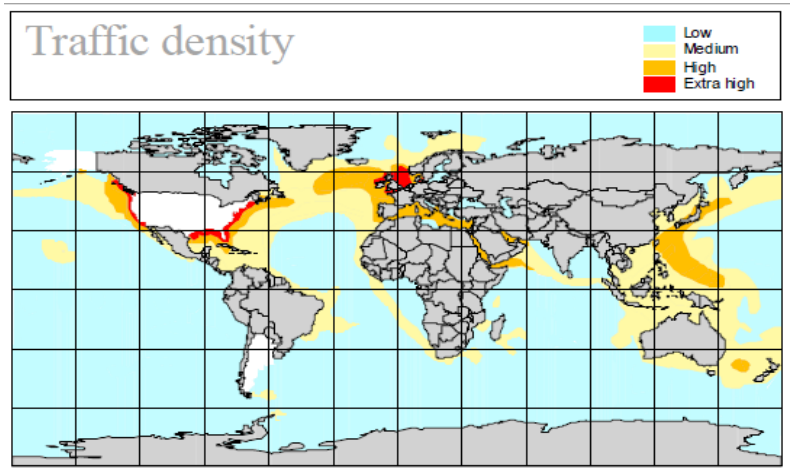


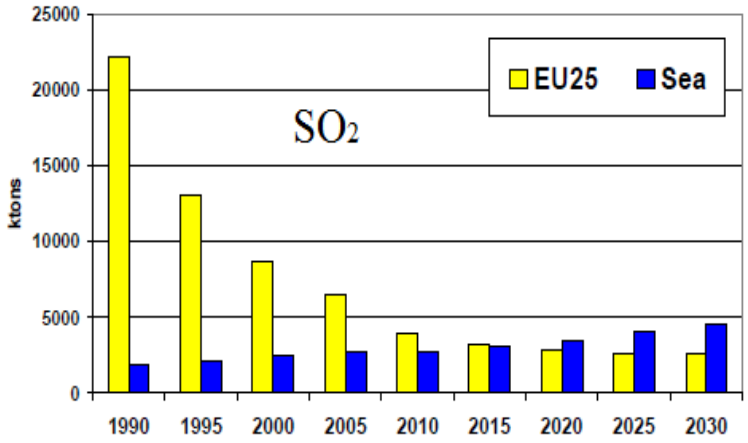
Marine transportation

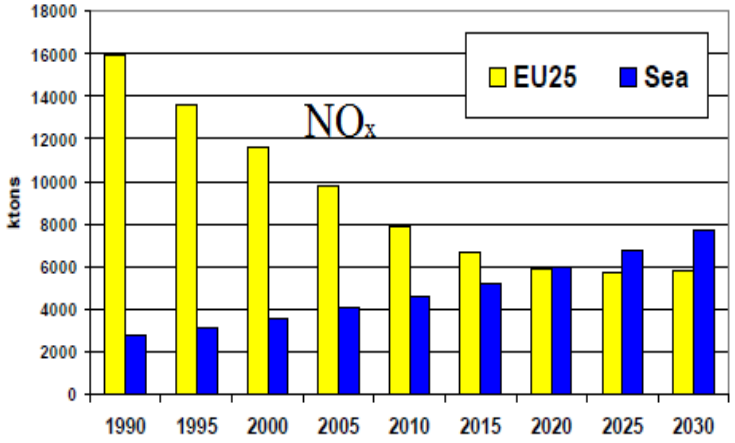
EMISSION

- Two stroke Diesel up to 81 MW
- 6 to 14 pistons (each 1820 dm^3)
- Heavy oil
- Consumption 250 ton per day
- Typical off-gases – 13 % O_2, 5,2% CO_2, 5,35% H_2O,
- 1500ppmv NO_x, 600ppmv SO_x, 60 ppmv CO, 180 ppm VOC

Ships – big emitters



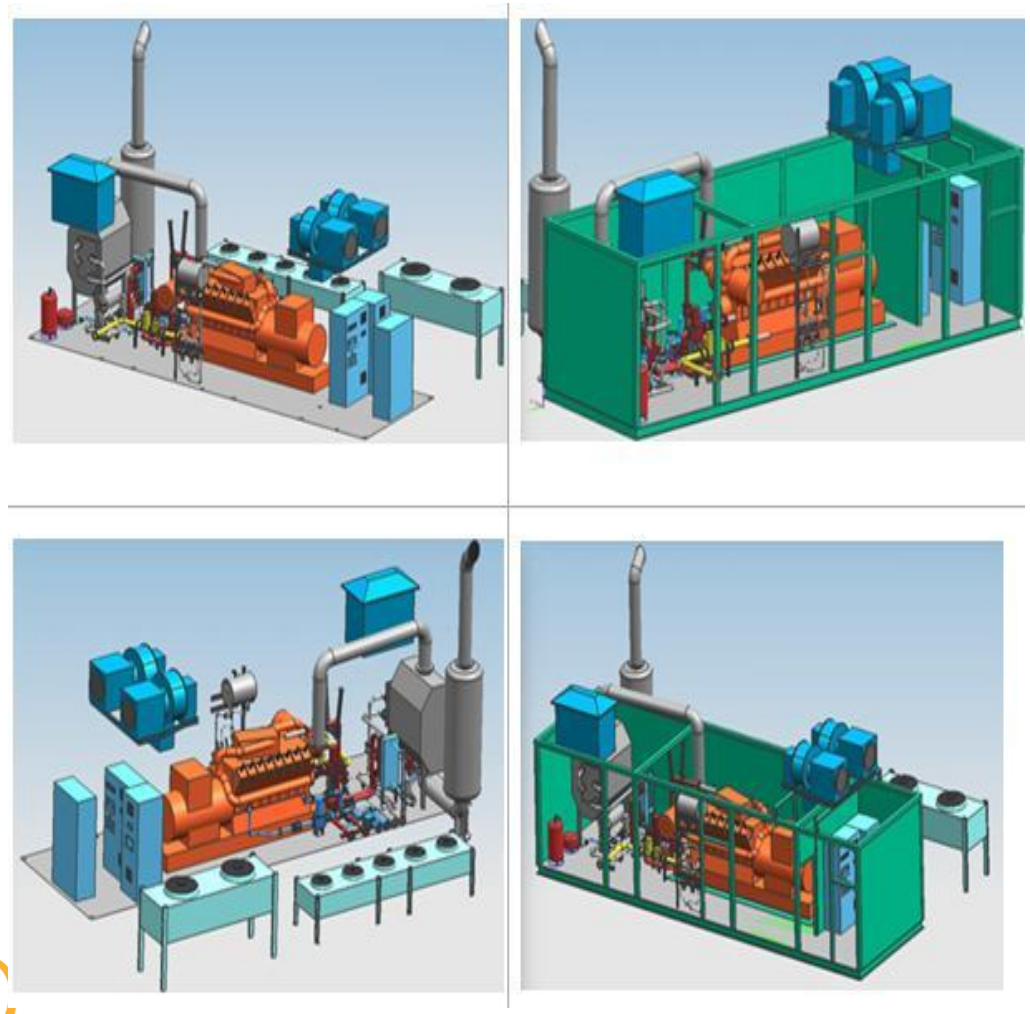




Emission Control Areas

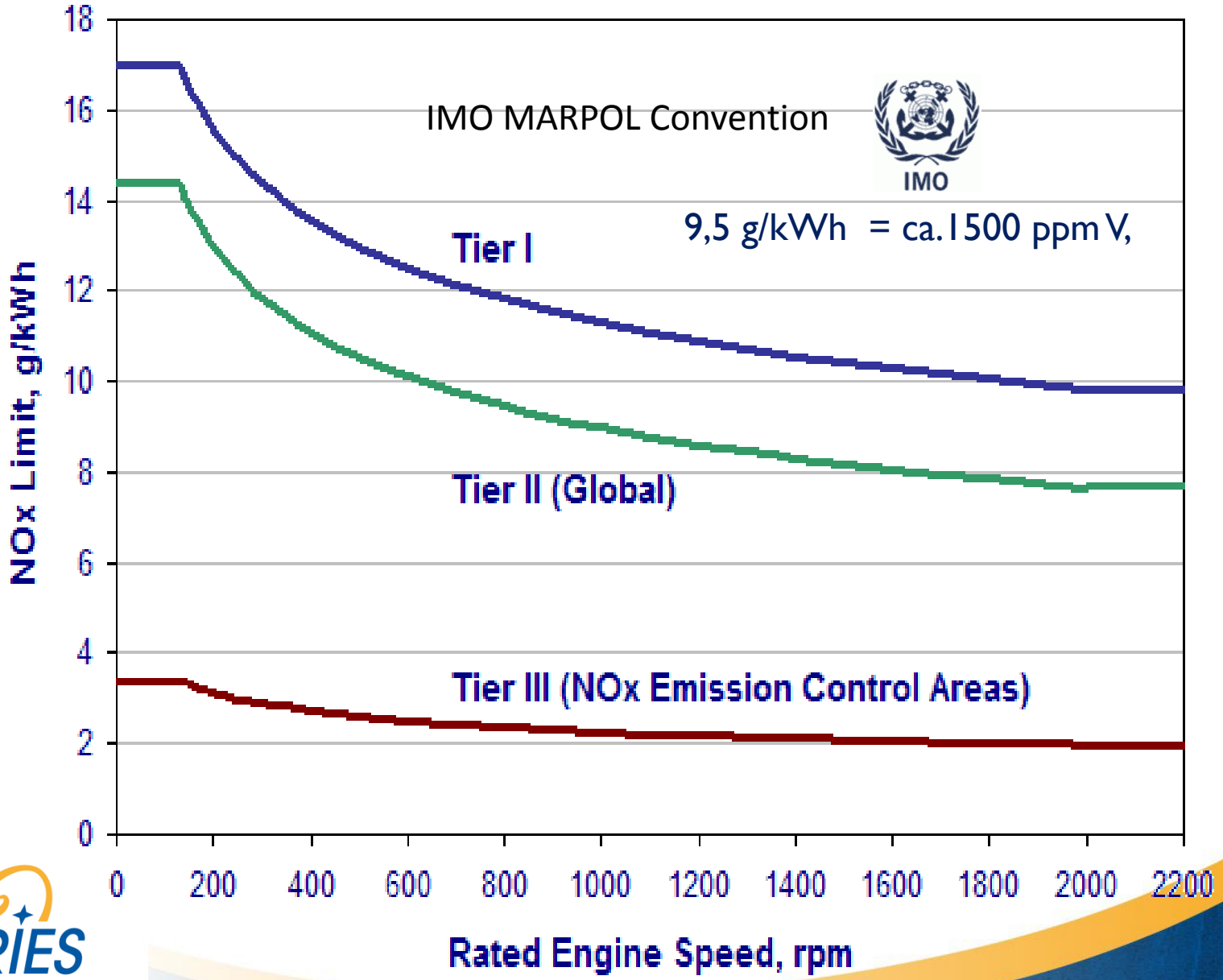
IMO MARPOL Convention

Stationary power Diesel units

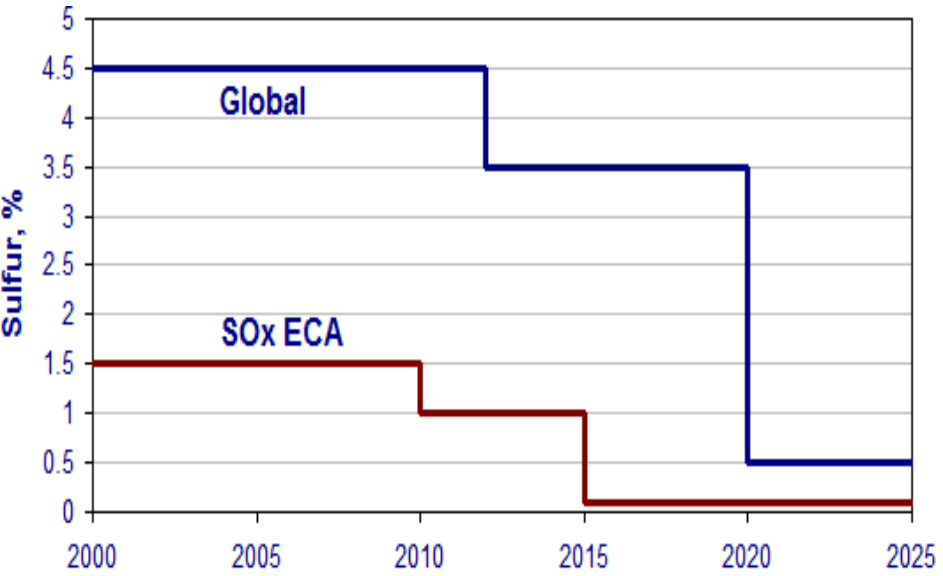


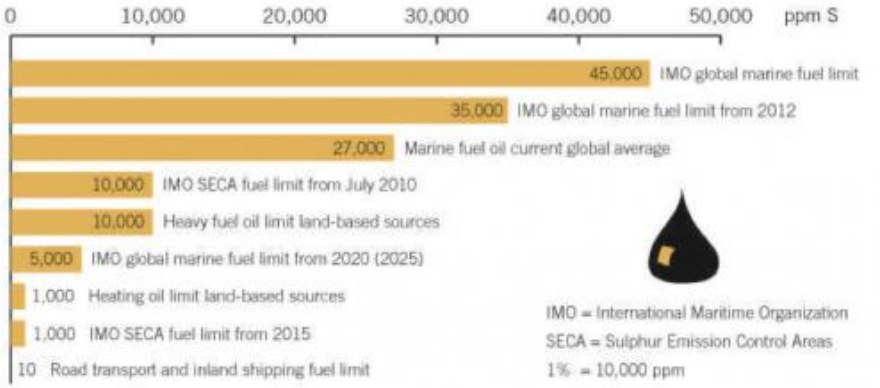
- Poland, Szpital Miejski Sochaczew – 412 kWe
- Poland, Huta Miedzi Głogów – 936 kWe
- Poland, Elektrownia Opole – 1058 kWe
- Poland, Elektrownia Bełchatów – 2106 kWe
- Greece, Andros – 3104 kWe
- Greece, Ikaria – 3104 kWe

Emission standards



MARPOL Annex VI Sulfur limits in fuel





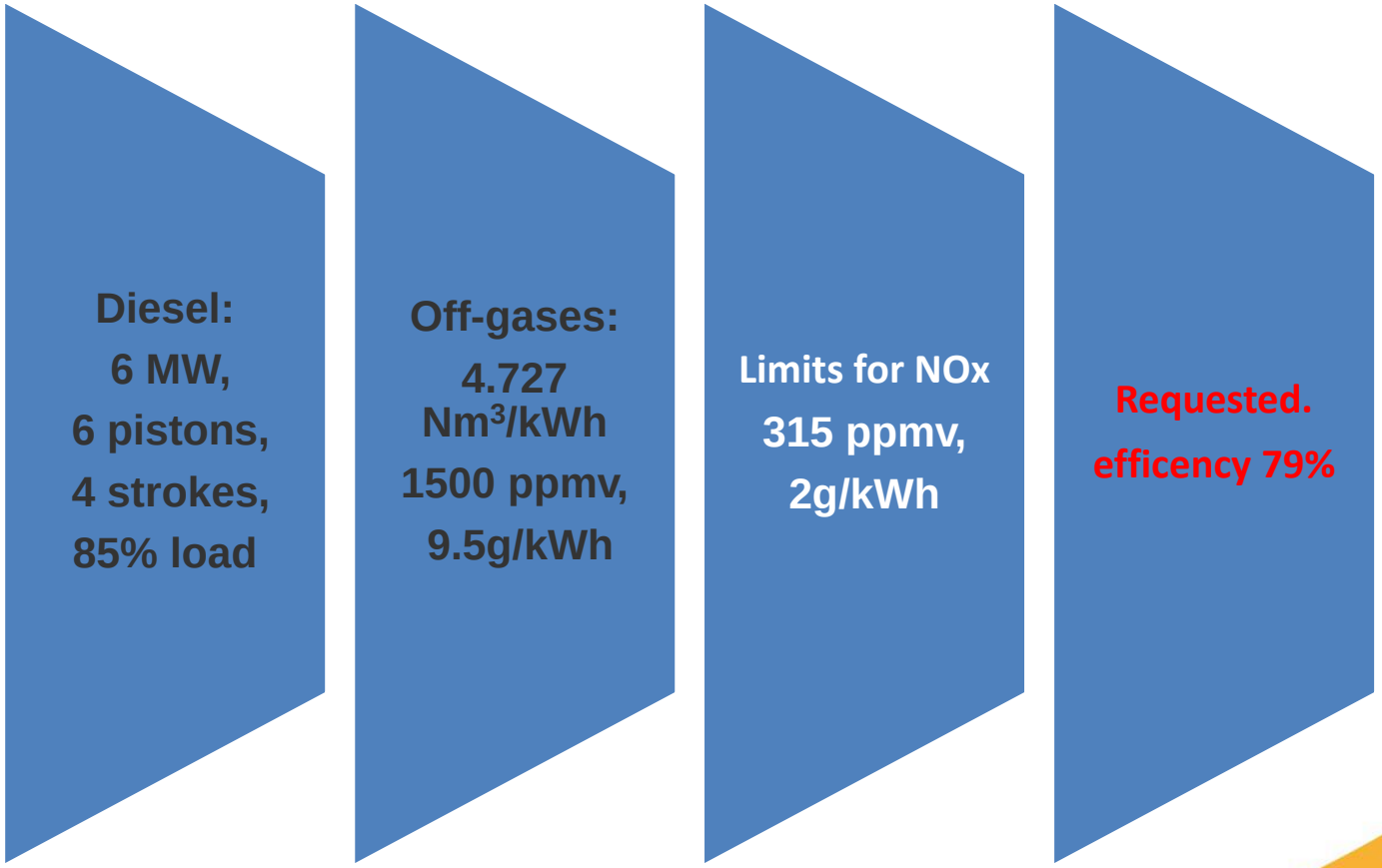
- Approved alternative is off-gases purification (open sea and ECA). For 1,5% S in fuel for SOx ECAs, ship has to be equipped in FGT SOx ≤ 6 g/kWh (recalculated as SO_2).

Fines at North America's SECAs - using high sulfur fuel(or lack of de-SOx unit)

	Table 3	
Actual Fuel Sulfur Content, % m/m[14]	Penalty over duration of violation, first offense – Table 3 ($)	
	Violation of 1.00% sulfur limit (**U** = MT of fuel burned while in the U.S. ECAs)	Violation of 0.10% sulfur limit (**U** = MT of fuel burned while in the U.S. ECAs)
3.5 or higher	$400*U	$750*U
3.0	$350*U	$700*U
2.5	$300*U	$650*U
2.0	$250*U	$600*U
1.5	$200*U	$550*U
1.25	$150*U	$500*U
1.10	$100*U	$450*U
1.00	N/A	$400*U
0.80		$350*U
0.60		$300*U
0.40		$250*U
0.20		$200*U
0.15		$150*U
0.10		N/A

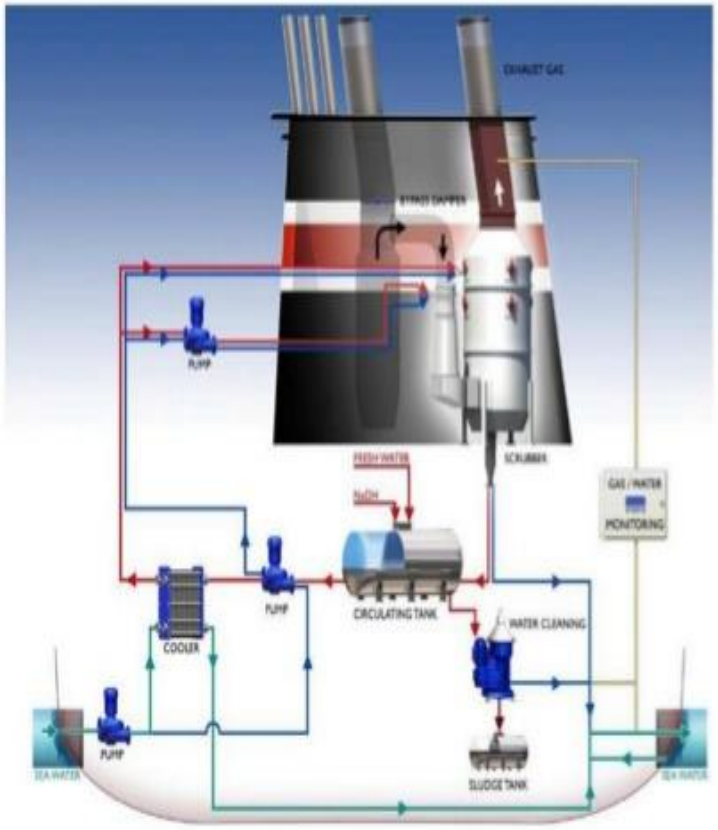
For $ 400 over due and consumption of 50 ton daily:
$ 400 * 50 ton = $ 20,000 /day; in the close future $ 750 * 50 ton = $ 37,500 / day

Emission and standards



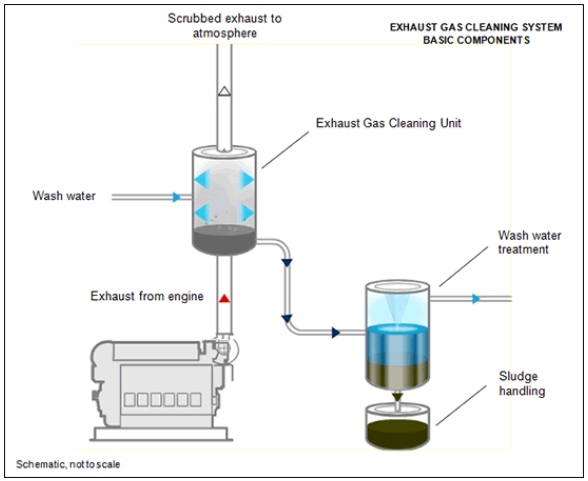
Scrubber technology: How does it work?

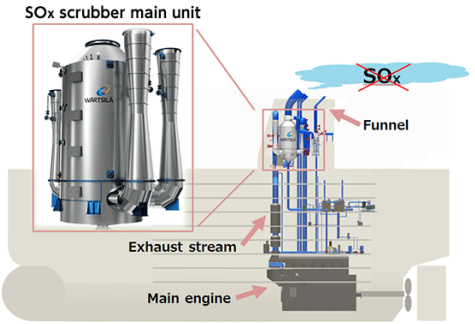
- SOx is removed via using wash water.
- System includes:
  - Water supply
  - Water treatment
  - Exhaust gas and water monitoring
  - Supply to ship of treatment agent.
- Types
  - Fresh water
  - Sea water
  - Hybrid



Source: Force Technology, 2012

See: http://www.youtube.com/watch?v=J8_D7ASh0_g





- Sea Water Scrubbing based on SO_2 in sea water
- Waswater is dumped into sea
- Removal of NOx is low due to low NO solubility in water.
- SCR has to be approved

Is sence to use fuel like in cars ?

- **Ship with engine 25 MW fire ca. 20 000 ton per year.**
- **Fuel with 0,1 % S increase cost by 3 - 5 millions $US annually .**
- **And what about NOx ?**
- **And what in the future with VOC (PAH) ?**

SOx and NOx removed in one step

ELECTRON BEAM FGT

Industrial partners

- From the very beginning, the company is focused on developing diesel technology. This experiences led the MTU company to leading position among the manufacturers of the land and sea applications.
- “Dostarczamy niezawodne urządzenia, które wytwarzają energię.” “We are providing only reliable power-generating devices ““Поставляем надёжные устройства, которые вырабатывают энергию.” “Поставляємо надійні пристрої, які виробляють електроенергію.”

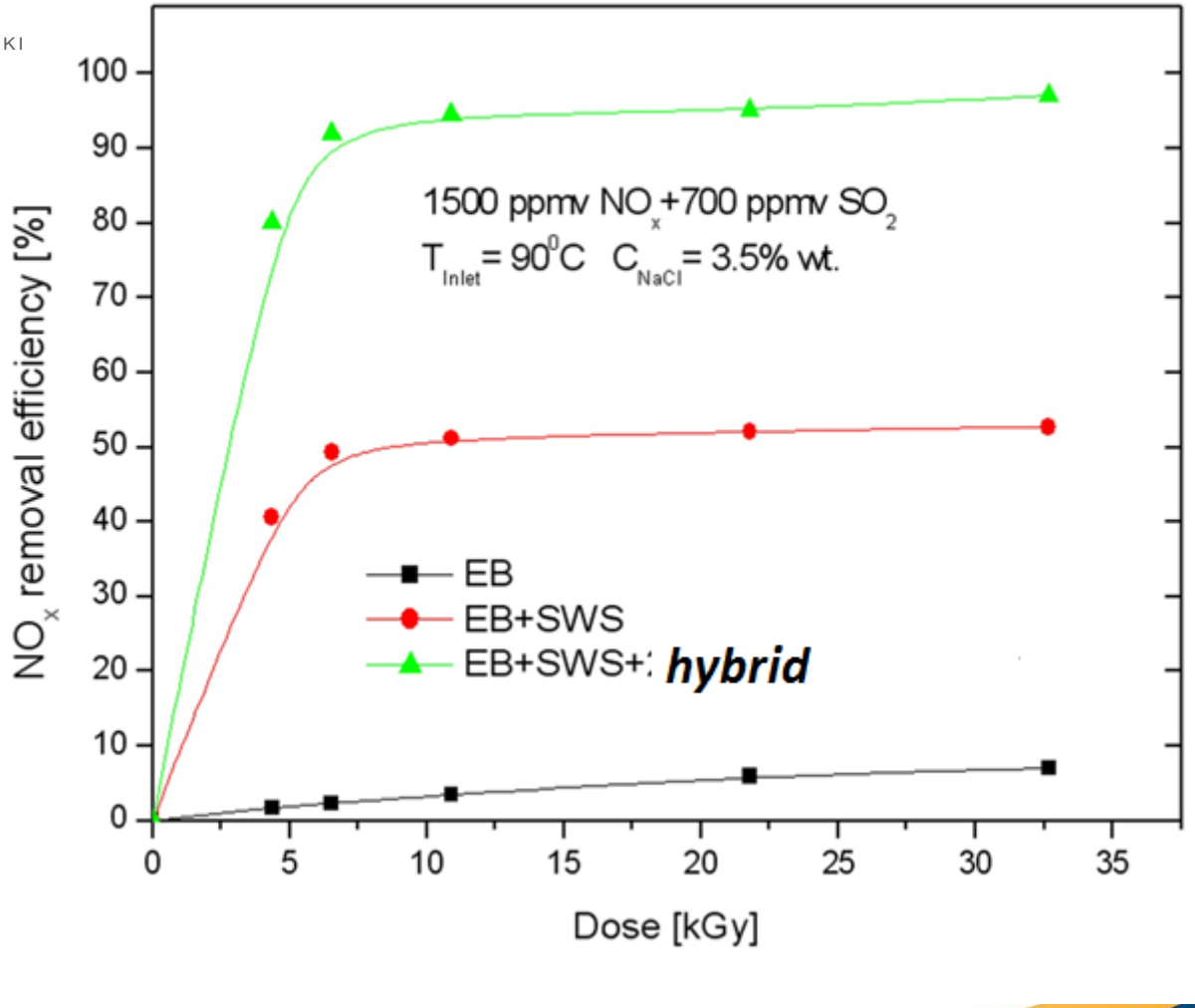
Hybrid new solution !

~~Futher developments underway.~~

NARODOWE CENTRUM NAUKI

Narodowe Centrum Badań i Rozwoju

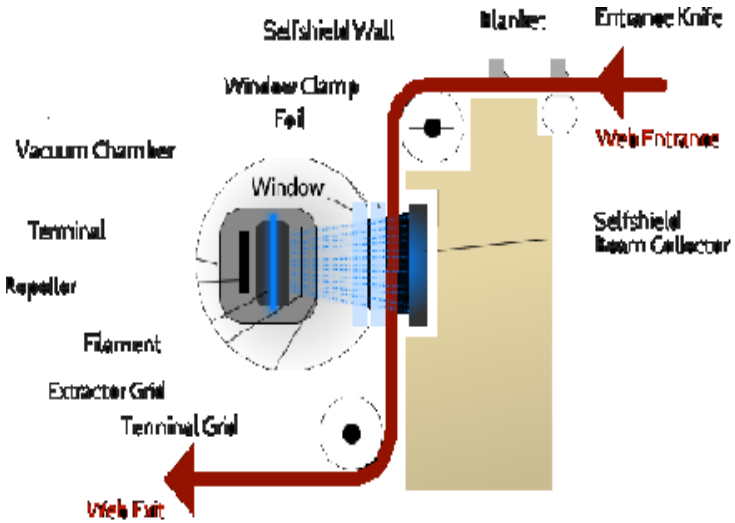
TANGO 2



Low energy ebeams

ESI – "EZCure®"

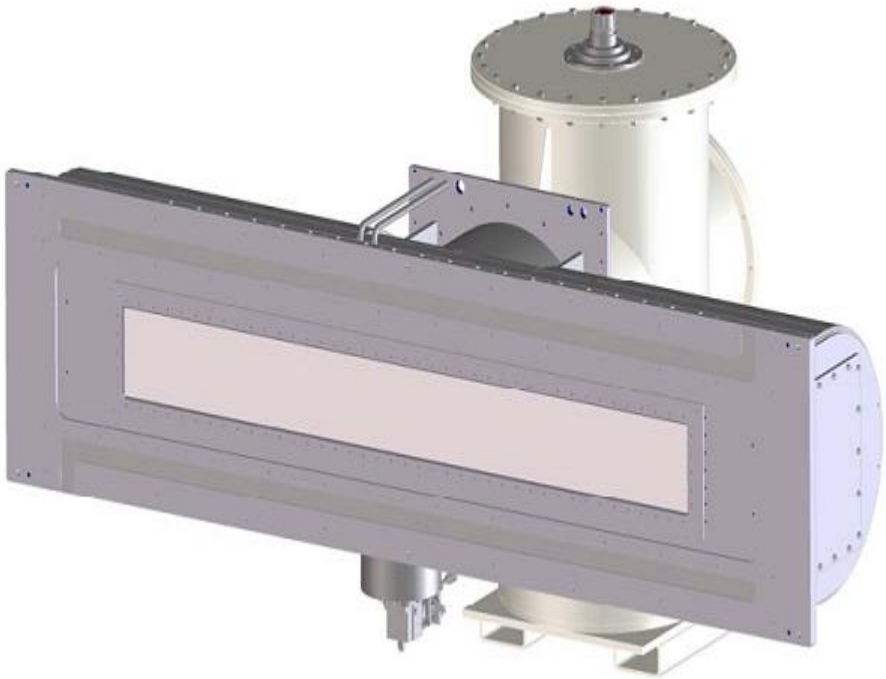
Energy Science Inc.



100 – 300 keV

ESI CB-300

Linear cathode eb machine

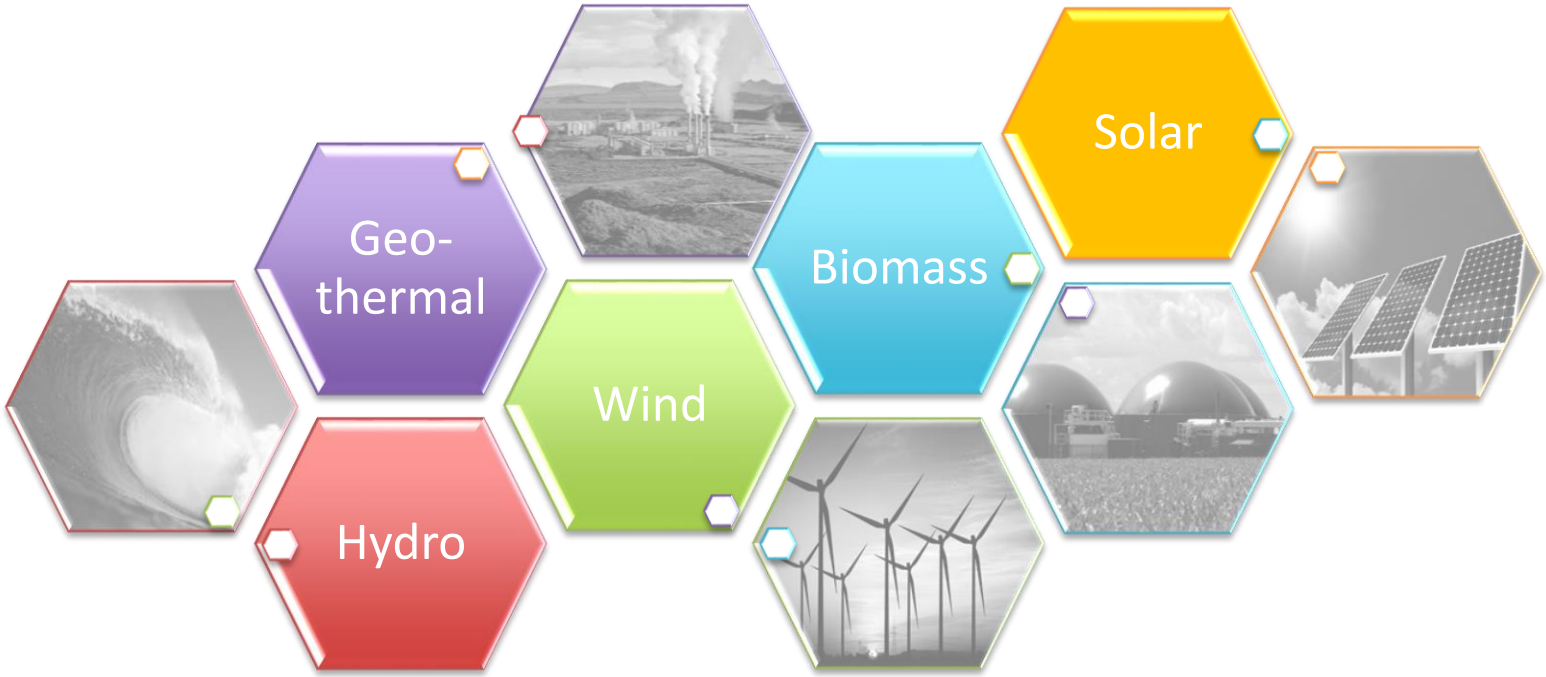


CROSSLINKING AB

- Energy: 75 - 250 kV
- Current: 0 - 2000 mA
- EB width: 400 - 3000 mm
- Dose uniformity: < 10 %

-No window cooling needed.

RENEWABLE ENERGY SOURCES



Industrial partners

- **Biopolinex Sp. z o. o.** is building on the basis of owned patent rights, the so-called “MEB system” (small bio-methane heat and power stations) which are the perfect solution for agricultural farms, processing plants, dairies, manufacturers of pig and cattle meat as well as others with resources of biomass.
- **BIOGAS POWER PLANTS; БИОГАЗОВЫЕ ЭЛЕКТРОСТАНЦИИ; BIOGAZOWNIE**

BIOGAS

- Biogas is produced by the biological breakdown of organic matter in the absence of oxygen.
- Biogas consist mainly of methane and carbon dioxide and a very small amounts of other substances, but its composition varies depending upon the origin of used feedstock.
- It can be used as a low - cost fuel for heating purpose also in modern waste management facilities where it can be used to generate and electrical power.
- The combustion of biogas reduces the emission of sulfur dioxide and nitrogen oxides in comparison to the combustion of fossil fuels.
- Biogas production is a versatile biotechnology capable of converting almost all types of biomass to methane and carbon dioxide under anaerobic (absence of oxygen) conditions.

Biomass for biogas production

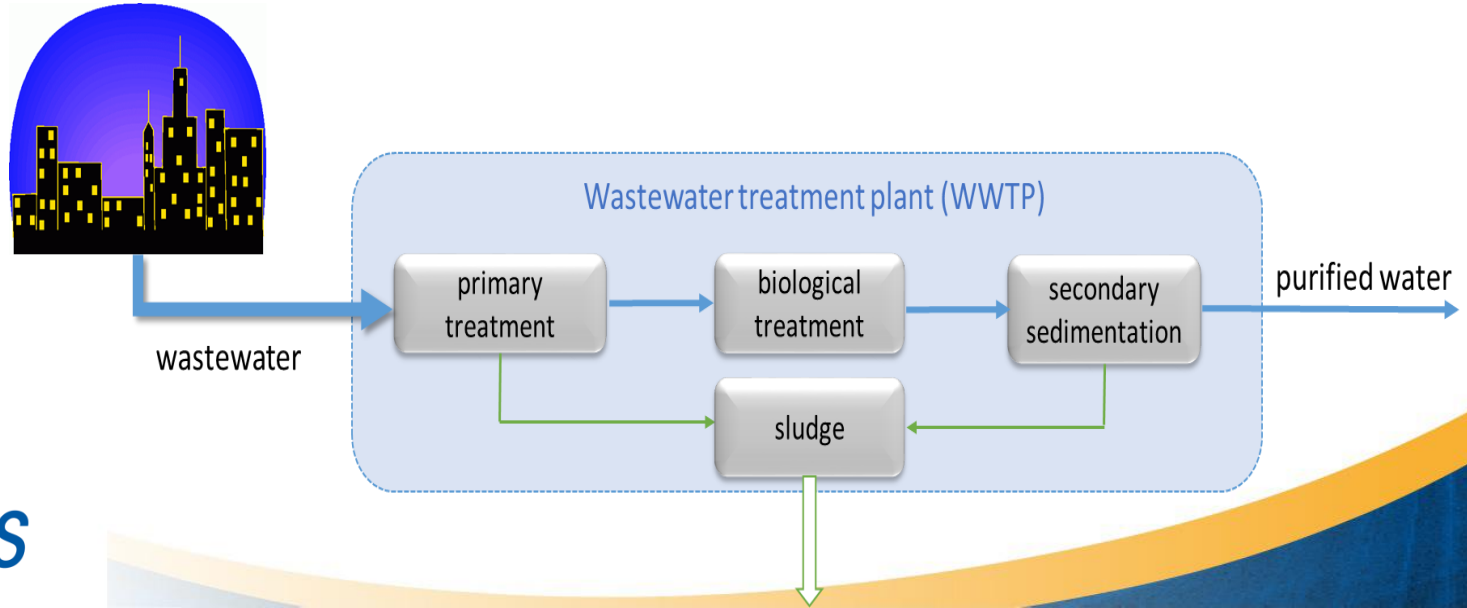
Country	Reference	Total biogas production From agricultural residues, industrial wastewater, biowaste, landfills and sewage sludge	Biogas production in WWTPs only from sewage sludge	
	Year	GWh/y	GWh/y	% of total production
Australia		n.a.	n.a.	n.a.
Austria	2013	570 3)	n.a.	n.a.
Brazil	2014	613 3)	42 3)	7 %
Denmark	2012	1.218 1)	250 1)	21 %
Finland	2013	567 2)	126 2)	22 %
France	2012	1273 3)	97 3)	8 %
Germany	2014	41.550 2)	3.050 2)	7 %
Ireland		n.a.	n.a.	
Norway	2010	500 1)	164 1)	33 %
South Korea	2013	2.578 1)	969 1)	38 %
Sweden	2013	1.686 1)	672 1)	40 %
Switzerland	2012	1.129 1)	550 1)	49 %
The Netherlands	2013	3.631 1)	711 1)	20 %
United Kingdom	2013	6.637 3)	761 3)	11 %

1) Energy generated as gross gas production
2) Energy generated as electricity, heat, vehicle fuel or flared (excluding efficiency losses)
3) Electricity generation only (excluding efficiency losses)
n.a: data not available

http://www.iea-biogas.net/files/daten-redaktion/download/Technical%20Brochures/Wastewater_biogas_grey_web-1.pdf

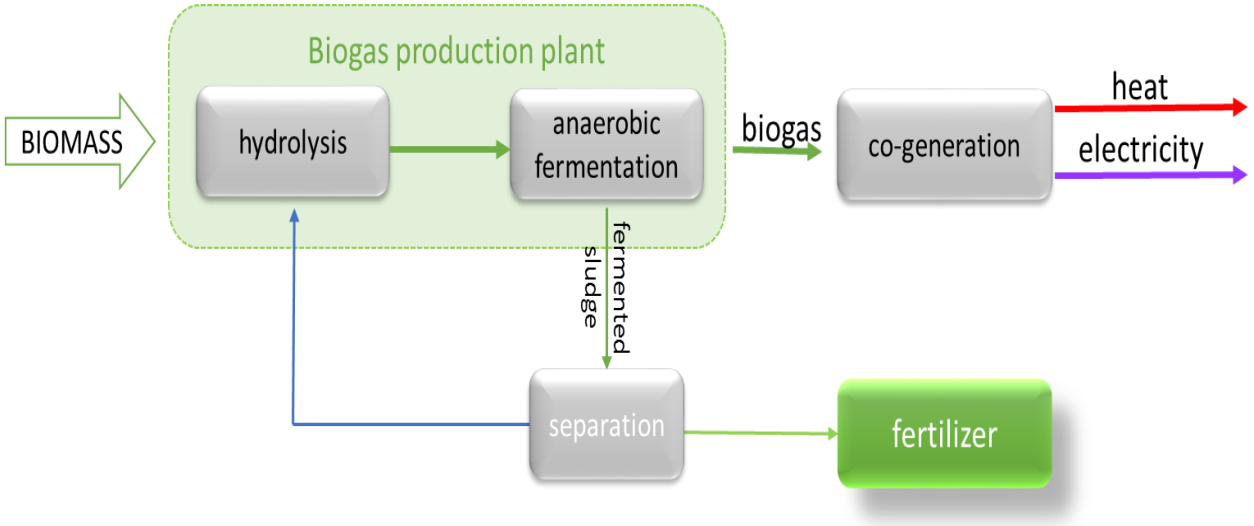
Waste Water Treatment Plants

- In wastewater treatment plants (WWTPs) sewage sludge is produced as part of the water cleaning process.
- The sludge contains the particles removed from the wastewater, which are rich in nutrients and organic matter, leaving the water clean for its release into nature. Growing population centers and expanding industry, which are increasingly well served by wastewater treatment facilities, result in rapid growth of sewage sludge production



Biogas production using sewage sludge

The sludge is pumped into the anaerobic reactors where digestion takes place, usually at mesophilic temperature (35 – 39 °C). During a retention time of around 20 days, microorganisms break down part of the organic matter that is contained in the sludge and they produce biogas, which is composed of methane, carbon dioxide and trace gases. Biogas is used to feed cogeneration systems in order to simultaneously produce heat and electricity.

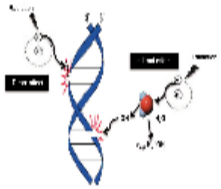


Advanatges of anearobic sludge fermentation process

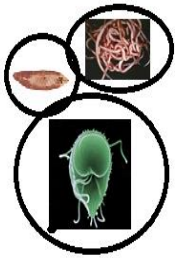
- Post-fermentation slurry contains 3 – 5% of dry matter,
- Dry matter content can be increased up to about 35% applying dewatering process,
- The volume of organic matter is reduced by about 50% in comperison to unfermented substrate,
- Improvement of fertiliser value eg. a part of the organic nitrogen is converted to ammonium, which is more easily accessible for plants,
- Reduction of methane emission to the atmosphere in comparison to untreated sludge,
- Odour reduction.

Sludge Disinfection

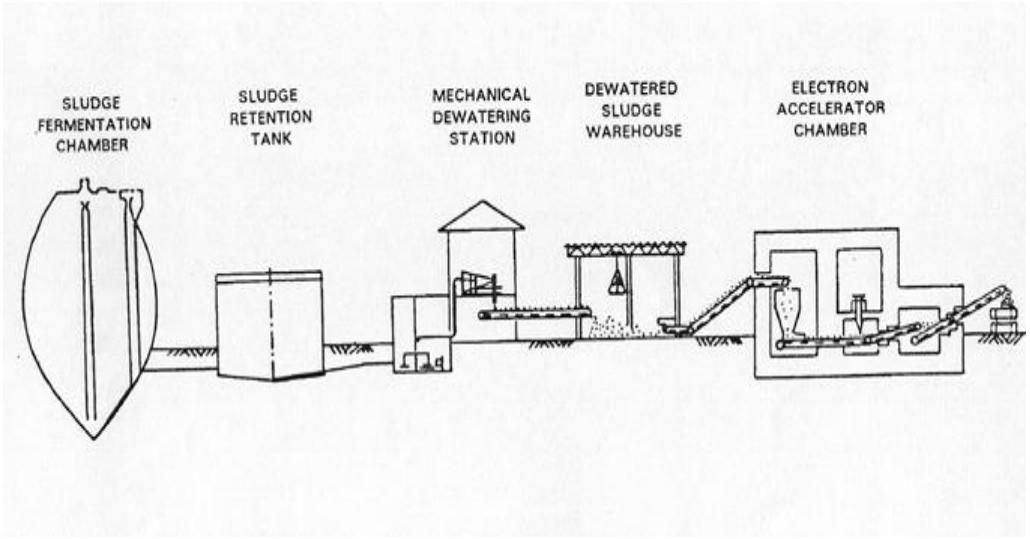
- The sludge of municipal wastewater origin is biologically contaminated by viruses, bacteria and eggs of parasites.
- Anaerobic fermentation can reduce number of pathogenic microorganisms but can't eliminate them completely.
- Dissinfection process must be applied.
- Under irradiation the decomposition of pollutants and elimination of microorganisms in water undergo due to reaction of water radiolysis products.

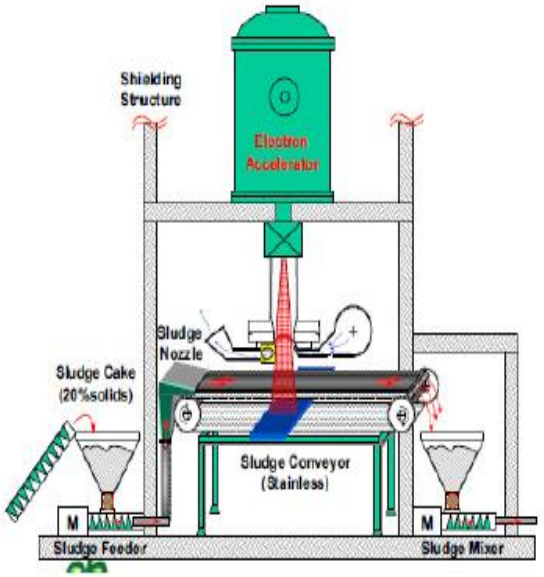


$$H_2O \xrightarrow{\text{radiation}} \bullet OH, H\bullet, e^-_{aq}, H_2, H_2O_2$$



Pilot experiments





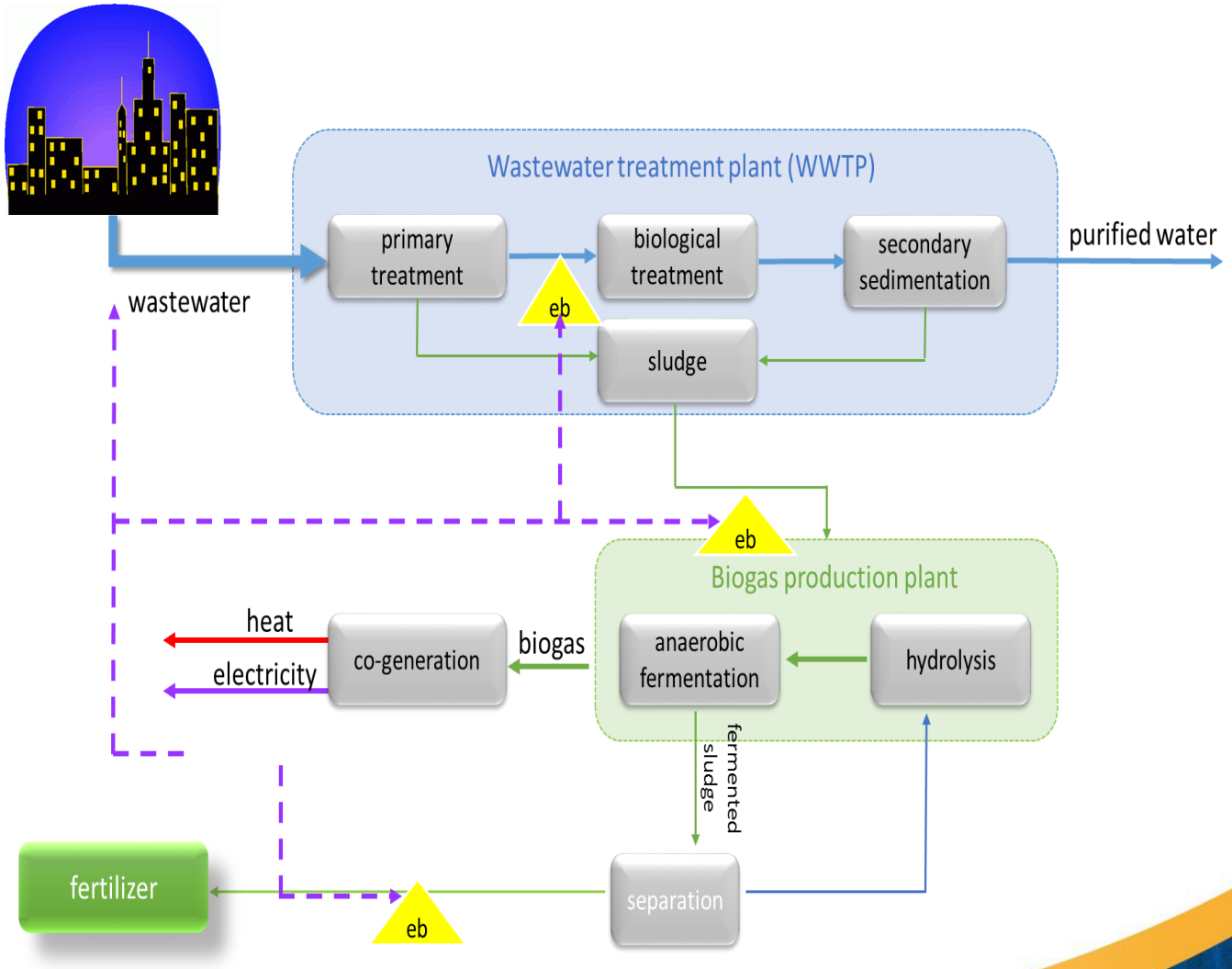
Bacteria	Dose [kGy] [1]			
	0	5.0	6.0	7.0
Total bacteria content (in 1 ml)	1.1×10^9	2.7×10^7	6.5×10^6	1.1×10^5
Spore-forming bacteria (in 1 ml)	4.1×10^6	1.4×10^5	9.3×10^4	-
Coliform counts	10^{-5}	10^{-5}	10^{-3}	10^{-2}
Clostridium perfringens counts	10^{-4}	10^{-4}	10^{-3}	10^{-2}

Dose [kGy]	Living eggs [number/kg dry matter]			
	Ascaris sp. (A)	Trichuris sp. (T)	Toxocara sp. (T)	Total (ATT)
0	90	90	60	240
5.0	30	0	0	30
6.0	0	0	0	0
7.0	0	0	0	0

Biogas plants – INCT experience

Participation in the design and start-up of biogas plants with capacity of 1.2 MW in Koczergi and Międzyrzec etc.

Hybrid biogas - eb system



We need new solutions to preserve the environment – zero energy sludge hygenization plant!

wastewater

Wastewater treatment plant (WWTP)

primary treatment

biological treatment

secondary sedimentation

purified water

sludge

Biogas production plant

anaerobic fermentation

hydrolysis

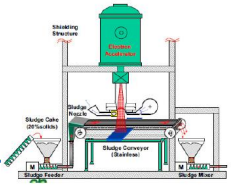
fermented sludge

biogas

co-generation

heat

electricity



separation

fertilizer

Advantages of proposed solution:

- Environmental friendly technology
- Biogas production is disposal of problematic wastes
- Production of renewable power through combined heat and power cogeneration
- Production of microbiologically safe organic fertiliser
- Technology can be applied in any place with sufficient biomass resources while there is no need to ensure external electric energy supply


Thank you !