Can Renewable Energies Be Vulnerable to Climate Change?

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Introduction

COPPE UFRJ Programa de Planejamento Energético

- Growing body of knowledge and experience in weather risk management in the energy industry has spurred a rapidly growing research interest at the nexus between weather and energy
- Increased interest has been fuelled especially by the growing interest in RE
- But weather information is also critical to the energy supply from other energy sources:
  - e.g. offshore oil operations
  - as well as to energy demand generally

Introduction

- Information from weather forecasts is routinely employed in the energy sector to assist in decision making by:
  - Producers
  - Network operators
  - Traders
  - Regulators
- Such information is used for several purposes:
  - From operational forecasting
  - To the direct pricing of energy
  - To the trading of energy and financial contracts

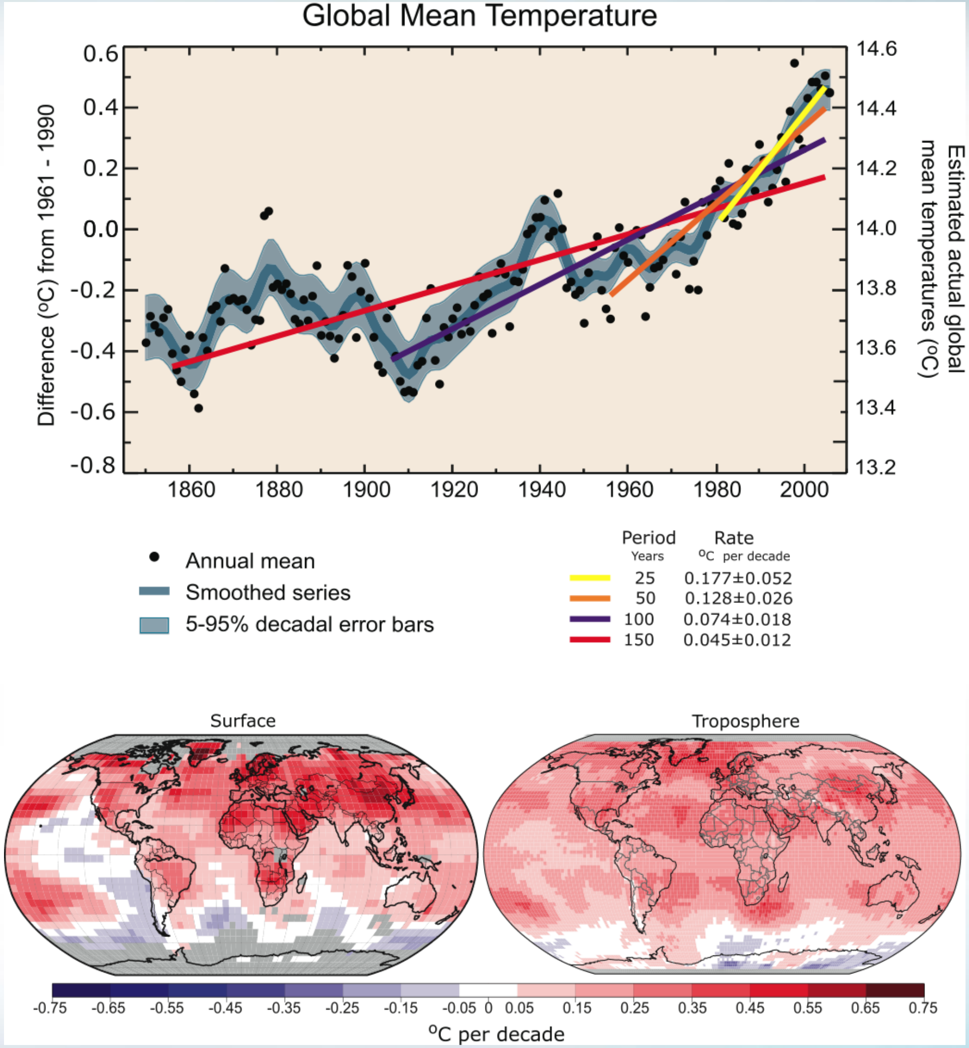
Key questions we will try to answer

- With the threat of Climate Change, should the energy decision process now turn also to other meteorological information:
  - Seasonal
  - Decadal
  - Climate change forecasts?

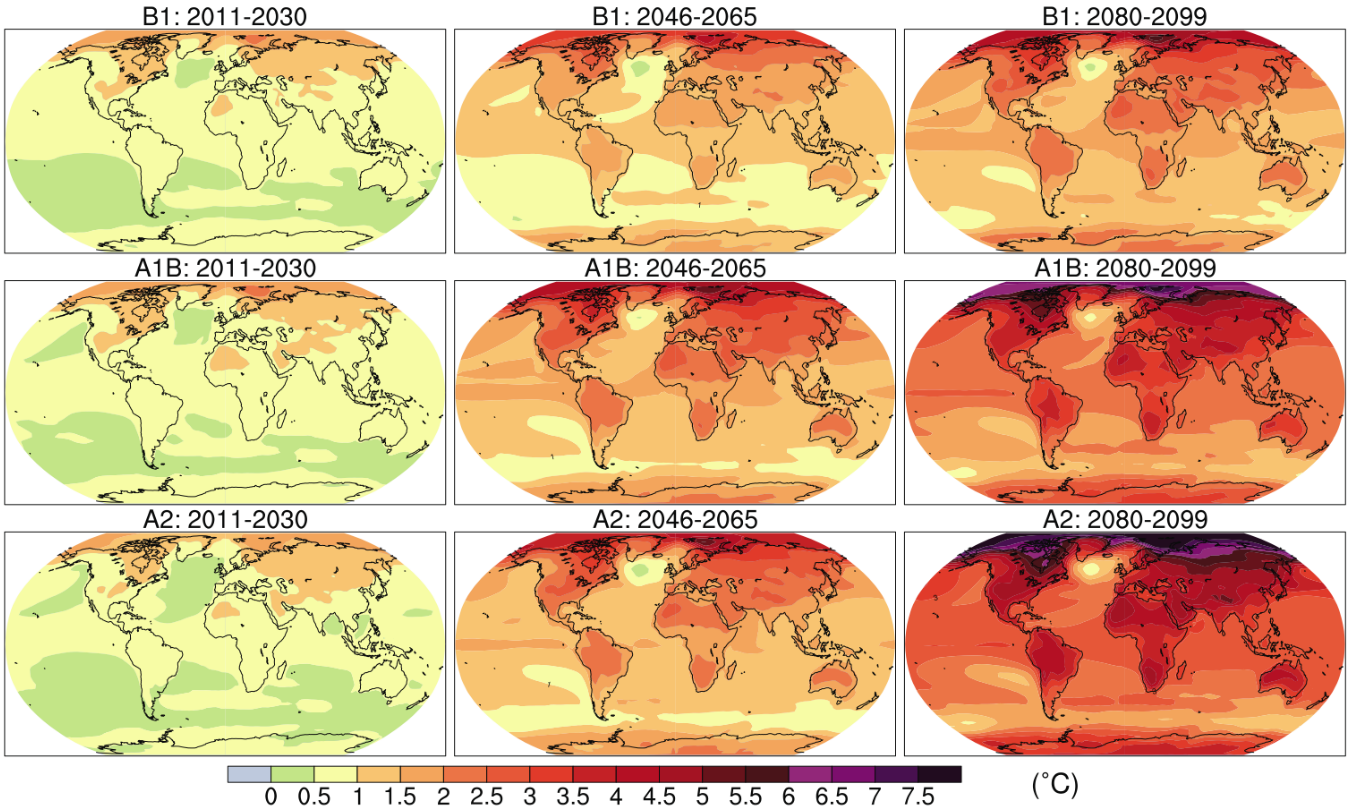
- Are REs (more) vulnerable to Climate Change?

- Are countries that rely heavily on RE more vulnerable to Climate Change?

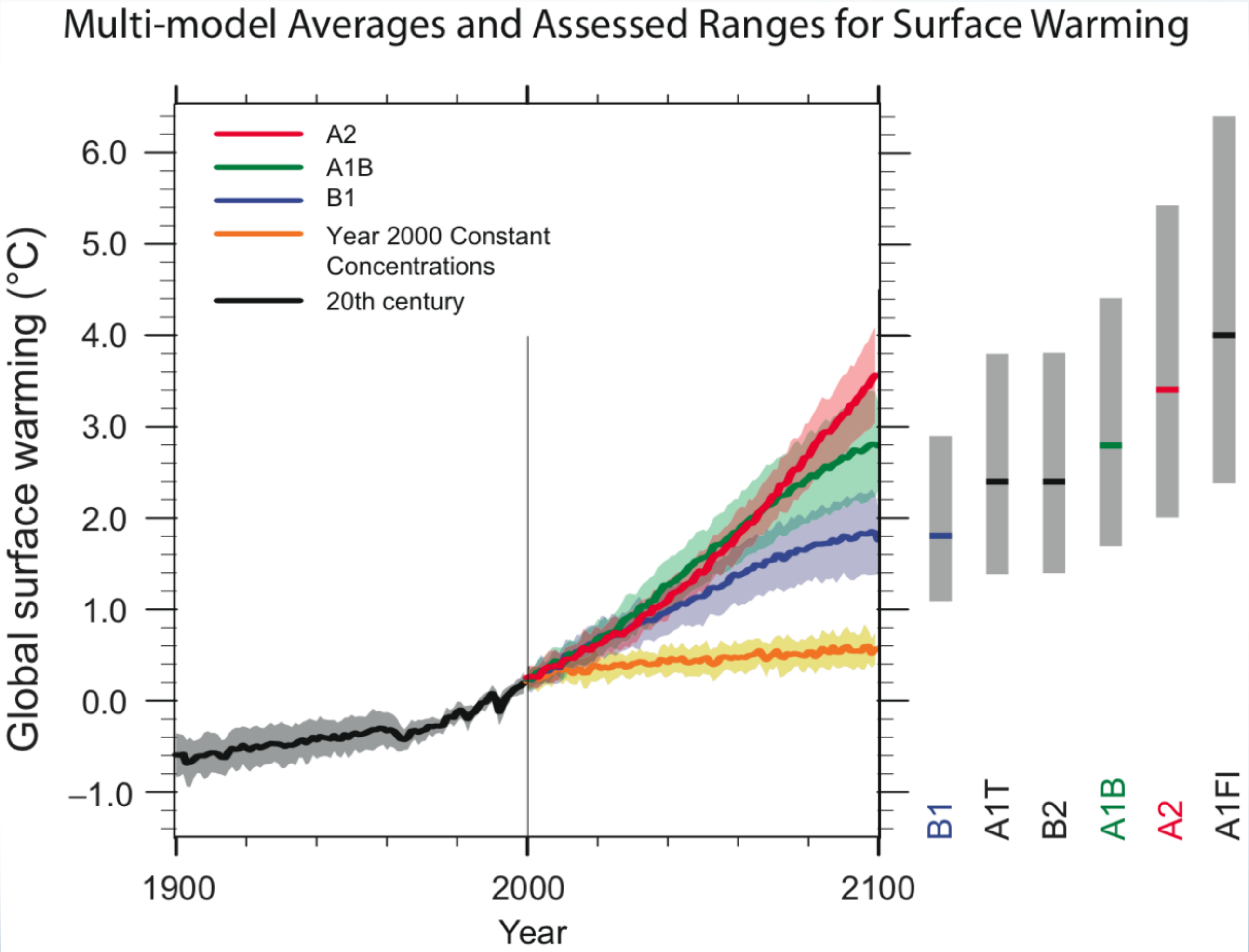
Setting the stage: linear patterns for global mean temperature increases



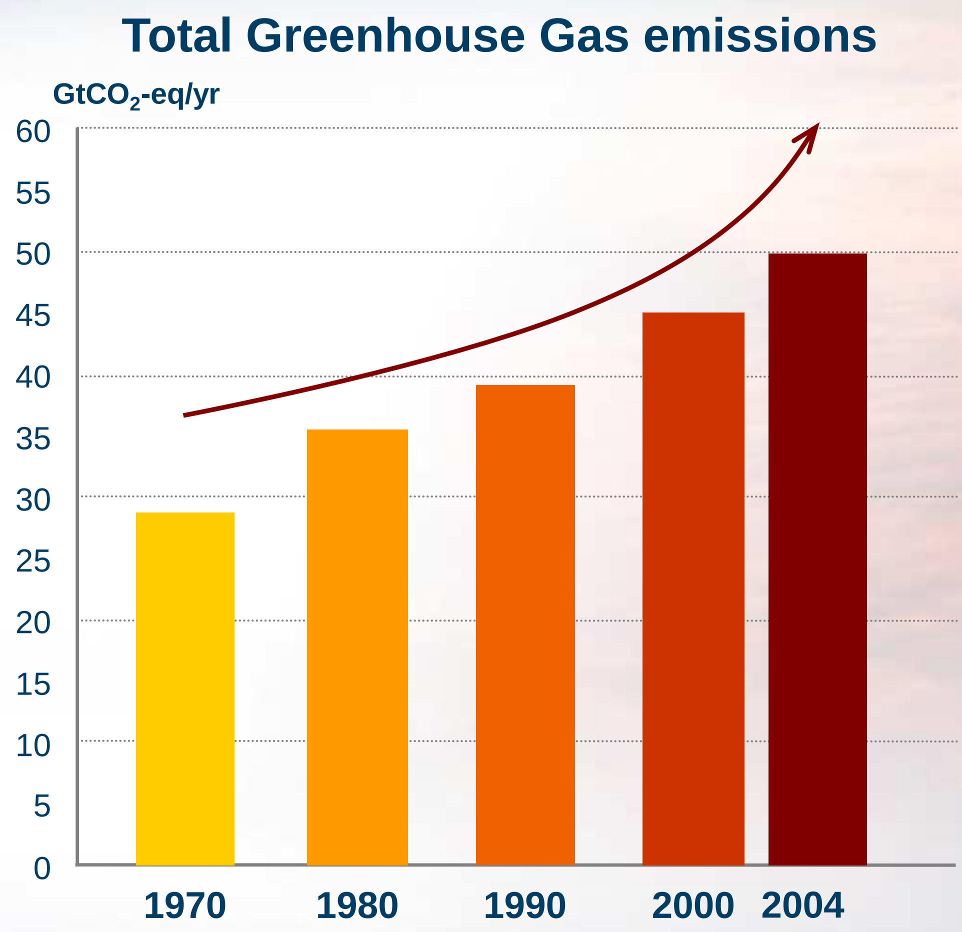
Setting the stage: multi-model mean of annual mean surface warming



Setting the stage: temperature increases up to 2100

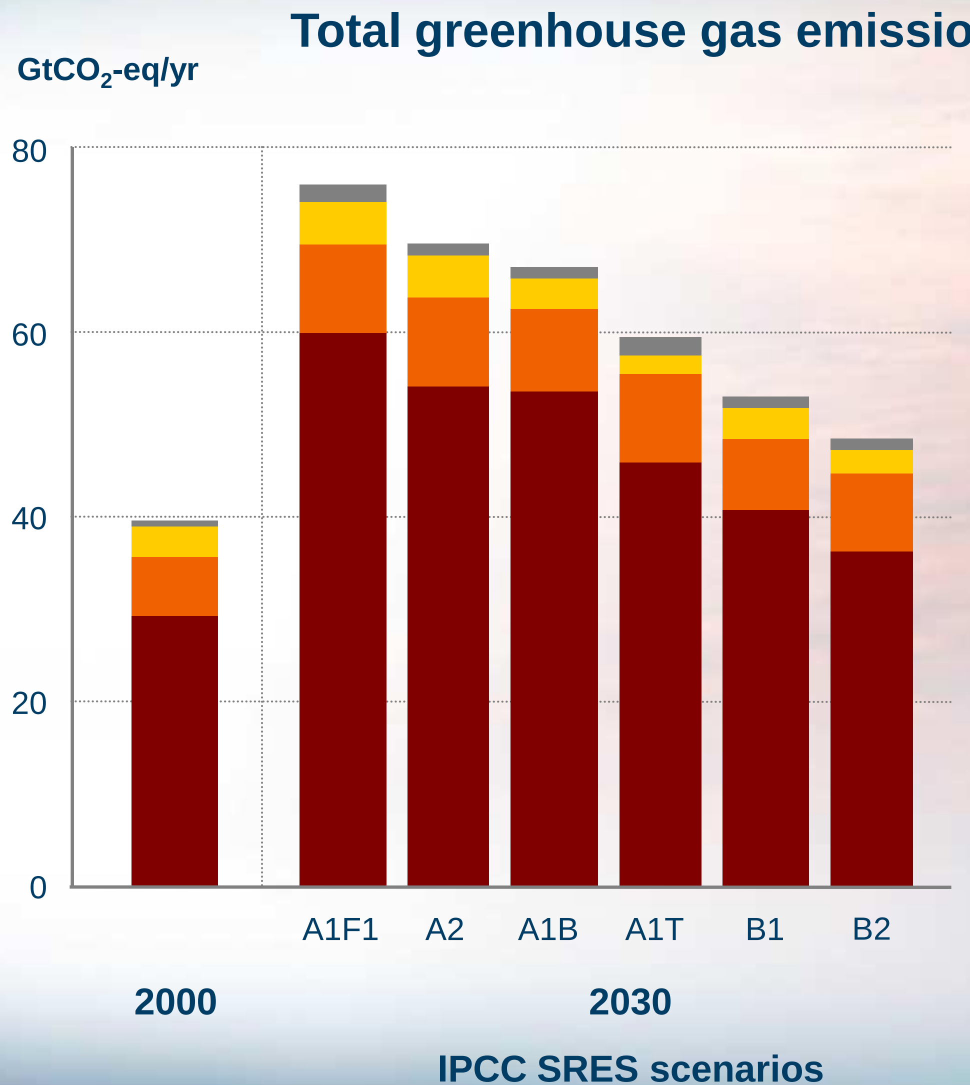


Setting the stage: the challenge



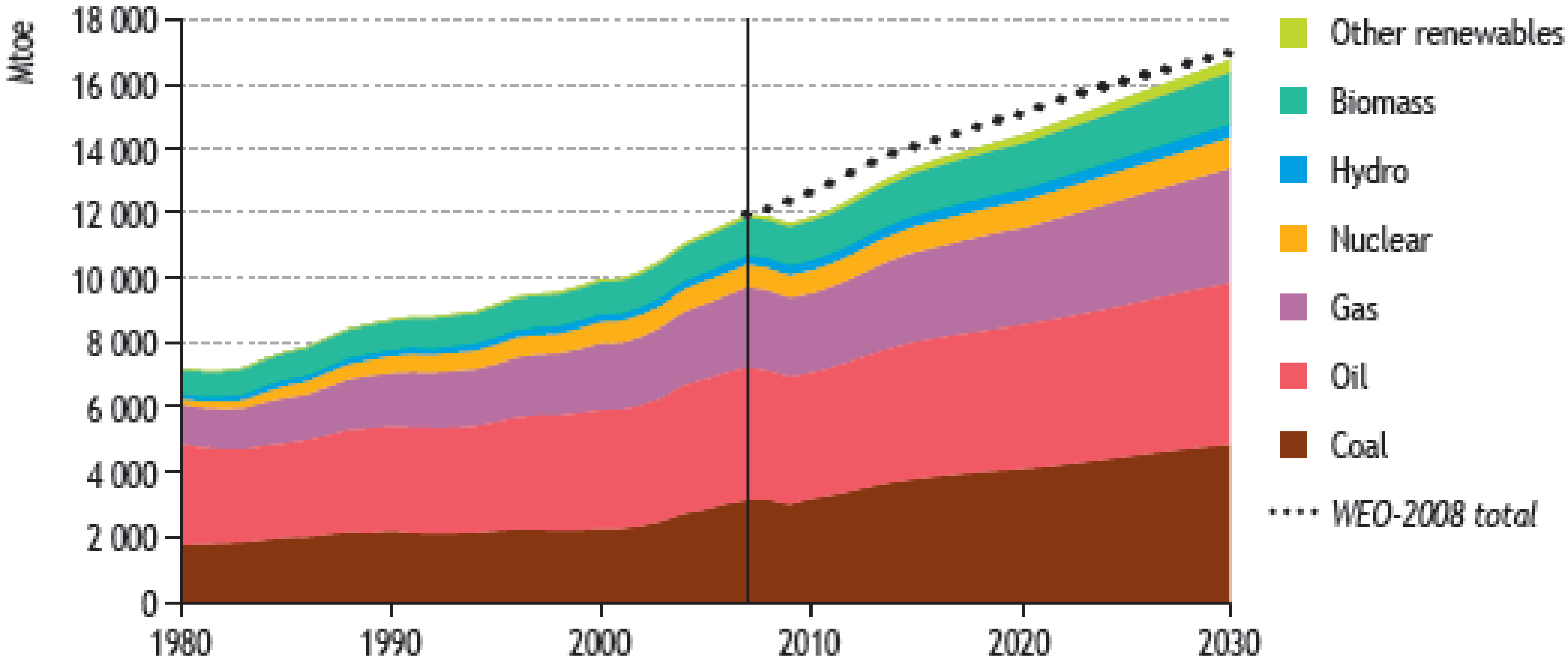
Between 1970 and 2004 global greenhouse gas emissions have increased by 70%

Setting the stage: global greenhouse gas emissions will continue to grow



By 2030 there will be a 25-90% increase in greenhouse gas emissions compared with 2000 unless additional policy measures are put in place

Setting the stage: world primary energy demand (WEO 2009 reference scenario)



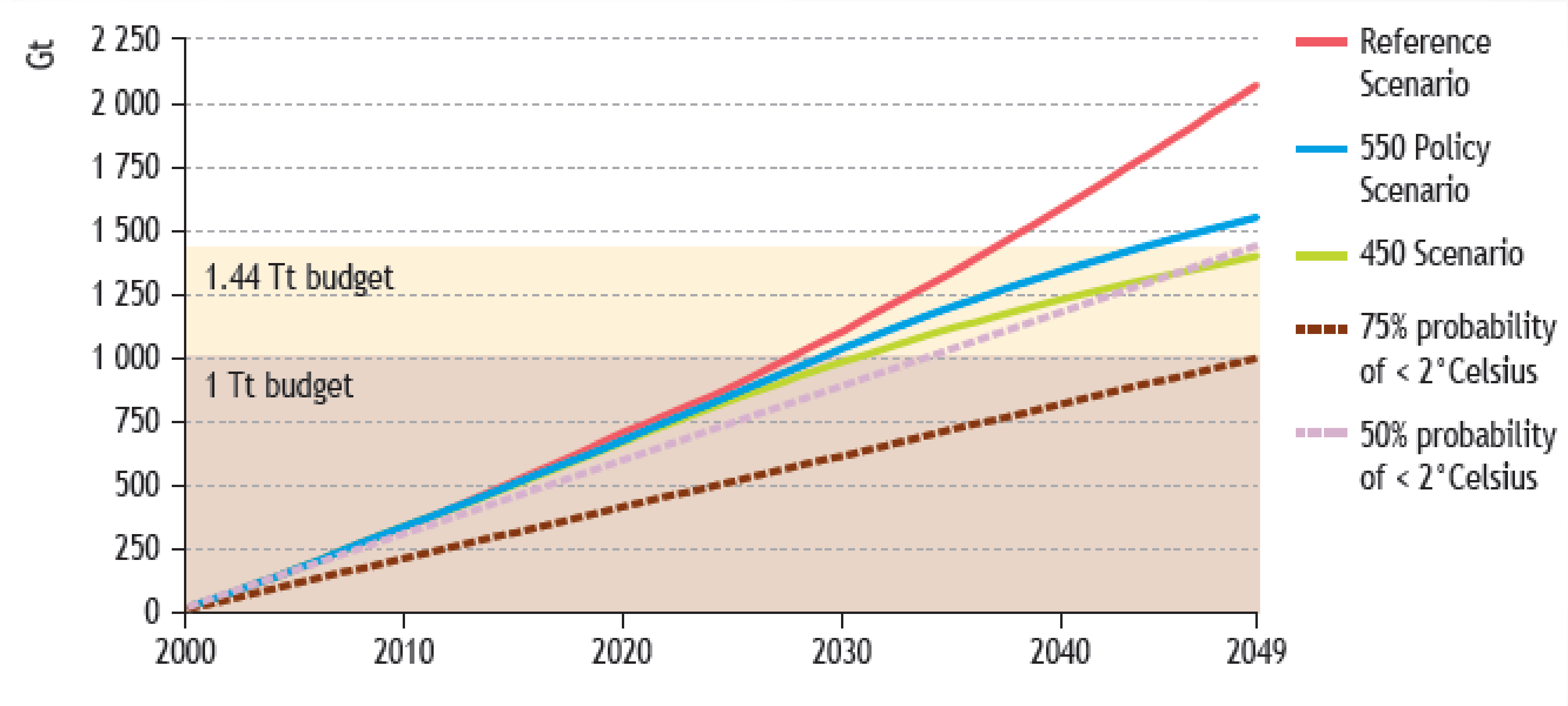
Setting the stage: IPCC AR4 stabilization categories

Category	CO_2 concentration at stabilisation (2005 = 379 ppm)[b]	CO_2-equivalent concentration at stabilisation including GHGs and aerosols (2005=375 ppm)[b]	Peaking year for CO_2 emissions[a,c]	Change in global CO_2 emissions in 2050 (percent of 2000 emissions)[a,c]	Global average temperature increase above pre-industrial at equilibrium, using 'best estimate' climate sensitivity[d,e]	Global average sea level rise above pre-industrial at equilibrium from thermal expansion only[f]	Number of assessed scenarios
	ppm	ppm	year	percent	°C	metres	
I	350 – 400	445 – 490	2000 – 2015	-85 to -50	2.0 – 2.4	0.4 – 1.4	6
II	400 – 440	490 – 535	2000 – 2020	-60 to -30	2.4 – 2.8	0.5 – 1.7	18
III	440 – 485	535 – 590	2010 – 2030	-30 to +5	2.8 – 3.2	0.6 – 1.9	21
IV	485 – 570	590 – 710	2020 – 2060	+10 to +60	3.2 – 4.0	0.6 – 2.4	118
V	570 – 660	710 – 855	2050 – 2080	+25 to +85	4.0 – 4.9	0.8 – 2.9	9
VI	660 – 790	855 – 1130	2060 – 2090	+90 to +140	4.9 – 6.1	1.0 – 3.7	5

Setting the stage: different carbon budgets

Probability of keeping global temperature increase below 2°C	CO_2 budget (all sectors) 2000-2049	Corresponding *WEO* Scenario
Likely (75%)	1 trillion tonnes	-
Moderate (50%)	1.4 trillion tonnes	450 Scenario
Unlikely (25%)	1.6 trillion tonnes	550 Policy Scenario
Extremely unlikely (<5%)	2.1 trillion tonnes	Reference Scenario

Setting the stage: different carbon budgets



Setting the stage: emission reductions from a IEA 450 ppm scenario

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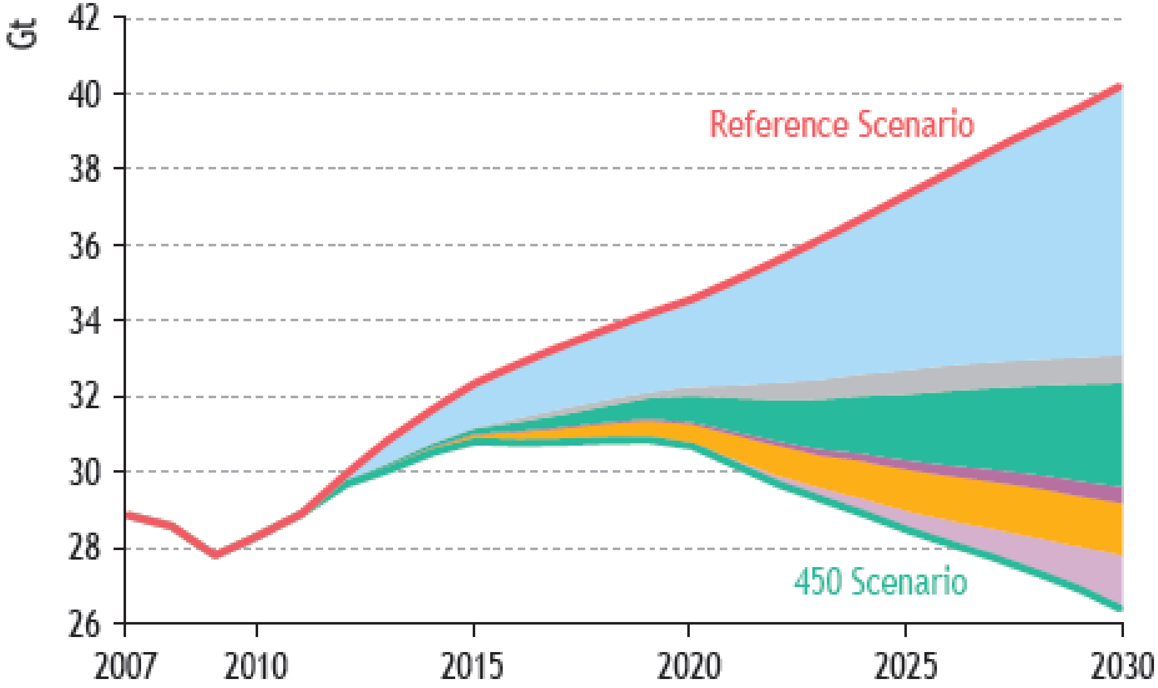
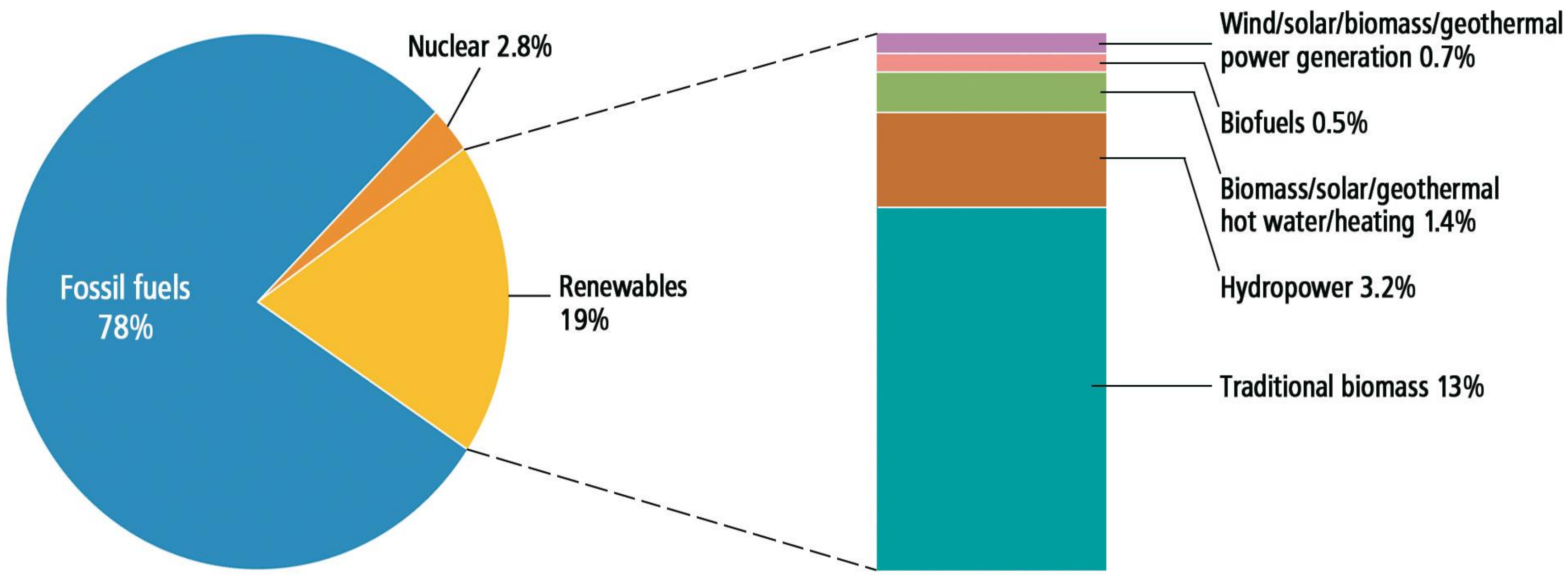
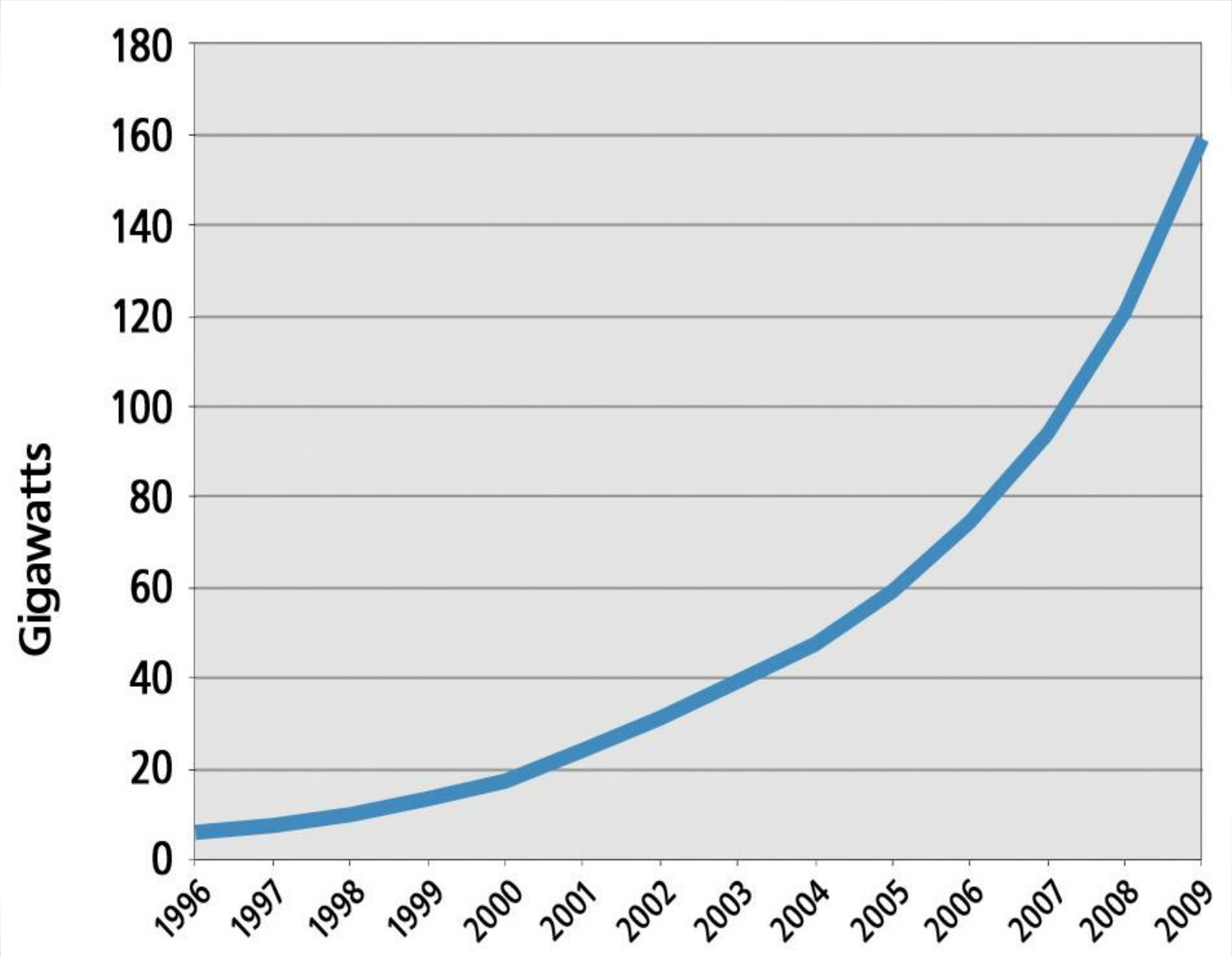


	Abatement ($Mt\ CO_2$) 2020	2030
Efficiency	2 517	7 880
End-use	2 284	7 145
Power plants	233	735
Renewables	680	2 741
Biofuels	57	429
Nuclear	493	1 380
CCS	102	1 410

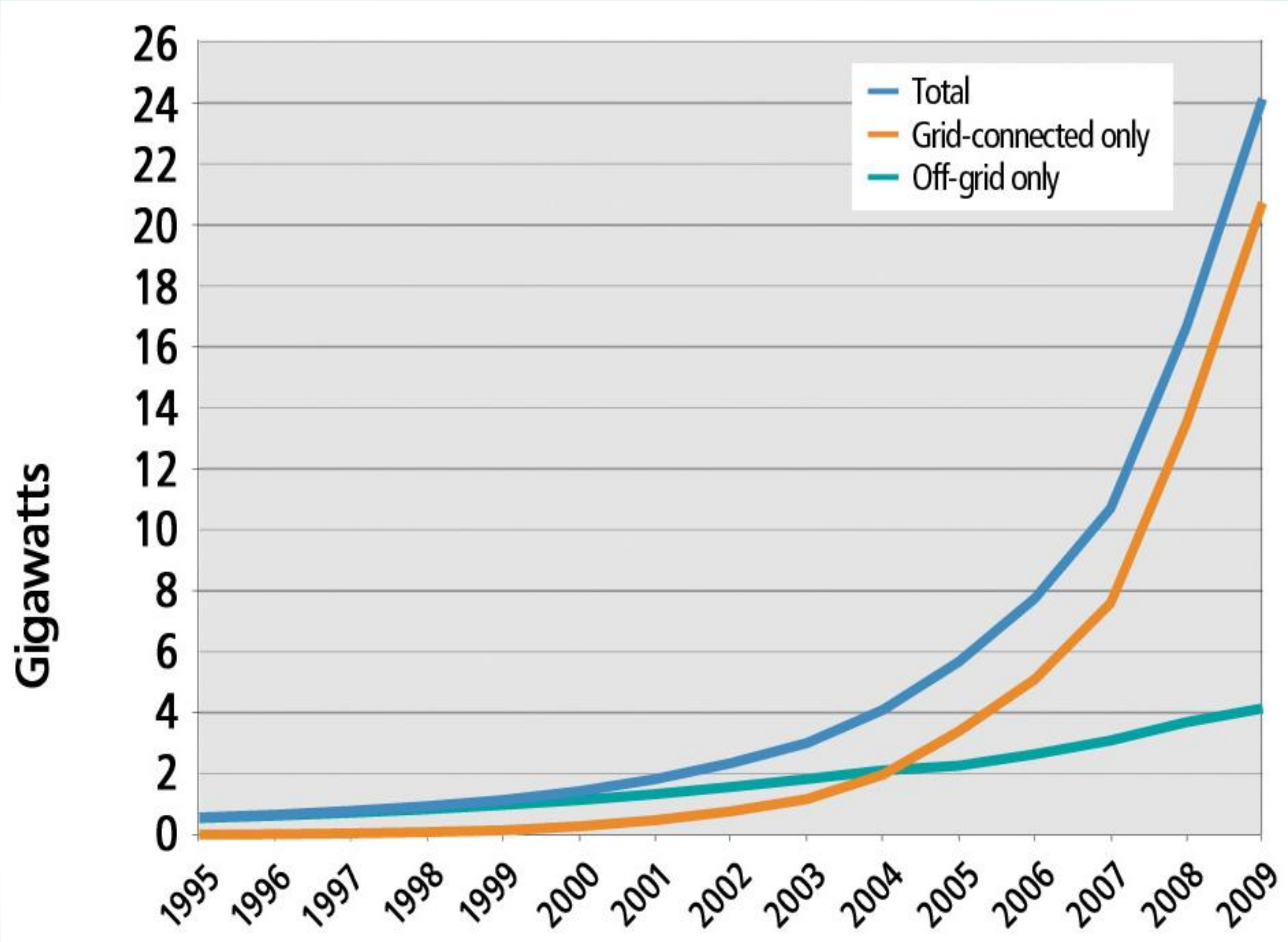
Setting the stage: RE share of global final energy consumption, 2008



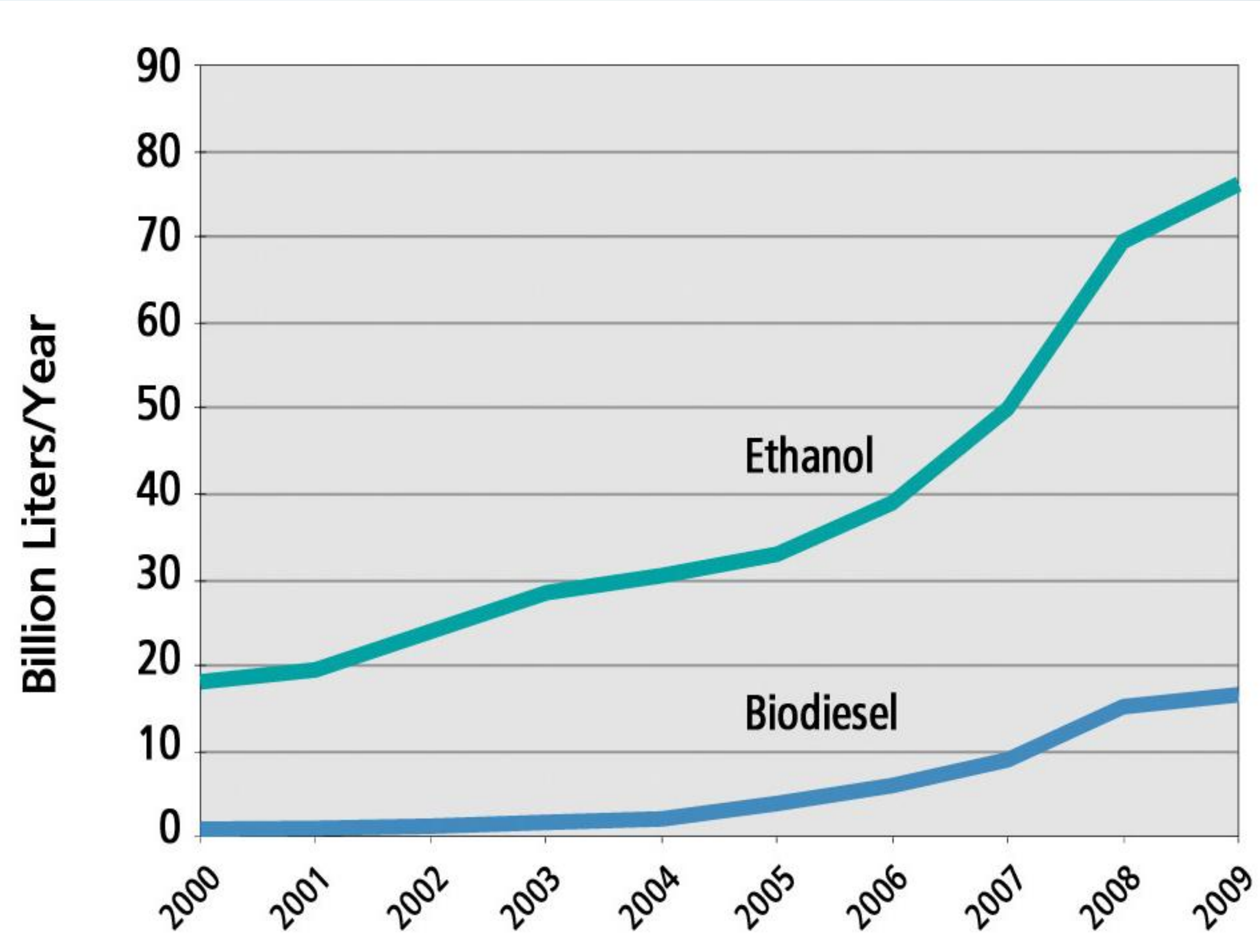
Setting the stage: existing world wind power capacity



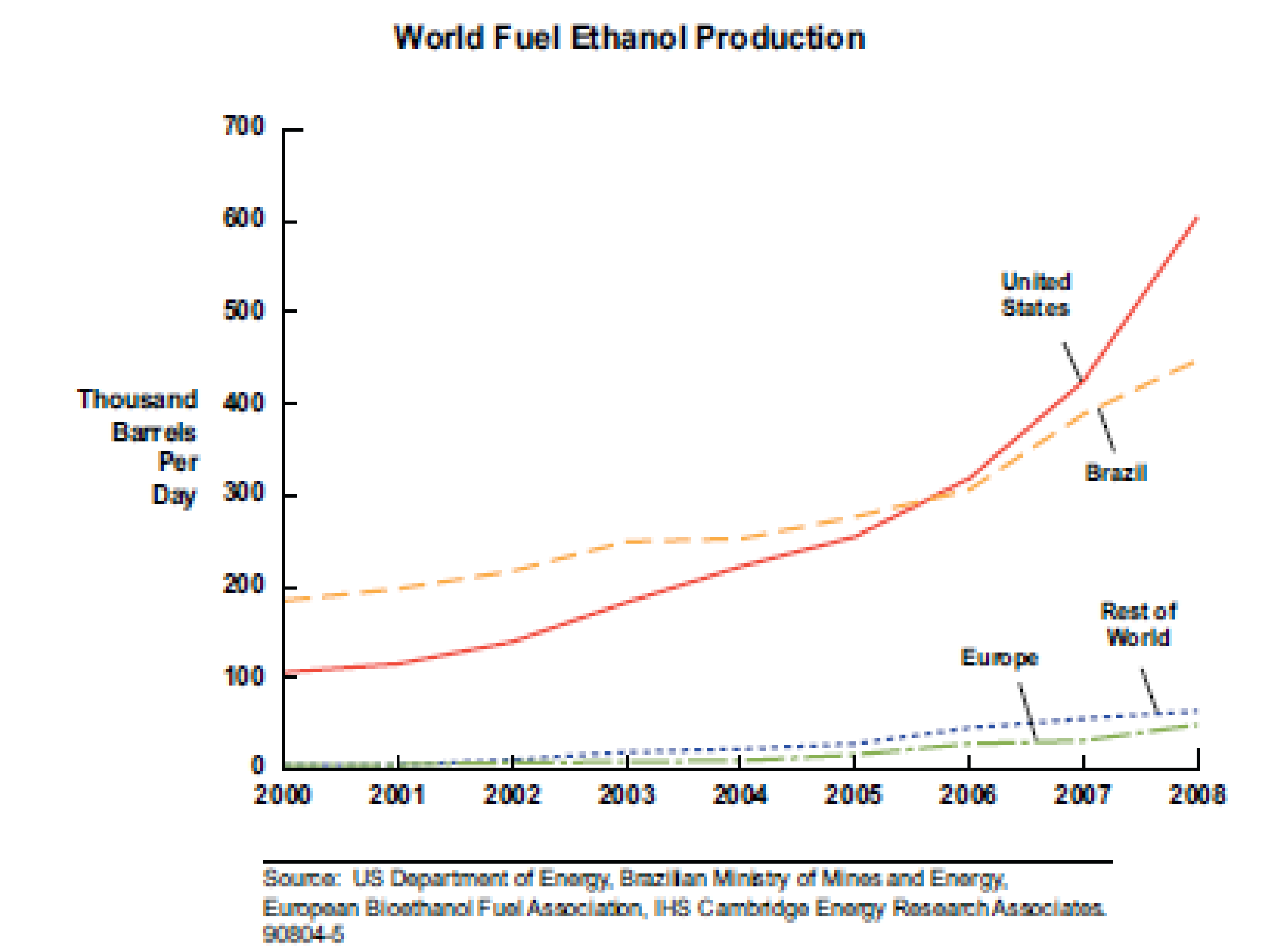
Setting the stage: existing world solar PV power capacity



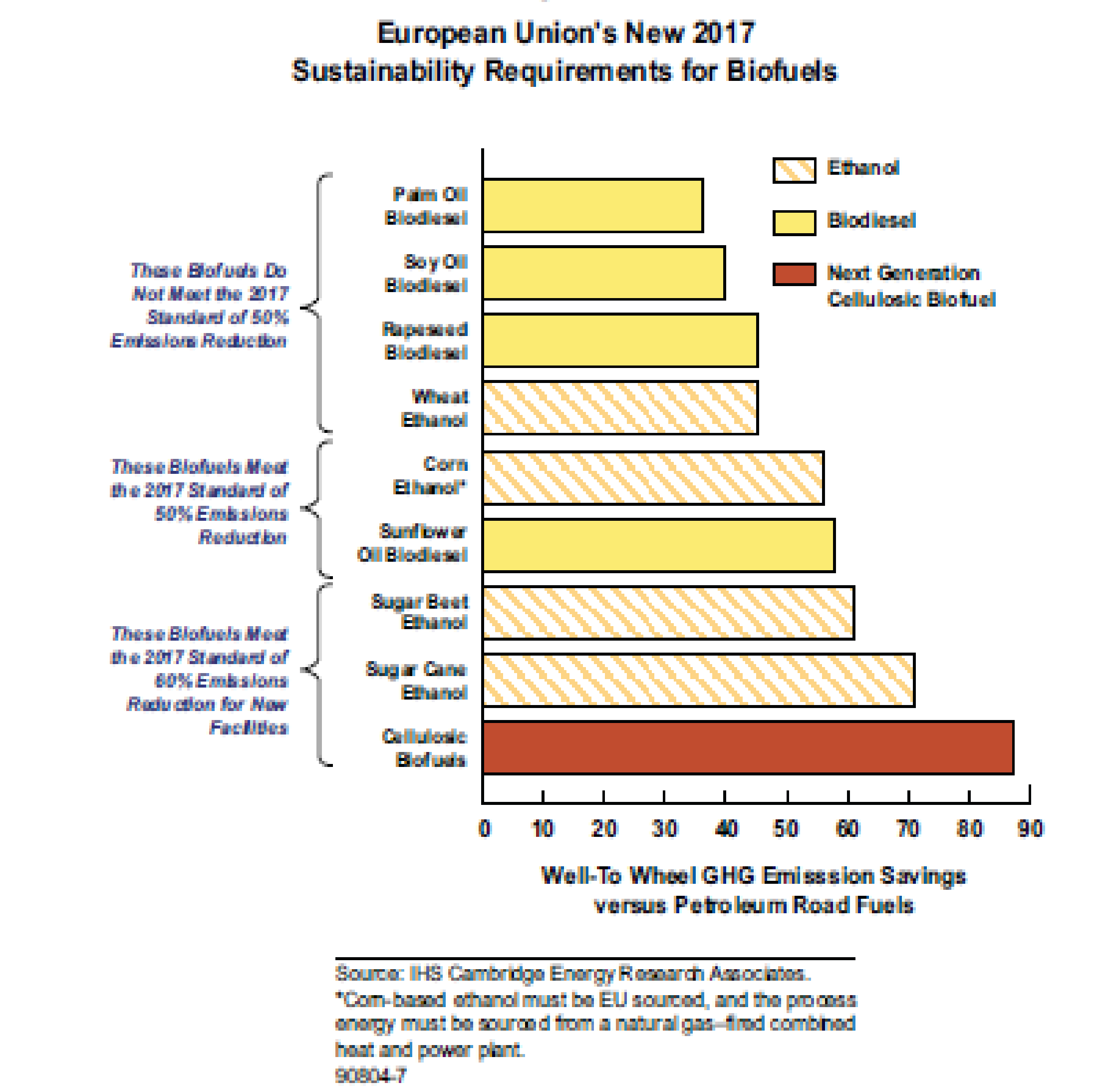
Setting the stage: world ethanol and biodiesel production



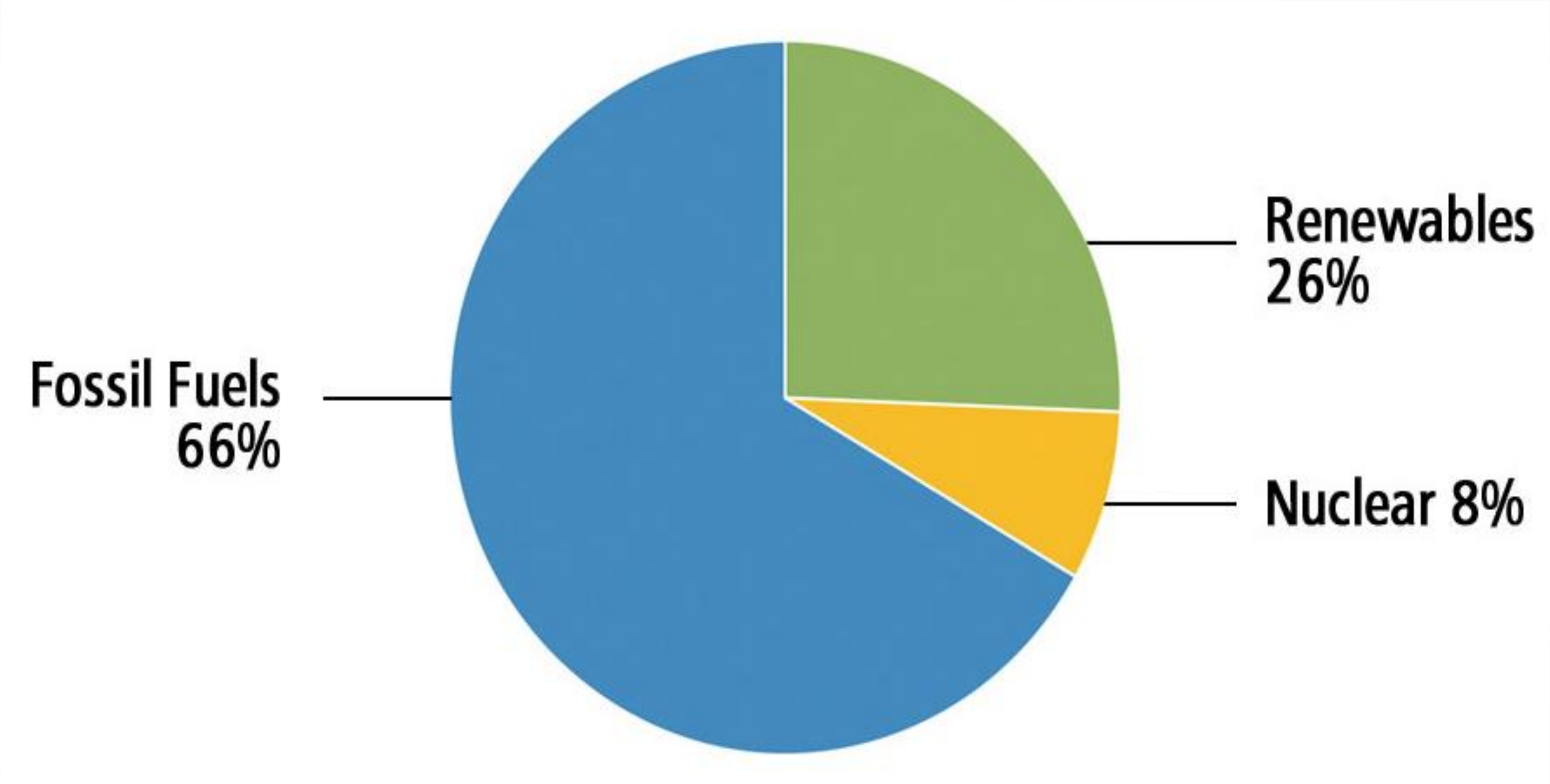
Setting the stage: world ethanol production



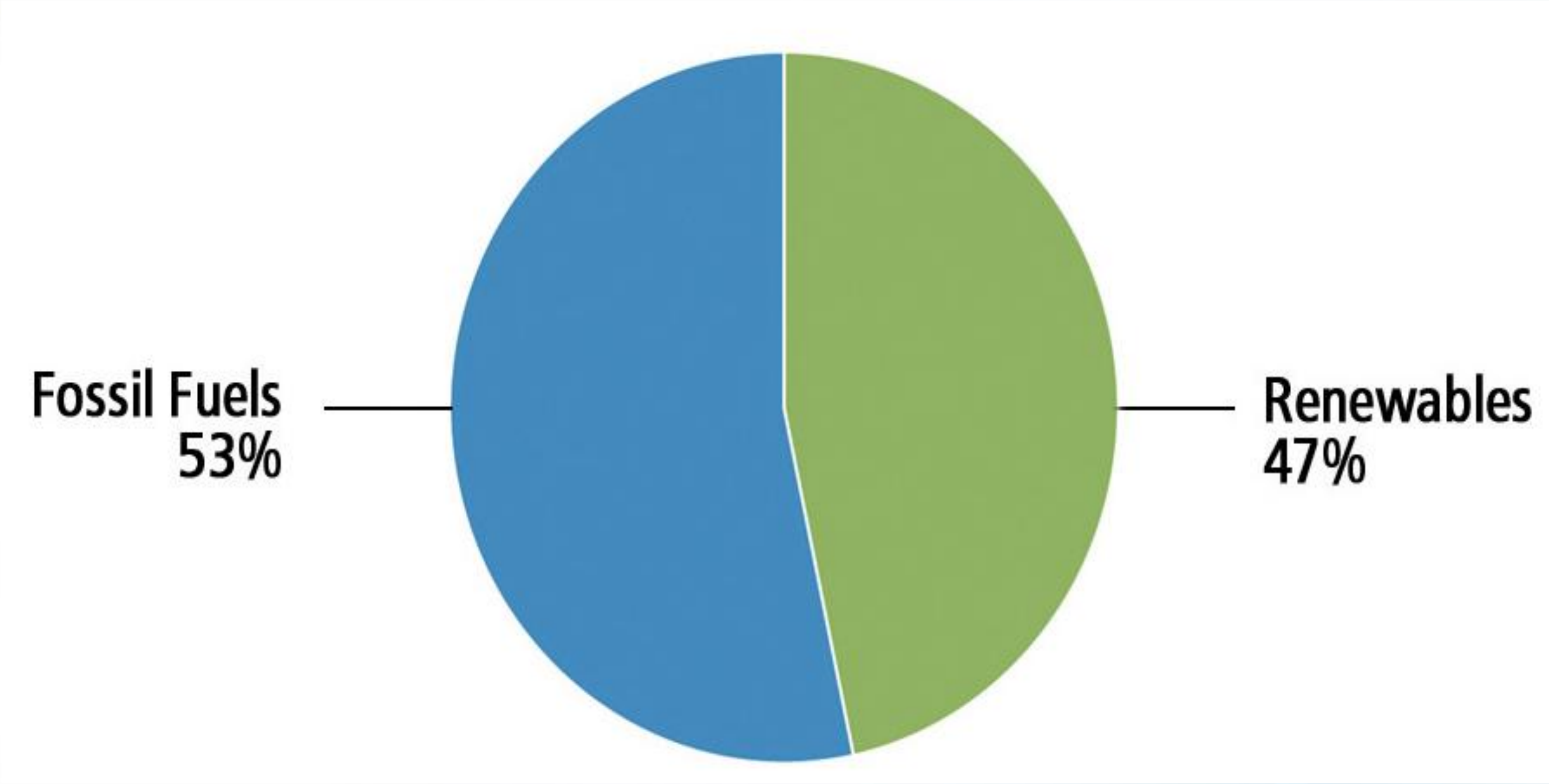
Setting the stage: sustainability requirements for biofuels



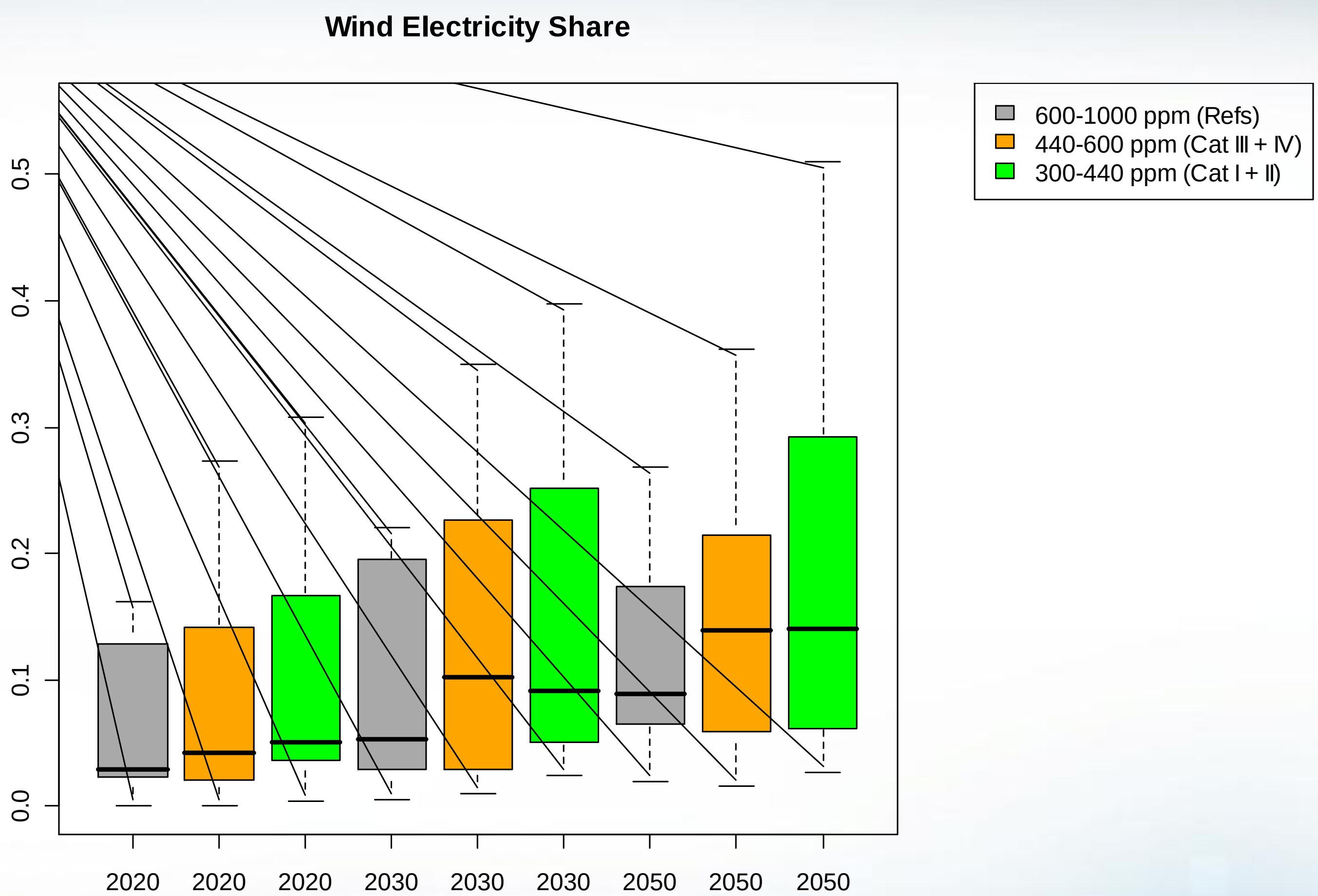
Setting the stage: world power generating capacity by source, 2009



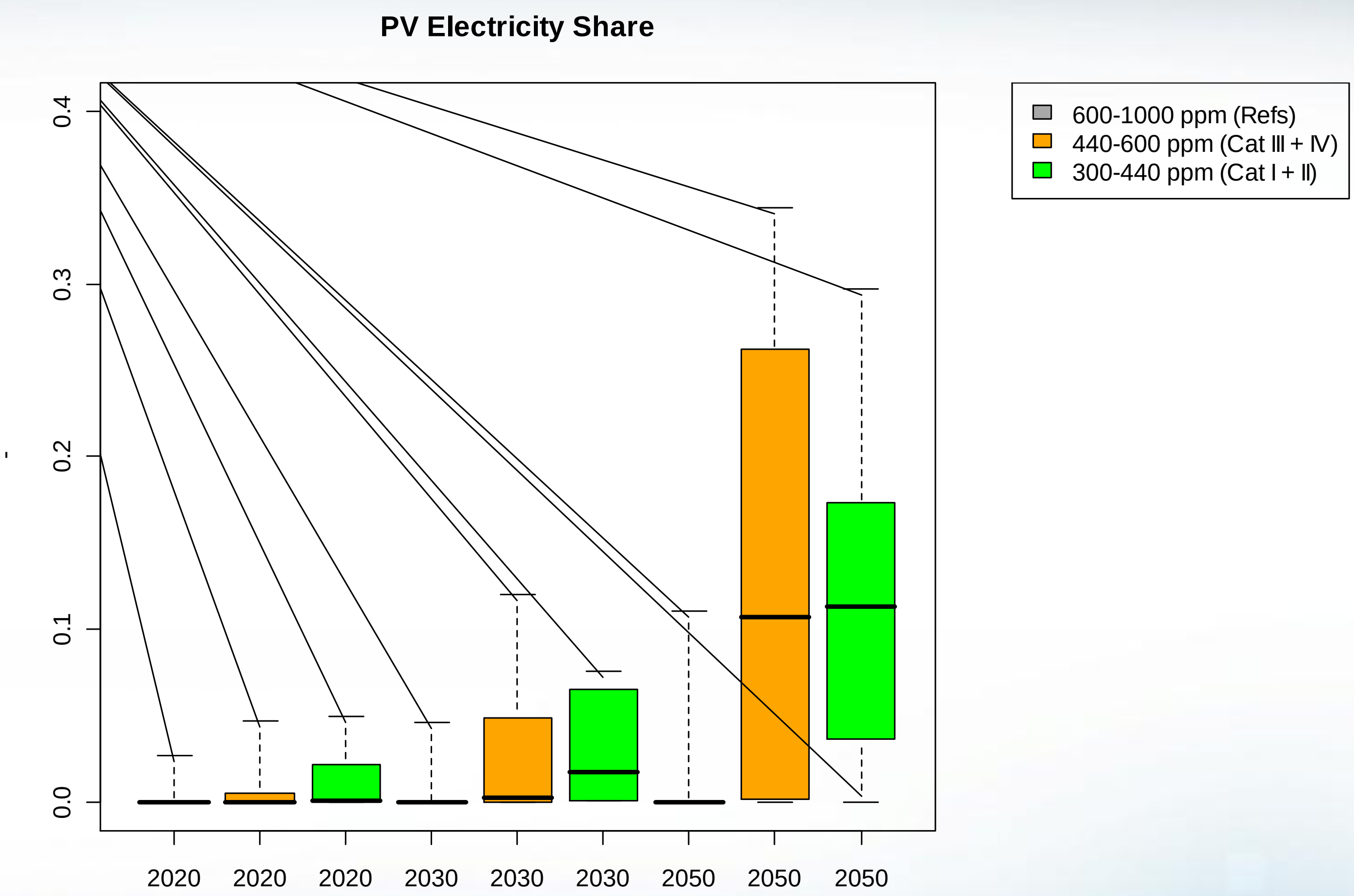
Setting the stage: new power capacity added world wide, 2008-2009



Setting the stage: wind electricity share into the future (126 scenarios)



Setting the stage: PV electricity share into the future (126 scenarios)



RE is an important part of the solution of the Climate Change problem but ...

- RE represents an important alternative for mitigating global climate change
- RE also represents an important alternative for increasing a country's energy security by reducing its fossil fuel production and/or importing needs
- But, because they are strongly dependent on climate conditions, REs may be vulnerable to climate change themselves, making them less reliable than otherwise expected
- But, how vulnerable are hydro, wind or biofuels?

Brazil: a case study

Why Brazil?

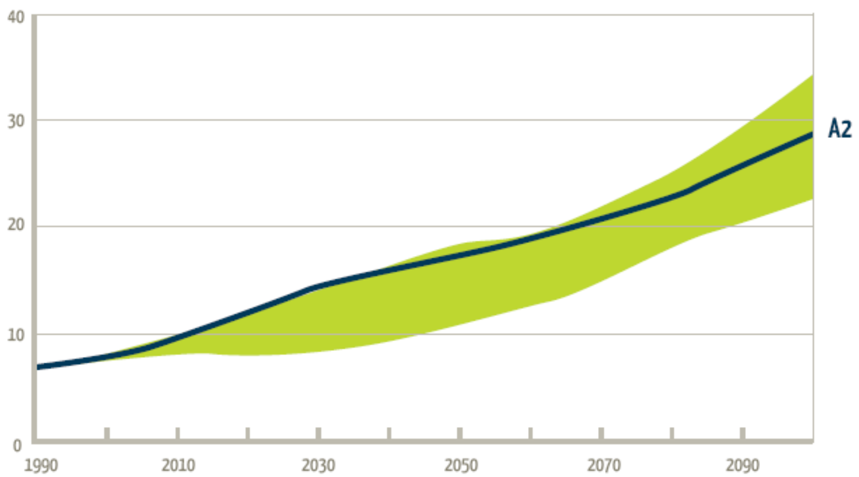
- Strong dependence on renewable energy
- Renewable energy responsible for more than 45% of all energy consumed in the country in 2009
- Hydro responsible for more than 85% of all electricity generated that same year
- Gross wind potential of 1.26TW, capable of generating more than 3,000TWh/yr compared to a consumption of some 500 TWh/yr as of today
- Ethanol already surpassed gasoline as a motor fuel

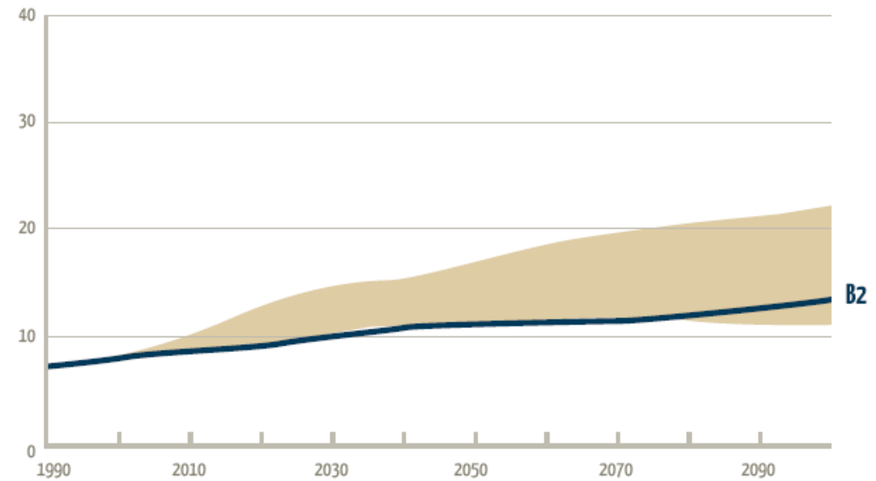
What are the likely impacts of climate change on energy security in Brazil?

- On hydro?
- On wind?
- On biofuels production?
- On energy demand?
- What kind of adaptation strategies may be required?

GCC Scenarios Utilized

- IPCC A2 and B2 emission scenarios



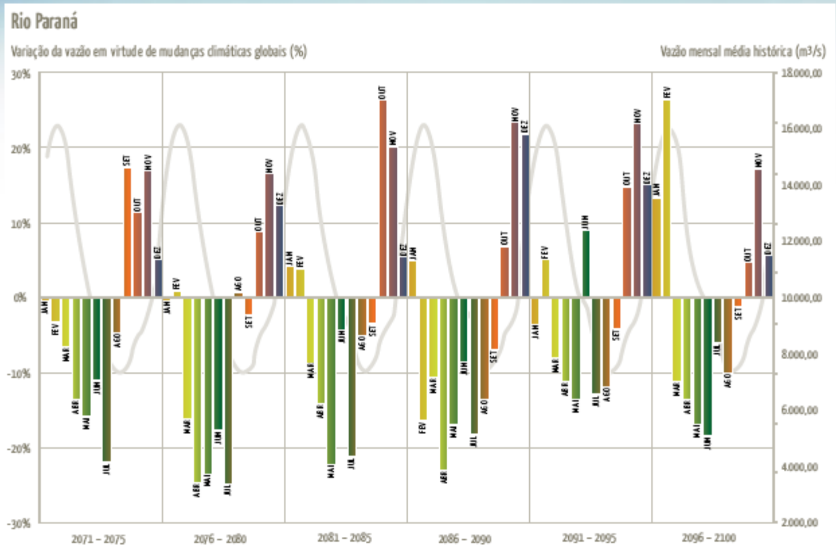


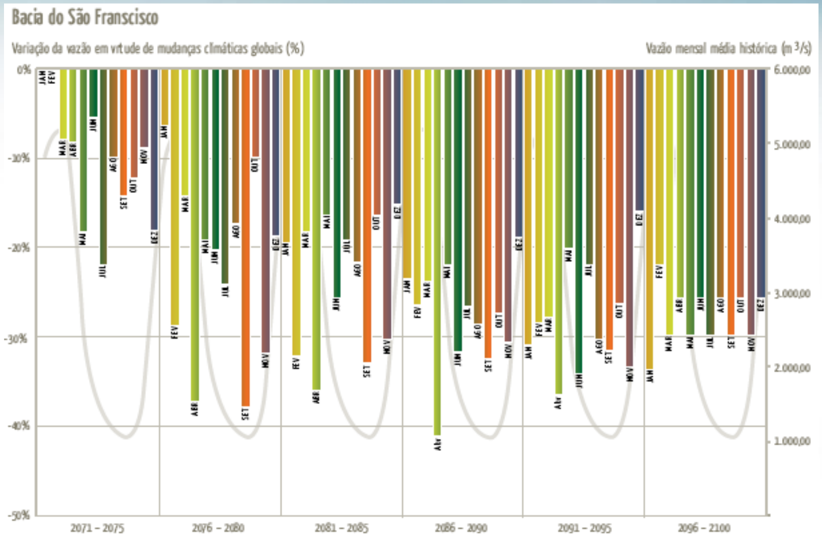
- Transformed in long-term climate projections by CPTEC/INPE

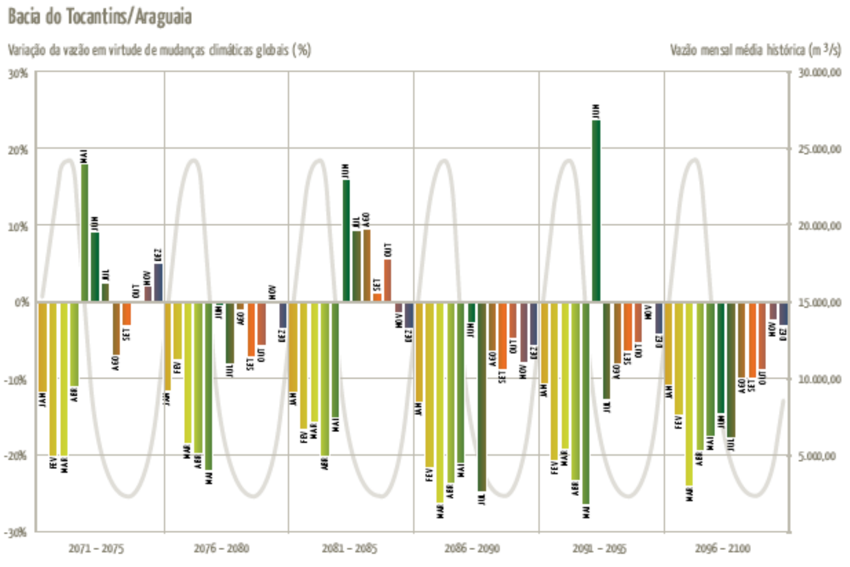
Hydro - Methodology

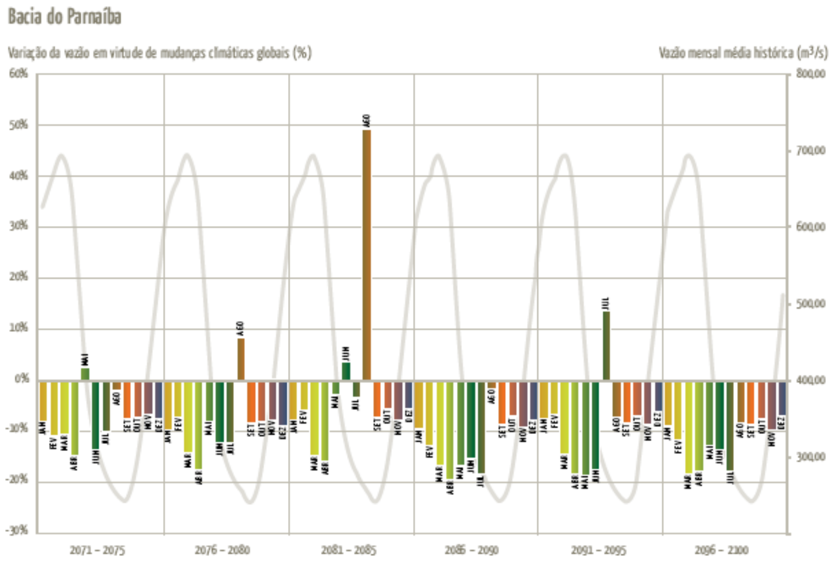
- A2 and B2 climate scenarios:
  - Precipitation and temperature → Natural water flows to the hydro reservoirs
- New group of water flow series
  - Montly series for 2025-2100
  - Given the limitation on the availability of rainfall figures, the impacts of the GCC scenarios on the flow regime in the relevant Brazilian basins (195 hydro plants of the Brazilian interconnected power system) were assessed based on estimates of the future flows using univariate time-series models
- Operation model of the hydro system in the country – **SUISHI-O**
  - Firm energy (guaranteed) → Capacity factor
  - Average energy (average generation over time)

Example for 2071-2100: A2 scenario – variation in relation to reference projections

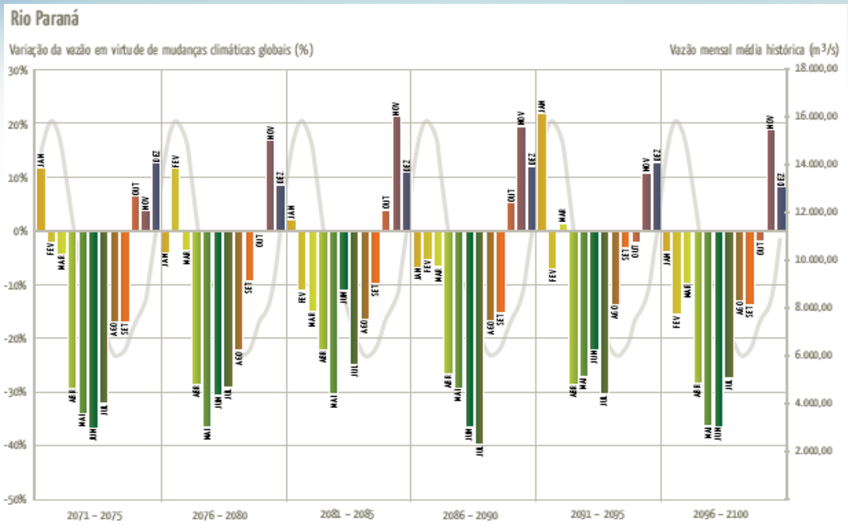


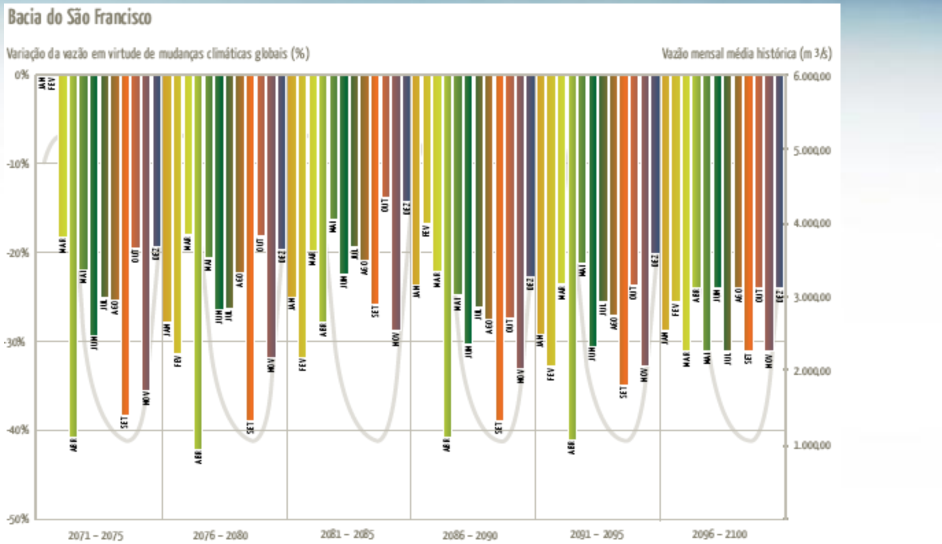


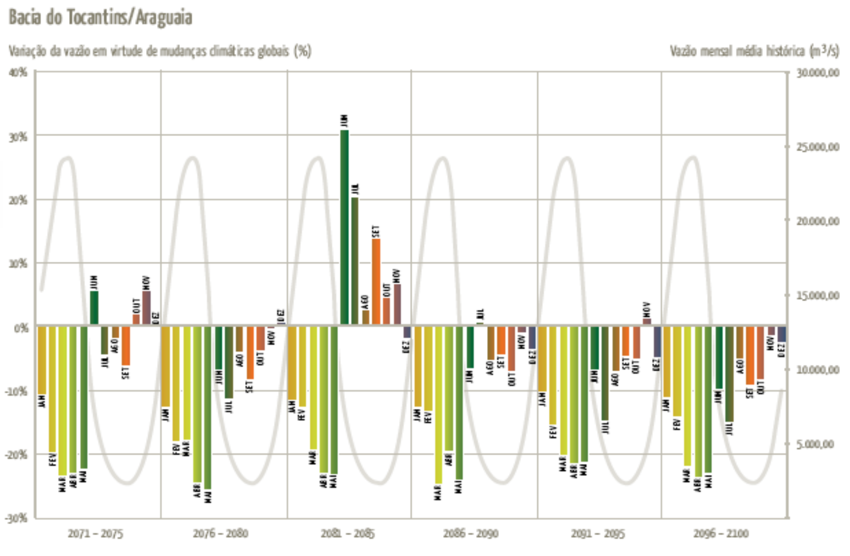


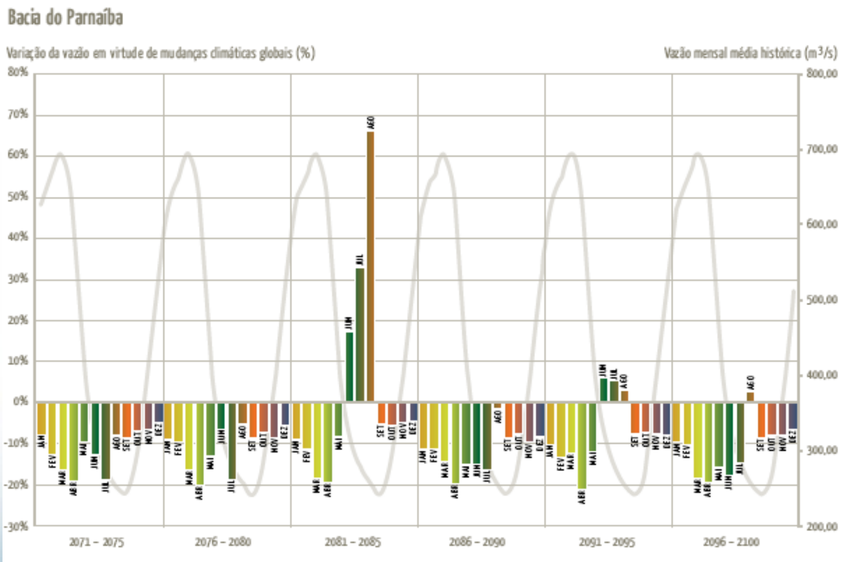


Example for 2071-2100: B2 scenario – variation in relation to reference projections









Hydro – Results SUISHI-O

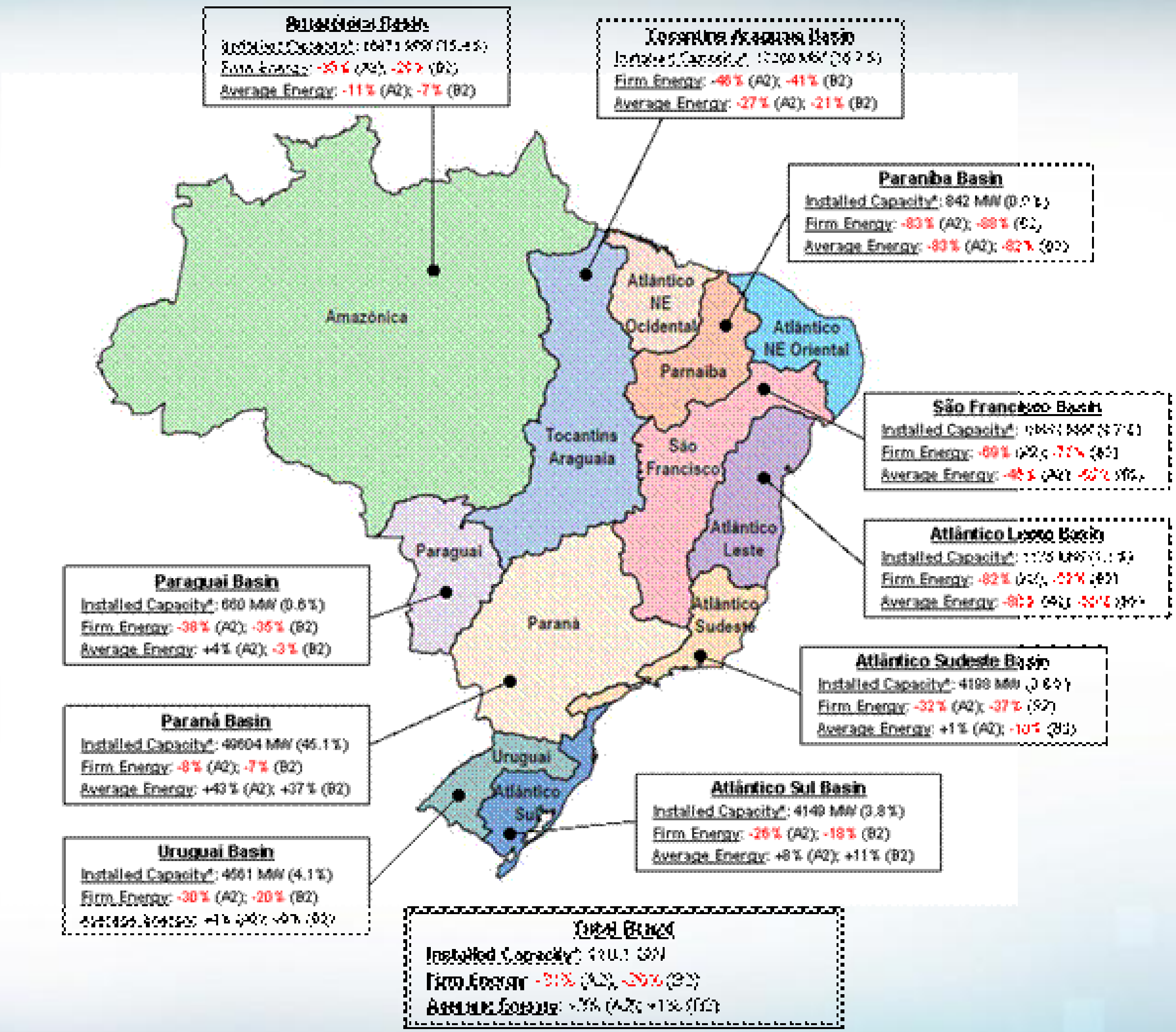
Bacia	Histórico MWmédio*		Variação em Relação ao Cenário Referência A2		B2	
	E. Firme	E. Média	E. Firme	E. Média	E. Firme	E. Média
Amazonas	9425	10628	-36%	-11%	-29%	-7%
Tocantins Araguaia	7531	10001	-46%	-27%	-41%	-21%
São Francisco	5026	5996	-69%	-45%	-77%	-52%
Parnaiba	236	293	-83%	-83%	-88%	-82%
At. Leste	496	565	-82%	-80%	-82%	-80%
At. Sudeste	1937	2268	-32%	1%	-37%	-10%
At. Sul	1739	2037	-26%	8%	-18%	11%
Uruguai	1715	1996	-30%	4%	-20%	9%
Paraguai	375	426	-38%	4%	-35%	-3%
Paraná	22903	29038	-8%	43%	-7%	37%
TOTAL	**51382**	**63247**	**-31,5%**	**2,7%**	**-29,3%**	**1,1%**

Nota: Com base na configuração do sistema projetada para 2016 (EPE, 2007b).
*: MWmédio indica a quantidade de energia gerada supondo o fator de capacidade médio.

Projected Firm Capacity Factors by Plant Size and Sub-system

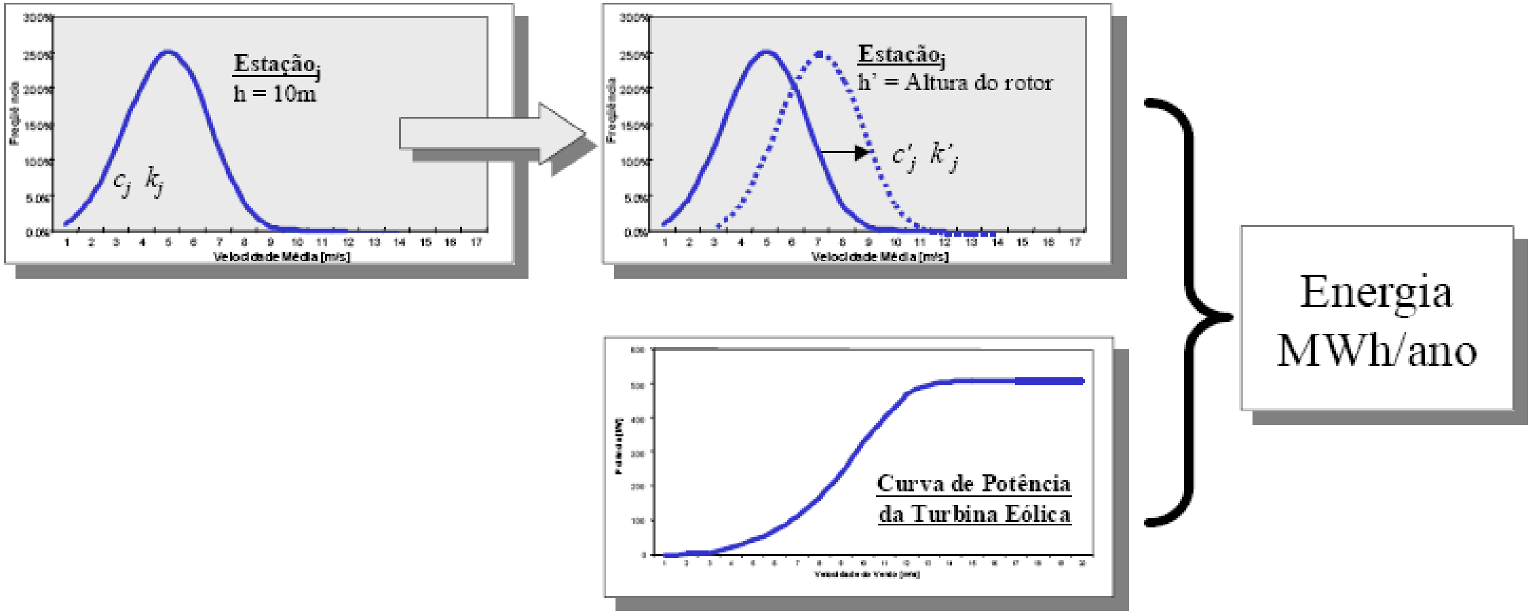
	Capacity Factor		
Sub-System	Historical	A2	B2
S/SE/MW			
<30MW	**58.0%**	**40.2%**	**39.7%**
>30; <300MW	**48.5%**	**31.6%**	**32.1%**
>300MW	**44.6%**	**38.7%**	**39.5%**
N/NE			
<30MW	**58.0%**	**43.4%**	**48.8%**
>30; <300MW	**42.4%**	**21.5%**	**23.3%**
>300MW	**49.6%**	**25.5%**	**26.8%**

Projected Impacts on Hydropower Production



Wind Energy - Methodology

- Wind speed projections 50x50km – number of occurrences with average annual speeds higher than 6m/s (excluding preservation and aquifer areas)
- Gross wind potential: wind distribution vs. power curve



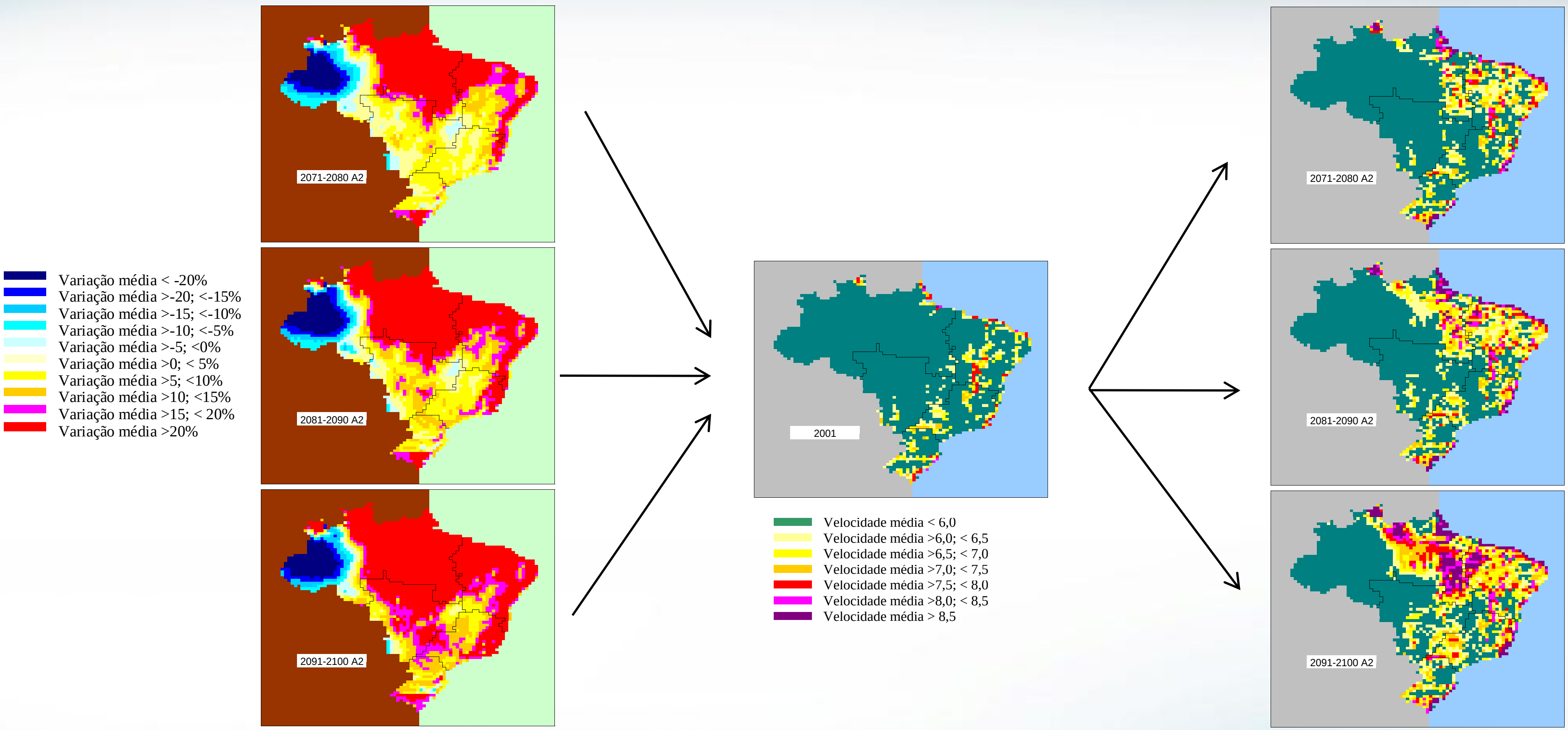
Fonte: Dutra (2007)

Wind Energy - Methodology

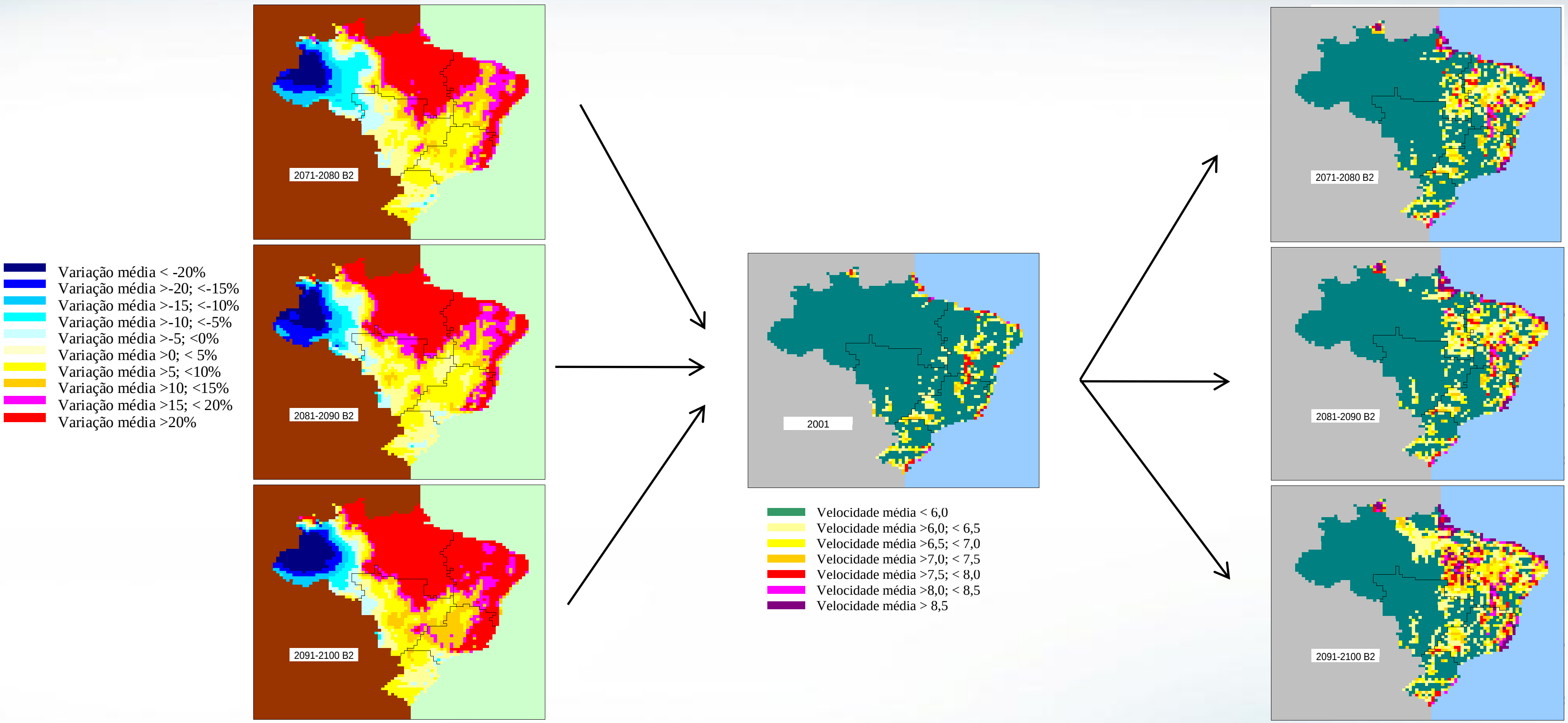
- *Baseline* adjustment – spatial compatibilization with the Brazilian Wind Atlas (CEPEL, 2001) and application of the average wind speed variations between the A2 and B2 scenarios projections and the *baseline*

- Assumptions for calculating the wind potential:
  - No assumption with regard to changes in the distribution of wind speed with respect to its average
  - Wind technology assumed to be kept fixed
  - No changes in the rugosity of the terrain assumed

Wind Energy – Results A2



Wind Energy – Results B2



Wind Energy - Results

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- Average wind speeds increase substantially in the coastal areas in general and in the North/Northeast regions in particular in both scenarios, mainly in the A2 scenario

- Average capacity factors by region and in Brazil as a whole increase as a function of a greater relative share of high speed winds

- As a result wind energy will present an even greater opportunity in the future in the country

Liquid Biofuels Production – Results

- Biodiesel – two crops examined: soya and sunflower
  - Areas with low production risks will be reduced for both crops
  - Lack of water in the Northeast may lead to a migration of both crops to the South of the country
- Ethanol – sugarcane
  - No negative impacts expected, although sugarcane may migrate to other regions leading to land competition with food crops

Bio-fuels in Brazil: a parenthesis

Bio-fuels use are, in no way, a new idea

First pure-ethanol Brazilian vehicle (1931)

Henry Ford, ethanol vehicle (1896)

Ethanol Addition into Gasoline

1930 blending depending of the harvest yield

1979 20% v/v addition variable

1980 20% v/v addition continuously

1982 increase to 22% v/v continuously

1988 reduction to 18% in some regions

1993 blending by law (22% v/v)

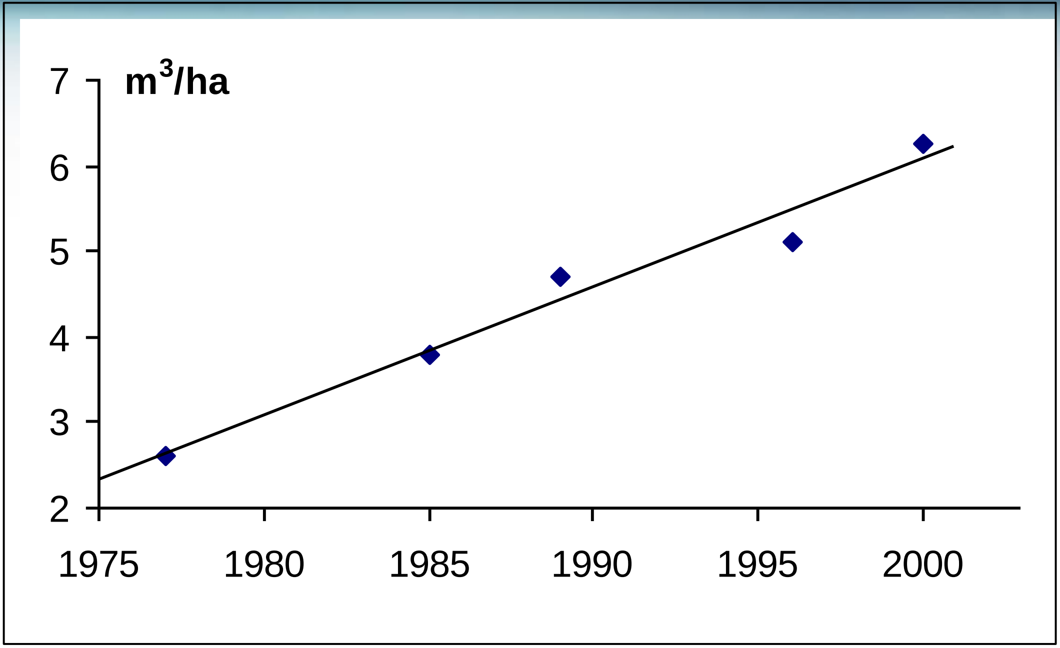
2001 blending between 20 to 24% v/v (*)

2002 law fixing the addition of 20 min. to 25% max. v/v (*)

2003 launched flex-fuel-vehicles (FFV)

(*) in accord to ethanol availability

Ethanol Productivity in Brazil



Main factors:

- **Gains in the agricultural phase**
- **Extended harvest season**
- **Integration and flexibilization of processes (sugar + ethanol + electricity + others)**

Source: L.A. Horta Nogueira

Possible Gains in Productivity

	2005		2015		2025	
Technology	l/tc	l/ha	l/tc	l/ha	l/tc	l/ha
Conventional	85	6,000	100	8,200	109	10,400
Hydrolysis	--	--	14	1,100	37	3,500
Total	85	6,000	114	9,300	146	13,900

Source: CANAPLAN

Sugarcane for Ethanol in Brazil

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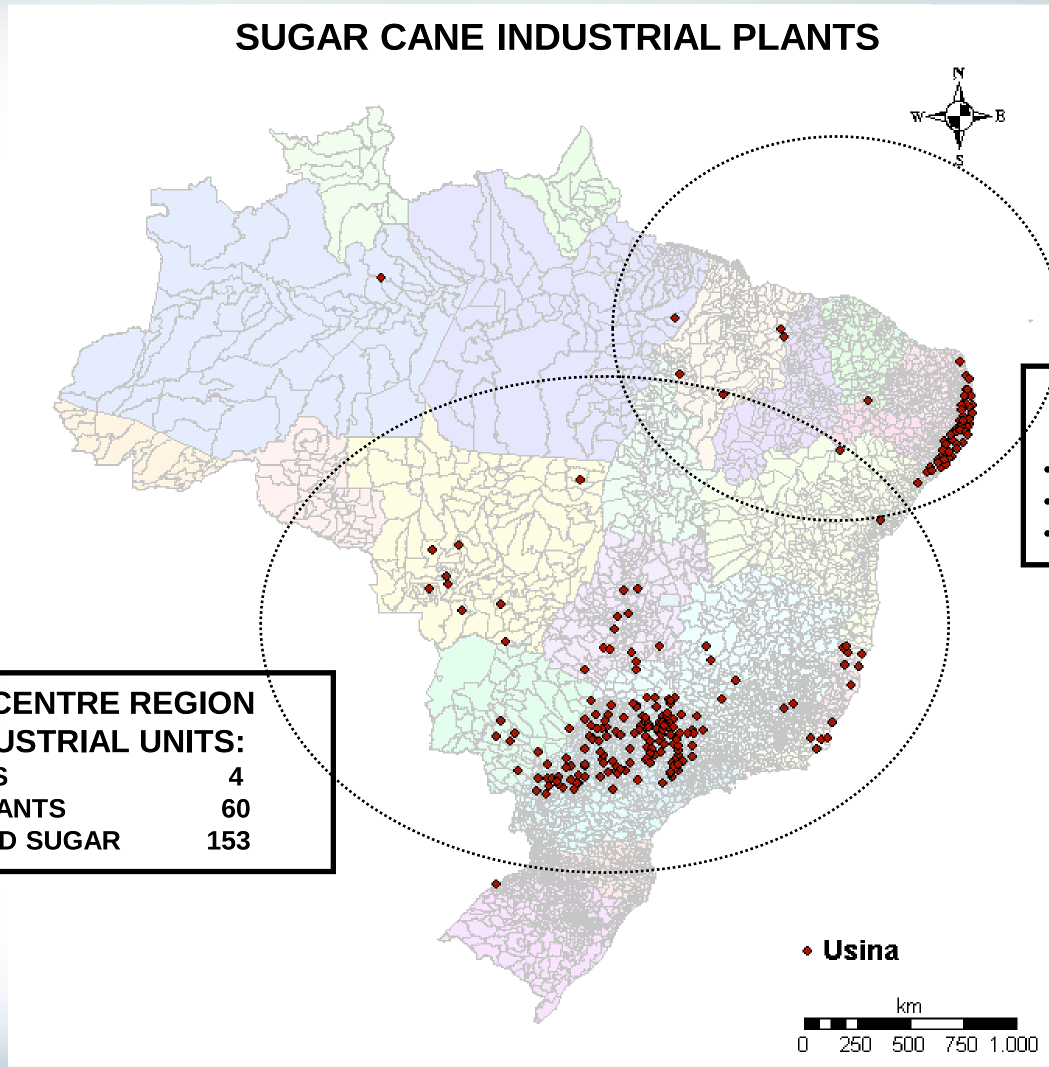
- Some 8 million ha planted with sugarcane (10% of the area under agriculture)
- 55% processed for ethanol in some 400 plants, with some 40 new plants under construction
- More than 600,000 people working directly in the sugar and alcohol industry in Brazil (plus other indirect jobs)

Localization of Ethanol Destileries

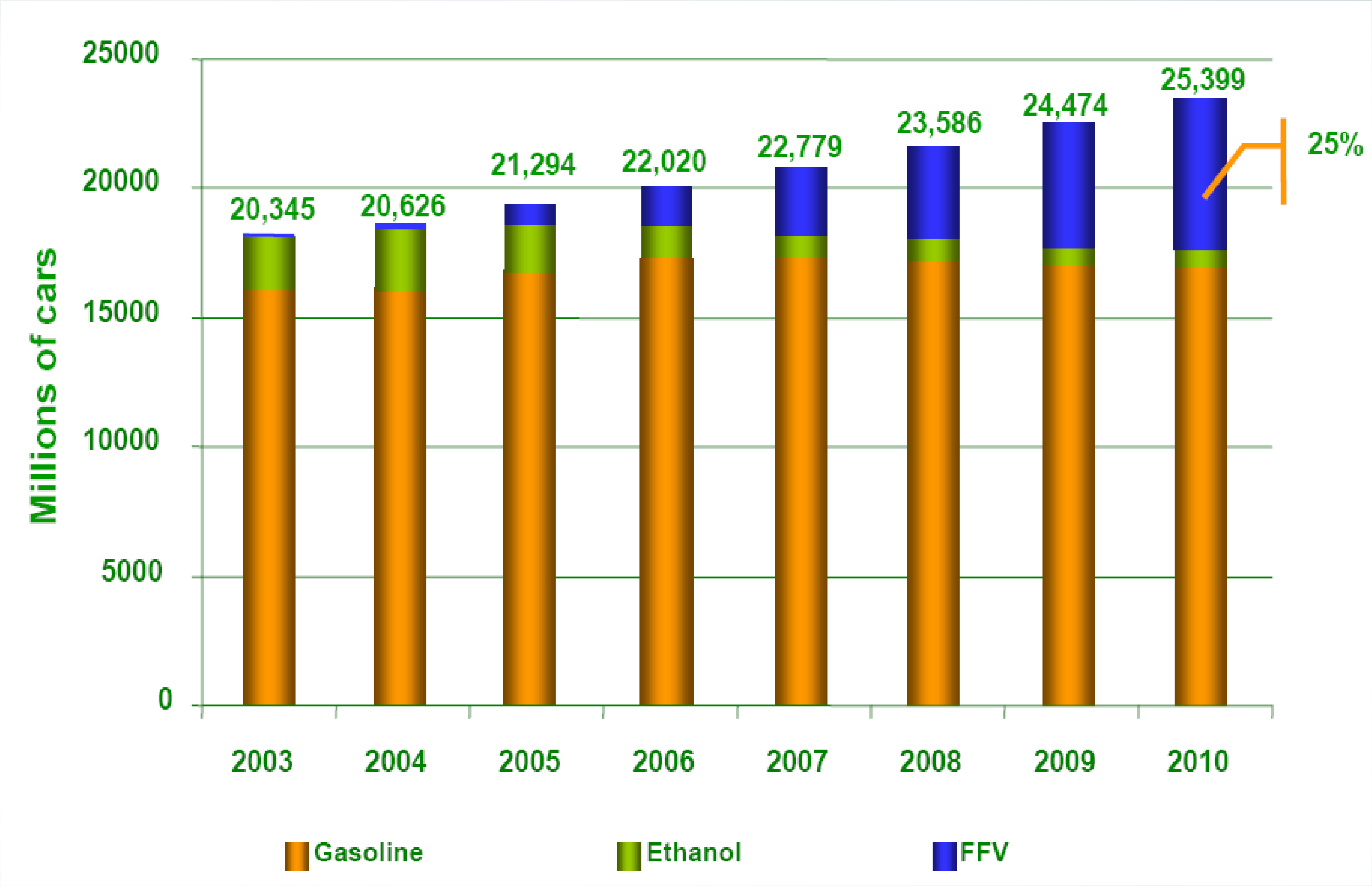


NORTH-NORTHEAST REGION
87 INDUSTRIAL UNITS:
- SUGAR MILLS 9
- ETHANOL PLANTS 28
- ETHANOL AND SUGAR 50

SOUTH-CENTRE REGION
217 INDUSTRIAL UNITS:
- SUGAR MILLS 4
- ETHANOL PLANTS 60
- ETHANOL AND SUGAR 153

(Source: MME, 2005)

Some 25% of the Brazilian fleet of automobiles are FFV



Models for Bio-diesel Production (Source: L. A. Horta Nogueira)

Soya harvesting in Mato Grosso state, 2004

Castor harvesting in the semi-arid of Piaui state, 2005

Liquid Biofuels

- The country's main producing regions will continue to be within the temperature limits for sugarcane. Even if cultivation becomes unfeasible in some specific regions (State of Para, e.g.), other regions can take up the slack, especially the Midwest
- The production of biodiesels (soy and sunflower) can be affected negatively by GCC, mainly in the Northeast, with a shift of suitable growing zones for oilseed crops to the South region

Electricity Demand - Methodology

Increase in electricity consumption due to extra air conditioning

<u>Residential and Services Sectors</u>

- 2 factors considered:
  - Increase in average temperature: COP effect
  - Increase in number of warm days: *Degree-Days effect*

Electricity Demand - Results

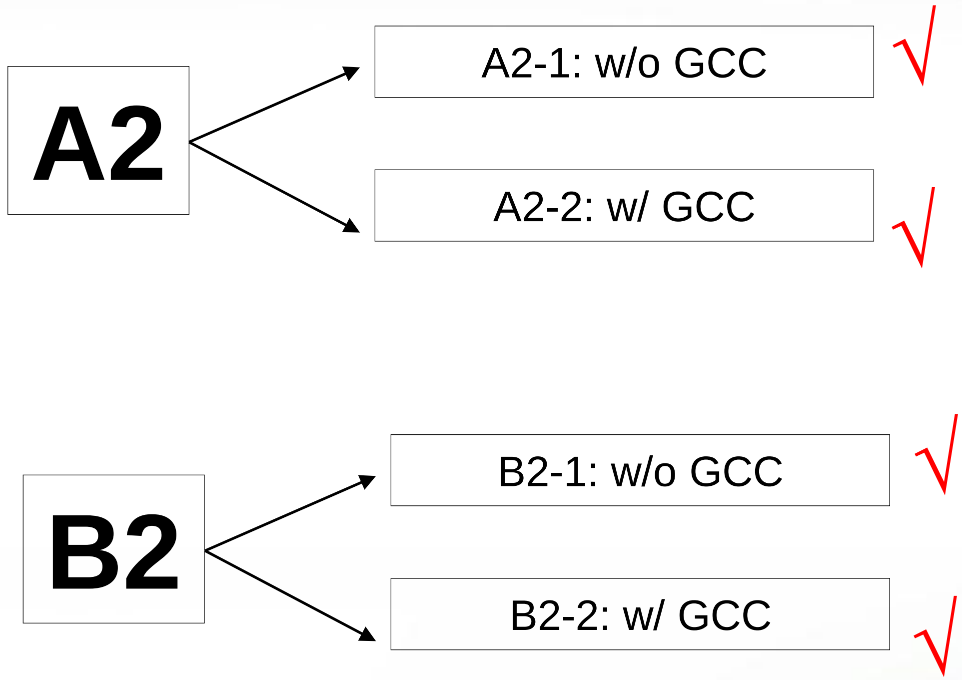
- Increase in electricity consumption in air conditioning

Ano	Residencial		Serviços	
	Cenário A2	Cenário B2	Cenário A2	Cenário B2
2030	17%	13%	9%	4%
2035	20%	26%	12%	8%

- Increase in the electricity consumption of the sector

Ano	Residencial				Serviços			
	Cenário A2	Cenário A2	Cenário B2	Cenário B2	Cenário A2	Cenário A2	Cenário B2	Cenário B2
2030	3,0%	7.723	2,4%	5.452	3,1%	7.121	1,5%	3.612
2035	4,4%	13.085	6,1%	16.068	4,7%	12.464	3,0%	8.387

Adaptation of the energy system



Scenario A2 – variation in firm energy in 2035

	Energy		Capacity
	TWh	var %	GW
Hydropower			
Small (<30MW)	**-12 (↓)**	**-30% (↓)**	**0.0**
Medium (>30MW; <300MW)	**-63 (↓)**	**-36% (↓)**	**0.0**
Large (>300MW)	**-87 (↓)**	**-28% (↓)**	**0.0**
Sugar-cane Bagasse			
BP 22 bar	0	0%	0.0
BP 42 bar	0	0%	0.0
Cascade Cogeneration	**-20 (↓)**	**-57% (↓)**	**-3.7 (↓)**
CEST	**99 (↑)**	**143% (↑)**	**13.2 (↑)**
BIG-GT	0	0%	0.0
Municipal Solid Waste	0	0%	0.0
Wind Power	**21 (↑)**	**39% (↑)**	**10.0 (↑)**
Natural Gas	**133 (↑)**	**135% (↑)**	**32.9 (↑)**
Nuclear	**45 (↑)**	**58% (↑)**	**6.1 (↑)**
Coal	0	0%	0.0
Diesel Oil	0	0%	0.0
Oil	0	0%	0.0

Scenario B2 – variation in firm energy in 2035

	Energy		Capacity
	TWh	var %	GW
Hydropower			
Small (<30MW)	**-12 (↓)**	**-30% (↓)**	**0.0**
Medium (>30MW; <300MW)	**-61 (↓)**	**-35% (↓)**	**0.0**
Large (>300MW)	**-80 (↓)**	**-26% (↓)**	**0.0**
Sugar-cane Bagasse			
BP 22 bar	0	0%	0.0
BP 42 bar	0	0%	0.0
Cascade Cogeneration	**-12 (↓)**	**-100% (↓)**	**-2.3 (↓)**
CEST	**77 (↑)**	**49% (↑)**	**10.3 (↑)**
BIG-GT	0	0%	0.0
Municipal Solid Waste	0	0%	0.0
Wind Power	**24 (↑)**	**26% (↑)**	**11.5 (↑)**
Natural Gas	**124 (↑)**	**147% (↑)**	**30.2 (↑)**
Nuclear	0	0%	0.0
Coal	**53 (↑)**	**134% (↑)**	**8.6 (↑)**
Diesel Oil	0	0%	0.0
Oil	0	0%	0.0

Results – Adaptation - 2035

- Brazil's electric power system will need to expand its installed capacity by some 60 GW to cope with the loss of firm energy from the hydropower system
- This new installed capacity would require extra 90-120 billion dollars in investments in new capacity
- On average, especially for natural gas-fired plants, this new installed capacity will not be used. It is an insurance against the loss of reliability of the system
- Under critical conditions, natural gas compensates for hydro losses, but GHG emissions from power generation increases

Conclusions

- REs present a substantial economic potential for mitigating GHG emissions over the coming decades
- At the same time, REs are increasingly seen as a fundamental pillar for improving a country’s energy security
- On the other hand, because they are strongly dependent on climate conditions, REs may be vulnerable to the very problem they try to fight
- And as a consequence, REs may not contribute to mitigating climate change and to improving energy security as much as they promise, or as much as it is expected from them

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