



Universidade Federal do Rio de Janeiro
Escola Politécnica, Depto. de Recursos Hídricos e Meio Ambiente

COGENERATION OF ELECTRICAL AND THERMAL ENERGY FROM BIOGAS IN WASTEWATER TREATMENT PLANTS THE CASE OF BRAZIL

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Brazil and Latin America



Brazil

Area: 8,6 million km²

Population: 187 million

Water Supply: ~ 95% *

Sewerage: ~ 51% *

Wastewater treatment: ~ 35% **

- * % of the urban population
- ** % of the sewer system = ~17% of the urban pop.



Sanitation in Brazil

Population → Total - % Urban - %

Water Supply 81.2 94.7

Sewerage 43.2 50.6

Wastewater Treatment 34.6 *

(*) = 17% of the urban pop., SNIS, 2008



Infant Mortality – Year 2010

Wealthy countries

- Sweden - 2.7
- Japan - - - 2.7
- Italy - - - - 3.3
- Norway - - 3.4
- France - - 3.8
- UK - - - - - 5.3
- USA - - - - - 6.7

Developing countries

- Cuba - - - - 5.2
- Chile - - - - 6.5
- Argentina -12.8
- China - - - 15.4
- Colombia- 15.3
- Mexico - - 16.5
- Brazil - - - 19.9

Very poor countries

- Chade - - 114.4
- G.Bissau 158.6
- Mali - - - 161.0
- Nigeria - 168.7
- Angola - 180.2



Health & Sanitation

- Year Infant Mortality in Brazil
 - 1970 120,7 /1000 born, under 1 year old
 - 1990 52,0
 - 2010 19,9
-
- Brazil should meet the millenium goal



The Urban Challenge

Materials

Food

Energy

Water

Chemicals



Wastewater

**Emissions CO₂
NO_x SO₂**

Solid Wastes



The Urban Challenge



Materials

Food

Energy

Water

Chemicals



Wastewater

Emissions CO₂
NO_x SO₂

Solid Wastes



Recycle - Reuse - Treat



The Urban Challenge



Materials

Food

Energy

Water

Chemicals



Wastewater

Emissions CO₂
NO_x SO₂

Solid Wastes



Recycle - Reuse – Treat – Recover Energy



Challenge – Wastewater Treatment

- Enormous advancement in wastewater technology in Brazil
- Economical processes for wastewater treatment have been well established
- There is a good Brazilian experience with new and applicable technology
- How experts, federal and state agencies are facing the question ?



Investigation & Research Funding Water Utilities

- ✓ FINEP, a governmental organization, under Ministry of Science and Technology;
- ✓ Has been financing a special research program on wastewater treatment since 1996; specially on anaerobic processes;
- ✓ 15 universities form the research network

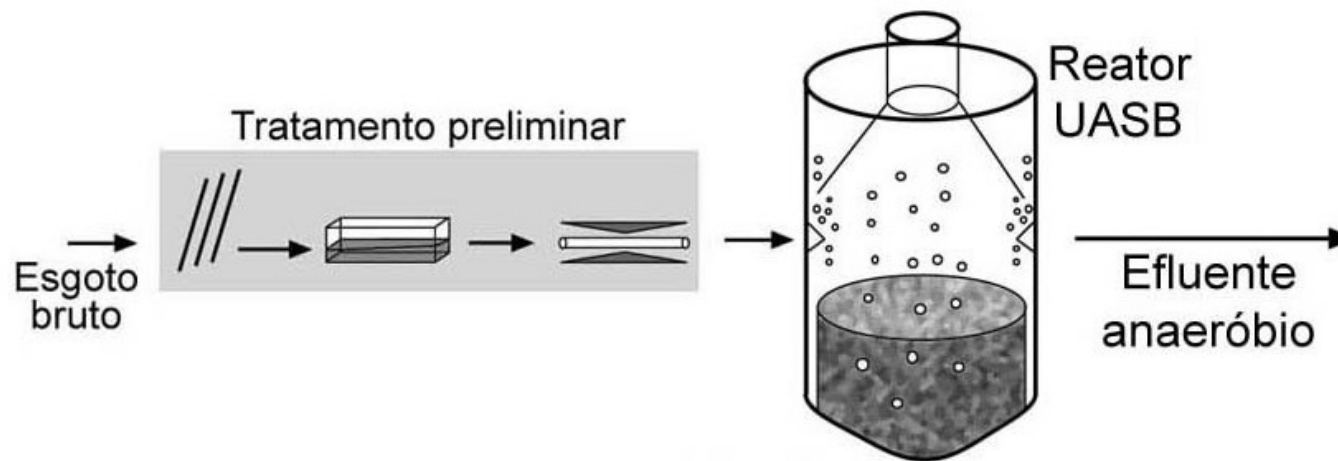


Wastewater Treatment Research Center, UFRJ



UASB = Upflow Anaerobic Sludge Blanket Reactor

One of the new economical processes
developed for WWTP.



UASB

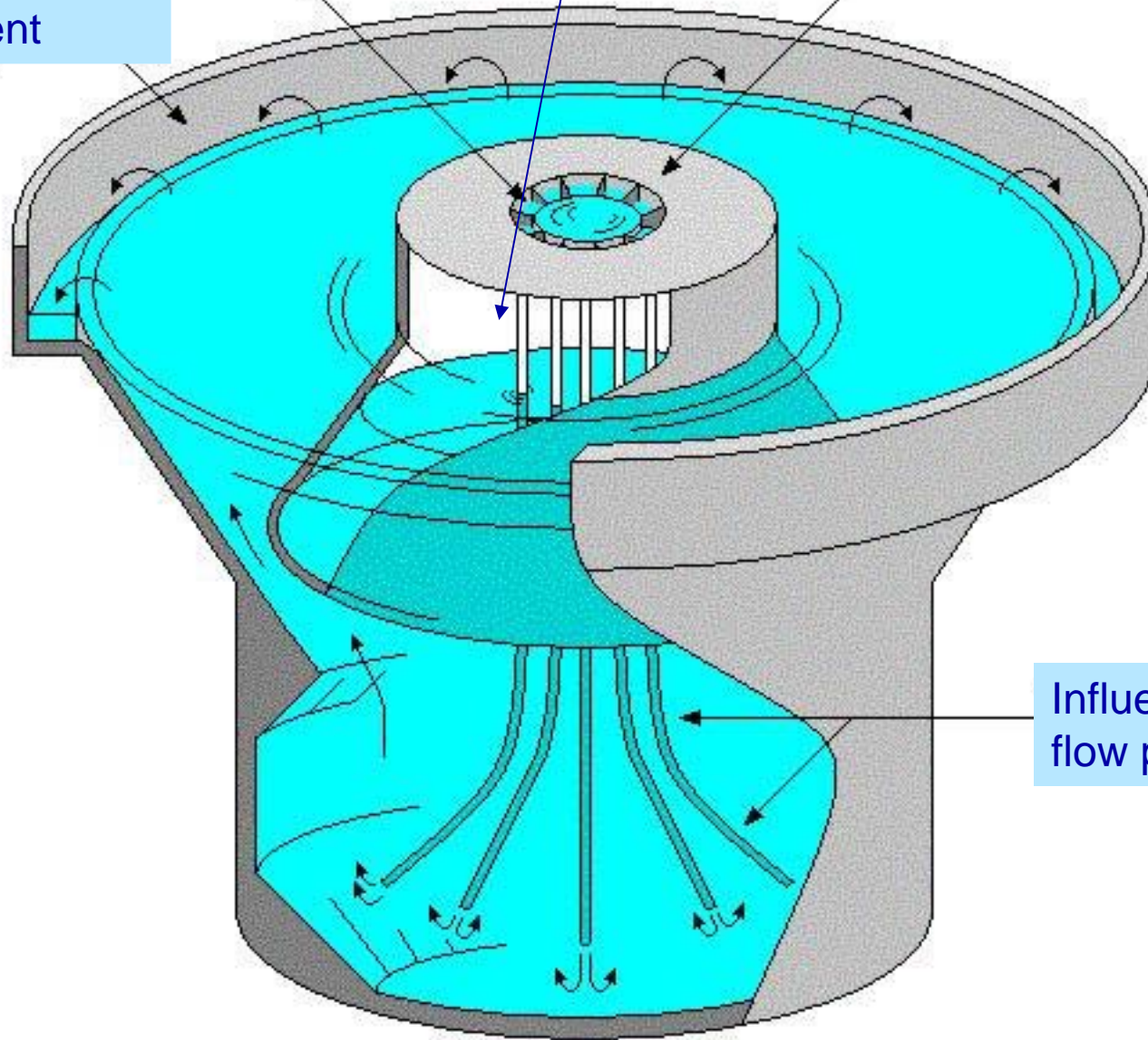
Influent

UASB Effluent

Biogas
acumulation

Phase
separator

Influent
flow pipes

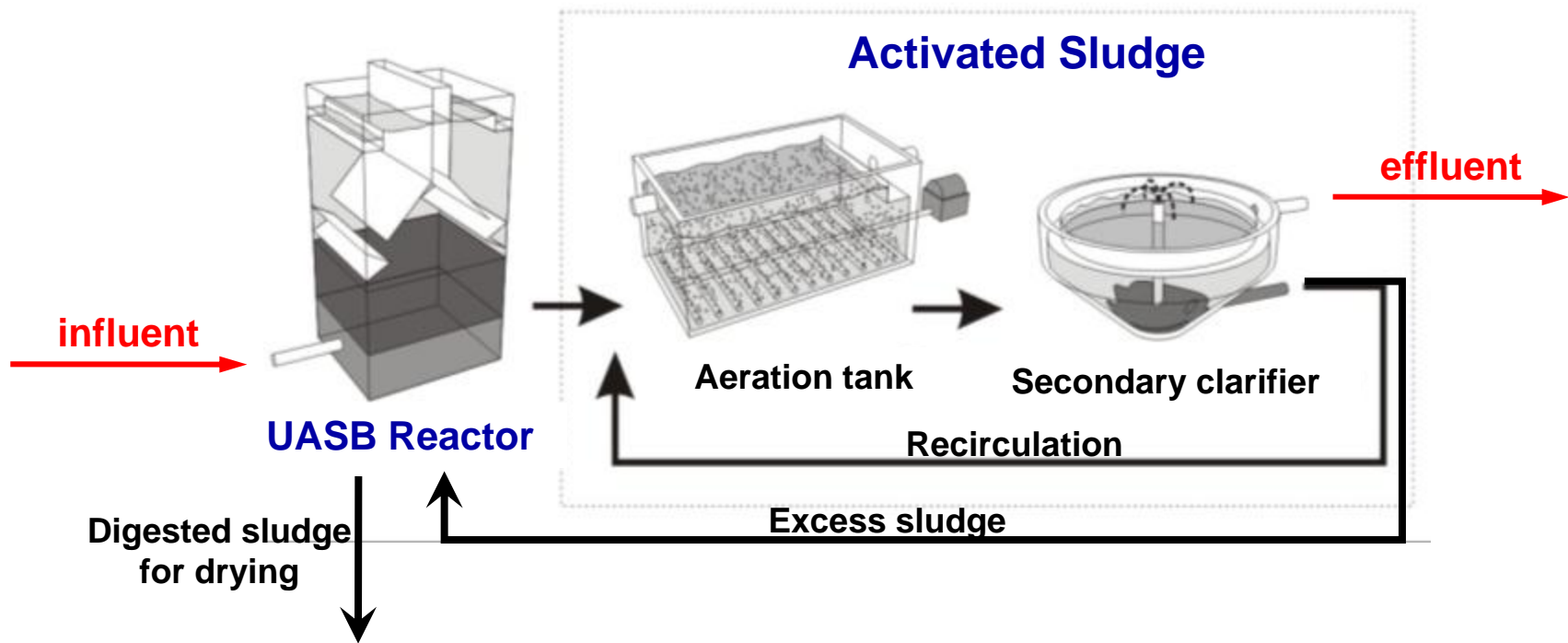


UASB

- compact system, using a small surface area;
- ✓ practically no equipment in the anaerobic process, with low construction and operational costs;
- ✓ very low energy consumption;
- ✓ low excess sludge produced;
- ✓ **INTENSE BIOGAS PRODUCTION.**



UASB + Activated Sludge



UASB Reactors + Posttreatment

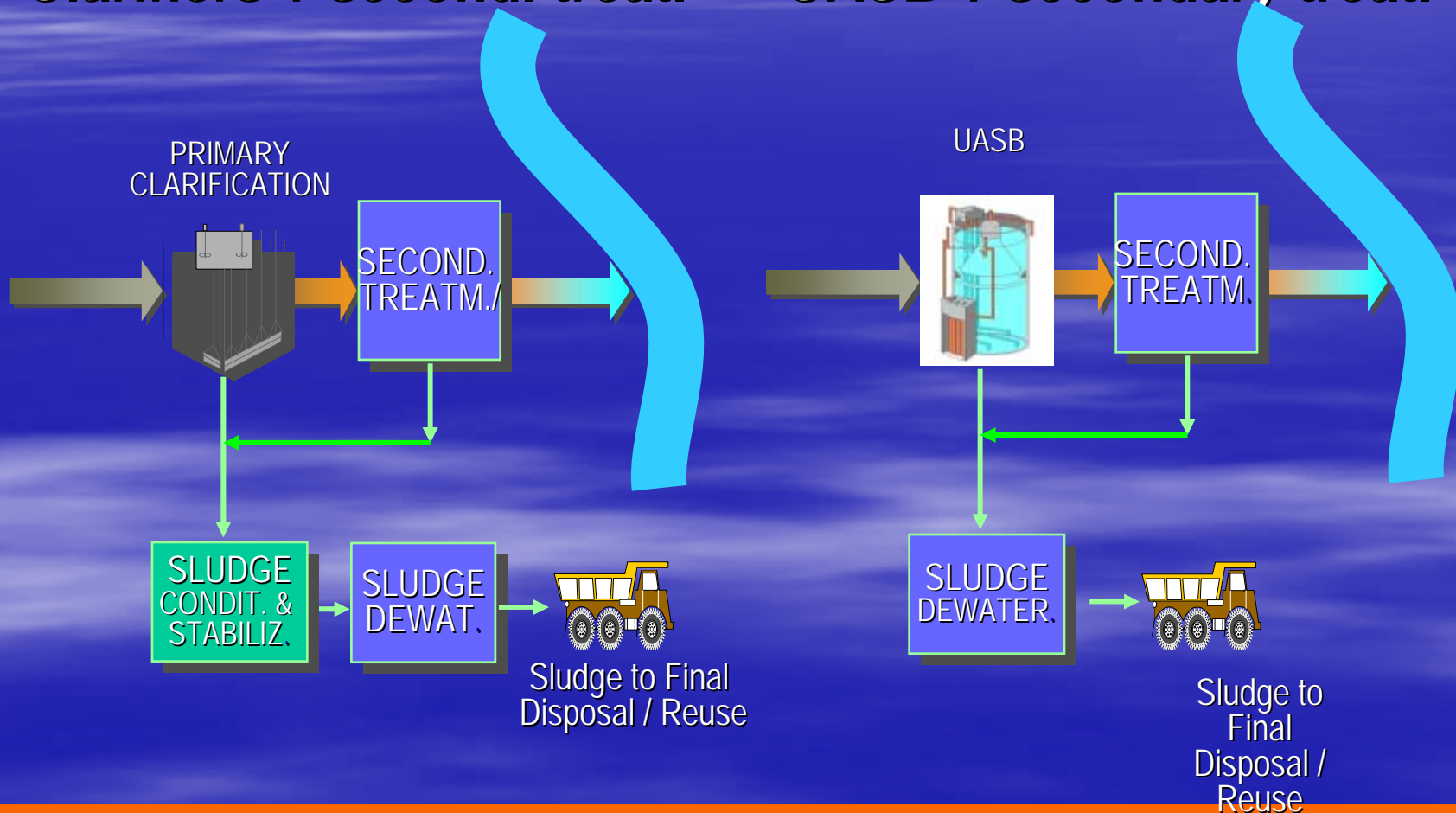
Possibility of Energy Recovery
from the Biogas produced



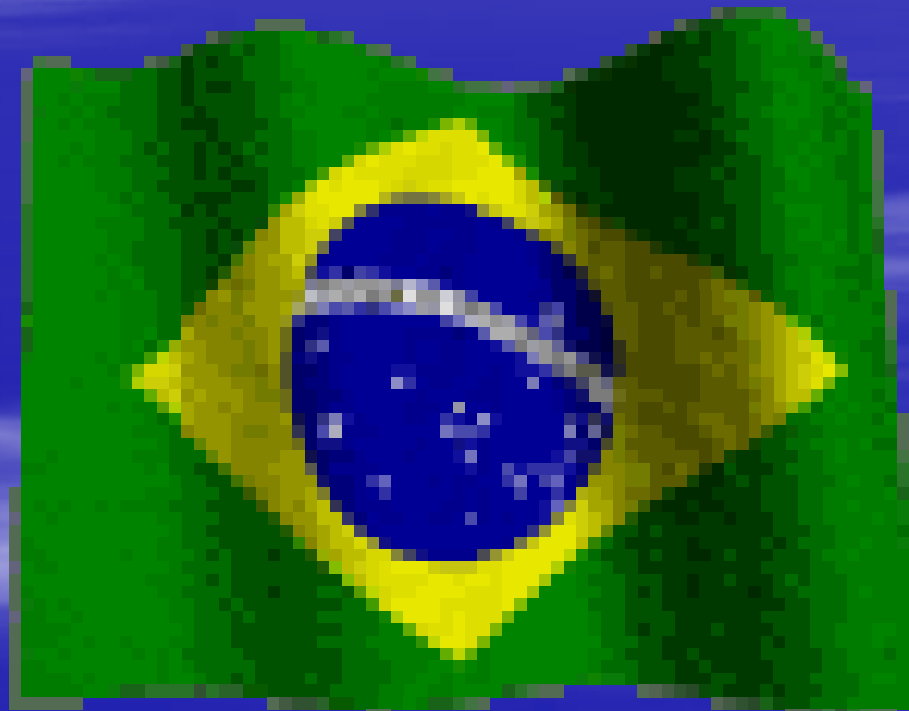
A new design

Clarifiers + second. treat.

UASB + secondary treat.



UASB IN BRAZIL



S.Jorge WWTP – Alm. Tamandaré 20,000 inhab.



Cambuí WWTP - Campo Largo, 30,000



Barreto WWTP – Niterói, 60,000



Rio das Ostras WWTP – 150,000



Sul WWTP – Londrina, 225,000



Piçarrão WWTP – Campinas, 250,000



Gama WWTP – Brasília, 300,000



Atuba Sul WWTP – Curitiba - 580,000



Onça WWTP – Belo Horizonte 1,500,000



Yes – we can !

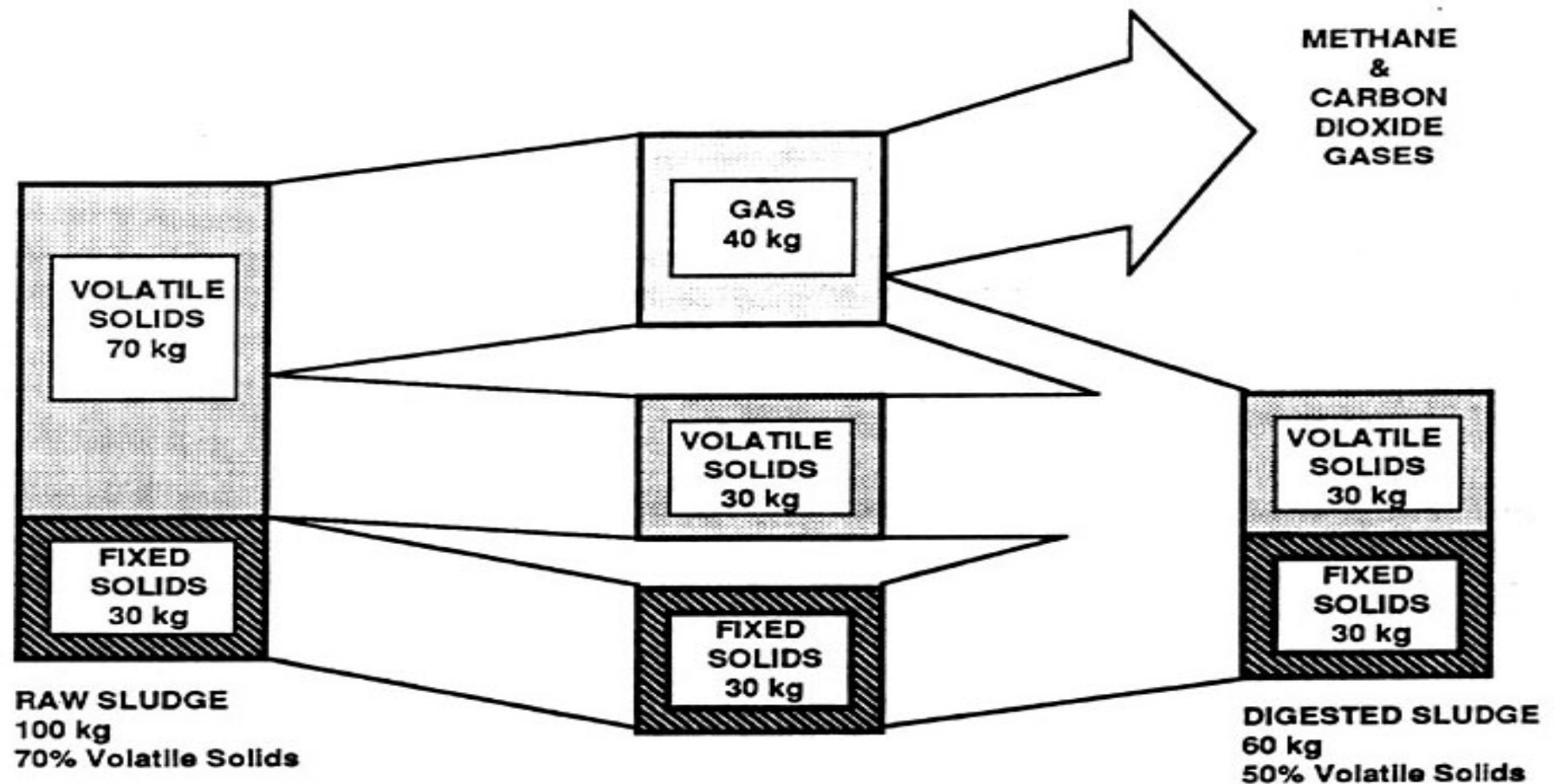
- We can afford adjusting our technology for our own conditions
- We can afford building cost-effective WWTP
- We can win the challenge of poverty, of public health, of water management, of environmental protection
- We can produce biosolids for agriculture
- **We can recover energy from our WWTP**
- **We can manage a sustainable sanitation program**



Burning gas x Energy recovery



Conversion of Volatile Solids into Methane Gas



Energy Recovery

<u>Gás</u>	<u>Heat Power, kJ/m³</u>
■ Propane (comercial)	45,800
■ Butane (comercial)	44,600
■ Natural gas	37,300
■ Methane	35,800
■ Digestion gas (*)	22,400

(*) For 65% methane in the biogas



Energy Recovery

- Heat power (biogas) = 22,400 kJ/m³
- 5 to 20 L gas/person.day (conv. plant)
- For a 200,000 people Conv. Plant (*):
 - $0.020 \times 200,000 = 2,000 \text{ m}^3 \text{ biogas/day}$
 - $2,000 \times 22,400 = 4.5 \times 10^7 \text{ kJ/d} = 1.6 \times 10^{10} \text{ kJ/y}$
 - = **$4.6 \times 10^6 \text{ kWh/y}$**

(*) with the maximum gas production



Energy consumption at the WWTP

Typical WWTP uses ~ 1,200 kWh/MG treated

- Aeration = 52%
- Solids processing = 30%
- Influent pumping = 12%
- Internal recycle pumping = 3%
- Nutrient removal generally increases overall energy costs



Energy consumption at the WWTP

- 200,000 people
- X 40 gal/hab.d = 8 MGD = 2,920 MGY
- Consumption Rate ~ 1,200 kWh/MG treated
- Energy Use ~ $2920 \times 1200 = 3.5 \times 10^6$ kWh/y
- Production, max.gas rate ~ 4.6×10^6 kWh/y
- Production, avg.gas rate ~ 2.3×10^6 kWh/y
- Production, min.gas rate ~ 1.2×10^6 kWh/y



Does it pay off ???

- Costs of
 - Investments (Equipments & Construction)
 - Energy (Demand & Consumption)

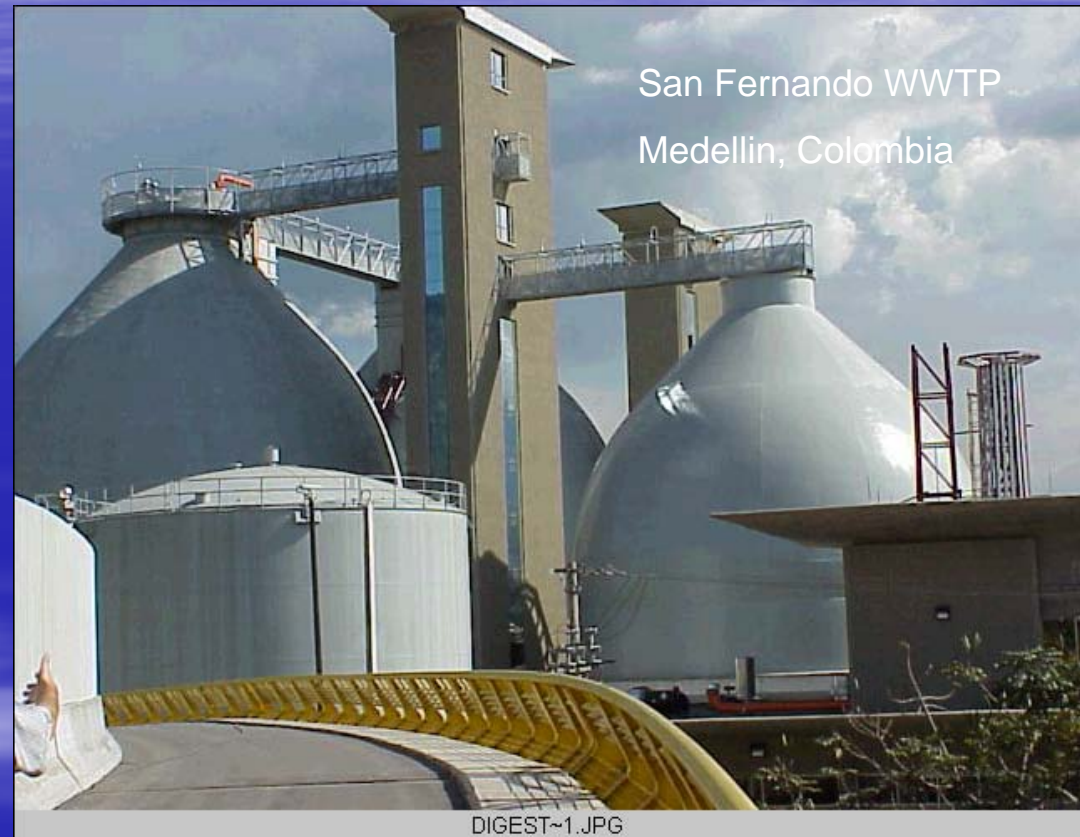
- Feasibility

- Plant flow, local aspects



Energy recovery at conventional WWTP

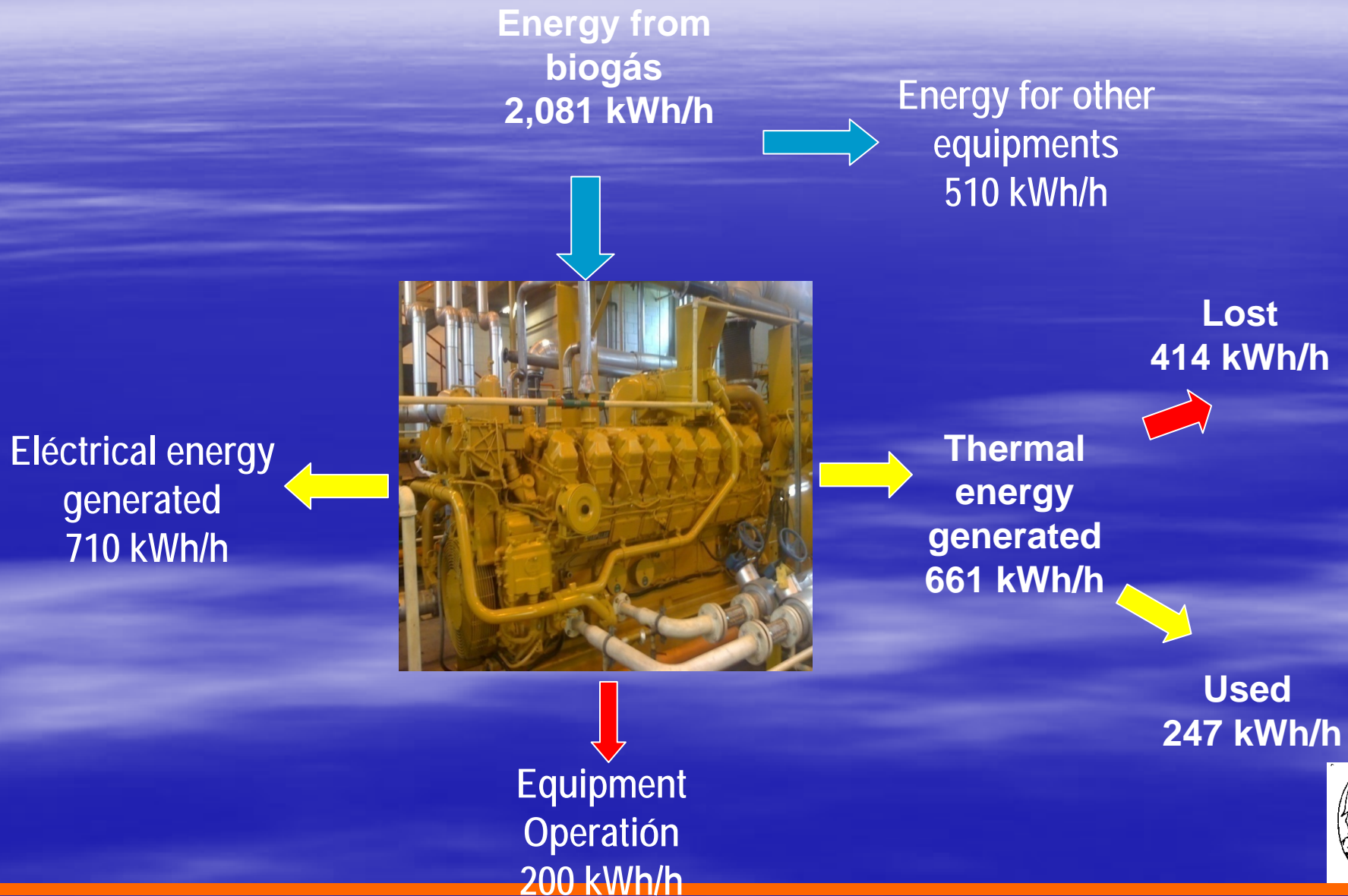
- Electrical energy
- Thermal energy
- Heat exchangers
- Fuel for thermal sludge driers





San Fernando WWTP
Medellin, Colombia

San Fernando WWTP, energy recovery



Along the 7 first years of operation the San Fernando WWTP produced 25,000,000 m³ biogás (65% CH₄ y 33% CO₂), or 52,000 ton CO₂ e/year

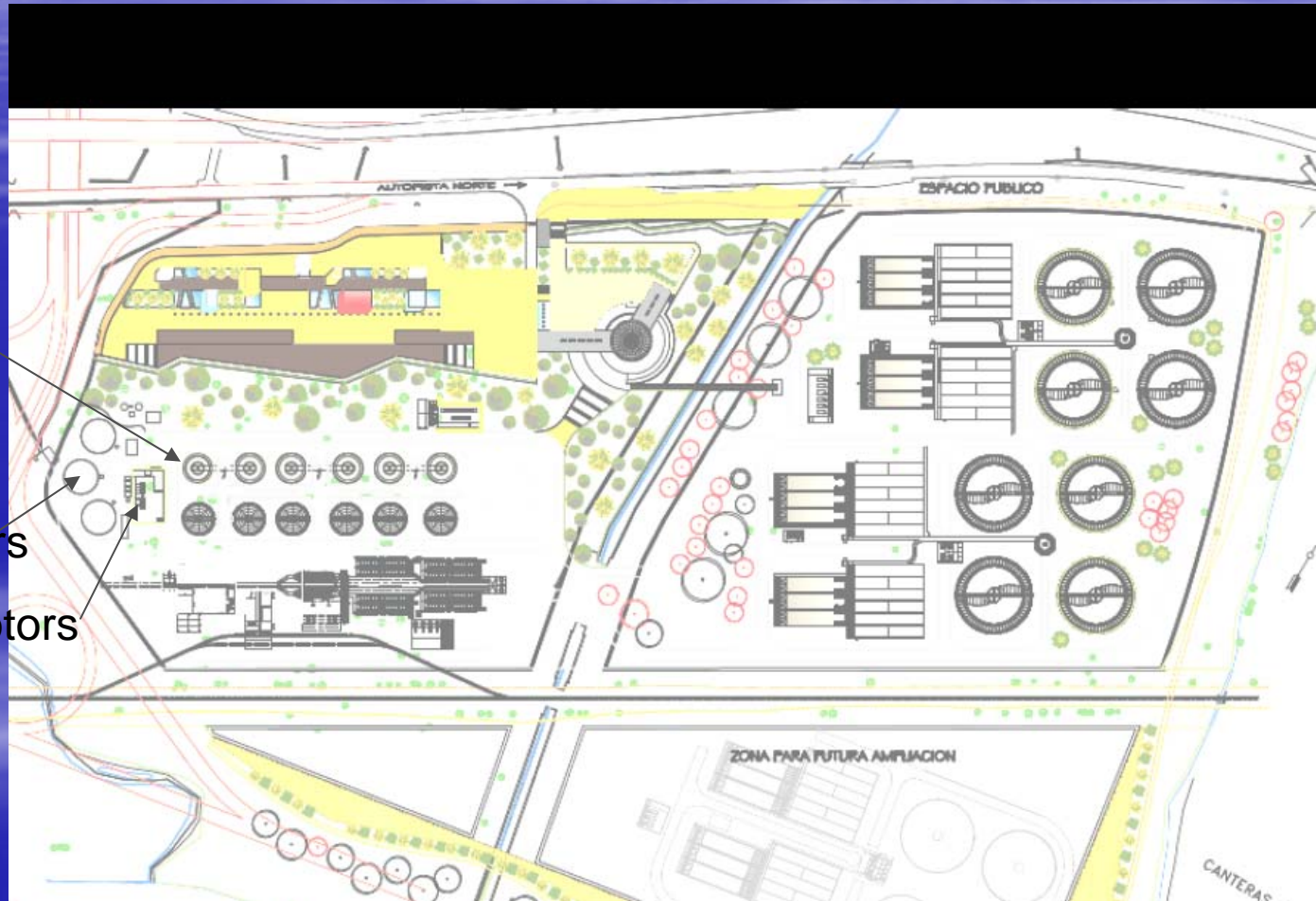


Bello WWTP, Medellin, Colombia

Digestors

Gas holders

Energy motors



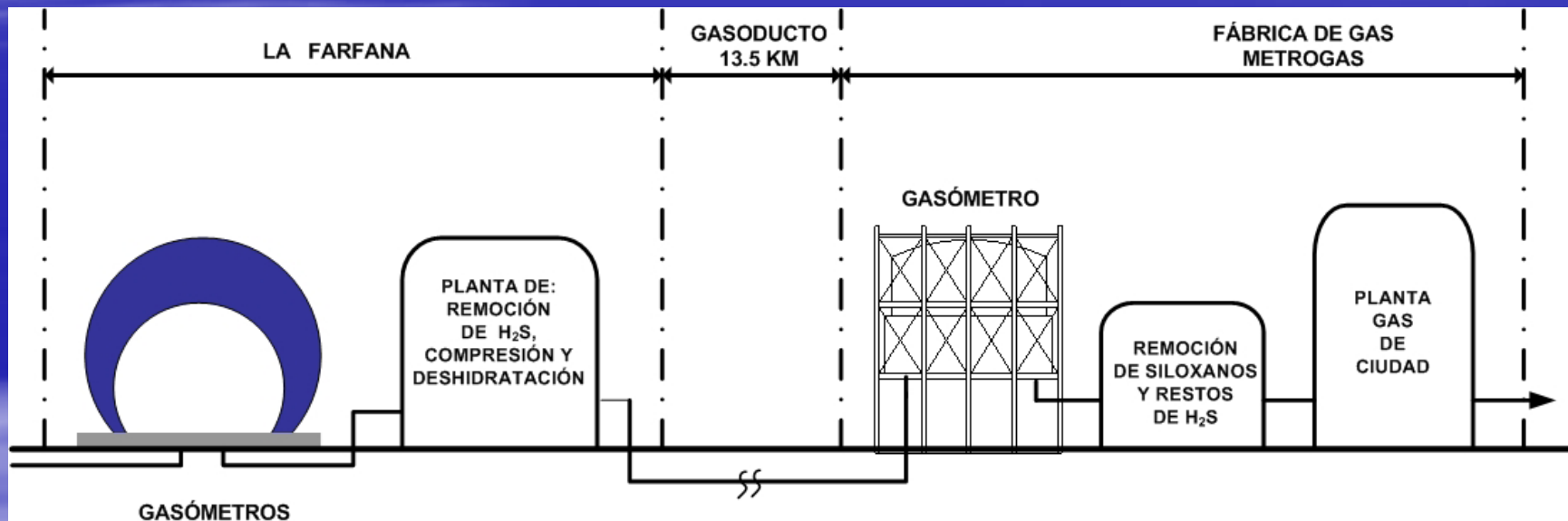
Huge experience in Chile



- La Farfana , 9 m³/s
- Santiago, Chile
- 30 – 40 MM³/year
- Energy for the plant
- Heat for digestors
- Gas to the city Metrogas Company



Metrogas - La Farfana project (US\$ 5 million)



Energy recovery: from UASB reactors and from conventional WWTP digestors

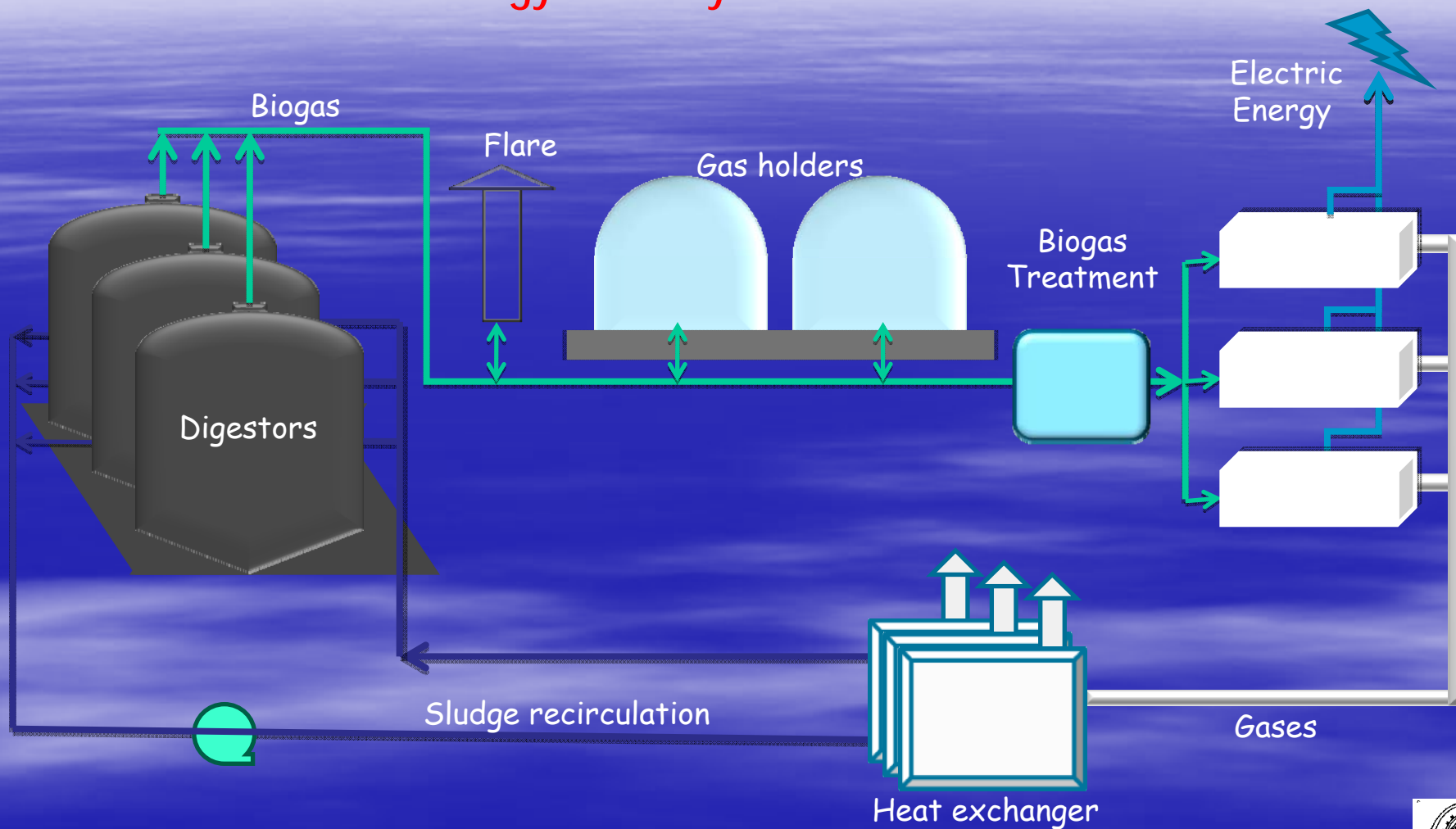
- Arrudas WWTP, Belo Horizonte, Brasil – Activated Sludge with energy recovery from the digestors biogas.



Arrudas WWTP
Belo Horizonte, Brasil



Energy recovery at Arrudas WWTP



Energy recovery at Arrudas WWTP

- Gas purification
- Microturbines



Barueri WWTP
São Paulo, Brasil





Alegria WWTP
Rio de Janeiro

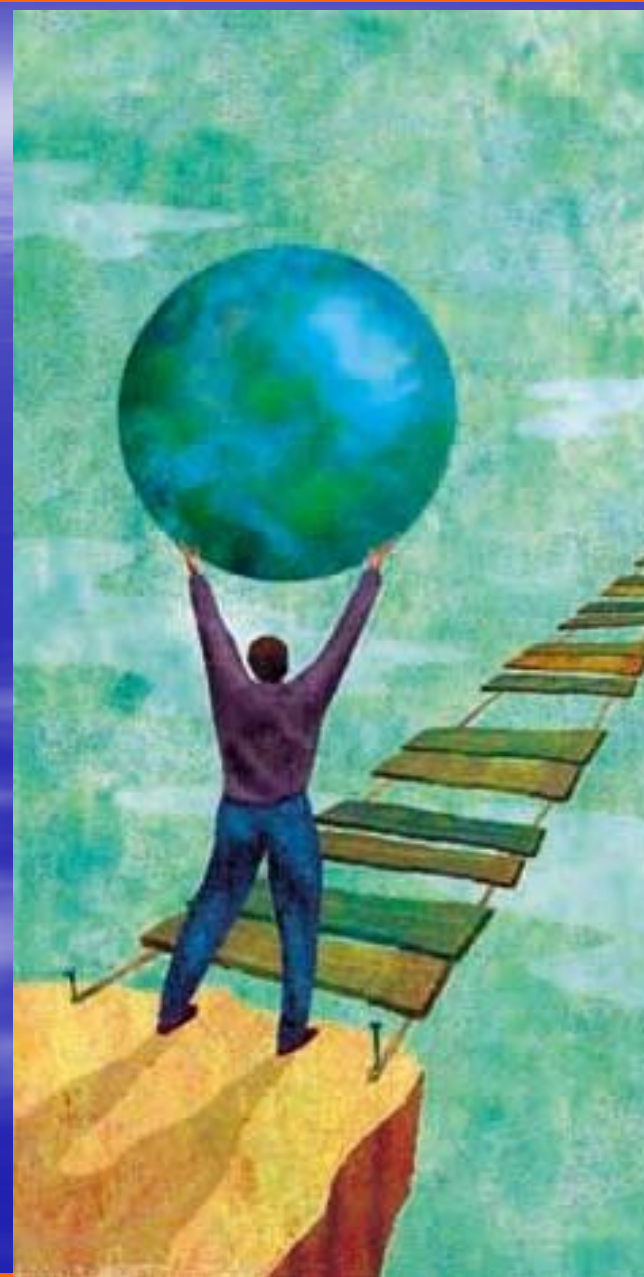
Think big: can we make sanitation sustainable?

- An evaluation of sanitation, health implications, costs, development, economy.
- Economical x new technologies
- Biofilm control technology ?
- Nanotechnology ?
- New membranes ?
- **Sludge and Biogas recovery ?**



MAKING SANITATION SUSTAINABLE

CAN WE MAKE IT ?



THANK YOU

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