Carbon Sequestration Technological Development in Brazil

United Nations Expert Group Meeting on Carbon Dioxide Capture and Storage and Sustainable Development – New York, September 10 to 11th, 2007

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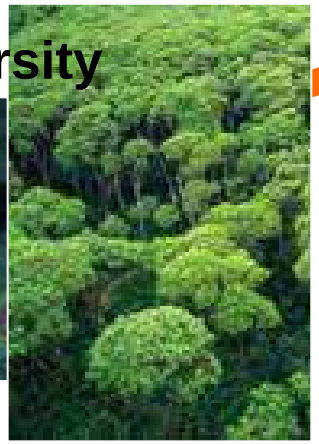
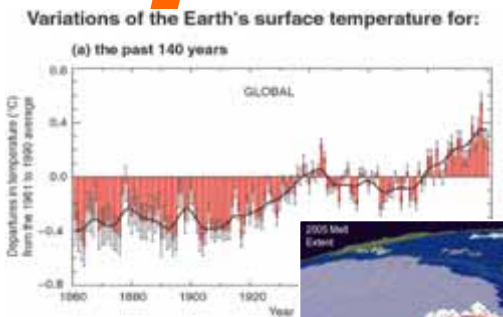
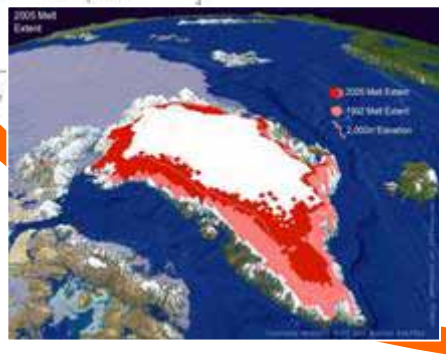
XXI Century's Interconnected Challenges

Biodiversity



Energy





Cimate Change

Sustainable Consumption of Resources

Ref.: Ricardo Castello Branco in “The importance to Petrobras of R&D with focus in biodiversity” at The Biodiversity and the Oil and Gas Industry’s Seminary, Rio de Janeiro, June, 2006

Greenhouse Gases – GHG – Main Emissions Sources

The increase in GHG concentration in atmosphere is mainly caused by the population growth with unsustainable consumption standards

Climate Change Mitigation: Why? How? So ...

- **One of the major corporate social and environmental responsibility of a petroleum/energy sector is to mitigate the climate change that was in part caused, without our knowledge for many years, by fossil fuels combustion emissions.**

- **There are 7 ways to promote this mitigation:**

  - **Energy efficiency**
  - **Decarbonization (C/H relation): coal, oil and natural gas**
  - **Renewable energy**
  - **Hydrogen**
  - **Nuclear**
  - **Forest conservation**
  - **Carbon sequestration**

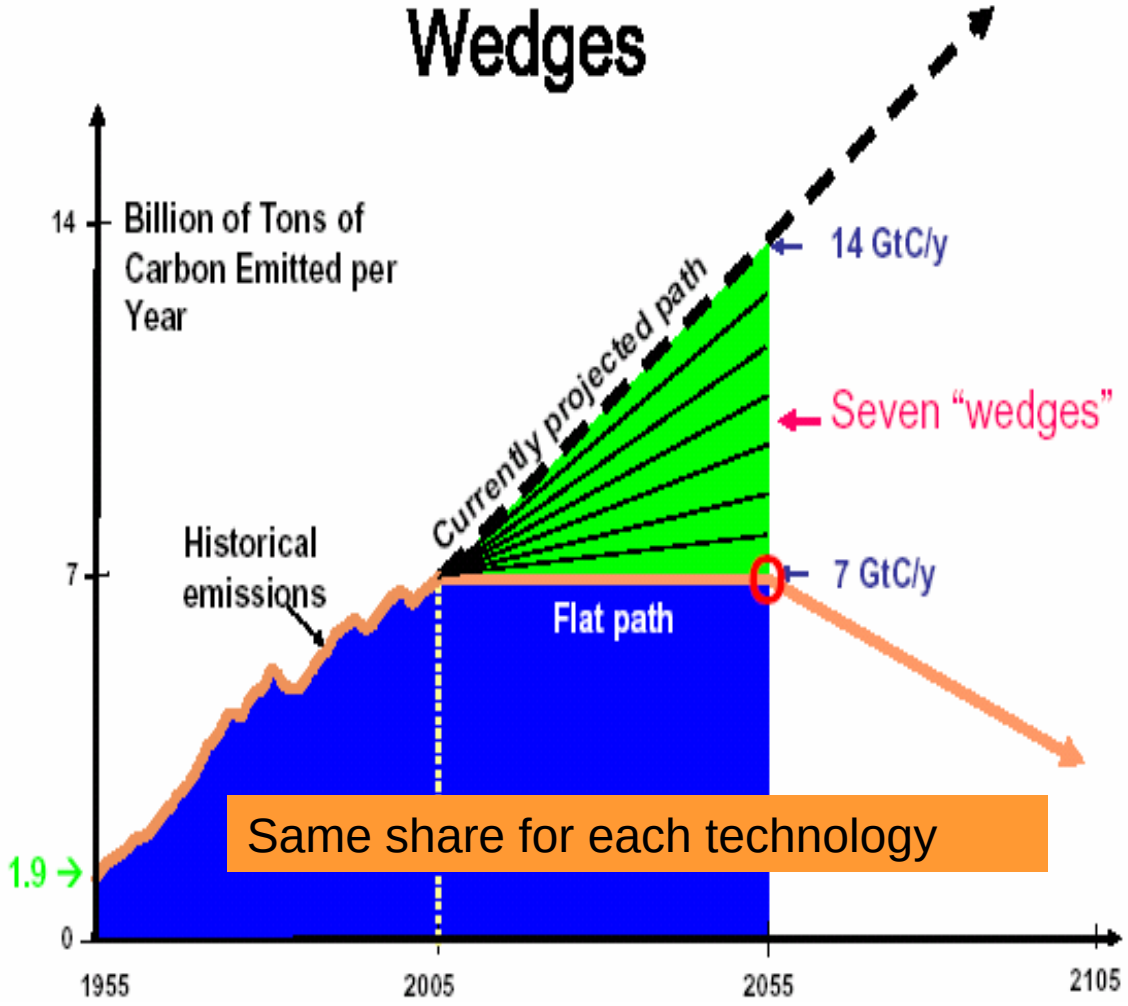
- **In the next 50 years, energy consumption will remain carbon-based. This will imply in a growing CO_2 emission scenario.**

- **The CO_2 atmospheric levels can not transpass the 550 ppm concentration. If this happen, Earth can reach a situation where there will be no return to equilibrium. Carbon sequestration is the key to keep the concentration near the actual 380 ppm.**

Petrobras Climate Change Mitigation Approach for Energy and Mobility with Sustainability

PETROBRAS

Technology Dimension for Climate Change Mitigation: The 7 wedges - Socolow Approach



Source: Pacala and Socolow, Science, vol.305, 2004

Less CO_2 or CO_2-free emission processes

- **Energy Efficiency**
- **Renewable energy**
- **Decarbonization of fossil fuels (coal / oil / gas)**
- **Hydrogen**
- **Nuclear Energy**

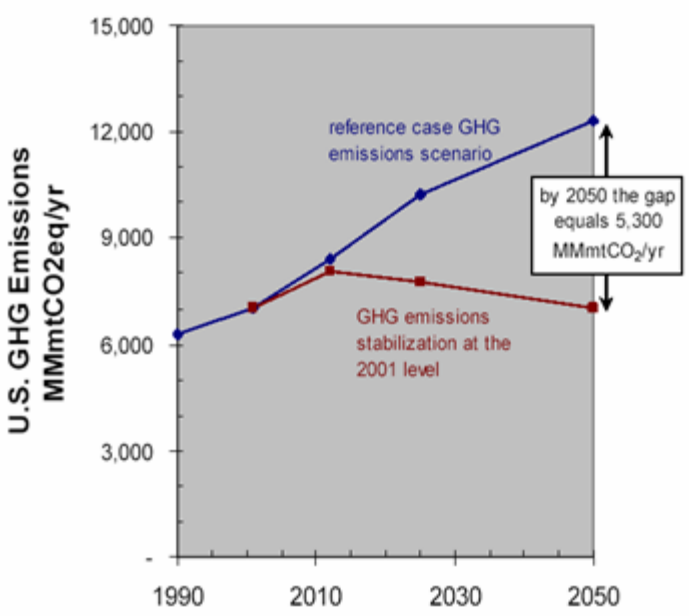
CO_2 capture and storage from industry processes or from atmosphere

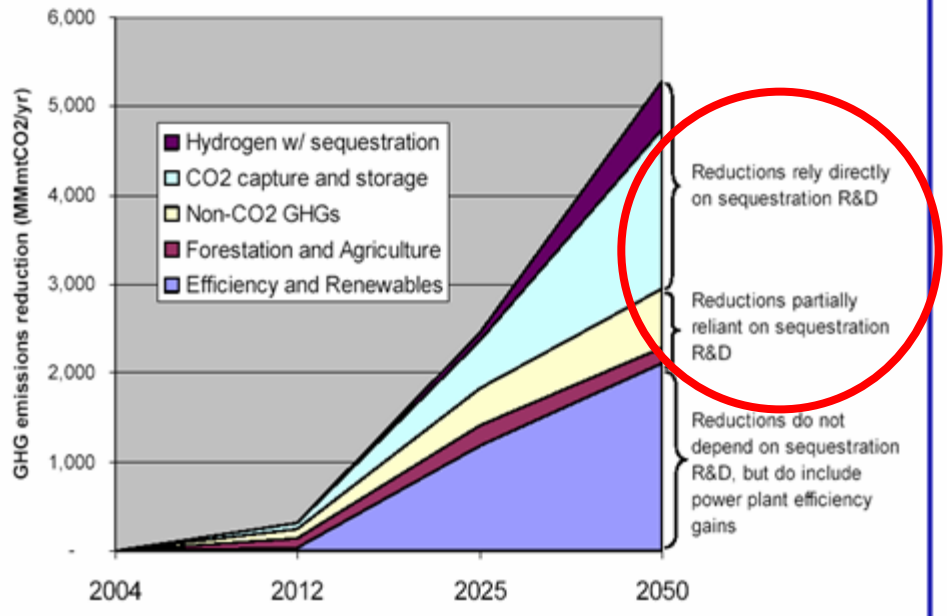
- **Carbon Sequestration**
- **Forest conservation**

Technology Dimension for Climate Change Mitigation: Different Scenarios

U.S. DOE Office of Fossil Energy / National Energy Technology Laboratory – NETL - Scenarios

Figure 3. U.S. GHG Emissions Scenarios . . . and Technologies to Fill the Gap





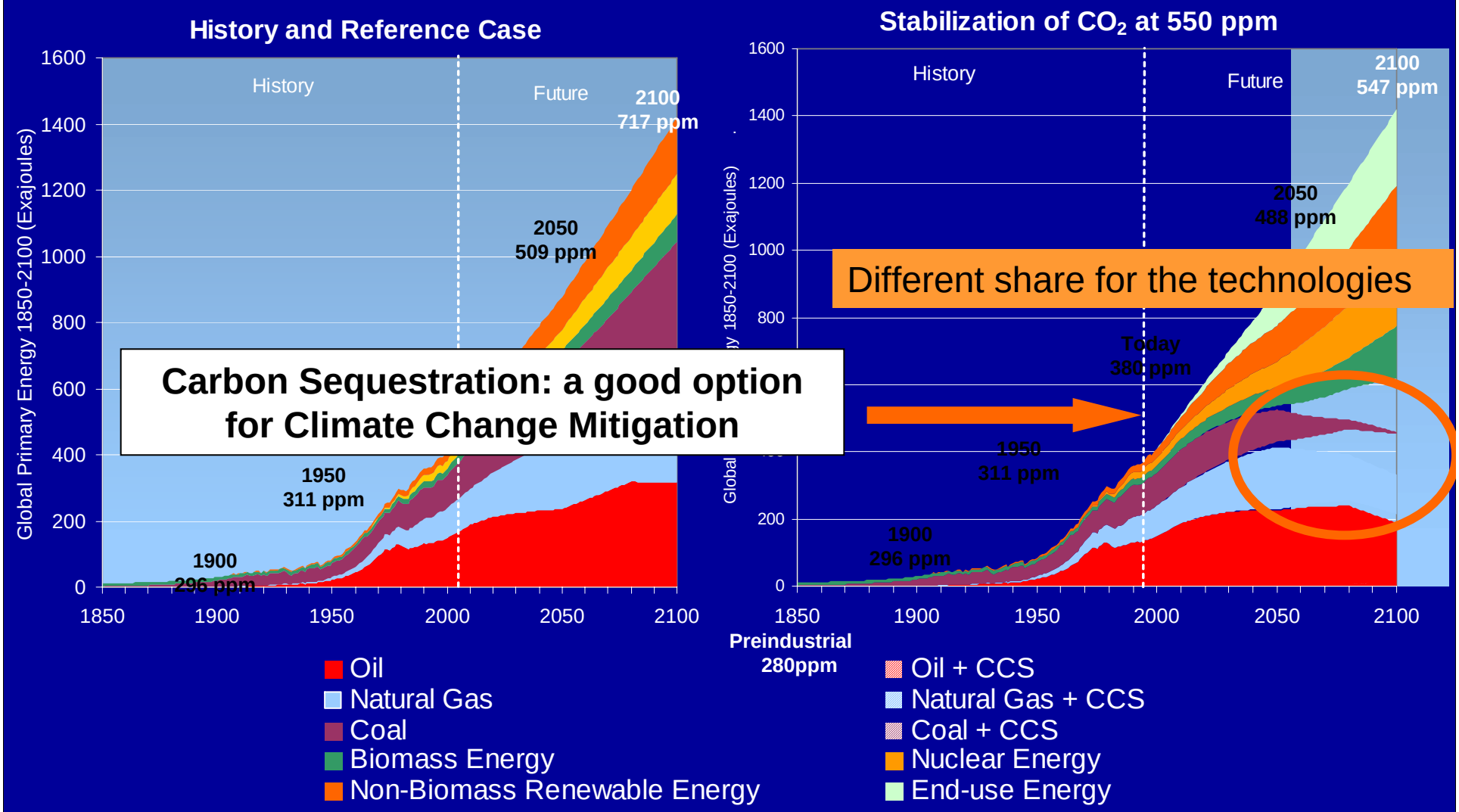
Different share for the technologies

Carbon Sequestration: the great option for Climate Change Mitigation

Source: DOE/NETL Roadmap, in: "Carbon Sequestration – Technology Roadmap and Program Plan 2005". United States Department of Energy – Office of Fossil Energy – National Energy Technology Laboratory - May 2005.

Technology Dimension for Climate Change Mitigation: DOE Scenario

The CO_2 concentrations stabilization means radical changes in the global energy system

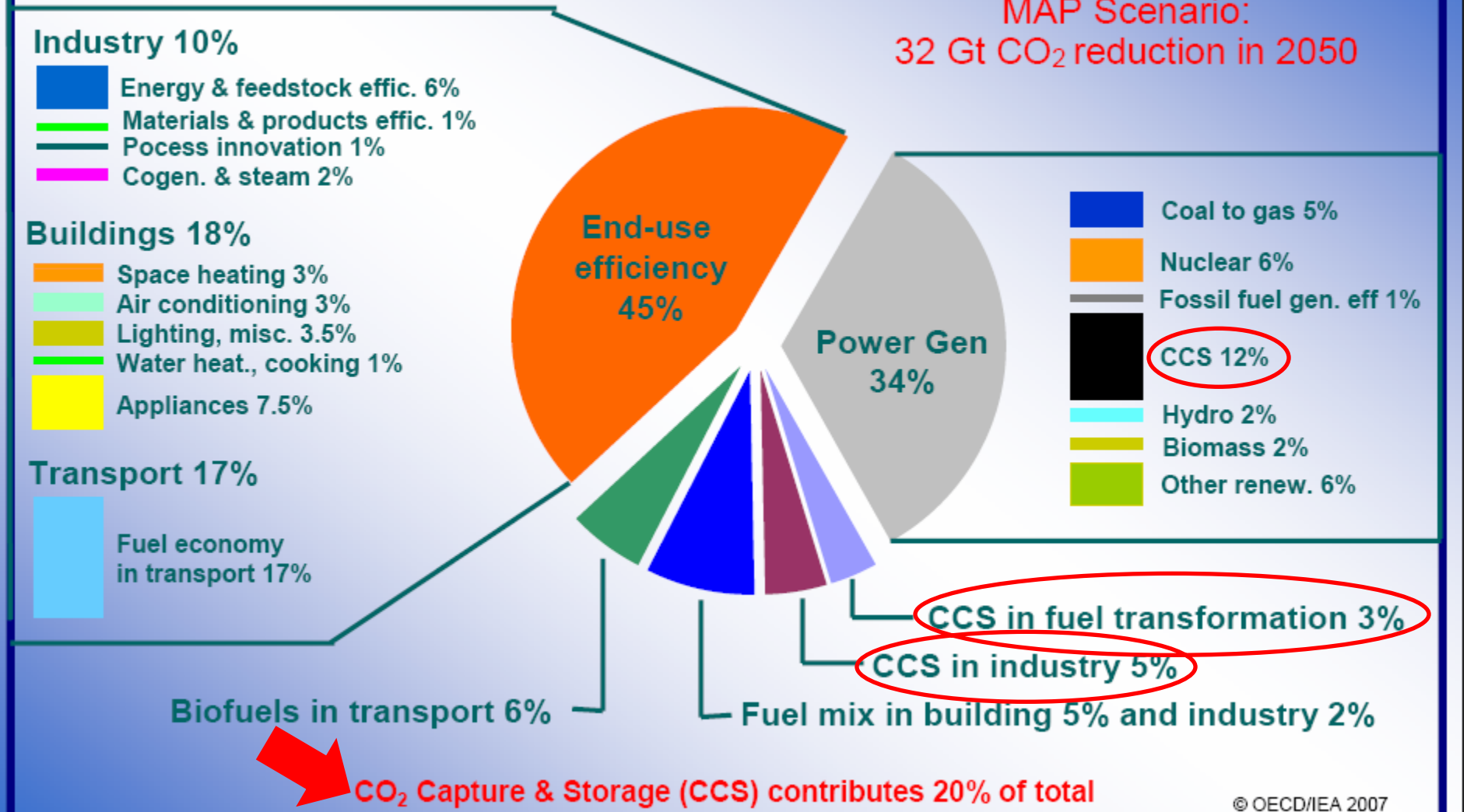


Ref.: Jim Dooley in " Overview of Issues and Need for Carbon Management at the Workshop on Capacity Building for CCS, May 2007, Pittsburgh - USA

IEA Energy Technology Perspectives

Emission reduction by sectors

MAP Scenario:
32 Gt CO_2 reduction in 2050



CO_2 Capture & Storage (CCS) contributes 20% of total

Petrobras Climate Change Mitigation Approach for Energy and Mobility with Sustainability

PETROBRAS

Social Dimension for Climate Change Mitigation

An important dimension for climate change mitigation is the SOCIAL: education and cultural changes that promotes people´s change of habits and consumers, voters and investor's pro-active actions ...

Some possibilities:

- **Individual transportation reduction**
- **Decrease energy and water consumption**
- **Consumption reduction;**
- **Residue's production reduction**
- **Domestic waste burning extinction**
- **Population growth rate reduction**
- **Increase soil permeability in urban areas**

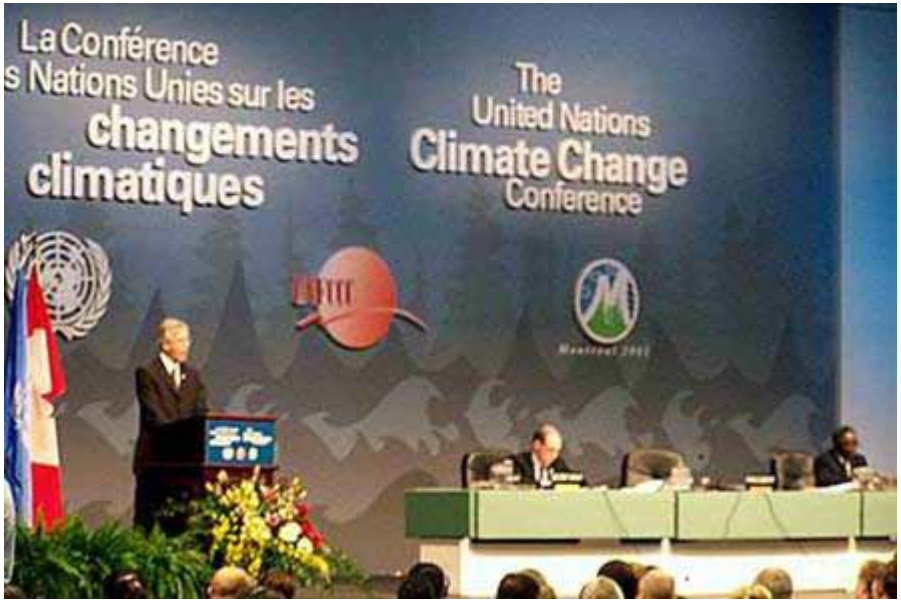
Adapted of: Duailibi, M. in - 1st Brazilian Carbon Sequestration and Climate Change Seminary, Aprill 2007 – Natal/RN

Petrobras Climate Change Mitigation Approach for Energy and Mobility with Sustainability

PETROBRAS

Policy Dimension for Climate Change Mitigation

An important dimension for climate change mitigation is the policy with legislation, regulation and incentives to mitigate climate change and to reduce impacts and vulneratilities and implement adaptation measures to combat climate change effects



How Carbon Sequestration is considered in PETROBRAS?

Petrobras 2015 Strategic Plan

MISSION

Operate in a safe and profitable manner in the oil, gas and energy industry in Brazil and abroad, with social and environmental responsibility, providing products and services that meet client´s needs and that contribute to the development of Brazil and the countries in which it operates.

2015 VISION

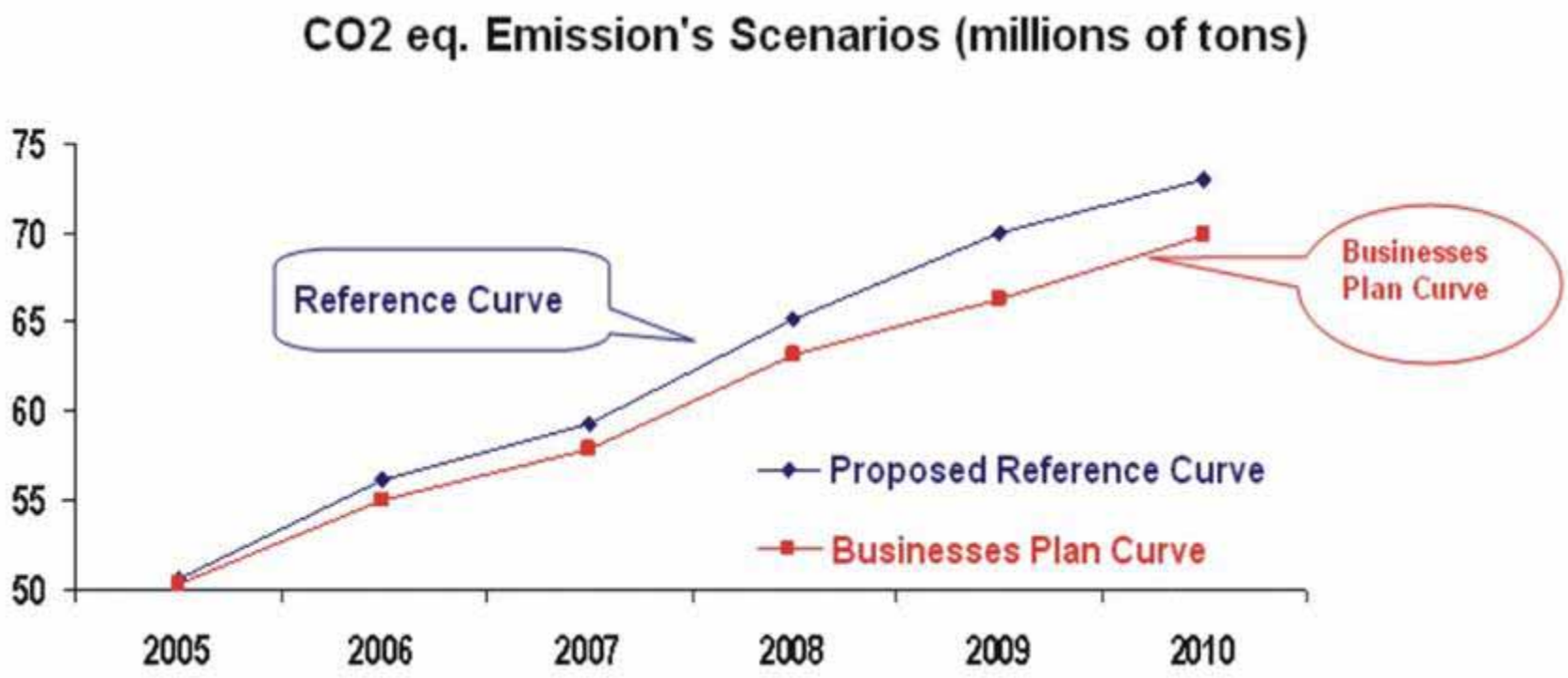
Petrobras will be an integrated energy company with a strong presence in the international market and as a leading force in Latin America, focusing in profitability and social and environmental responsibility.

Petrobras and Climate Change

- **Acknowledges that climate changes are strongly affected by GHG emissions;**
- **Acknowledges that the need for energy supply is growing, and the need to provide this energy without raising climate instabilisation is necessary;**
- **Determines strategies, limits and GHG avoided emission goals in the Strategic Plan;**
- **Develops projects with companies and scientific comunity in Brazil and abroad.**

Ref.: Petrobras – Gestão de emissões Atmosféricas – Relatório de Desempenho, dez/2005

PETROBRAS and Climate Change



We reached the total of **2,03** millions of tons of $CO_{2\ eq.}$ avoided in 2006

	$CO_{2\ eq.}$ (Millions of tons)						Total
	2006	2007	2008	2009	2010	2011	2006-2011
Avoided emissions considering the Businesses Plan	1,13	1,79	3,56	4,15	3,93	3,93	18,50

And since August 2007....

PETROBRAS Strategic Plan – 2020

- To invest in research, development and demonstration of technologies for climate change mitigation and reduction of the carbon risk of our activities, including technologies of carbon sequestration.

- To invest in research to improve the climate change global themes comprehension, providing scientific support to the decisive processes, allowing the anticipation of adaptation measures through Petrobras activities potential impacts and vulnerabilities.

- To develop methodology to evaluate the environmental performance of our products on their life cycle.

CO_2 and Carbon Sequestration Capacity Building Process and Technological Development (I)

- Petrobras experience with CO_2 injection and management for EOR since 1987
- Brazilian Universities - PUCRS, UNIFACS – CCS Knowledge and R&D activities since 2003
- CO_2 sources and sinks for CCS in Bahia State – UNIFACS in 2003
- Petrobras Research Center Carbon Sequestration and Ecosystem Conservation activities (since 2003)
- Petrobras Research Center R&D CO_2 capture in partnership with Regina University/Canada in 2003
- Petrobras Research Center and Brazilian Academia R&D carbon biomass fixation in different Brazilian Ecosystems (since 2003)
- Brazilian participation on the Carbon Sequestration Leadership Forum (CSLF) (since 2003)

CO_2 and Carbon Sequestration Capacity Building Process and Technological Development (II)

- Petrobras affiliation to the Joint Implementation Project CO_2 Capture phase 2/UK (2005)
- Brazilian CO_2 sources and sinks – evaluation of Brazilian Geological Storage Potential - PUCRS in 2006
- Petrobras Research Center CCS group (since 2006)
- Petrobras Research Center Climate Change and Carbon Sequestration Technologies Network (2006)
- Petrobras 1st Carbon Sequestration International Seminar- Oct/2006
- Climate Change and Carbon Sequestration Brazilian Seminars and CCS courses – Natal/RN, Apr/ 2007 and Cuiabá/MT, Aug/2007
- Carbon Sequestration Capacity building on May 2007 in Pittsburgh/USA, with the visit to the DOE's National Energy Technology Laboratory
- CCS Recôncavo Basin Pilot Project with French Institute of Petroleum – IFP, Aug/2007

CO_2 and Carbon Sequestration Capacity Building Process and Technological Development (III)
Short term actions:

- Establishment of PETROBRAS Strategic and Technological Program on Climate Change Mitigation with focus on CCS - PROCLIMA (Sept/2007)
- CCS Capacity building with DOE/USA and the Carbon Sequestration Leadership Forum(CSLF) in Porto Alegre/RS, Oct/2007
- Petrobras, Pontifical Catholic University of Rio Grande do Sul and Brazilian Coal Association agreements with DOE/NETL (in negociation)
- CO_2 Storage and Ethics Workshop, Rio de Janeiro, Oct/2007
- Brazilian CCS Roadmap Workshop, Porto Alegre, Oct/2007
- Implementation of four R&D centers for CO_2 Capture (absorption and chemical looping), geological storage, and carbon biomass fixation in UNIFACS, INPE, PUCRS and UFPR (2007-2008).
- Petrobras 2nd Carbon Sequestration International Seminar- Sep/2008
- **Petrobras Pilot and Demonstration CCS in Aquifer, Petroleum Reservoirs and Coal Seams (to be started in 2008)**

World Technological Development Stage (CCS projects)

Demonstration

Industrial

- CARSON (4,0 mil.ton/year); 2011 – EUA;
- HALTEN (2,5 mil. ton/year); 2012 Norway;
- WEYBURN (1,8 mil. ton/year); 2000 to 2004 – Canada
- SALT CREEK (1,8 mil. ton/year); since 2004 – EUA;
- IN SALAH (1,2 mil. ton/year); since 2004 – Algeria;
- MILLER (1,3 mil. ton/year); 2009 – Scotland;
- MONGSTAD (1,3 mil. ton/year); 2014 – Norway;
- FUTUREGEN (1 - 2,5 mil.ton/year); 2013 – EUA;
- SLEIPNER (1,0 mil. ton/year); since 2006 – Norway;

Pilot

- ECBM; 1997 to 2007 – Canada
- ECBM; since 2002 – China;
- CASTOR; since 2004 – Europe
- CANMET; since 2004 Canada
- CO_2 SINK; since 2004 – Germany
- MEMBRANES; 2003 to 2010 – EUA;
- ITC CO_2 CAPTURE; since 1999 – Canada
- CCS ON BASALTIC FORMATIONS; since 2006 – India
- PROJETO FRIO; 2002 to 2003 – EUA;
- RECOPOL; 2001 to 2004 – Poland;
- LACQ BASIN; 2008 – France
- ZAMA; since 2006 – Canada;

PETROBRAS

R&D

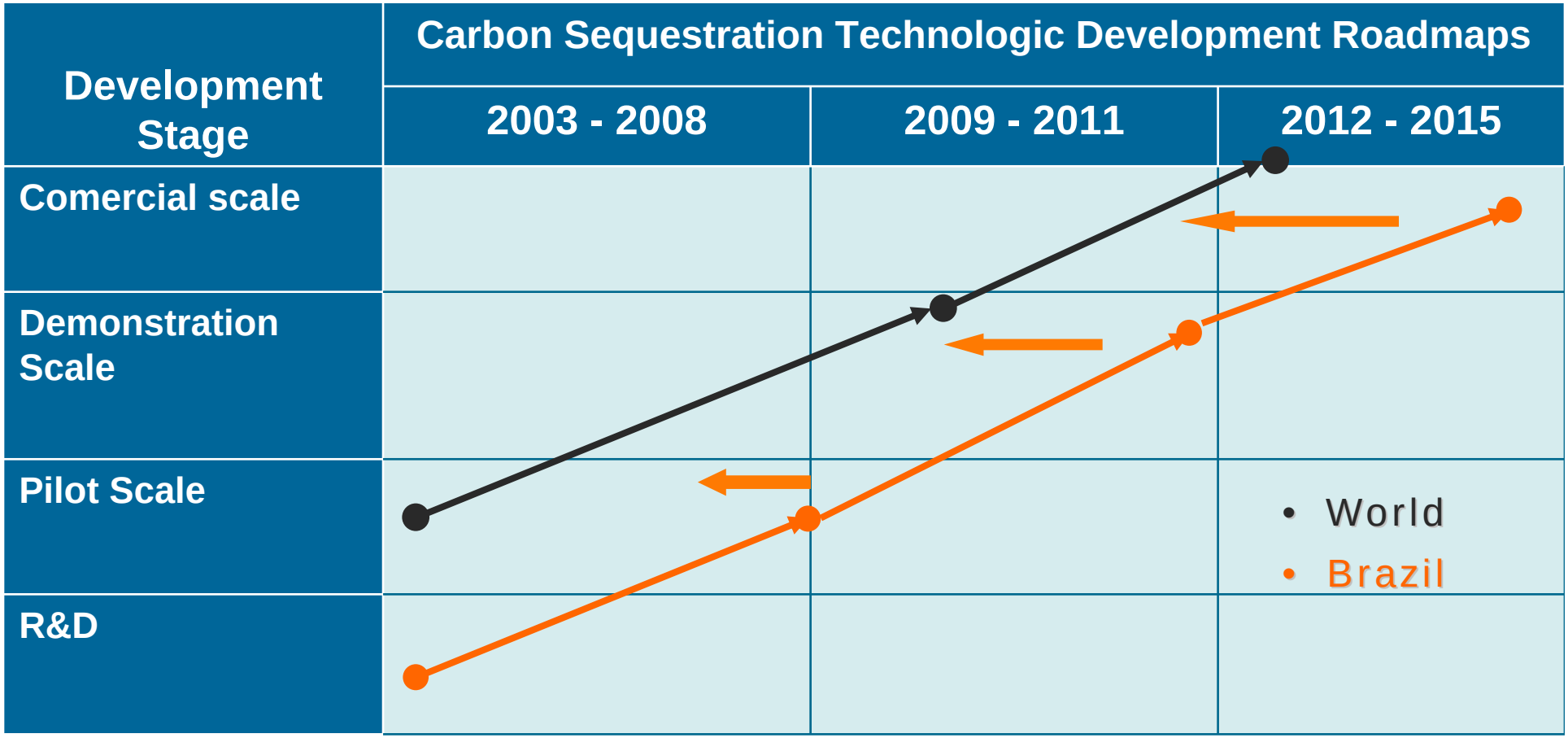
CCP II

ENCAP Integrated Project

MITSUI & CO., LTD.

Updated – Apr 2007

Carbon Sequestration Technological Development Roadmaps



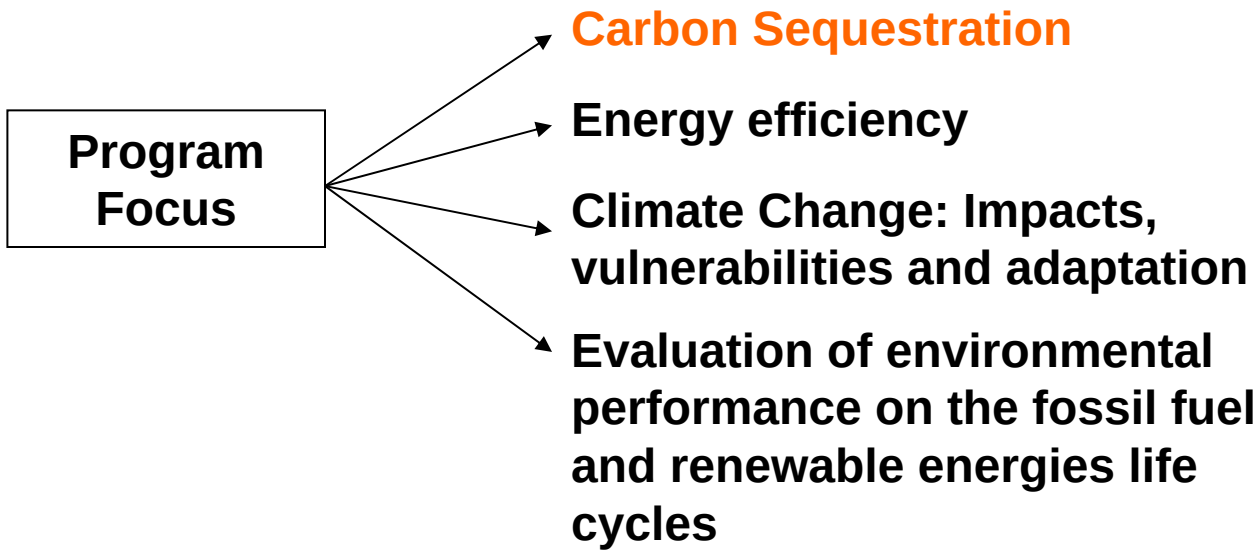
PETROBRAS Carbon Sequestration Technological Roadmap

Development Stage	PETROBRAS Carbon Sequestration Technological Roadmap		
	2003 - 2008	2009 - 2011	2012 - 2015
Comercial Scale			
Demonstration Scale			
Pilot Scale			
R&D			

09 Sept 2007

PETROBRAS Climate Change Mitigation Technologies Program - PROCLIMA

Goals (2007-2012) – Provide technological solutions to mitigate Petrobras activities and products influence on global climate change



Main Goals of PROCLIMA related to carbon sequestration	MILESTONES
1. To develop technologies of CO_2 separation and capture that allow a significant cost reduction on current capture prices (50% reduction) to be used on the GHG avoided emissions on industrial units	• Demonstration: 2009 (250 tons CO_2/day) • Industrial: 2012 (900 tons CO_2/day)
2. To develop CO_2 storage technologies, risks evaluation, measurement, monitoring and verification, assuring the geological storage security.	• Pilot: 2008 (350 tons CO_2/day) • Demonstration: 2012 (900 tons CO_2/day)
3. To implant a pilot/demonstration reforestation project to evaluate the biomass carbon fixation and attainment of carbon credits	. Demonstration : 2009 (1,000 ha)

World Technological Development Stage (CCS projects)

PETROBRAS

Demonstration

Industrial

CARSON (4,0 mil.ton/year); 2011 – EUA;

CAMPOS (3,9 mil. ton/year); 2008 – Brazil (PETROBRAS);

MIRANGA (2,9 mil. ton/year); 2008 – Brazil (PETROBRAS);

HALTEN (2,5 mil. ton/year); 2012 - Norway;

POTIGUAR (1,9 mil. ton/year); 2011 – Brazil (PETROBRAS);

WEYBURN (1,8 mil. ton/year); 2000 to 2004 – Canada

SALT CREEK (1,8 mil. ton/year); since 2004 – EUA;

IN SALAH (1,2 mil. ton/year); since 2004 – Algeria;

MILLER (1,3 mil. ton/year); 2009 – Scotland;

MONGSTAD (1,3 mil. ton/year); 2014 – Norway;

FUTUREGEN (1 - 2,5 mil. ton/year); 2013 – EUA;

SLEIPNER (1,0 mil. ton/year); since 2006 – Norway;

Pilot

AQUÍFERO RIO-POJUCA; 2007 – Brazil (PETROBRAS);

ECBM; 1997 to 2007 – Canada

ECBM; since 2002 – China;

CASTOR; since 2004 – Europe

CANMET; since 2004 Canada

CO_2 SINK; since 2004 – Germany

CARBOMETANO BRASIL PROJECT (ECBM); 2009 – Brasil (PETROBR

ITC CO_2 CAPTURE; since 1999 – Canada

CCS ON BASALTIC FORMATIONS; since 2006 – India

PROJETO FRIO; 2002 to 2003 – EUA;

RECOPOL; 2001 to 2004 – Poland;

LACQ BASIN; 2008 – France

ZAMA; since 2006 – Canada;

CARBOGIS (UCG + CCS); 2011 – Paraná Basin (PETROBRAS & LLNL NETL)

R&D

CCP II

CLIMATE CHANGE AND CARBON SEQUESTRATION NETWORK

ENCAP Integrated Project

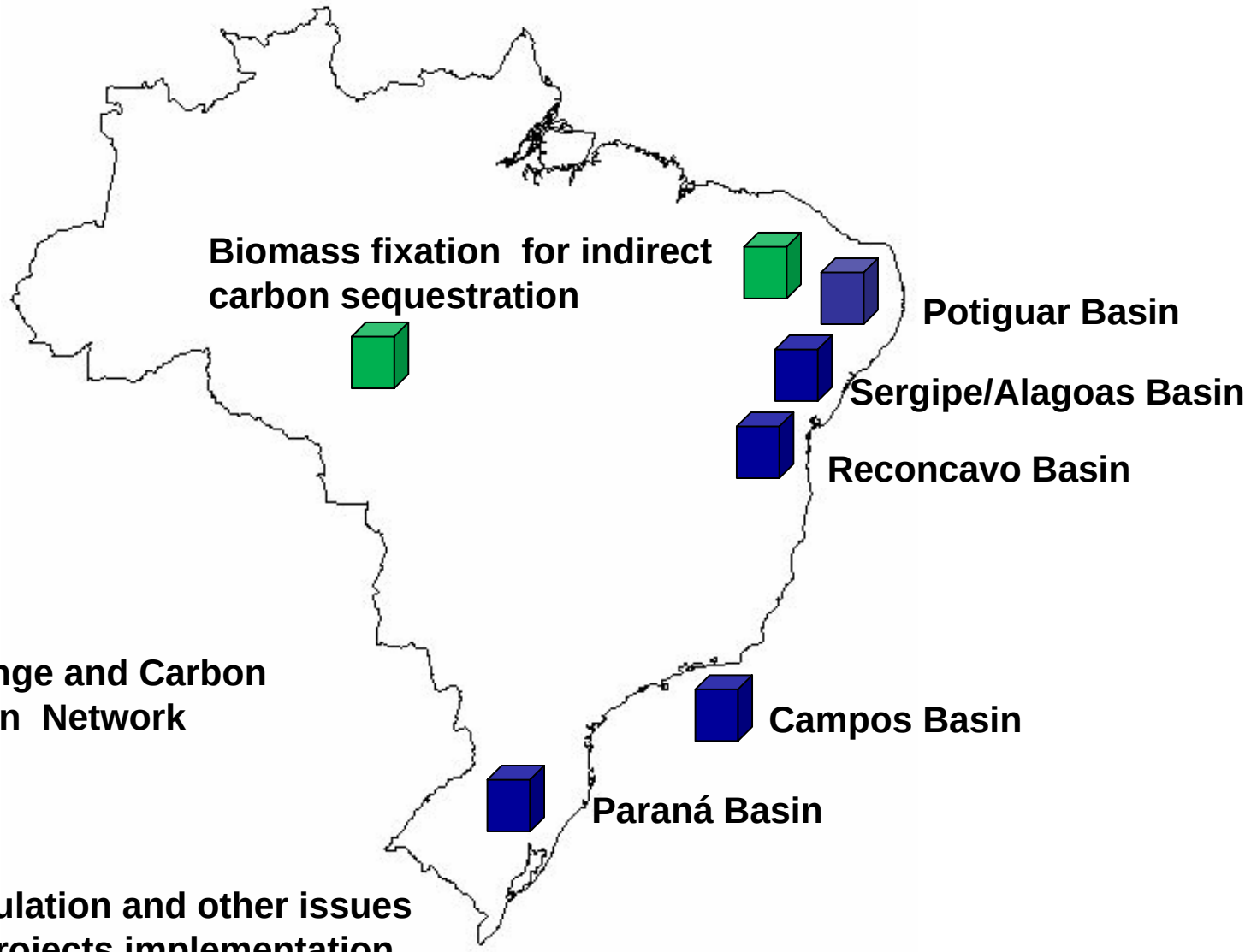
MITSUI & CO., LTD.

Updated – Sep/2007

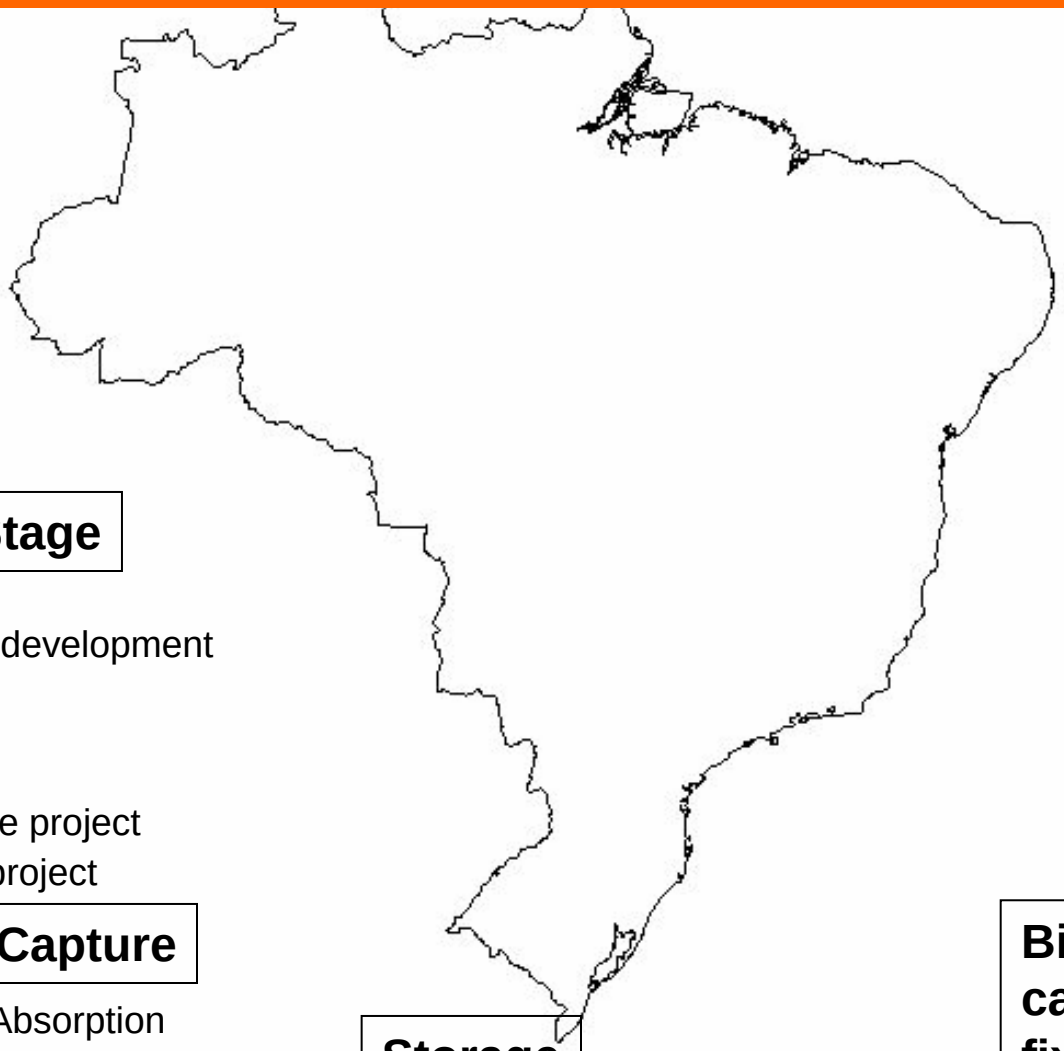
Petrobras R&D, Pilot and Demonstration Investments in Carbon Sequestration

- **2003 to 2008 - U$ 25 million (R&D)**
- **2008 to 2014 - U$ 65 million (Pilot &Demonstration)**

Carbon Sequestration Technological Development in Petrobras – Sistemic Project Portfolio



Carbon Sequestration Technological Development in Petrobras – the Roadmap



Development Stage

- R&D Infrastructure development
- R&D scale projects
- Pilot scale project
- Demonstration scale project
- Commercial scale project

Capture

- Absorption
- Adsorption
- Membrane
- Chemical Looping
- Oxyfiring

Storage

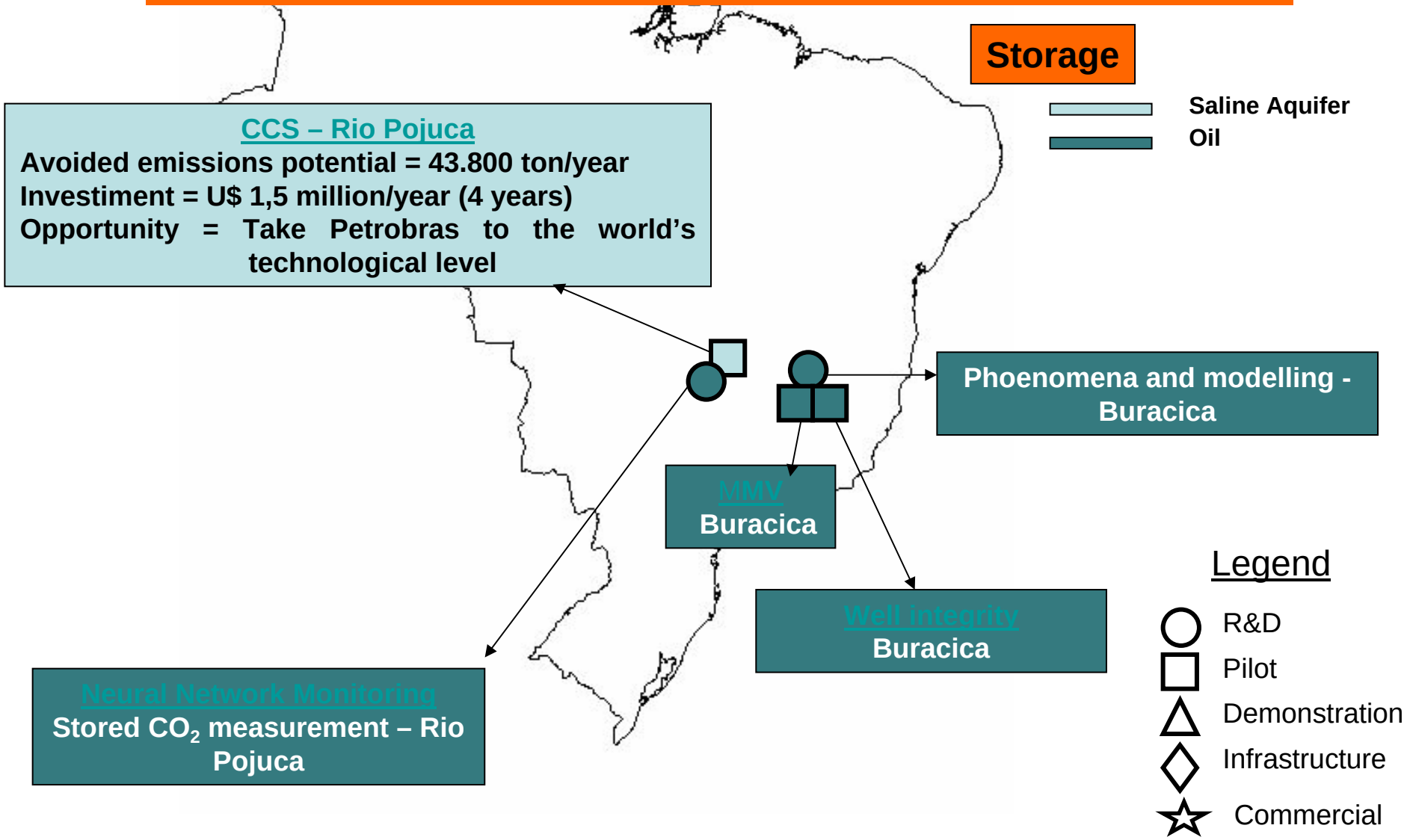
- Oil
- Saline aquifer
- Coal seams

Biomass carbon fixation

- Superior vegetables
- Soil
- Microalgae

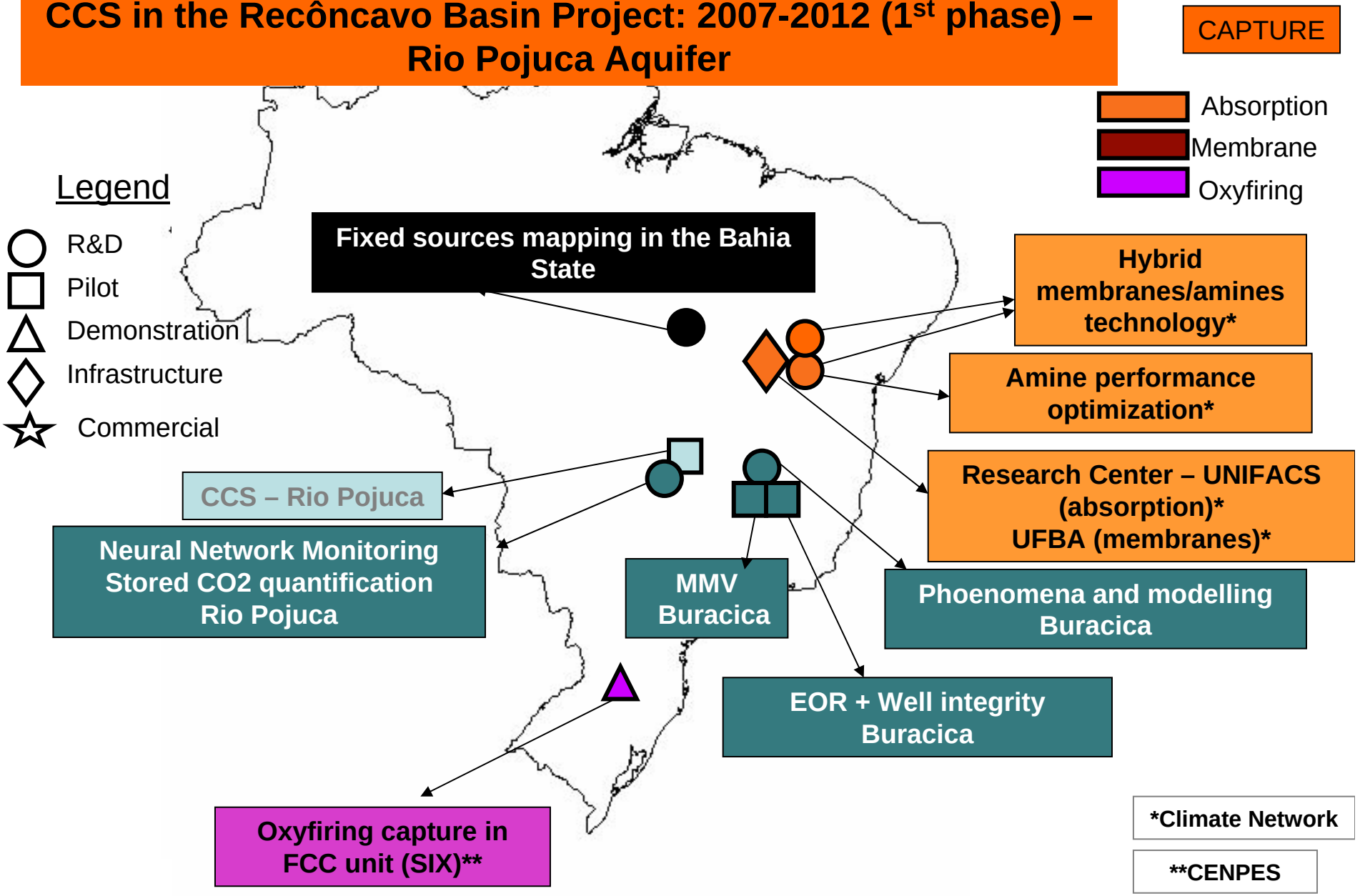
CCS in Reconcavo Basin: Aquifer Rio Pojuca and Miranga Petroleum Reservoir Pilot and Demonstration Projects

CCS in the Recôncavo Basin Project: 2007-2012 (1st phase) – Rio Pojuca Aquifer

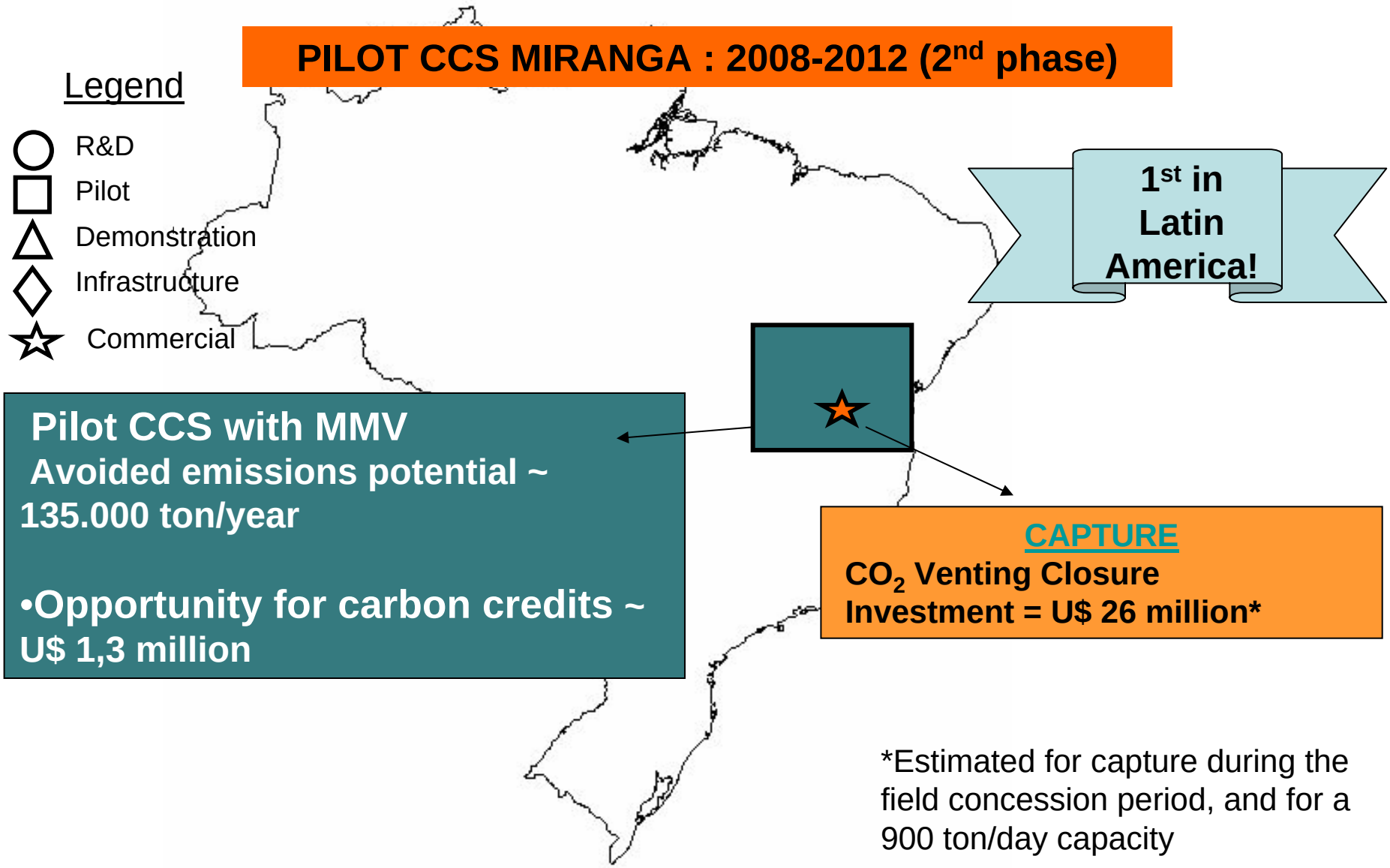


CCS in Reconcavo Basin: Aquifer Rio Pojuca and Miranga Petroleum Reservoir Pilot and Demonstration Projects

CCS in the Recôncavo Basin Project: 2007-2012 (1st phase) – Rio Pojuca Aquifer

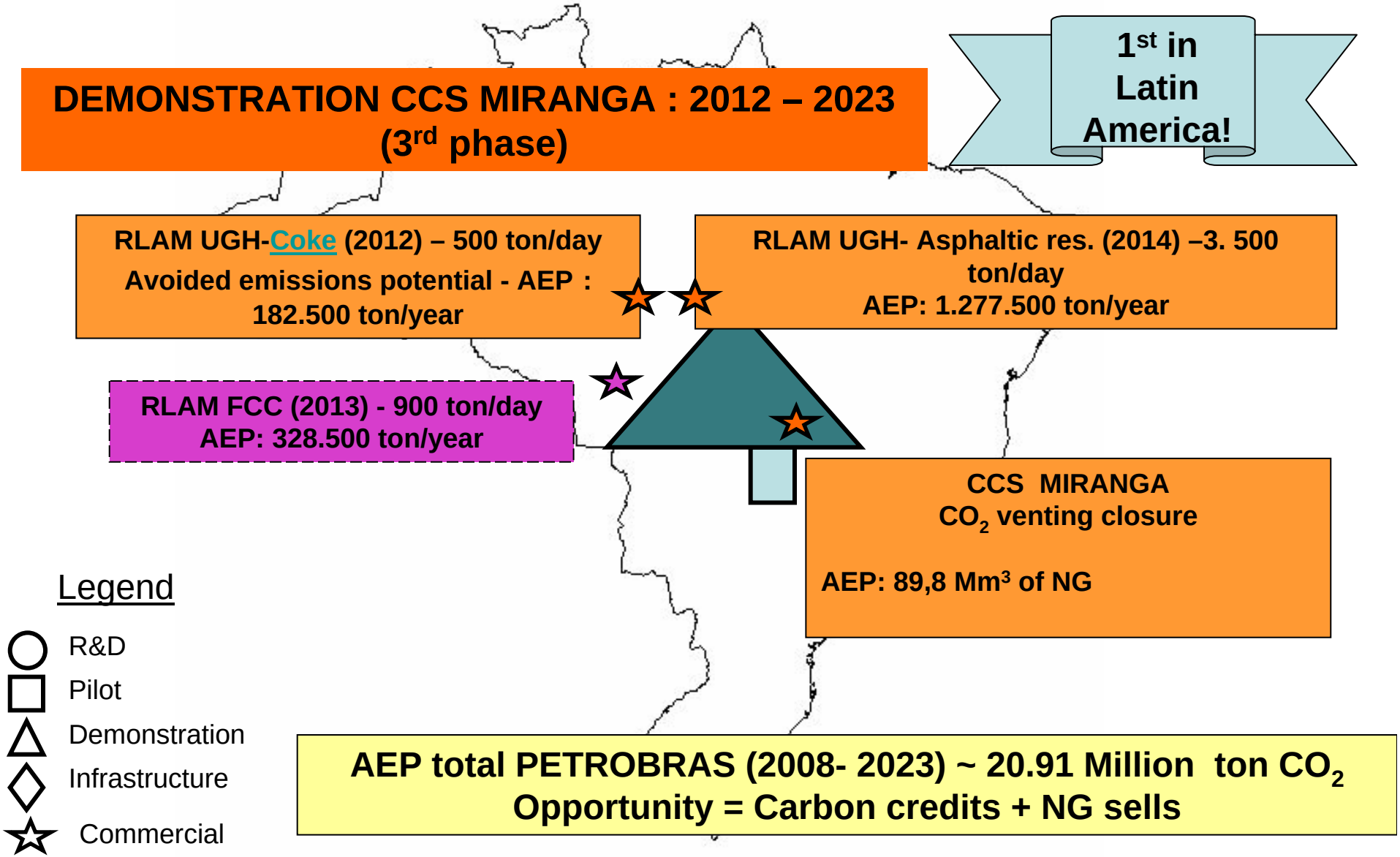


CCS in Reconcavo Basin: Aquifer Rio Pojuca and Miranga Petroleum Reservoir Pilot and Demonstration Projects

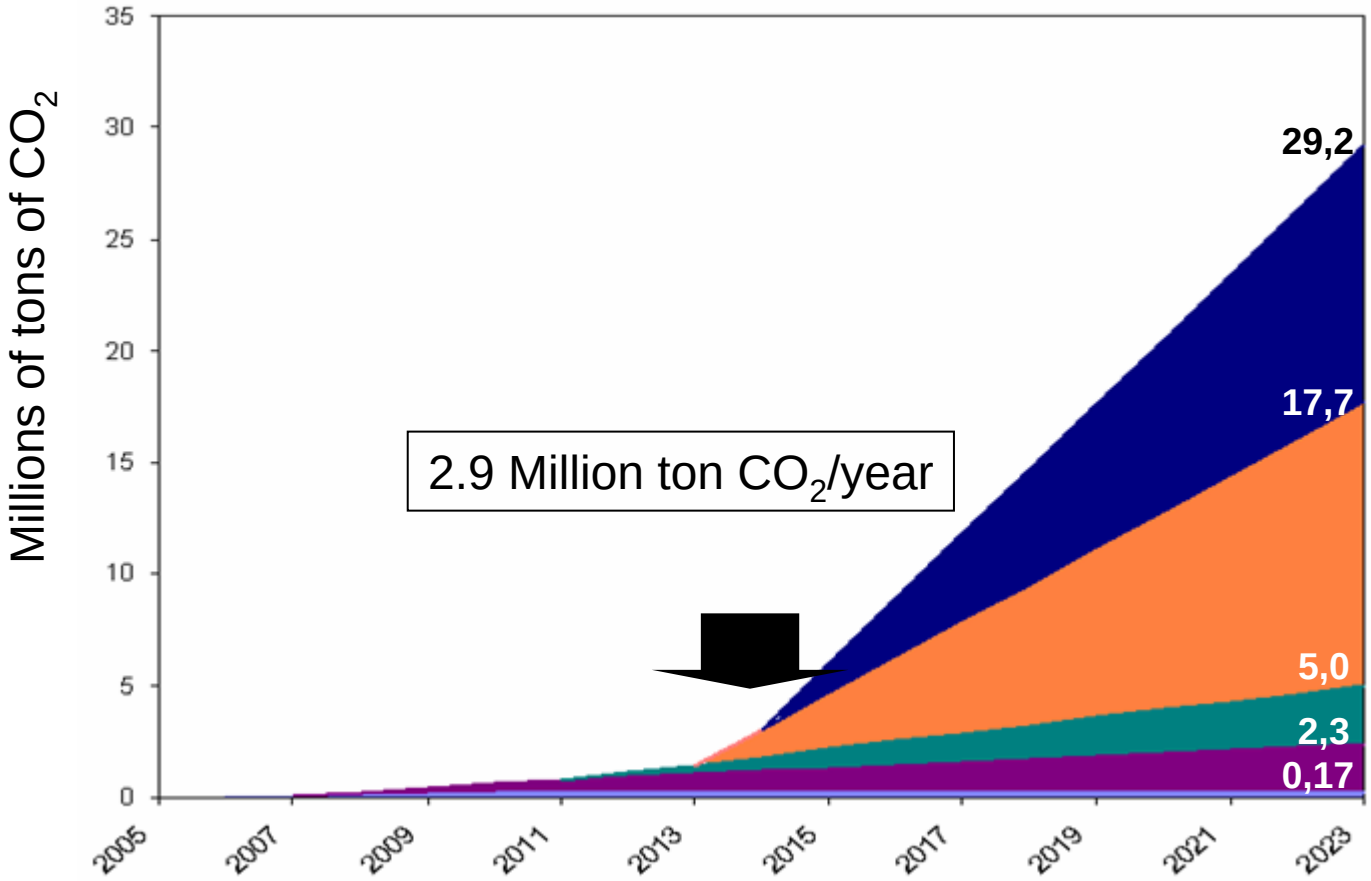


*Estimated for capture during the field concession period, and for a 900 ton/day capacity

CCS in Reconcavo Basin: Aquifer Rio Pojuca and Miranga Petroleum Reservoir Pilot and Demonstration Projects



CCS in Reconcavo Basin: Rio Pojuca and Miranga Projects
Avoided emissions potential



Aquifer	Miranga	Miranga + HGU coke	**Miranga + HGU Asphaltic residue**	Miranga + FCC
(120 tons/day)	(370 tons/day)	(600 tons/day)	(3.500 tons/day)	(3.500 tons/day)

CARBON SEQUESTRATION IN CAMPOS BASIN

New separation and capture process in production offshore facilities

CO_2 absorption capture data research

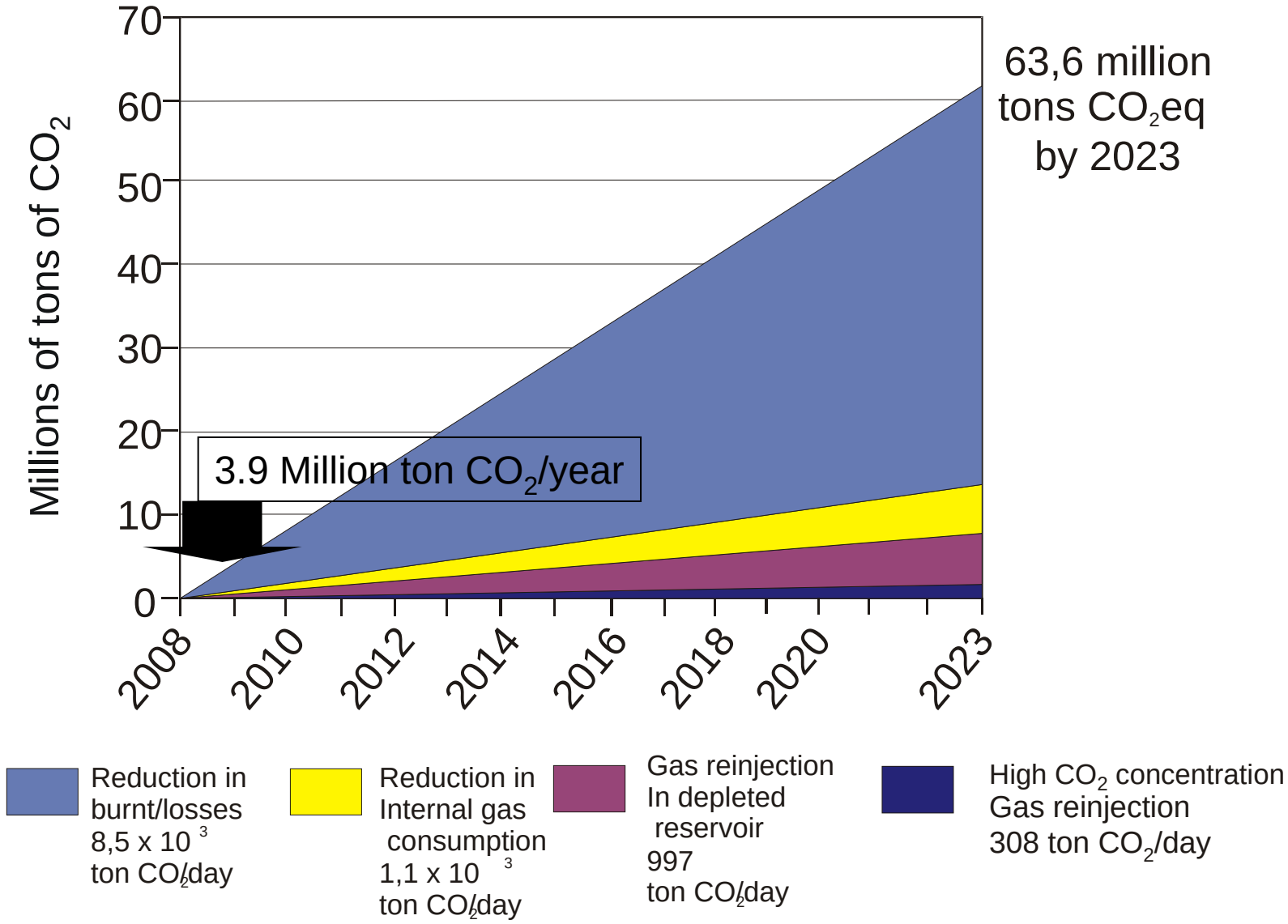
Modelling and simulation of natural gas purification processes with combined membranes technologies

Gas separation using membranes: Gas chain treatment in oil production aiming at CO_2 emissions reduction

GHG concentration in fixed turbines through combustion gases recirculation

R&D for an exausted gases recirculation system evaluation in microturbines

CAMPOS BASIN with CCS
Avoided emissions potential



CARBON SEQUESTRATION IN PARANÁ BASIN

- **Evaluation of Brazilian potential for the use of clean solid fossil fuels related with CO_2 storage in deep unmineable coal seams and in situ gasification**

  The main objective of this project is to assess Brazilian potential and location of deep coal reservoirs for ECBM-CO2 and in situ gasification.

- **Carbometano Brasil Project (SOTACARBO, CEPAC)**

  In order to start the R,D&D activities in the climate changeless coal technologies, it has been planned the Carbometano Project. Its objectives are:

  - Methane production from coal through CO_2 injection (ECBM);
  - Coal gasification for energy and clean fuels production.

  This project is in final negotiation with SOTACARBO.

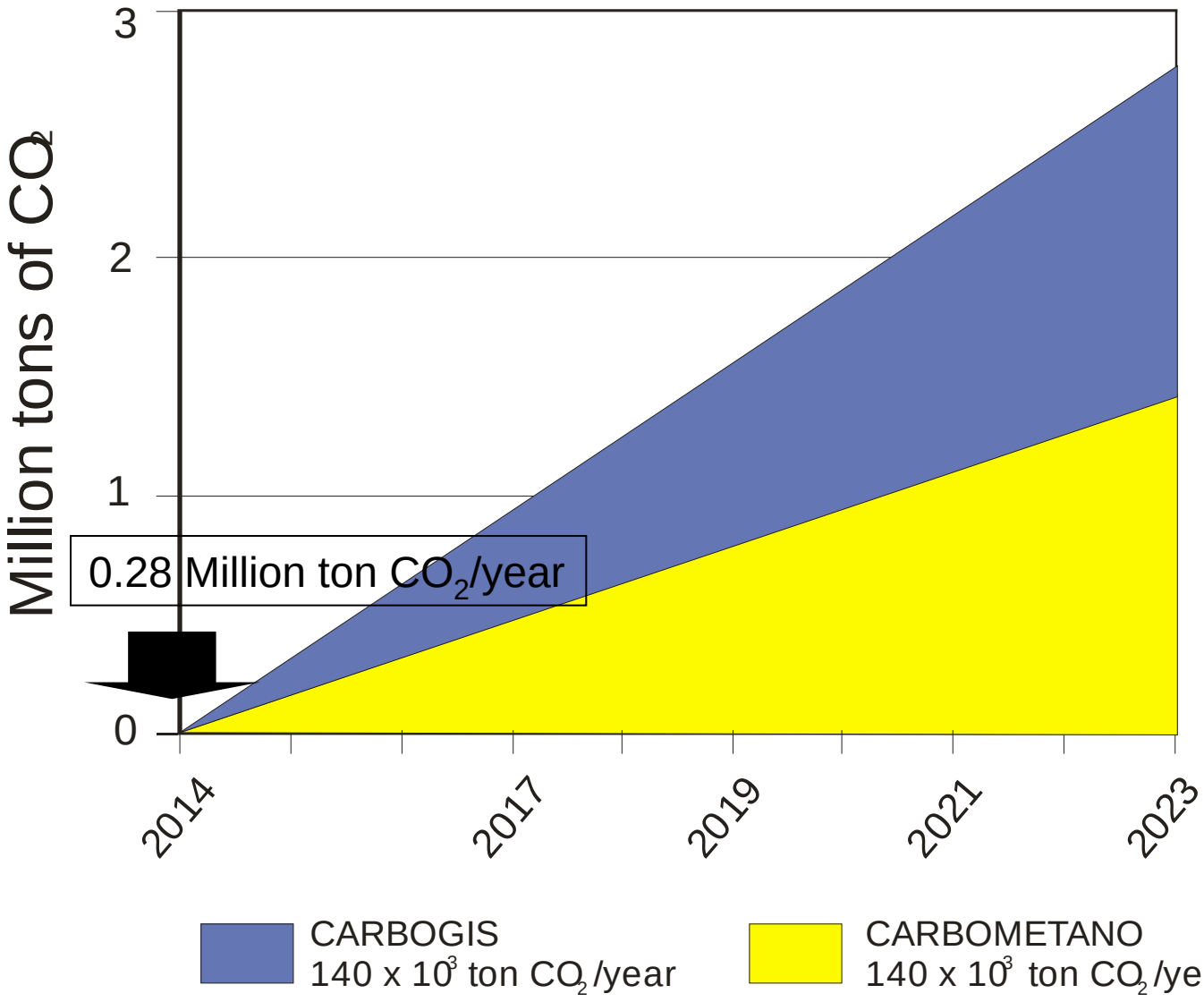
- **CarboGis Project (NETL, LLNL, CEPAC)**

  Objectives:

  - To use Brazilian deep coal resources and unmineable coal seams;
  - To produce clean fuels in a sustainable way;
  - To provide another source of energy for the future Brazilian needs;
  - To develop technologies for underground coal gasification - UCG;
  - CO_2 capture and storage development in UCG.

This project is in final negotiation with the Lawrence Livermore National Laboratory.

Coal Projects – Paraná Basin Project with CCS
Avoided emissions potential

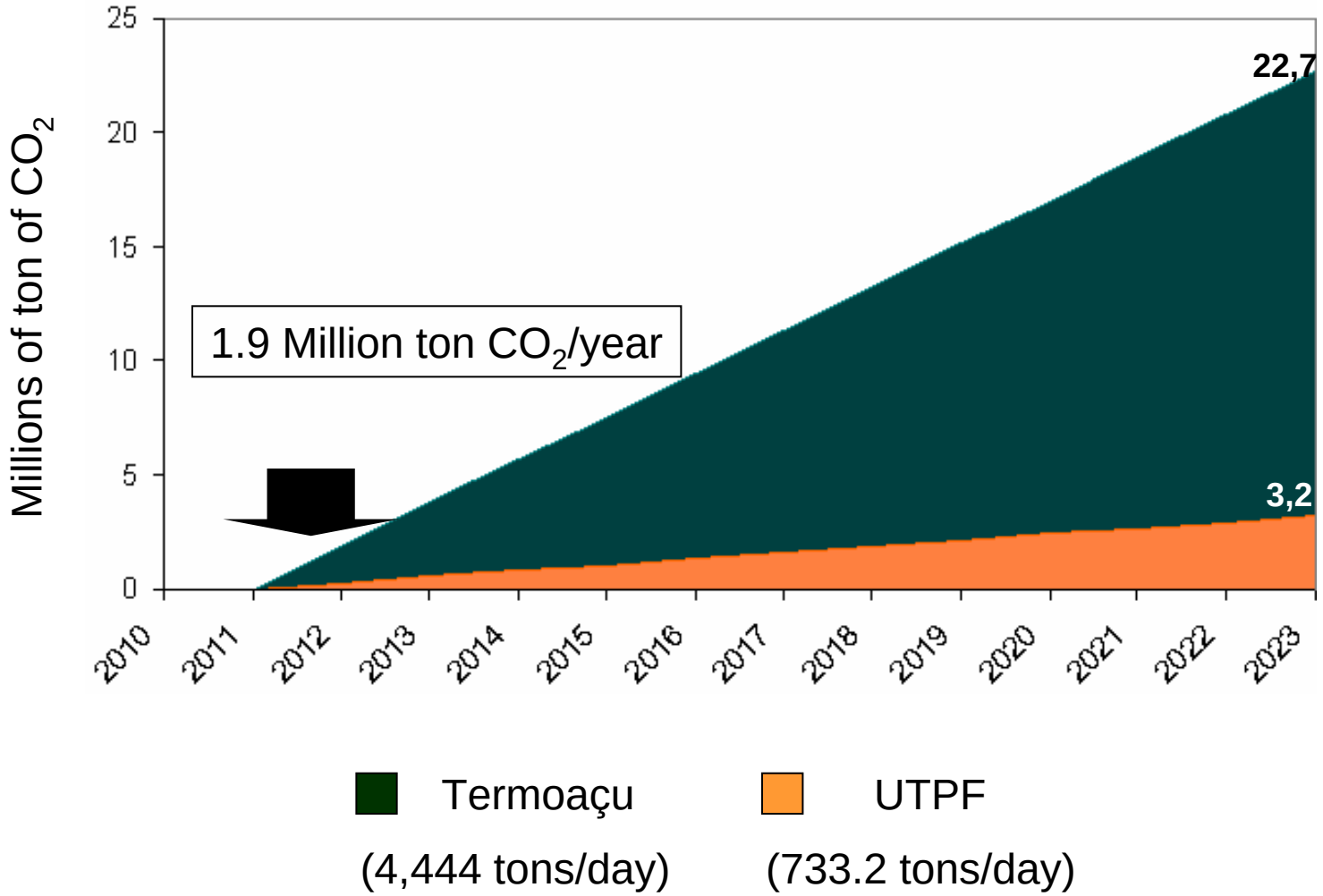


2,8 million tons CO_2 eq by 2023

CARBON SEQUESTRATION IN POTIGUAR BASIN

CO_2 capture in Termoaçu power plant and Petrobras Industrial Unit for EOR/CCS in Potiguar Basin

Potiguar Basin Project with CCS
Avoided emissions potential



Carbon Biomass Fixation First Results

Concerning biomass carbon fixation, we act in almost all Brazilian ecosystems. From Amazonia to Atlantic Forest, typical tropical forests, to Caatinga, Mangroove and Restinga, less compact forests. We also study carbon fixation in pine-trees, fast growing vegetation and microalgae. One of the main characteristics of the carbon biomass fixation R&D projects through reforestment is the socio-economic activities inclusion, in order to mantain this vegetation. This concept also adds activities like oil extraction from native plants seeds for biodiesel production, consequently generating profit and thereby developing this renewable energy source. In addition to these projects, the soil carbon is also been studied, objecting new tillages to greenhouse gases reduction in biofuels agrobusiness.

Biome	Average potential value of carbon sequestration (ton CO_2/ha/year)	Spacing* (m)	Density (trees /ha)
Amazon Forest (Native)	**17**	(5,0 x 2,0)	1.000
Atlantic Forest (Native)	**18,9**	(3,0 x 2,0)	1.667
Atlantic Forest (Intercropped 30% Eucalyptus e 70 % native)	**26,2**	Eucalyptus: (3,0 x 2,0) Native: (3,0 x 2,0)	Eucalyptus: 1.167 Native: 500
Amazon Forest (Intercropped 30% Palm e 70% native)	**15,3**		
Atlantic Forest (Intercropped 87 % Dendê e 13% native)	**17**	Dendê: (9,0 x 9,0) Native: (3,0 x 3,0)	Dendê: 135 Native: 900
Palm (Monoculture)	**11,2**	(9,0 x 9,0 x 9,0)	143
Castor (Monoculture)	**8**	(3,0 x 1,0)	3.333
Elephantgrass (monoculture)	**12,6**	(1,0 x 0,50)	20.000
Eucalyptus (monoculture)	**43,7**	(3,0 x 2,0)	1.667
Pinus (monoculture)	**23,1**	(2,5 x 2,0)	2.000
Hevea brasiliensis (monoculture)	**7**	(7,0 x 3,0)	476

Policy, regulation, incentives, public acceptance communication, technological and technical management for projects related to carbon capture and storage development and implementation

Objectives:

- To implant the Climate Change and Carbon Sequestration Network
- To estimulate policies and regulation and search for sponsors for CO_2 geological storage implementation as an option for climate change mitigation;
- To demontrate to Society through technical communications that CO_2 geological storage is ethical, safe, measurable and verifiable;
- To cooperate with the Science and Technology Ministry – MCT – aiming at the Brazilian Carbon Sequestration Technological Roadmap;
- To participate, representing Brazilian technical group, in the Carbon Sequestration Leadership Fórum – CSLF and in the G8+5 meetings about CCS;
- To participate in the technical Brazilian Delegation in the negotiations of the Conferences of the Parties (COP) and in the meetings of the Subsidiary Body for Scientific and Technological Advice (SBSTA) of the United Nations Framework Convention on Climate Change (UNFCCC).
- To colaborate with Brazilian States strategic plans to promote climate change mitigation, impacts risks and vulnerability, and stabllishing opportunities for CCS

Discussion

Brazil doesn`t have target obligations to reduce its emissions (UNFCCC common but different responsibilities principle) but it is committed to climate change mitigation.

Indeed we have a very clean energy matrix: 95% hydroelectricity , the PROALCOOL with 24% addition to gasoline since the 70's and now the Biodiesel in 2% added to Diesel.

Brazil has a particular emissions profile: 75% comes from deforestation and land use change and only 25% from fossil fuels. And from those approximately 15% only are from stationary sources and so CCS is not a technology to be largely implemented in Brazil .

But for Petrobras and other industries, and considering the local development that can come with CCS projects implementation (with EOR and ECBM activities, and our discussions that are beginning on social and environmental aspects of the sustainability of CCS and perhaps a sort of compensation of future hydrocarbon emissions to be used after their production on those activities) CCS is an important technology for climate change mitigation.

Conclusions

PETROBRAS, a company with environmental and social focus, is in a transition stage from oil company with CO_2 emissions to a clean and sustainable energy company, developing its business with profitability in a climate changeless scenario. CCS will play an important role in this transition

The company believes that carbon sequestration brings us the possibility to accomplish this transition, becoming viable to society a sustainable energy source, that will not cause irreversible damage to the environment. A climate changeless energy and mobility world.

The proposed projects – CCS in the Recôncavo Basin, Campos Basin, Potiguar Basin and Parná Basin to be implemented until 2014, will allow an ammount of almost 9 million tons of CO_2 avoided emissions/year, 18% of the Petrobras emissions in 2006

In 2014, Petrobras will be managing some of the world's biggest CO_2 geological storage projects, all together equivalent to almost nine times the Sleipner Project

Thank You

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