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Vienna International Centre, P.O. Box 300, 1400 Vienna, Austria
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Global Technology Roadmap for CCS in Industry

Policy Workshop – Report Annexes – Part II

7th and 8th April 2011
Rio de Janeiro, Brazil
Petrobras Research Centre, CENPES
(Centro de Pesquisa e Desenvolvimento Leopoldo A Miguez de Mello)

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Annexes

Annex 3: Presentations 6 to 8

6) Mr Yann Le-Gallo Sector focus: emissions sources and reservoirs matching
7) Mr Michael Godec Sector focus: Enhanced Oil Recovery
8) Mr Paulo Negrais

Consulting Engineering Operation

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Engineering for CO_2 geological storage

Global Technology Roadmap for CCS in Industry Policy Workshop

Sector focus: Qualitative Matching of Emissions Sources and Reservoirs Resources

Yann Le Gallo, Ph.D.
Operation Manager

Outline

- Overview of the study
- Storage resources assessment
  - Deep Saline Formations
  - Depleted Oil & Gas Fields
- CO_2 emission assessment
  - Location
  - Evolution scenario
- **Qualitative** source sink matching
  - Focus on Brazil
- Main conclusions and way forward

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Overview of the Study

Work Flow of the Study

High purity CO2
Natural Gas Processing
Coal-To-Liquid
Ethylen
Fertilizer/Amonia

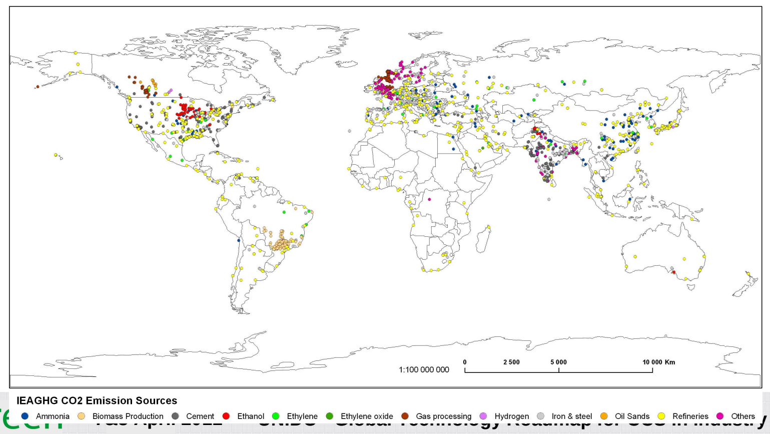
Cement
Klin/calcination

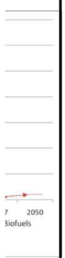
Iron and Steel
Blast Furnace
Direct Reduction of Iron
FINEX technologiies
Hisarma process

Downstream Oil and Gas (refineries)
Hydrogen
Cracking
Process heat

Biomass
Synthetic natural gas
Ethanol
Hydrogen
Black liquor (Pulp&Paper)

Industrial CO2 sources 2008
(IEA GHG CO2 source database)





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Work Flow of the Study

IEAGHG / GCCSI DFS suitability

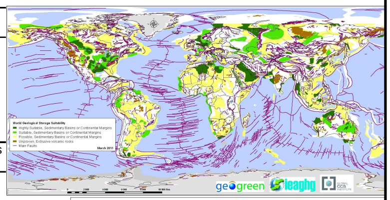
Oil and gas fields*

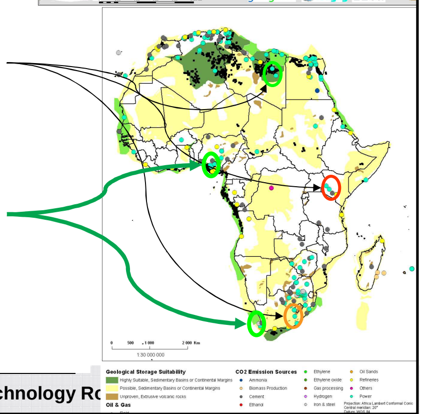
* Oil fields: use IEAGHG study
* Gas fields: use USGS database and correlation between Gas reserves and CO2 capacity and IEAGHG study

Sink Opportunity
DSF Suitability
Oil fields
Gas field capacity est.

Industrial CO2 sources
Evolution towards 2050

Source / sink matching on an area basis
Evolution towards 2050





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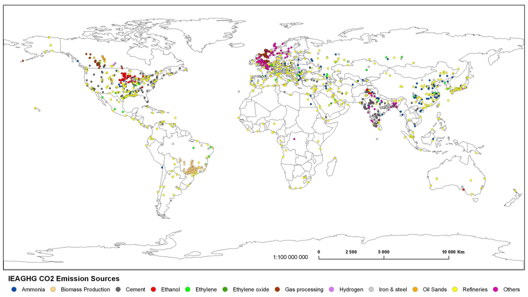
CO_2 emissions

2007 (reference) – 2050 (horizon)

CO_2 emissions

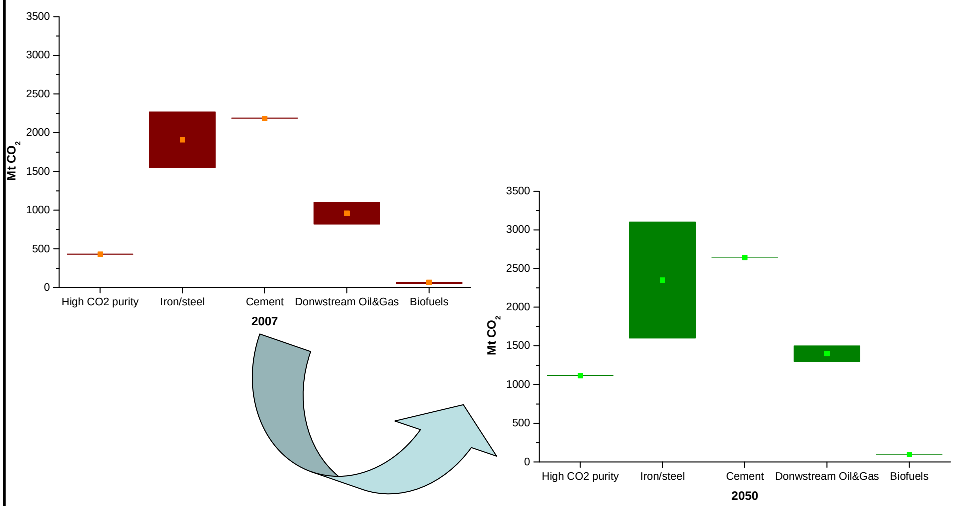
- Assumptions:
  - Constant carbon intensity
  - Growth of the existing sources
- Gaps in location of CO_2 emissions mainly in non-OECD



- UNIDO industrial sectors:

High purity CO_2	Natural Gas Processing
	Coal-To-Liquid
	Ethylene
	Fertilizer/Ammonia production
	Ethylene Oxide production
Iron and steel	Blast Furnace
	Direct Reduction of Iron
	FINEX technologies
	Hisarma process
Cement	Kiln
	Calcination
Downstream Oil and Gas (refineries)	Hydrogen production
	Cracking
	Process heat
Biomass	Synthetic natural gas
	Ethanol production
	Hydrogen from biomass
	Black liquor (Pulp & Paper)

Global evolution of the CO_2 Emission for each sector



Regional trends for Iron&Steel and Cement sectors following IEA ETP 2010 scenario

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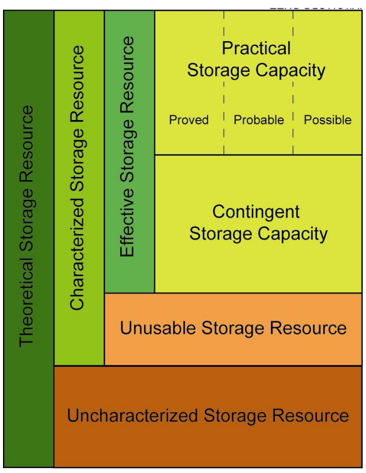
Storage Resources

Deep Saline Formations

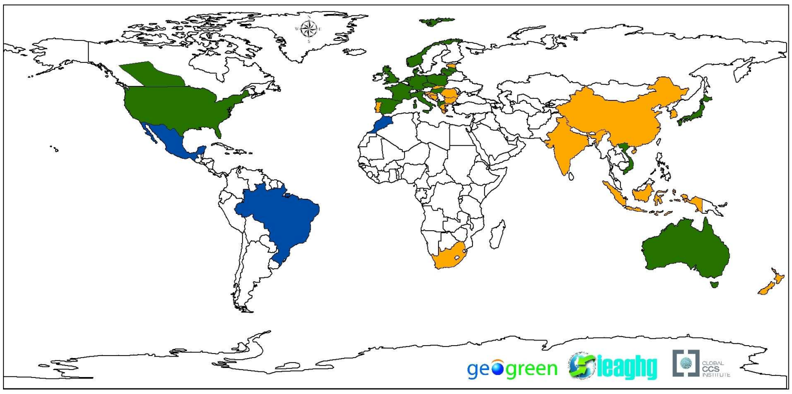
What is the storage ressource in deep saline formations?



Source IEA GHG, 2009

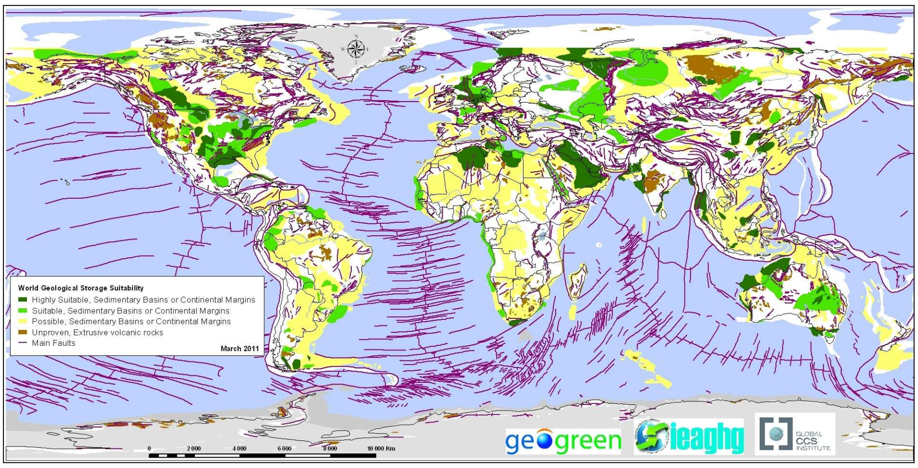
- No available map World Wide

- A few Initiatives (Characterized Resource) in OECD
- A few Initiatives (Theoretical Resource) Initiatives in non-OECD

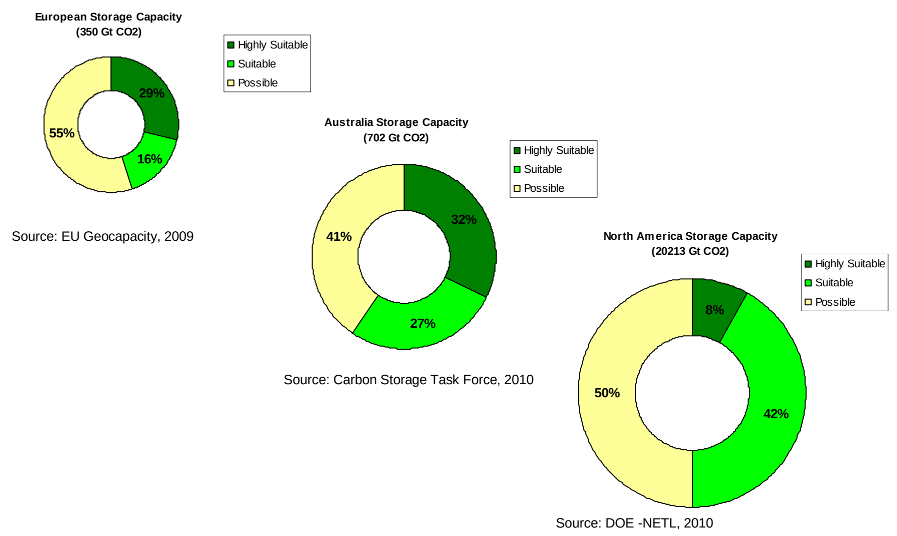


Deep Saline Formations Capacity Assessment Initiatives
Characterized | Theoretical | Under development
February 2011
0 2 000 4 000 6 000 8 000 10 000 Km

Suitability of Deep Saline Formations



Estimated Storage Resources in Deep Saline Formations



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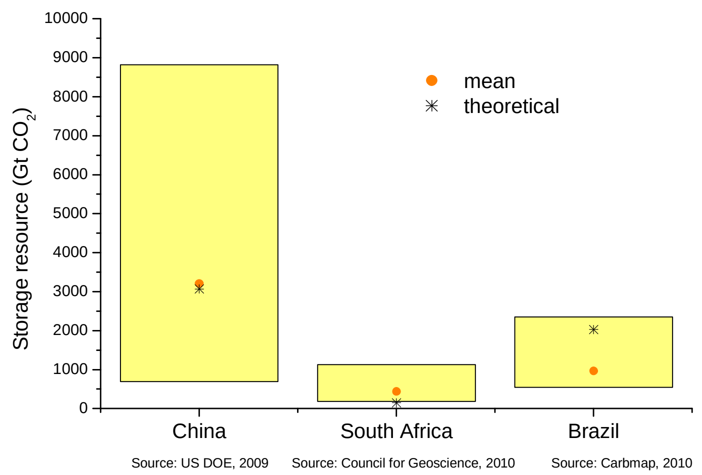
Estimating Storage Resources in Deep Saline Formations



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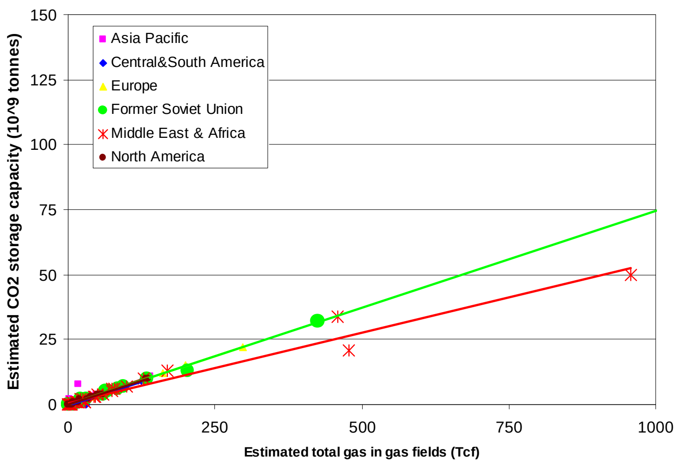
Storage Resources

Depleted Oil & Gas Fields

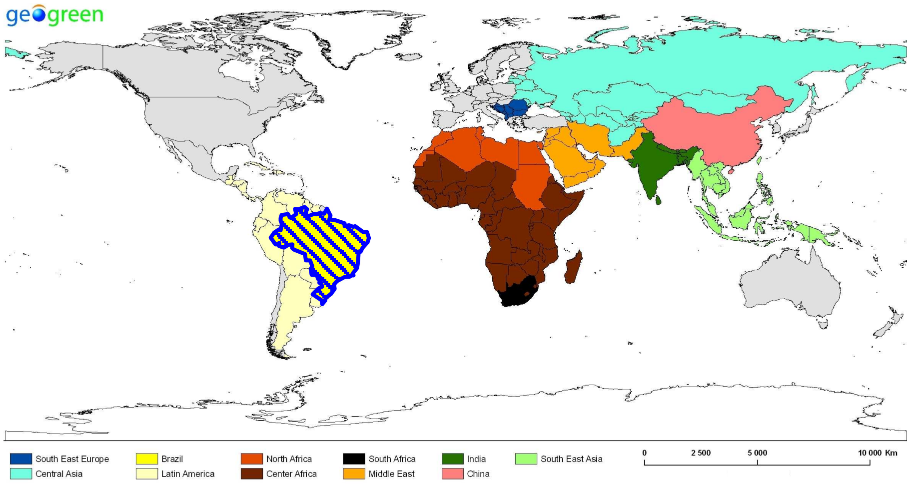
Estimating Storage Resources in Depleted Gas Fields



Adapted from IEA GHG, 2009

Estimating Storage Resources in Depleted Oil Fields : see next presentation

Regions considered in the study



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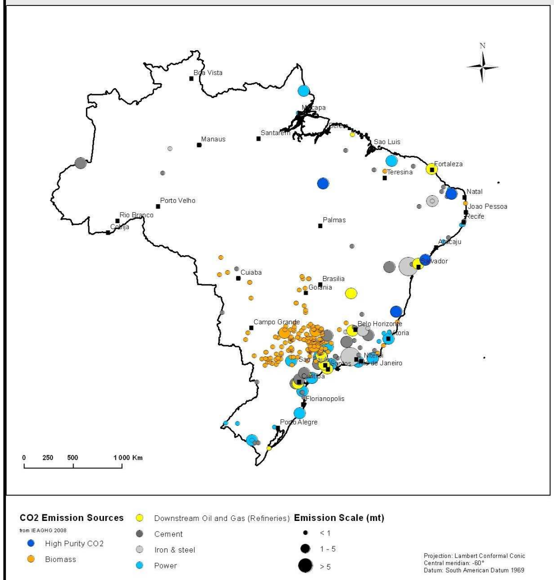
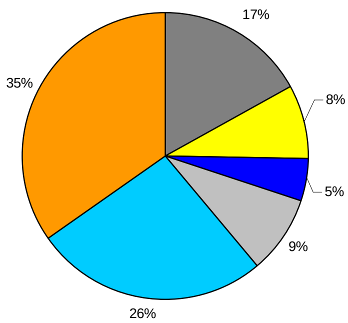
Qualitative Source - Sink Matching

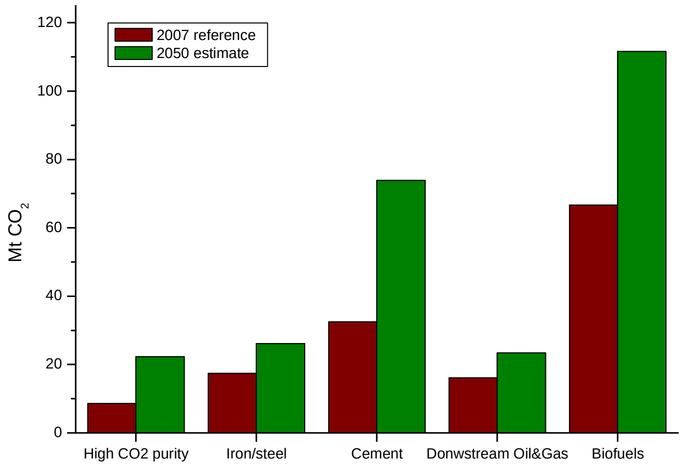
Brazil

CO_2 emissions in Brazil

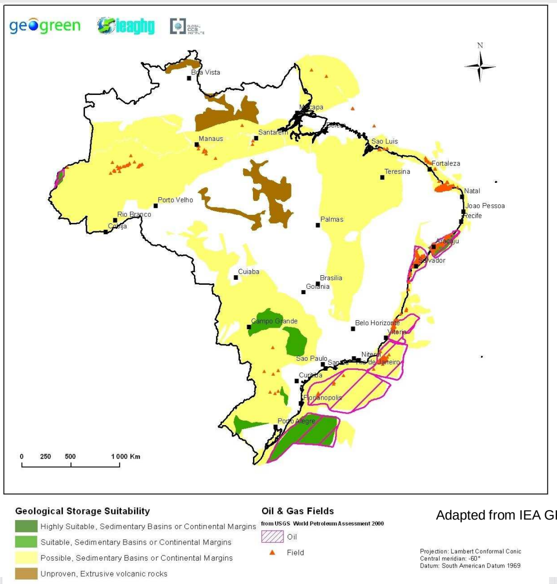




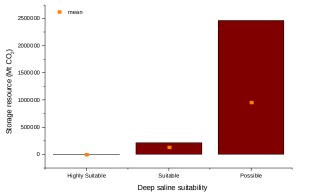
Expected evolutions scenario of CO_2 sources in Brazil



Storage Resources



Deep Saline Formations



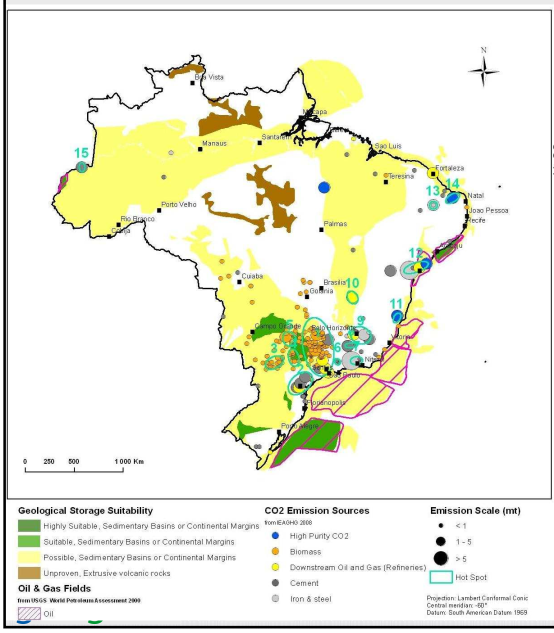
Depleted Oil & Gas Fields

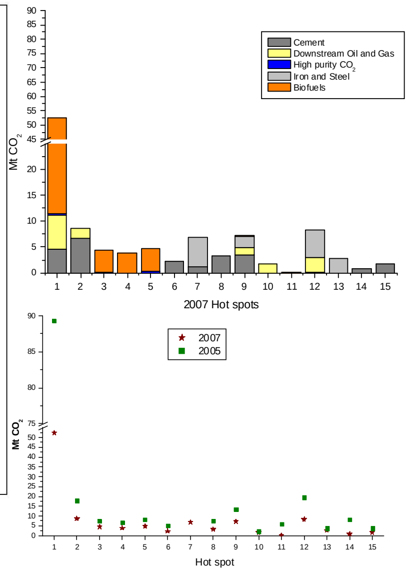
Storage resource	(Mt CO_2)
Oil fields	2700
Gas fields	12700
Total	**15400**

Not accounting for Presalt Deep Water plays

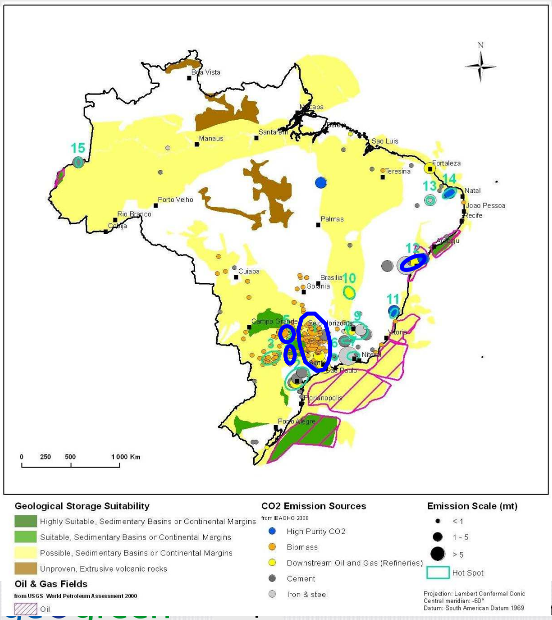
Adapted from IEA GHG (2011) & USGS (2000)

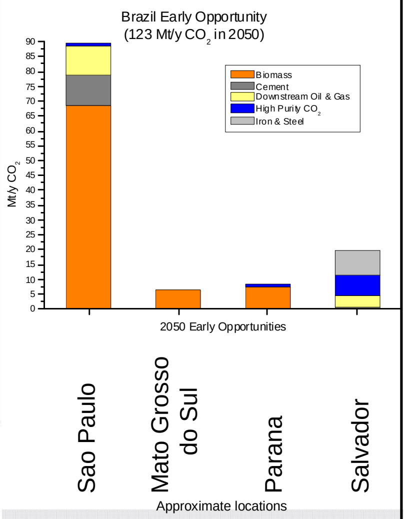
CO_2 emissions hot spots





Early opportunities





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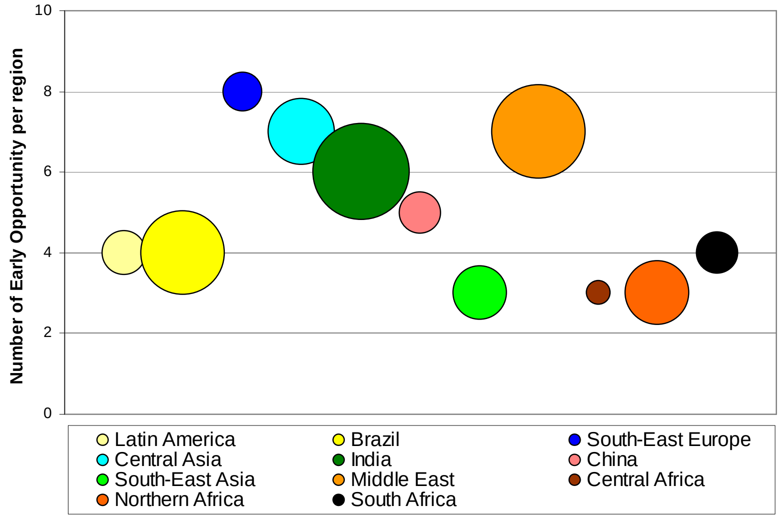
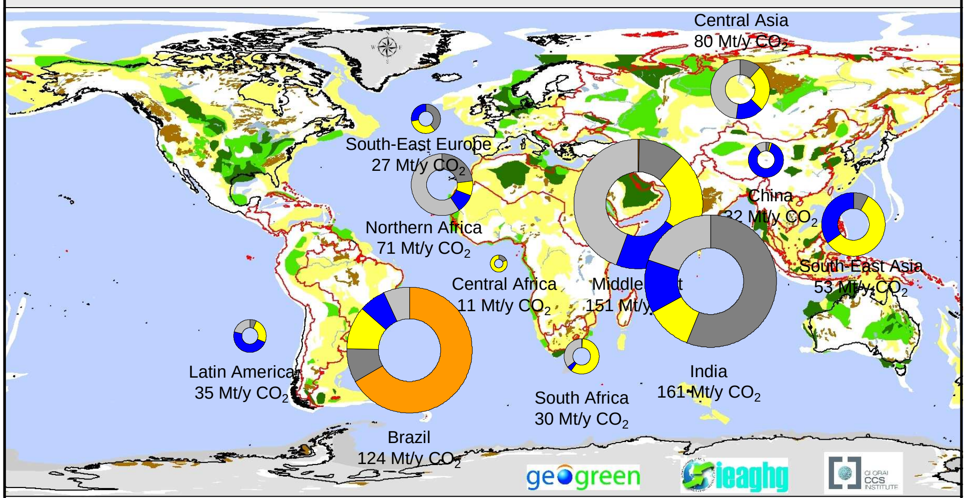
SYNTHESIS

Number and CO_2 Emission of Early Opportunities per region



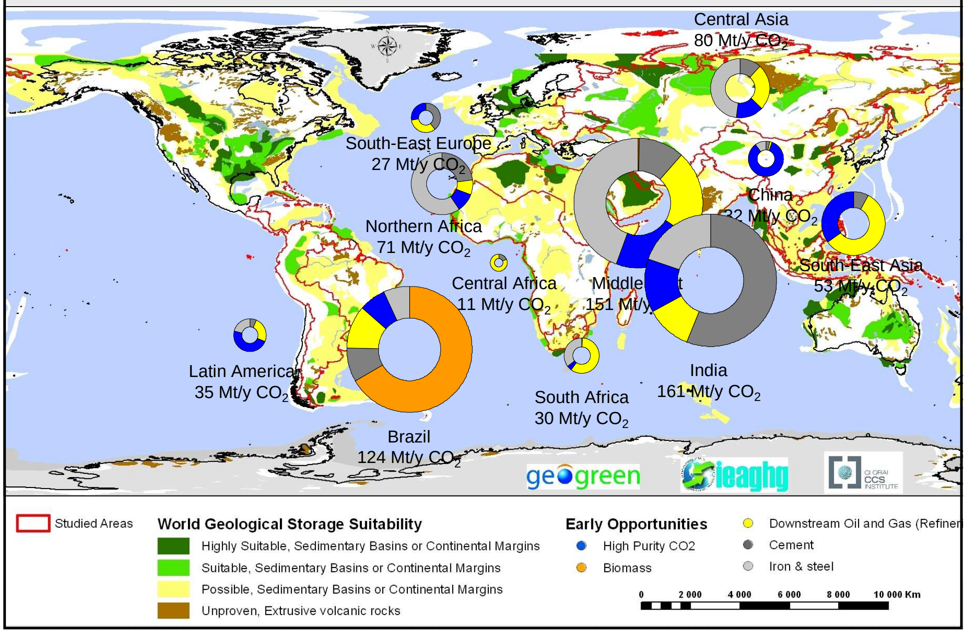


Studied Areas

World Geological Storage Suitability
- Highly Suitable, Sedimentary Basins or Continental Margins
- Suitable, Sedimentary Basins or Continental Margins
- Possible, Sedimentary Basins or Continental Margins
- Unproven, Extrusive volcanic rocks

Early Opportunities
- High Purity CO2
- Biomass
- Downstream Oil and Gas (Refiner
- Cement
- Iron & steel

0 2 000 4 000 6 000 8 000 10 000 Km



Key points

- Study limitations:
  - use publicly available data
  - CO_2 emission location and volume uncertainties
  - storage resources assessment based upon surface density correlations due to lack of data
- Main conclusions
  - Excess storage for Northern & Central Africa, Middle East and Central Asia
  - Storage shortage for India (geological limitations) and to some extent Brazil (source-sink matching)
  - Limited number of Early Opportunities in most regions due to lack of storage resources near industry hot spots.
- Likely competition with Power industry for storage space

Way Forward

- Given uncertainties on non-OECD storage resources:
  - Regional storage resource assessment should be initiated (Deep Saline Formation) to acquire or update geological knowledge
  - Site characterization to confirm storage capacity for First Of A Kind projects
- Given uncertainties on CO_2 sources:
  - Update source database particularly in non-OECD countries
  - Consistency checks with UNFCCC and IEA emission data

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Thank You For Your Attention

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ylg@geogreen.fr

www.geogreen.eu



CO_2 ENHANCED OIL RECOVERY Sectoral Assessment

Presenter: Michael L. Godec
Advanced Resources International

UNIDO/IEA Global Technology Roadmap for CCS in Industry Final Review Workshop

Rio de Janeiro, Brazil
April 7, 2011

Unconventional Resources • Enhanced Recovery • Carbon Sequestration

Advanced Resources International, Inc.



Main Topics of Presentation

- Status of CO_2-EOR
- How CO_2-EOR impacts CCS economics
- Global potential for CO_2-EOR
- Current activities and plans for CO_2-EOR and CCS
- Barriers to greater CO_2-EOR deployment
- Concluding thoughts and discussion

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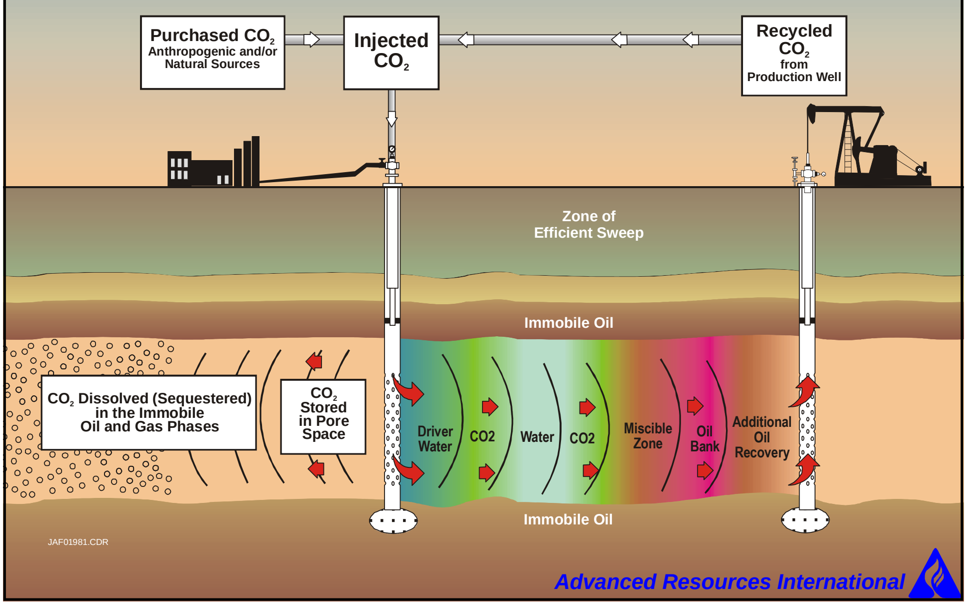
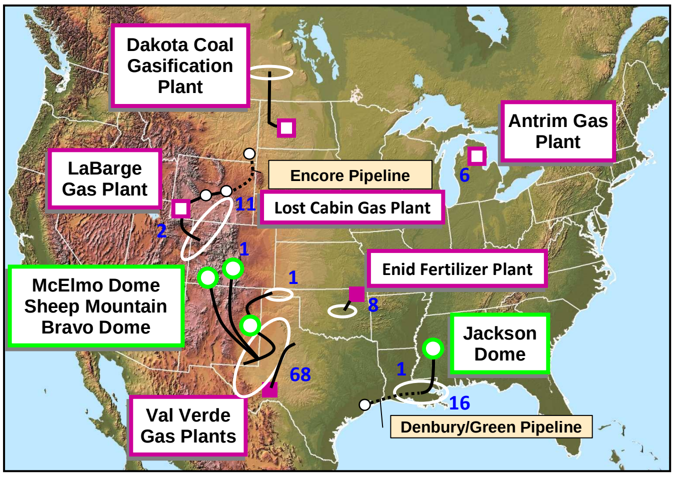
What is CO_2-EOR?



U.S. CO_2-EOR Activity – Oil Fields and CO_2 Sources



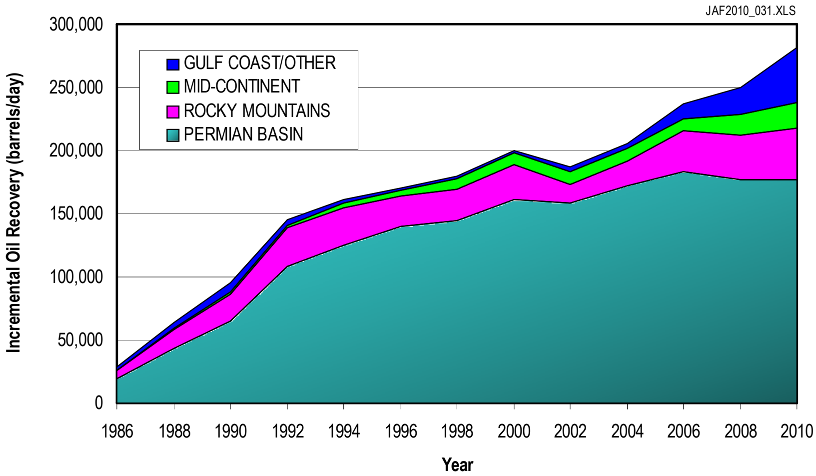
- 114 — Number of CO_2-EOR Projects
- Natural CO_2 Source
- Industrial CO_2 Source
- Existing CO_2 Pipeline
- CO_2 Pipeline Under Development

- Most CO_2-EOR activity currently in North America
- 114 projects produce 281,000 barrels per day in U.S.
- Additional projects planned to increase CO_2 supply to CO_2-EOR
  - Natural & anthropogenic
  - New CO_2 pipelines

Source: Advanced Resources International, Inc., based on Oil and Gas Journal, 2010 and other sources.

Advanced Resources International, Inc.

Growth Of CO_2-EOR Production in the U.S.



Source: Advanced Resources Int'l., based on Oil and Gas Journal, 2010.

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Significant Volumes of CO_2 Are Already Being Injected for EOR in the U.S.

State / Province for EOR / Storage	CO_2 Source Type and Location	CO_2 Supply (MMcfd) Geologic	Anthropogenic
Texas-Utah- New Mexico-Oklahoma	Geologic (Colorado-New Mexico) Gas Processing (Texas)	1,540	180
Colorado-Wyoming	Gas Processing (Wyoming)	-	320
Mississippi	Geologic (Mississippi)	900	-
Michigan	Ammonia Plant (Michigan)	-	15
Oklahoma	Fertilizer Plant (Oklahoma)	-	30
Saskatchewan	Coal Gasification (North Dakota)	-	150
TOTAL (MMcfd)		**2,440**	**695**
TOTAL (million tonnes per year)		**47**	**13**

** Source: Advanced Resources International, 2009*

***MMcfd of CO_2 can be converted to million metric tons per year by first multiplying by 365 (days per year) and then dividing by 18.9 * 10^3 (Mcf per metric ton)*

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Illustrative Costs for Representative CO_2-EOR Projects in the U.S.

Example EOR Field	East Texas Reservoir		California Reservoir		Oklahoma Reservoir	
Field Info						
Depth	5,750		5,319		6,700	
Total Oil Production (Million Barrels)	112.0		140.0		81.3	
Injected CO_2 (Tonnes/Bbl)	0.24		0.28		0.23	
Produced Oil (Bbls/ton of Captured CO_2)	**4.12**		**3.63**		**4.33**	
No of Patterns	24		40		257	
Capital Costs ($Million, discounted)						
Wells						
Sub Total	**$**	**81.81**	**$**	**123.59**	**$**	**843.54**
$/Bbl	**$**	**2.12**	**$**	**2.33**	**$**	**23.76**
Other						
CO_2 Recycling Plant	$	45.90	$	66.94	$	43.35
Trunkline Construction	$	3.15	$	3.15	$	3.15
Next Generation Capex	$	13.09	$	19.37	$	89.00
Cap Ex G&A	$	28.79	$	42.61	$	195.81
Pipeline to Field	$	54.30	$	54.30	$	54.30
Sub Total	**$**	**145.22**	**$**	**186.37**	**$**	**385.61**
$/Bbl	**$**	**3.76**	**$**	**3.52**	**$**	**10.86**
Total Capex	**$**	**227.03**	**$**	**309.96**	**$**	**1,229.15**
$/Bbl	**$**	**5.88**	**$**	**5.85**	**$**	**34.61**
O&M Costs ($/Bbl, discounted)						
Operating & Maintenance	$	0.73	$	0.85	$	6.33
Operating & Maintenance EOR	$	0.07	$	0.08	$	0.63
Lifting Costs	$	1.51	$	3.19	$	2.04
G&A	$	0.45	$	0.81	$	1.67
Pipeline	$	0.05	$	0.05	$	0.05
Total O&M Costs	**$**	**2.80**	**$**	**4.98**	**$**	**10.72**

Distribution of Economic Value of Incremental Oil Production from CO_2-EOR

(Given Fiscal Regime in the U.S.)

Notes		Oil Industry	Private Minerals	Federal/ State	Power Plant/ Transportation	U.S. Economy
1	**Domestic Oil Price ($/B)**	**$100.00**				
2	Less: Royalties	($17.50)	$14.60	$2.90		
3	• Production Taxes	($4.10)	($0.70)	$4.80		
4	• CO2 Purchase Costs	($17.50)			$17.50	
5	• CO2 Recycle Costs	($12.00)				$12.00
6	• Other O&M Costs	($8.00)				$8.00
7	• Amortized CAPEX	($4.00)				$4.00
	Total Costs	**($63.10)**			-	
	Net Cash Margin	**$36.90**	**$13.90**	**$7.70**	**$17.50**	**$24.00**
8	**Income Taxes**	**($12.90)**	**($4.90)**	**$17.80**	**?**	**?**
	Net Income ($/B)	**$24.00**	**$9.00**	**$25.50**		

JAF2011_008.XLS

1. Assumes $100 per barrel of oil.
2. Royalties are 17.5%; 1 of 6 barrels produced are from federal and state lands.
3. Production and ad valorem taxes of 5%, from FRS data.
4. CO_2 cost of $50/metric ton, including transport; 0.35 tonne of purchased CO_2 per barrel of oil.
5. CO_2 recycle cost of $20/ metric ton; 0.6 tonne of recycled CO_2 per barrel of oil.
6. Other O&M/G&A expenses from ARI CO_2-EOR cost models.
7. CAPEX from ARI CO_2-EOR cost models.
8. Combined federal and state income taxes of 35%, from FRS data.

Distribution of Economic Value of Incremental Oil Production from CO_2-EOR
(Given Fiscal Regime in the U.S.)

		Oil Price	
	Recipients of Revenues from CO_2-EOR	$75/B	$100/B
1	Oil Industry	$15.50	$24.00
2	Private Mineral Owner	$6.80	$9.00
3	Power Plant/CO_2 Transporter	$14.00	$17.50
4	Federal/State Governments	$17.70	$25.50
5	U.S. Economy	$21.00	$24.00
	TOTAL	$75.00	$100.00

JAF2011_008.XLS

*Range reflects: (1) 30 billion barrels of oil and 8.8 Gt of CO_2 demand using State-Of-The-Art CO_2-EOR at $75/B oil price/$40 mt CO_2 sales price and (2) 58 billion barrels of oil and 20 Gt of CO_2 demand using Next Generation CO_2-EOR at $100/B oil price and $50/mt CO_2 sales price.
**Total demand reduced by 2.1 Gt from natural sources and gas processing plants.

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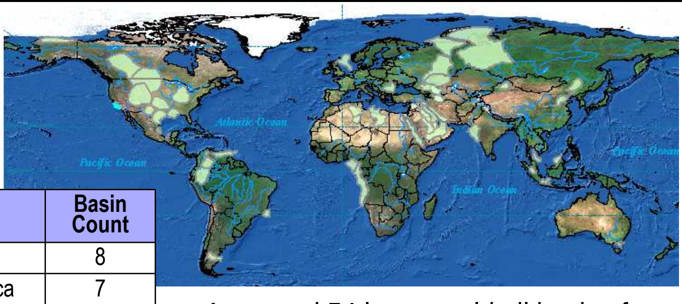
Basins Assessed for CO_2-EOR Potential



Region Name	Basin Count
Asia Pacific	8
Central and South America	7
Europe	2
Former Soviet Union	6
Middle East and North Africa	11
North America/Other	3
North America/United States	14
South Asia	1
S. Africa/Antarctica	2
Total	**54**

Assessed 54 large world oil basins for CO_2-based Enhanced Oil Recovery

- High level, 1st order assessment of CO_2-EOR and associated storage potential, using U.S. experience as analogue.
- Tested basin-level estimates with detailed modeling of 47 large oil fields in 6 basins.

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CO_2-EOR Potential in World's Oil Basins*

(Billions of Barrels)

Region	CO_2-EOR, Discovered Fields		CO_2-EOR, Undiscovered Resources	Total Potential
	Large	Small		
1. Asia Pacific	18	7	5	30
2. C. & S. America	32	12	16	60
3. Europe	16	6	6	28
4. FSU	79	29	44	152
5. M. East/N. Africa	231	85	96	412
6. NA/Other	18	7	4	29
7. NA/U.S.**	60	23	38	121
8. South Asia	-	-	-	-
9. S. Africa/Antarctica	15	5	29	49
TOTAL	**469**	**174**	**238**	**881**

* Includes potential from discovered and undiscovered fields, but not estimated future growth in discovered fields

** Not including offshore & Alaska

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CO_2 Storage Potential with CO_2-EOR (inc. Reserves Growth)

Region	CO_2-EOR Potential (Billion Barrels)	CO_2 Storage Potential (billion tonnes)
1. Asia Pacific	30	8
2. C. & S. America	60	20
3. Europe	28	8
4. FSU	152	42
5. Middle East/N. Africa		125
6. N. America/Non U.S	29	9
7. United States	121	34
8. South Asia	-	-
9. S. Africa/Antarctica	49	15
Subtotal	**881**	**261**
Add'l w/ Res. Growth	191	57
TOTAL	**1,072**	**318**

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CO_2 Requirements for CO_2-EOR That Could Be Supplied by Industrial Sources

50 Kilometer Case -- Large Discovered Fields Only					
Region	Number of Basins	EOR Potential (MMBbls)	Purchased CO_2 Required for EOR (MMmt)	High Purity CO_2 Emissions (%)	Total Industrial CO_2 Emissions (%)
Africa	6	35,642	10,474	0%	6%
Australia	1	1,286	324	0%	0%
Canada	2	5,747	1,763	37%	97%
China Region	3	14,022	3,838	9%	23%
CIS	5	73,018	19,897	1%	6%
East Asia	2	3,068	837	0%	2%
Eastern Europe	1	1,939	621	20%	74%
Latin America	6	40,959	13,167	1%	6%
Middle East	8	215,200	65,783	1%	3%
OECD Europe	1	14,373	4,031	9%	10%
South America	1	3,072	1,095	0%	2%
USA	14	60,204	17,205	16%	66%
Total	**50**	**468,530**	**139,034**	**4%**	**14%**

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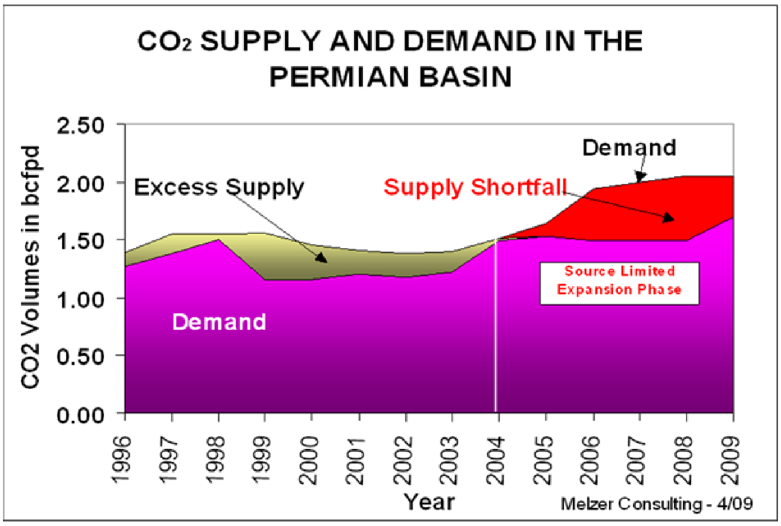
Since 2004, CO_2-EOR Demand for CO_2 has Exceeded CO_2 Supply in the Permian Basin



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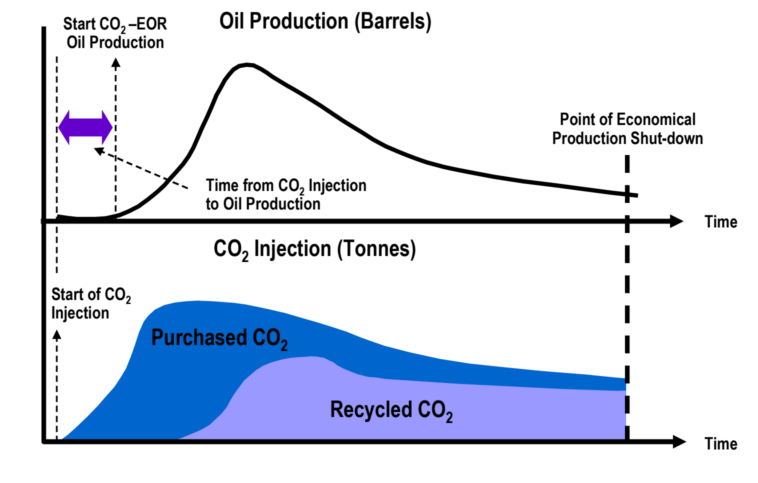
Profiles for CO_2 Injection and Oil Production in CO_2-EOR



Source: Bellona, 2005

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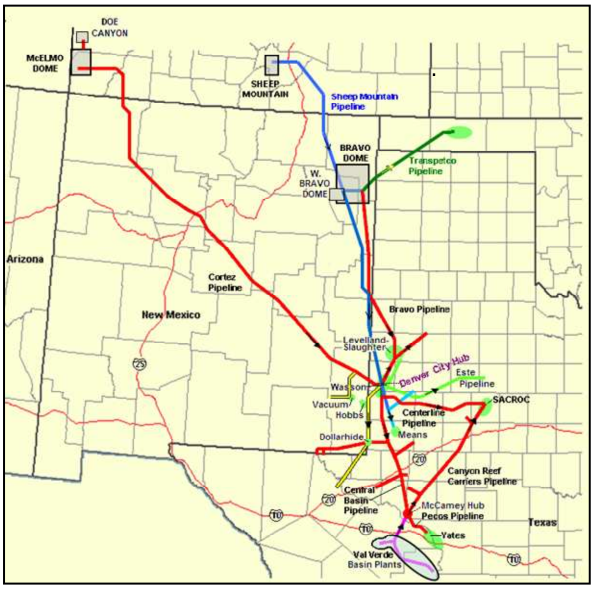
Existing CO_2 Pipelines (U.S. Permian Basin)



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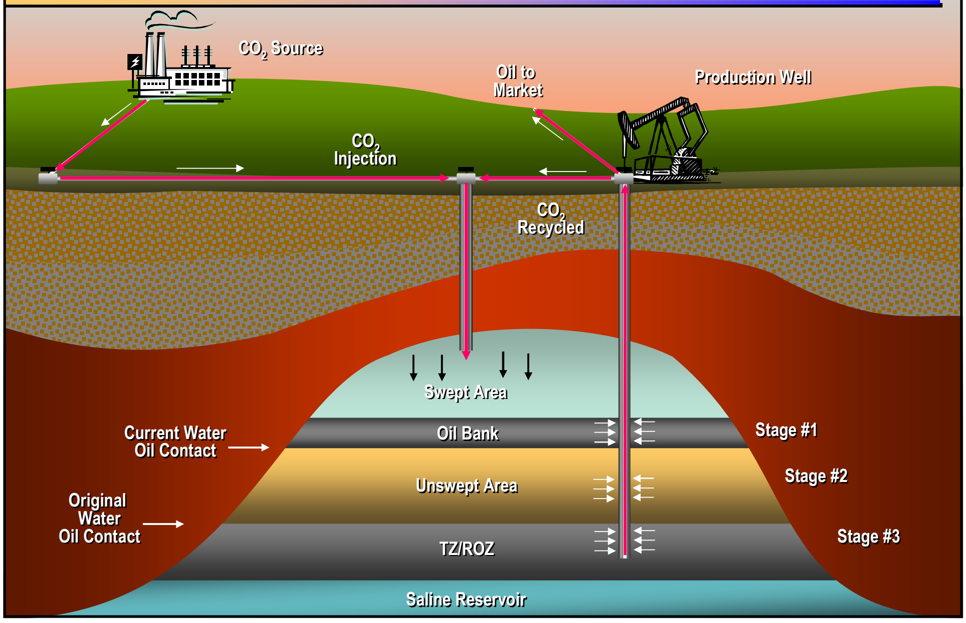
Integrating CO_2-EOR and CO_2 Storage Could Increase Storage Potential



Current Activities and Project Plans for CO_2-EOR and CCS

- In addition to > 120 CO_2-EOR projects being pursued around the world, the Global CCS Institute reports 77 large-scale integrated projects (LSIPs) at various stages of the asset life cycle
- Include 8 operating projects and 4 projects in the execution phase of the project life cycle
  - Vast majority in developed countries
- Of the 77 LSIPs, 34 (44%) are targeted for EOR applications. 5 of the 8 LSIPs and 3 of the 4 in execution are injecting CO_2 for EOR
- Outside of North America, the Global CCSI identified projects underway in China, Netherlands, UAE

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CCS Needs CO_2-EOR

Benefits of Using CO_2-EOR to Accelerate CCS Deployment

- ***Additional Revenues Offset the Costs of CCS***. The sale and use of captured CO_2 for EOR provides revenue that can offset the costs of CCS. The value of this offset is highly project dependent.
- ***Variety of Entities Benefit from these Revenues***. These include the oil producers, land owners, the sources of CO_2 emissions, the government, and the economy.
- ***CO_2-EOR Helps Overcome Other Barriers to CCS***. Enables CCS projects to be implemented while “thorny issues” (e.g., pore space rights, public acceptance) with saline formations are resolved.
- ***Increasing Energy Production***. Productive use of captured CO_2 emissions industrial facilities could increase oil production.
- ***Oil Production with Lower CO_2 “Footprint*.**” Oil production from CO_2-EOR has half the emissions of traditional EOR production; optimizing for CO_2 storage could result in an even smaller, and perhaps negative, “footprint”

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CO_2-EOR Needs CCS

Achieving the Benefits of Increased Domestic Production from CO_2-EOR Requires CO_2

- Growth in production from CO_2-EOR is now limited by the availability of reliable, affordable CO_2.
  - There are more prospective CO_2-EOR projects than there is CO_2 to supply them
- If increased volumes of CO_2 do not result from climate legislation or other policies stimulating CCS, then the benefits cited from CO_2-EOR may not be realized.
- Thus, not only does CCS need CO_2-EOR to ensure viability of CCS, but CO_2-EOR needs CCS to ensure adequate CO_2 to facilitate CO_2-EOR growth.
- This will become even more apparent as potential new targets for CO_2-EOR become recognized.

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Concluding Thoughts and Observations

1. ***CCS Benefits from CO_2-EOR***. The revenues (and cost avoidance) from sale of CO_2 to EOR (combined with other policies) can help make CCS economically feasible, overcomes some barriers to CCS, while producing oil with a lower CO_2 emissions "footprint."
2. ***CO_2-EOR Needs CCS.*** Large-scale implementation of CO_2-EOR is dependent on CO_2 supplies from industrial sources.
3. ***CO_2-EOR Offers Large CO_2 Storage Capacity.*** CO_2-EOR in oil fields can accommodate a major portion of the CO_2 captured from industrial facilities for the next 30 years.
4. ***Both CCS and CO_2-EOR Need Supportive Policies and Actions.*** Supportive policies and pre-built CO_2 pipelines would greatly accelerate the integrated use of CO_2-EOR and CCS.

Advanced Resources International, Inc.

Office Locations
Washington, DC
4501 Fairfax Drive, Suite 910
Arlington, VA 22203
Phone: (703) 528-8420
Fax: (703) 528-0439

Houston, Texas
11490 Westheimer, Suite 520
Houston, TX 77042
Phone: (281) 558-6569
Fax: (281) 558-9202

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Petrobras CCS Initiatives

Paulo Negrais Seabra, D.Sc.
Petrobras' Research and Development Center - CENPES

UNIDO Global Technology Roadmap on CCS in Industry — Rio de Janeiro, 7-8 April 2011

Agenda

- **Brazilian Climate Change Scenario**
- **Petrobras & CCS**
- **Petrobras R&D Portfolio**
- **Carbon Sequestration Technology and Climate Change Network**
- **CCS – Reconcavo Basin**
- **Pre-salt Development**

Brazilian Climate Change Scenario

- Brazil doesn't have target obligations to reduce its emissions but it is committed to climate change mitigation and recognizes the CCS technologies as an important option for a global climate change mitigation.
- Brazil has a very clean energy matrix: 46 % is renewable , 74% hydroelectricity, 24% addition of ethanol to gasoline since the 70's and now the biodiesel in 5% added to diesel.
- Brazil has a particular emissions profile: 80% of the GHG emissions comes from land use change, including conversion of forests to other uses,16.5% from fossil fuels.
- Forest conservation is one of the Government's priorities.
- Climate Change National Policy - approved in December 2009. Brazil is implementing voluntary mitigations actions to reduce from 36.1% to 38.9% of the GHG emissions projected to 2020.
- Climate Change National Fund Law approved in December 2009.
- Petrobras has discovered huge oil reserves in deep water – Pre-Salt.

Sources: Mines and Energy Ministry (2010); Empresa de Pesquisa Energética (2008)

Petrobras & CCS

How Carbon Sequestration is considered in PETROBRAS?

MISSION

Operate in a safe and profitable manner in Brazil and abroad, with **social and environmental responsibility**, providing products and services that meet clients' needs and that contribute to the development of Brazil and the countries in which it operates

2020 VISION

We will be one of the five largest integrated energy companies in the world and the preferred choice among our stakeholders.

Source: Petrobras' Annual Report 2008

Petrobras & CCS

PETROBRAS STRATATEGIC CLIMATE CHANGE PROJECT - Drivers

- Maximize the energy efficiency in the processes, projects, and products;
- Develop new business opportunities in the areas of biofuels, considering the contribution to the sustainability of business and the mitigation of global climate change;
- Invest in R&D of technologies for the mitigation of climate change:
  - Capture and geological storage of CO_2
  - Energy Efficiency
  - Investigate new uses for CO_2 as a raw material
  - Lifecycle assessment
  - Climate change impacts, vulnerability and adaptation

Source: Espinosa et. al. SPE International Conference on HSE in Oil and Gas Exploration and Production, 2010

Petrobras R&D Portfolio

- CENPES (Petrobras R&D Center) has 2 Technological Programs in CO2 Capture, Sequestration, Transport, Geologic Storage and Monitoring:
  - PROCLIMA - Technological Program on Climate Change, created in 2007, comprehensive and long-term
  - PRO-CO2 - Technological Program on CO2 management of Presalt, created in 2009, with a focus on the issues of CO2 in the development of Santos Basin Presalt cluster (short term).
- Joint industrial projects with energy companies and international operators;
- Multiclient projects : CO2 Capture Project (CCP); CO2PIPETRANS & CO2QUALSTORE (DNV);
- Strategic alliances with national and international research institutions;
- Participation in international institutions: International Petroleum Industry Environmental Conservation Association (IPIECA), CCS - Society of Petroleum Engineers (SPE), Carbon Sequestration Leadership Forum (CSLF) e WBCSD (World Business Council for Sustainable Development).
- Investments of US$ 200 million – 2010 to 2015

Carbon Sequestration Technology and Climate Change Network

OBJECTIVE :

Implant and consolidate the technological and infra-structure base in the country with extensive capacitating to understand Petrobras´ challenges in Carbon Sequestration and climate change, with research in lab scale, pilot and demonstration projects for the final implantation of such results in the company.

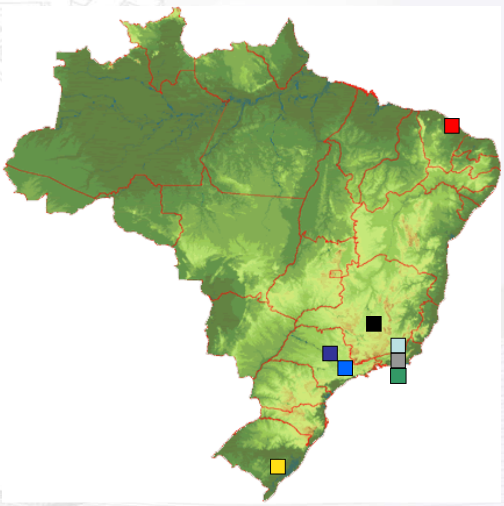
Research Institutions that are part of the network:
PUCRS, UNIFACS, UFPR, INPA, INPE, UFRJ, USP, FURG

PETROBRAS CENPES Centro de Pesquisa e Desenvolvimento

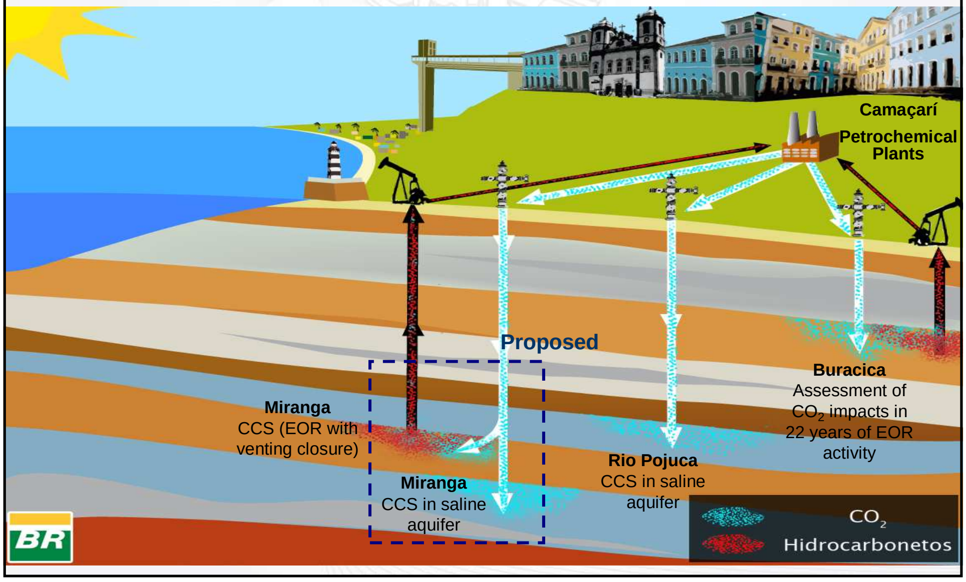
Carbon Sequestration Technology and Climate Change Network

CO2 Capture Projects

- Adsorption (UFC)
- Polymeric Membranes (UFRJ)
- Modeling and Technology Capture Simulation (UFRJ)
- Inorganic Membranes (UFMG)
- Chemical Looping (INPE)
- Ionic Liquids (PUCRS/UFRGS)
- Metal Organic Framework – MOFs (UFRJ)
- Nanostructured solids (UNICAMP)



CCS – Reconcavo Basin



CCS – Reconcavo Basin

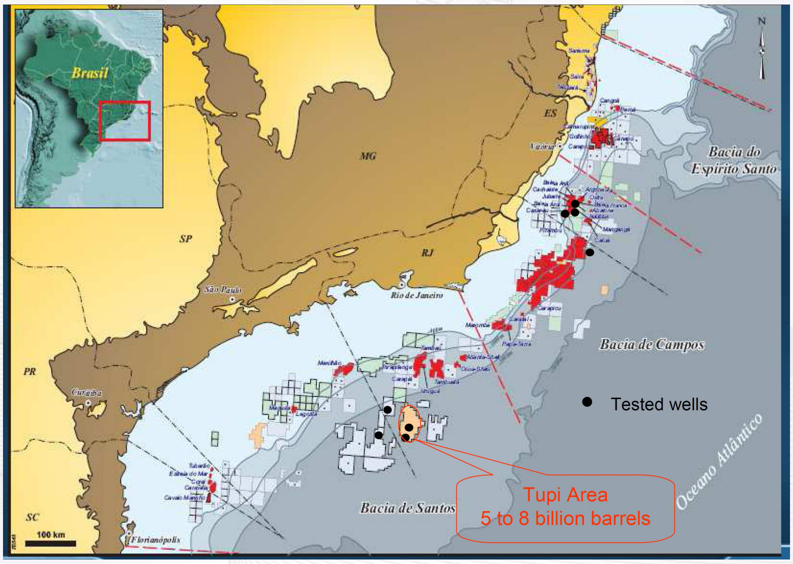
Buracica Field - 22 years of EOR-CO_2 impacts; excellent test fields to validate and develop CCGS technologies

- MMV (measuring, monitoring and verification): Technologies evaluation in Buracica Field, aiming at the future application in the Miranga Field (partnership with IFP).
- Rock/fluid interactions mechanisms: Injectivity & caprock integrity (Geochemical studies of reservoir and caprock).
- Well Integrity: Evaluation of CO_2 effects in the well/reservoir interface after 16 years of injection. Study with CCP (CO2 Capture Project) participation.
- Geochemical monitoring.

Rio Pojuca Aquifer

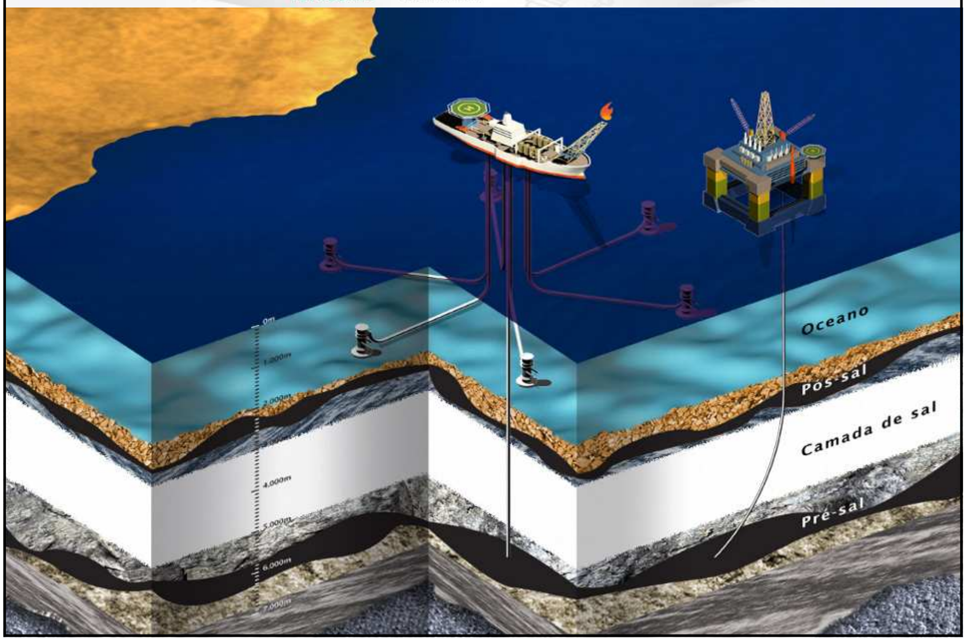
- CCGS Pilot in Saline aquifer: Study, dimension, select and test a saline aquifer - the first Petrobras pilot project in CO_2 storage.

Pre-salt Development



Source: Sampaio et. al. SPE International Conference on HSE in Oil and Gas Exploration and Production, 2010

Pre-Salt Scheme

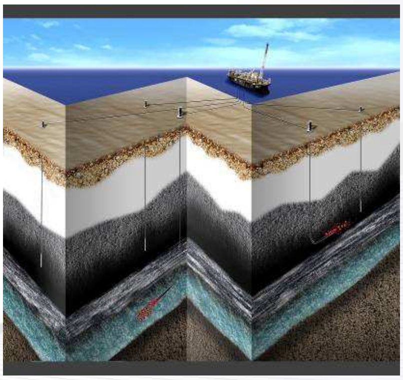


CO2 Geological Storage in the Pre-salt

Motivation:

High CO_2 content found in hydrocarbon in some wells.

Petrobras and partners do not consider venting the CO_2 associated to the produced gas.



Considered Alternatives:

- EOR in Pre-salt reservoirs
- EOR in Heavy Oil Fields
- Storage in Depleted Gas Fields
- Storage in Saline Aquifers

CCS in the Pre-salt – Present Results

- EOR (WAG) considered as the CO_2 storage alternative;
- CO_2 reinjection into aquifers considered as contingence;
- CO_2 capture available technologies being used by major players: membranes and absorption (amines) - selection depends upon the CO_2 content;
- Studies performed up to now in the Pre-salt Area indicates that membrane as potential technology;
- In parallel, efforts are being made to develop new options more appropriated to the Pre-salt scenario, together with providers and research institutions.

CO2 Geological Storage in the Pre-salt

- CO_2 impact on rigid pipes and risers – Sub-Sea
- Offshore CO2 Process – Reduce footprint, space and weight
- Flow Assurance with CO_2
- CO_2 Compression & Pumping System
- Reservoir: CO_2 monitoring strategies and technologies

Petrobras R&D Portfolio

SOME OTHERS ACHIEVEMENTS

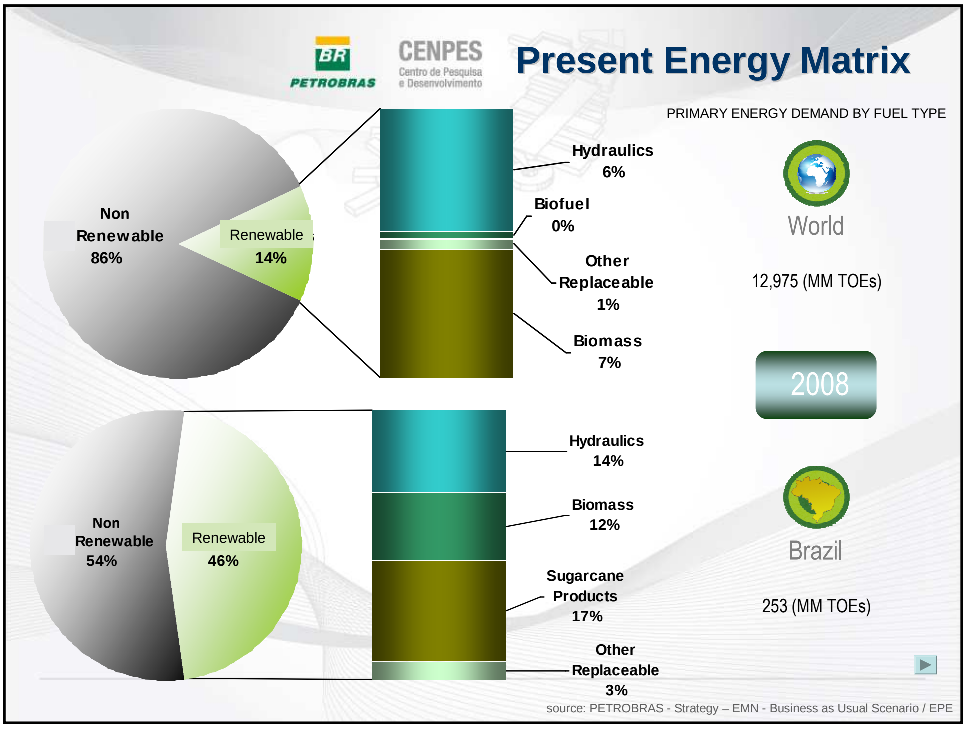
- R&D initiatives for carbon fixation in biomass with Brazilian universities (microalgae).
- Oxy-fired FCC Pilot Plant Demonstration - Vacuum Gasoil & Atmospheric Residue Feeds (CO2 Capture Project – Phase III)
- Participation on the Carbon Sequestration Leadership Forum (CSLF).
- Participation on IPCC's special report on CCS.
- Realization of a technological monitoring of CO_2 and climate change technologies.
- Basis for a creation of Integrated Center for CCS in Salvador.

Conclusions

- Petrobras is committed with Climate Change Mitigation, and has established voluntary objectives and targets related to emission intensity reduction;
- Strong investments in R&D is been done in Climate Change Mitigation technologies;
- Petrobras and partners are committed to reduce the emissions related to the CO_2 produced with the hydrocarbon in the Santos Pre-salt cluster;
- One of the most significant challenge with regard to CCS in a offshore oil environment is related to CO_2 capture process – space and weight of the processing plant;
- Petrobras will continue to analyze the possible alternatives to capture and store the CO_2 produced with the hydrocarbon in order to define the best one.

Thank you!

Paulo Negrais Seabra
Technological Program for Climate Change Mitigation - PROCLIMA
Petrobras' Research and Developemnt Center – CENPES
negrais@petrobras.com.br



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Present Energy Matrix
PRIMARY ENERGY DEMAND BY FUEL TYPE
Non Renewable 86%
Renewable 14%
Hydraulics 6%
Biofuel 0%
Other Replaceable 1%
Biomass 7%
World
12,975 (MM TOEs)
2008
Non Renewable 54%
Renewable 46%
Hydraulics 14%
Biomass 12%
Sugarcane Products 17%
Other Replaceable 3%
Brazil
253 (MM TOEs)
source: PETROBRAS - Strategy – EMN - Business as Usual Scenario / EPE

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANISATION
Vienna International Centre, P.O. Box 300, 1400 Vienna, Austria
Telephone: (+43-1) 26025-0, Fax: ((+43-1) 26025-69
E-mail: unido@unido.org, Internet: http://www.unido.org