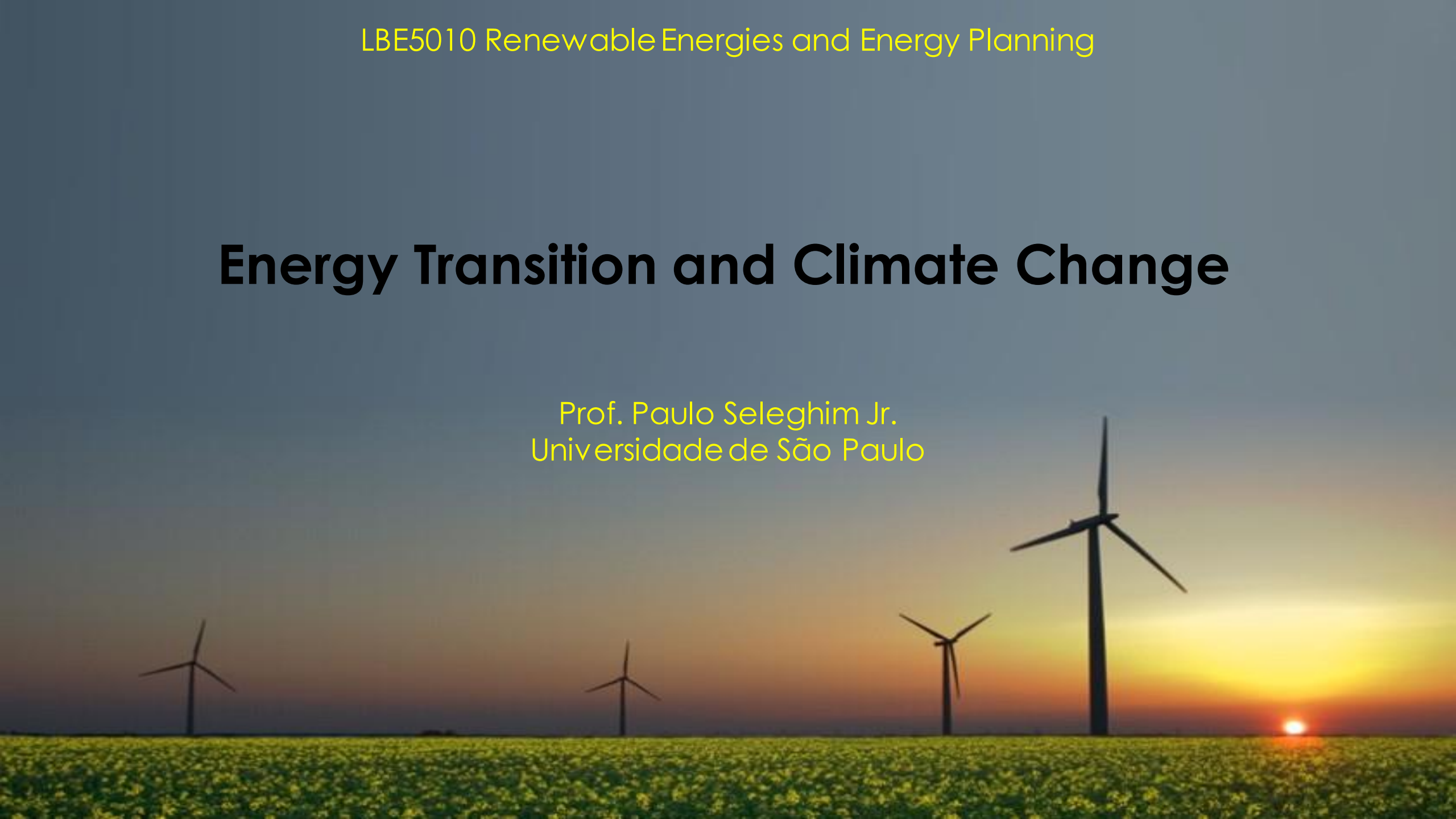
LBE5010 Renewable Energies and Energy Planning

Energy Transition and Climate Change

Prof. Paulo Seleghim Jr.
Universidade de São Paulo



THE PROBLEM:
Energy and Quality of Life

Energy for our organic processes

2500 cal/day

120 w

2000 W

90 W

Energy for our life style

500 EJ/year

7 billion people

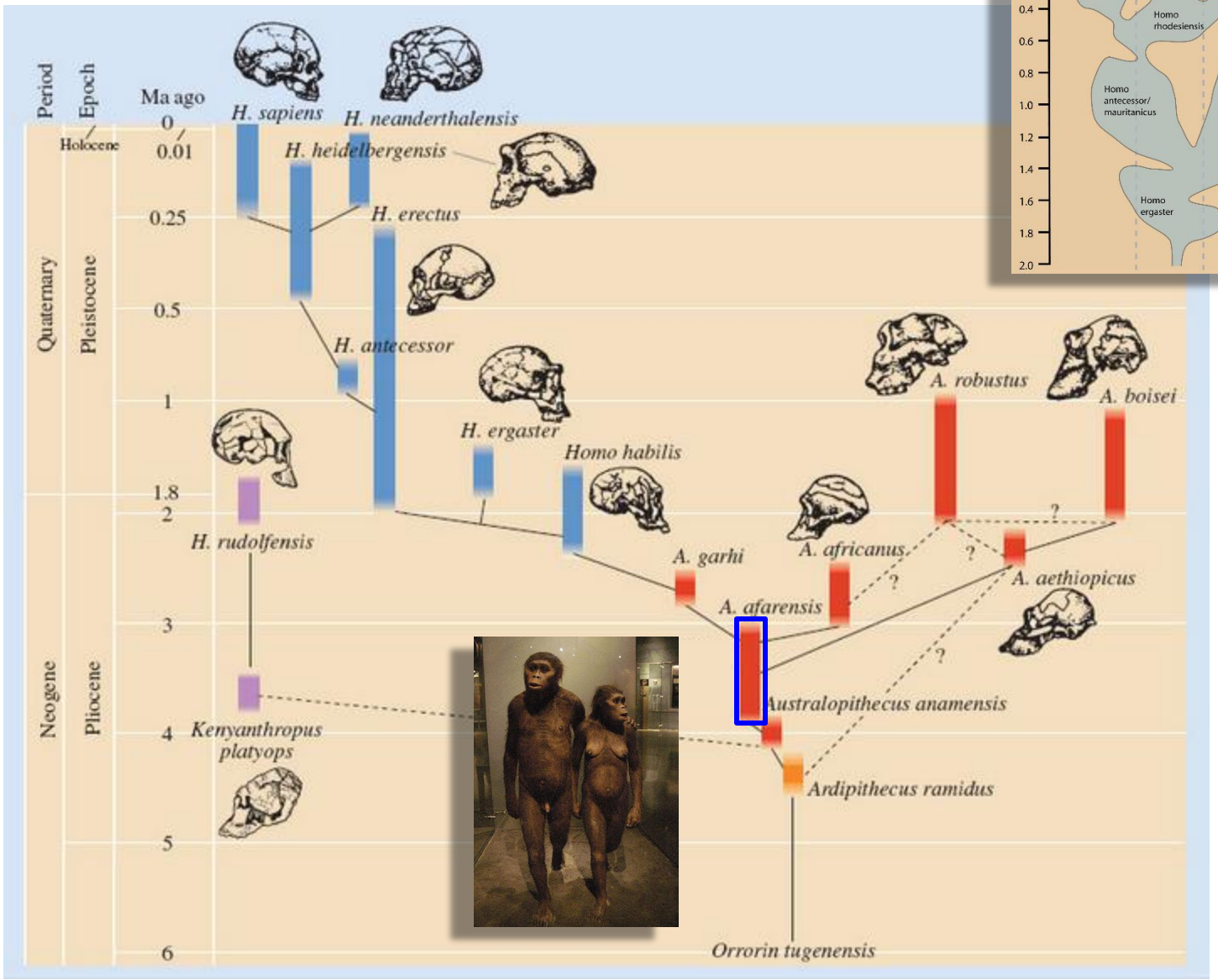
2300 w

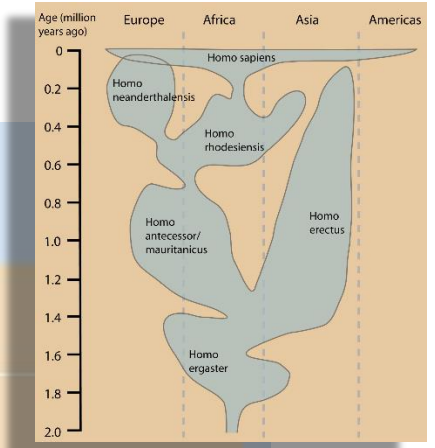
- industry and agriculture (28% =)
- transportation sector (27% ↑)
- services and buildings (36% ↓)

120 w

metabolism

$$\frac{2500\ \text{kcal}}{1\ \text{dia}} \times \frac{4{,}18\ \text{Joules}}{1\ \text{cal}} \times \frac{1\ \text{dia}}{24\text{h} \cdot 3600\ \text{s/h}} = 120{,}95\ \frac{\text{J}}{\text{s}}$$





Natural History Museum NYC

Lucy: Australopithecus afarensis

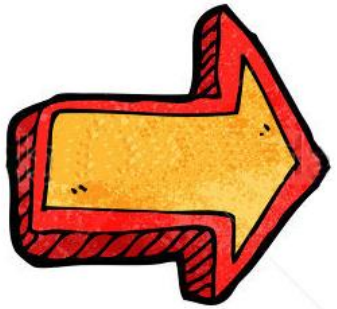
Energy and Social Development

120 w

metabolism

300 w

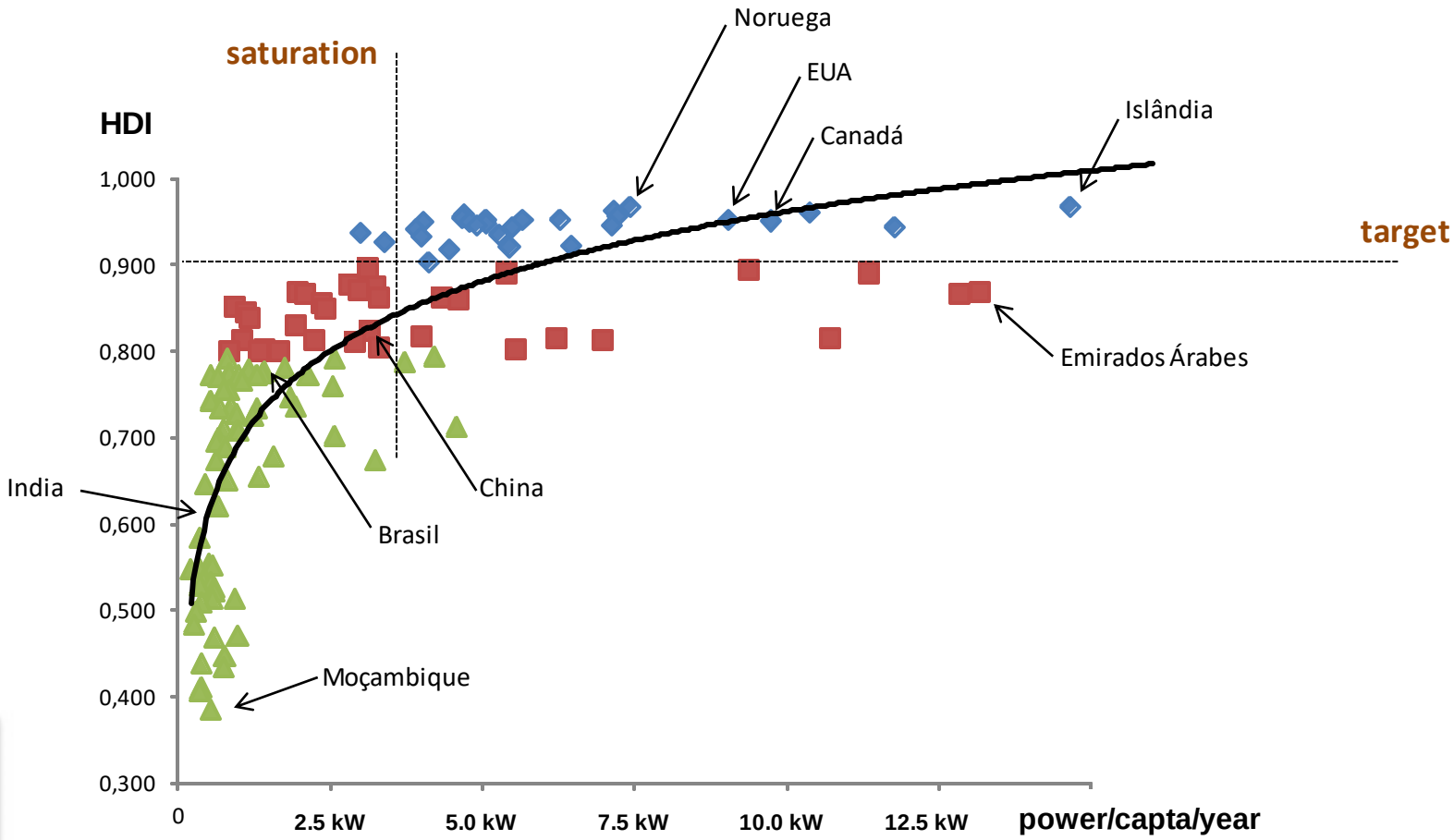
10.000 anos



5000 w

Canadá:	10.000W
França:	5.300W
Brasil:	1.800W
Índia:	750W
Afeganistão:	120W

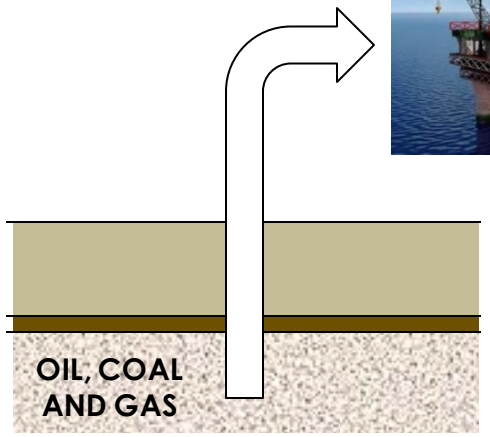
Energy and Social Development



Fossil carbon based economy...

120W

metabolism



16 TW

CO_2

energy

chemical compounds

3000W

$$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O + heat$$

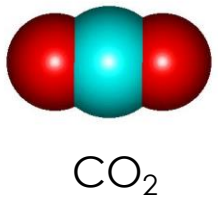
$\Downarrow \eta_{carnot}$

exergy

A Possible Solution...

Renewable carbon based economy... (**neutral**)

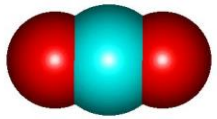
120W
metabolism



CO_2

88 J/g CO_2

16 TW

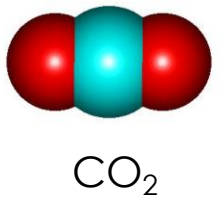


CO_2

energy

chemical compounds

Renewable carbon based economy... (**negative**)



CO_2

88 J/g CO_2

16 TW

energy

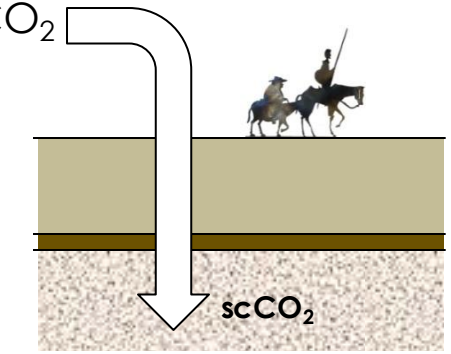
chemical compounds

$scCO_2$

120W

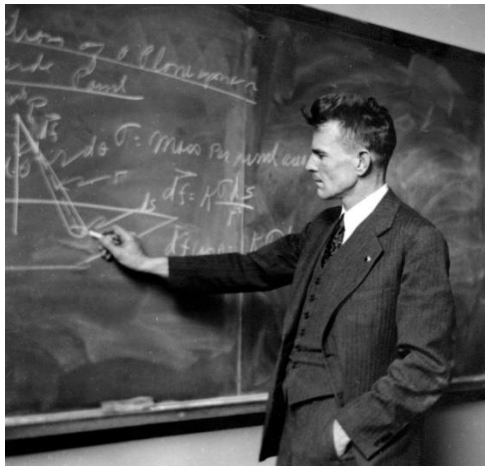
metabolism

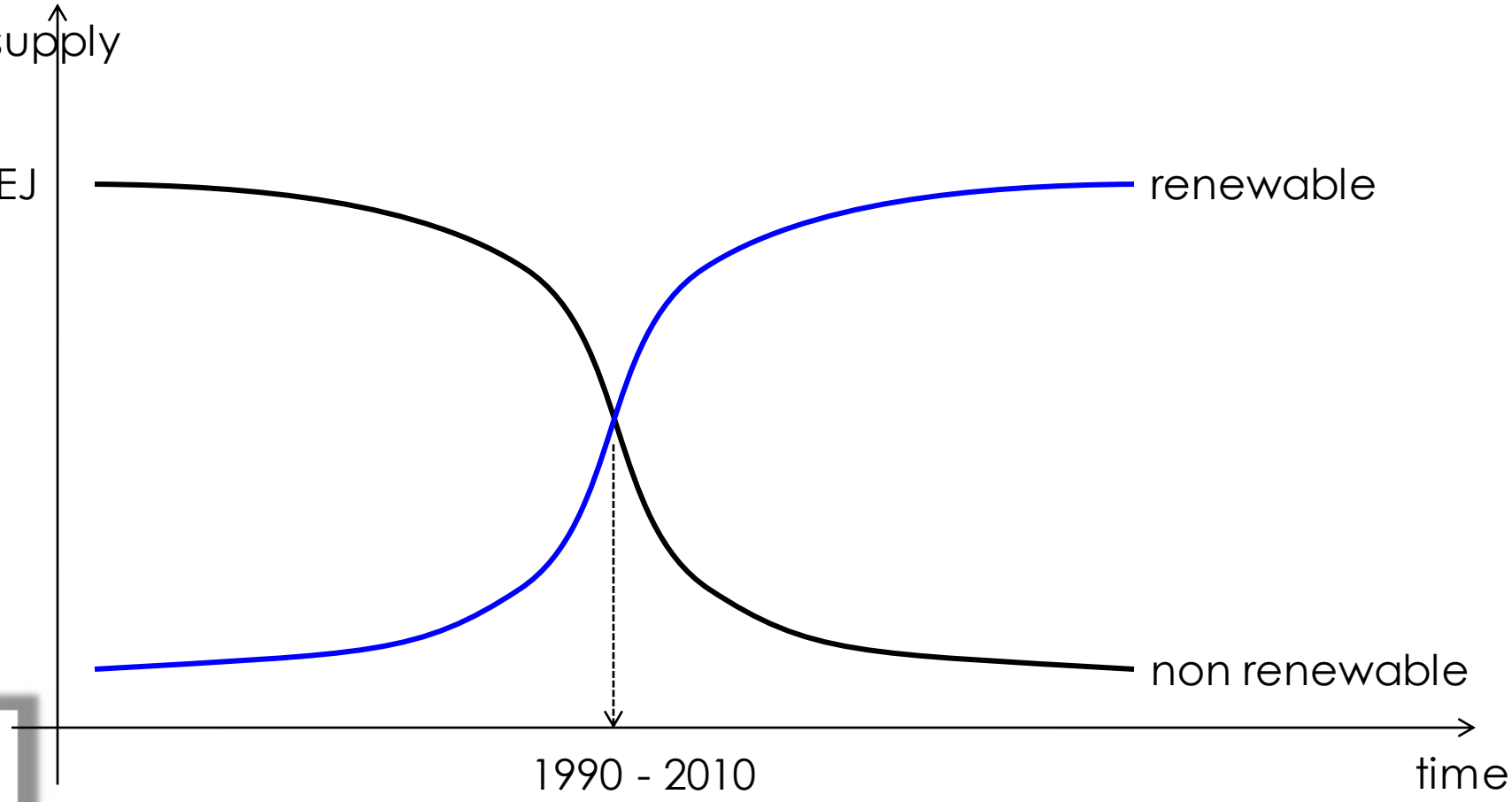
The loss of revenues from electricity is compensated by (actual) carbono credits



Displacement of fossil by renewable fuels: the Hubbert Law

Marion King Hubbert
10/1903 – 11/1989





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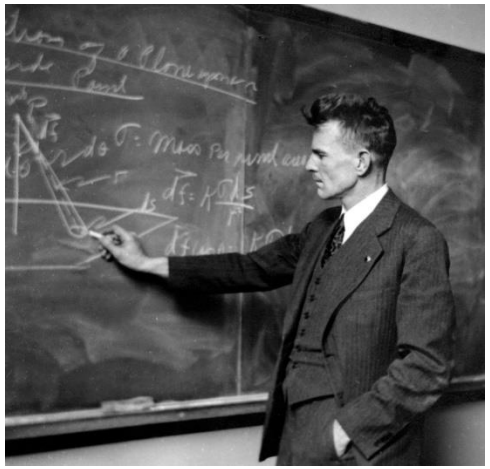
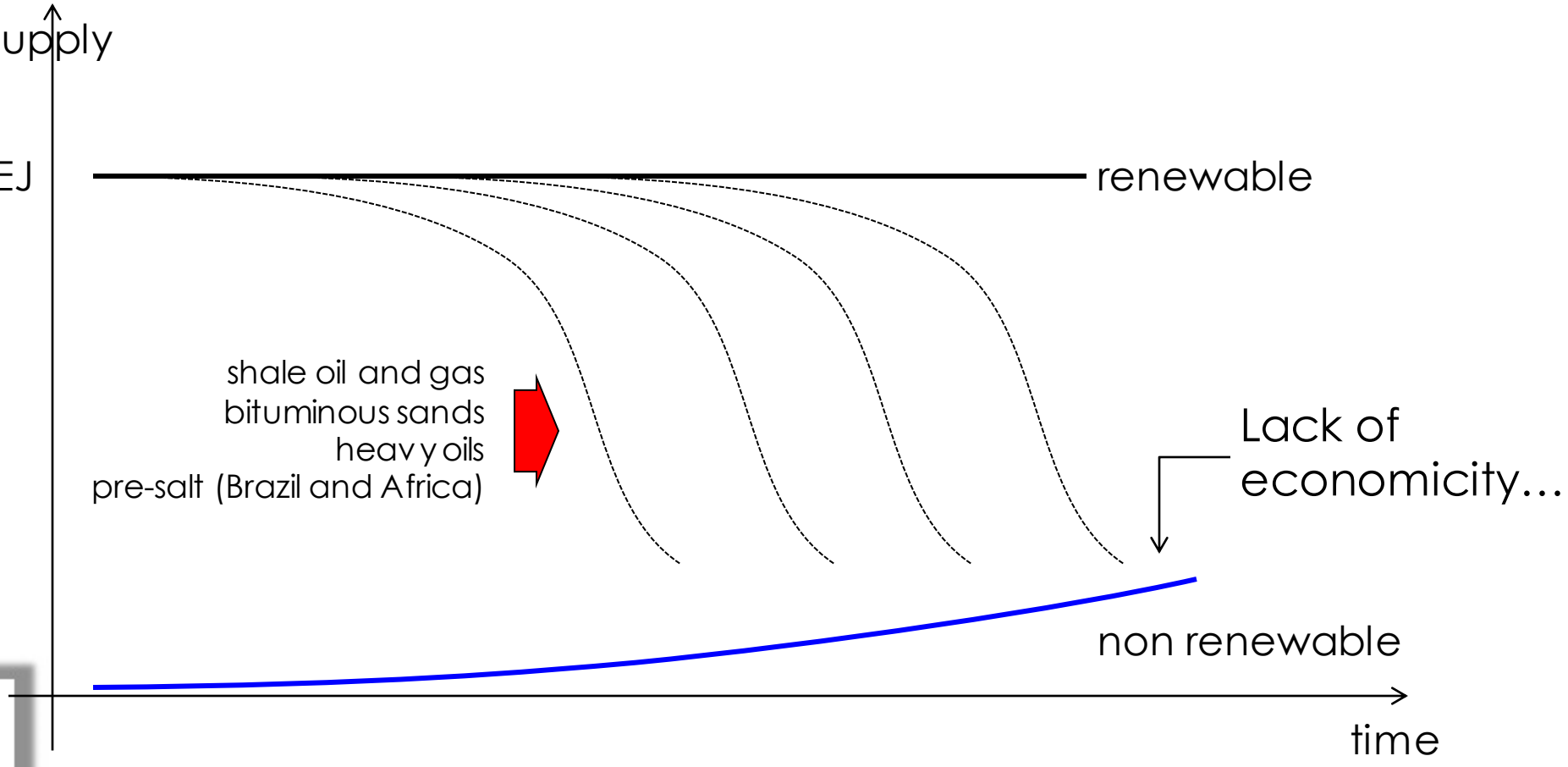
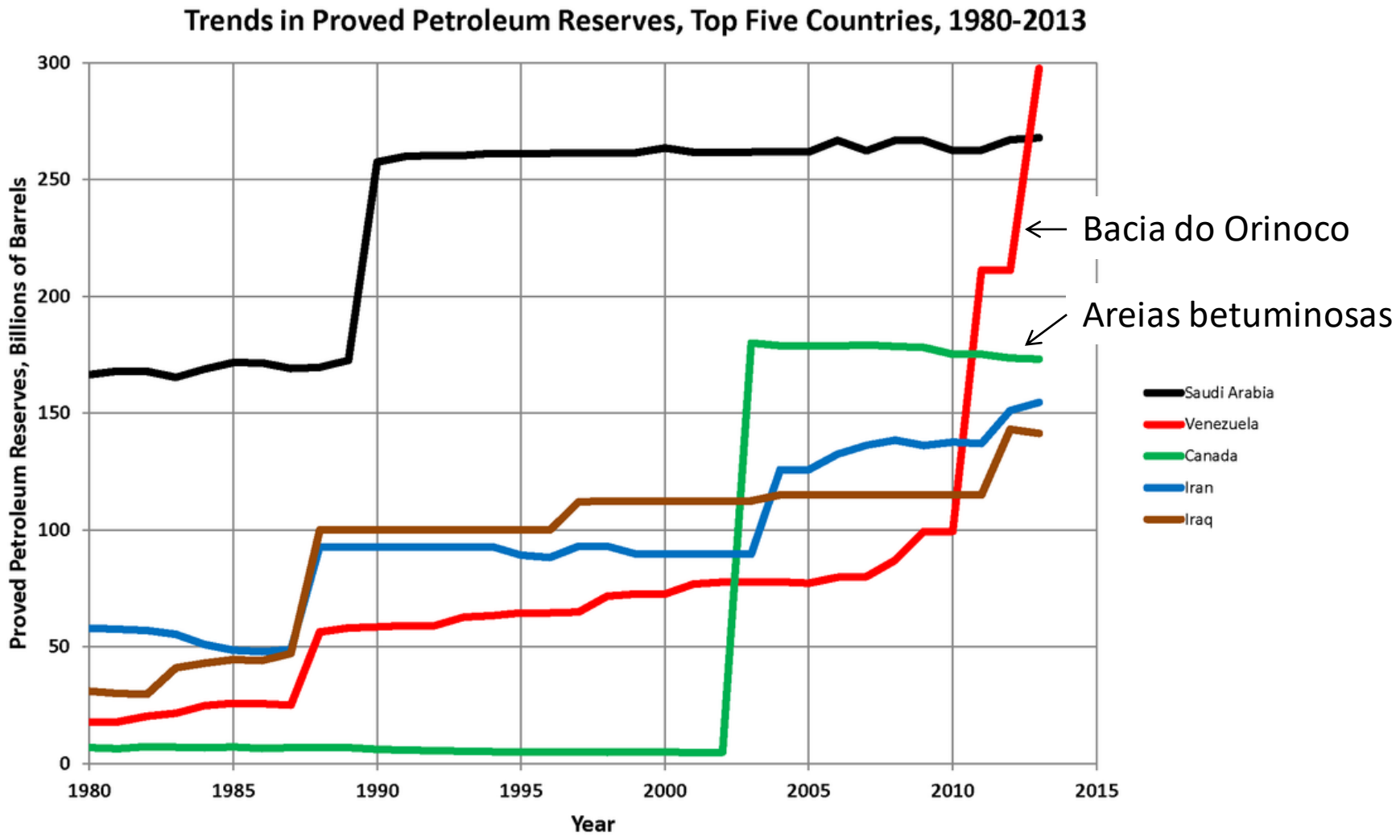
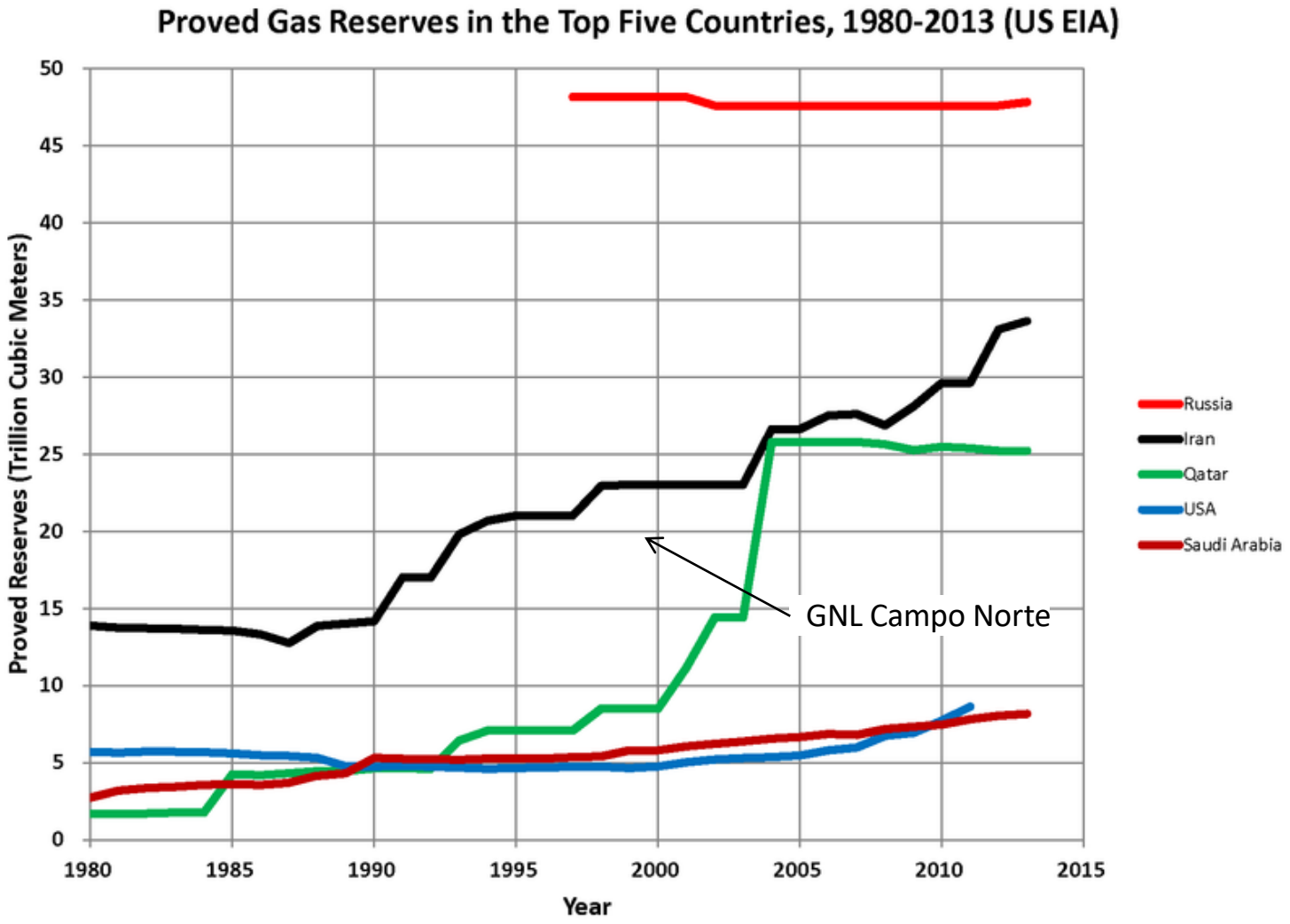






US Energy Information Administration



US Energy Information Administration

- As previsões para o declínio da produção mundial de petróleo e gás segundo a lei de Hubbert provaram-se prematuras

de

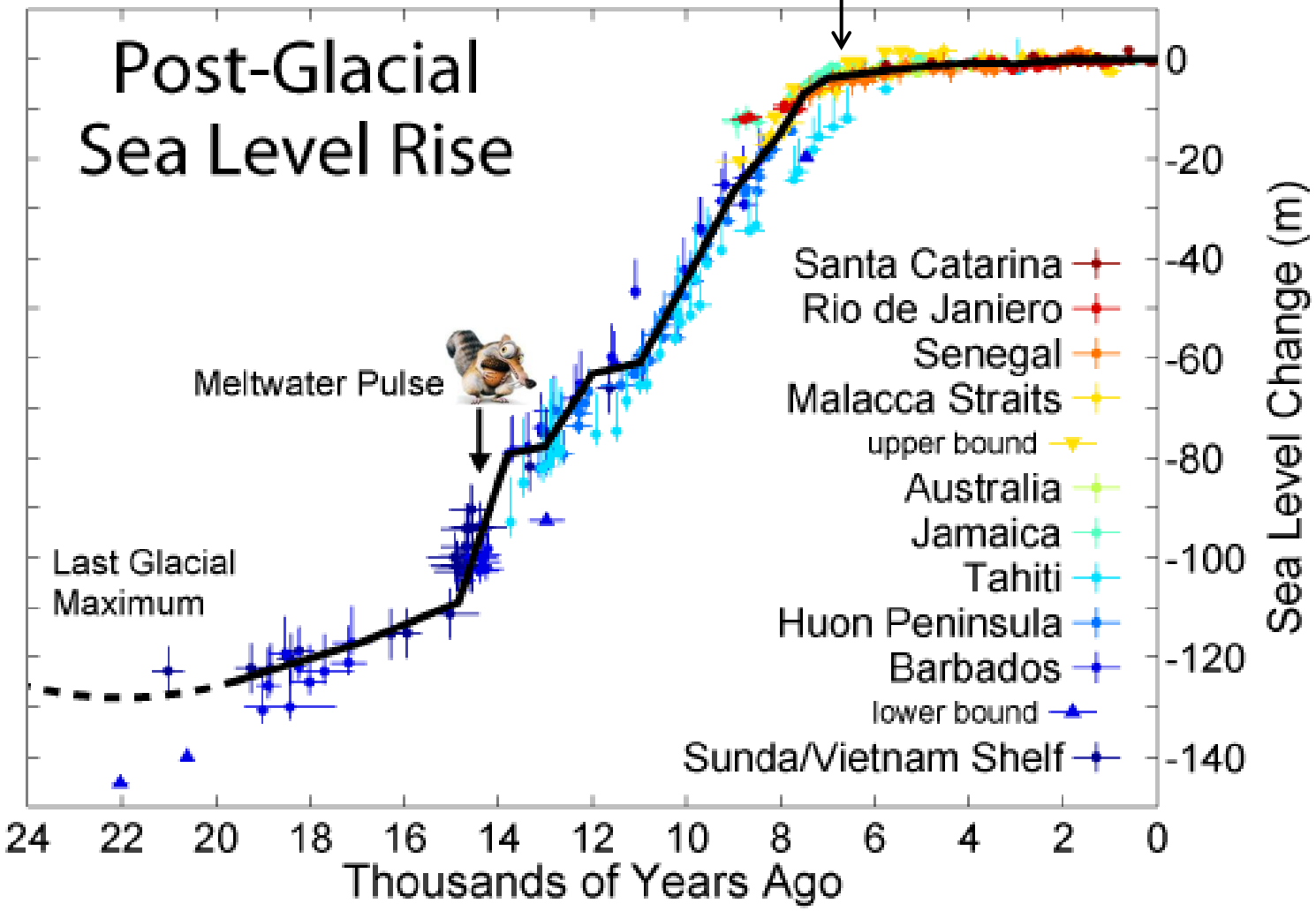
e

CO_2...

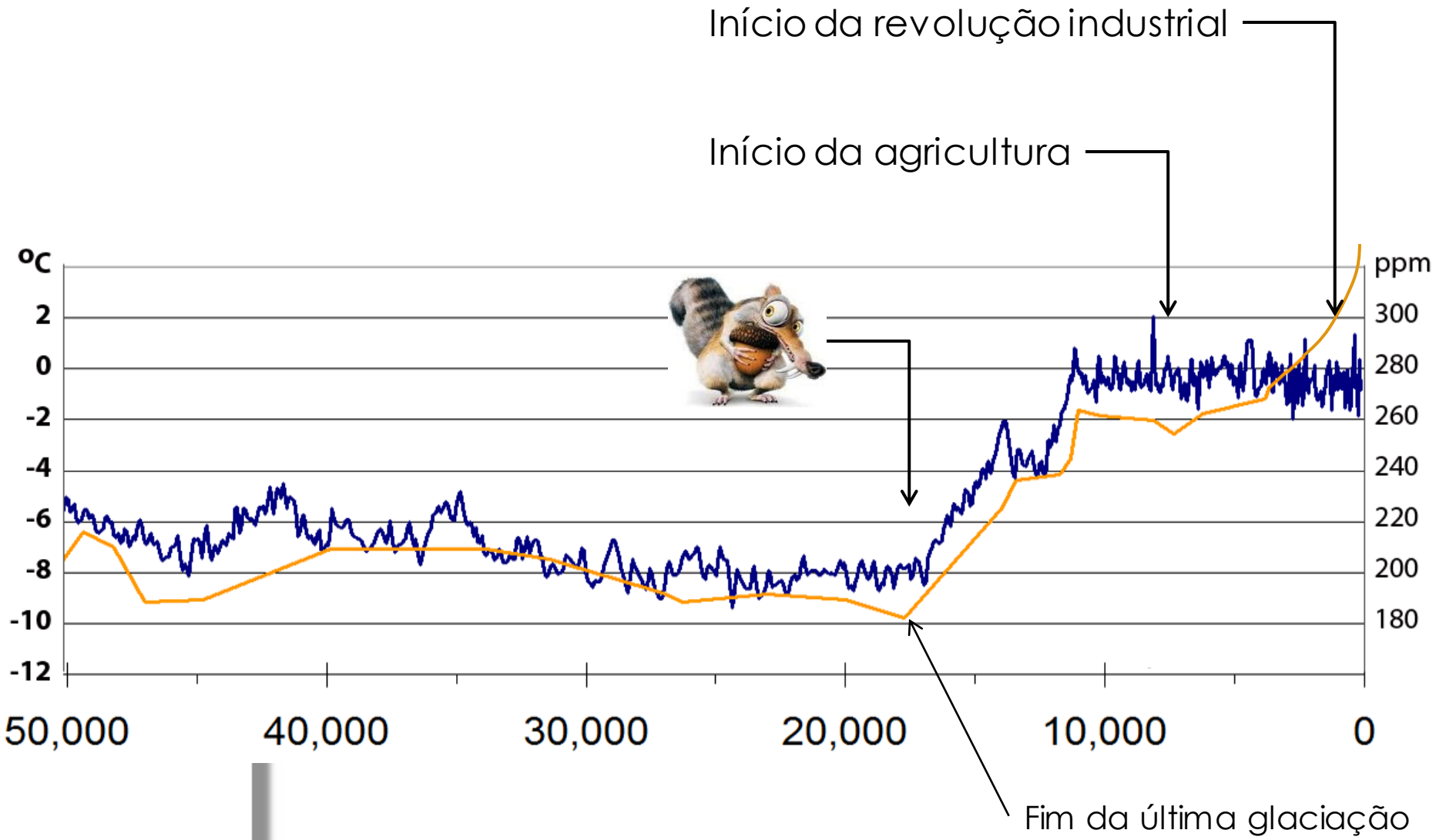
MUDANÇAS CLIMÁTICAS

O CLIMA E O SURGIMENTO DA VIDA

Início da agricultura

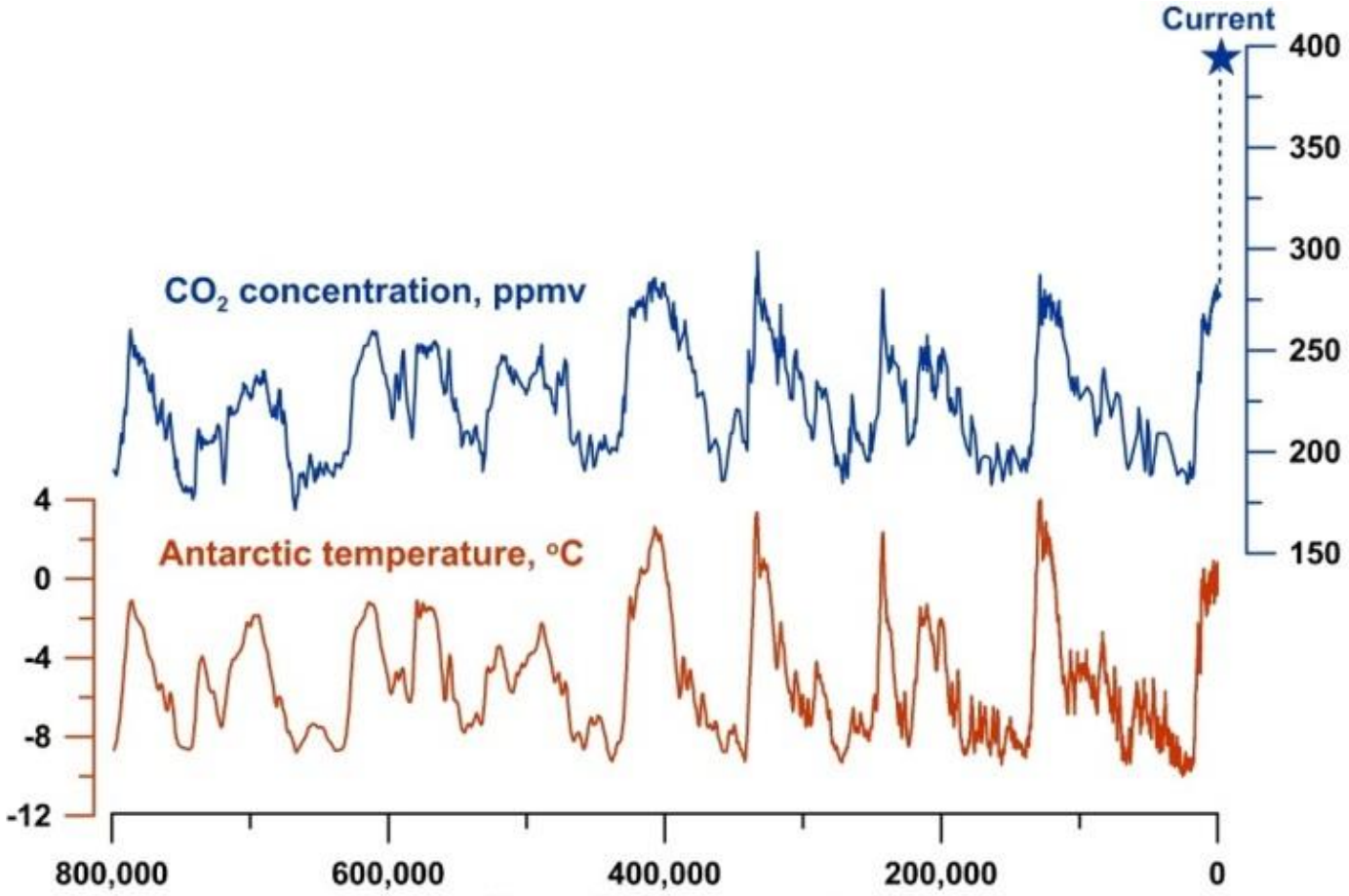


US Environmental Protection Agency (US EPA) (2010)



joannenova.com.au

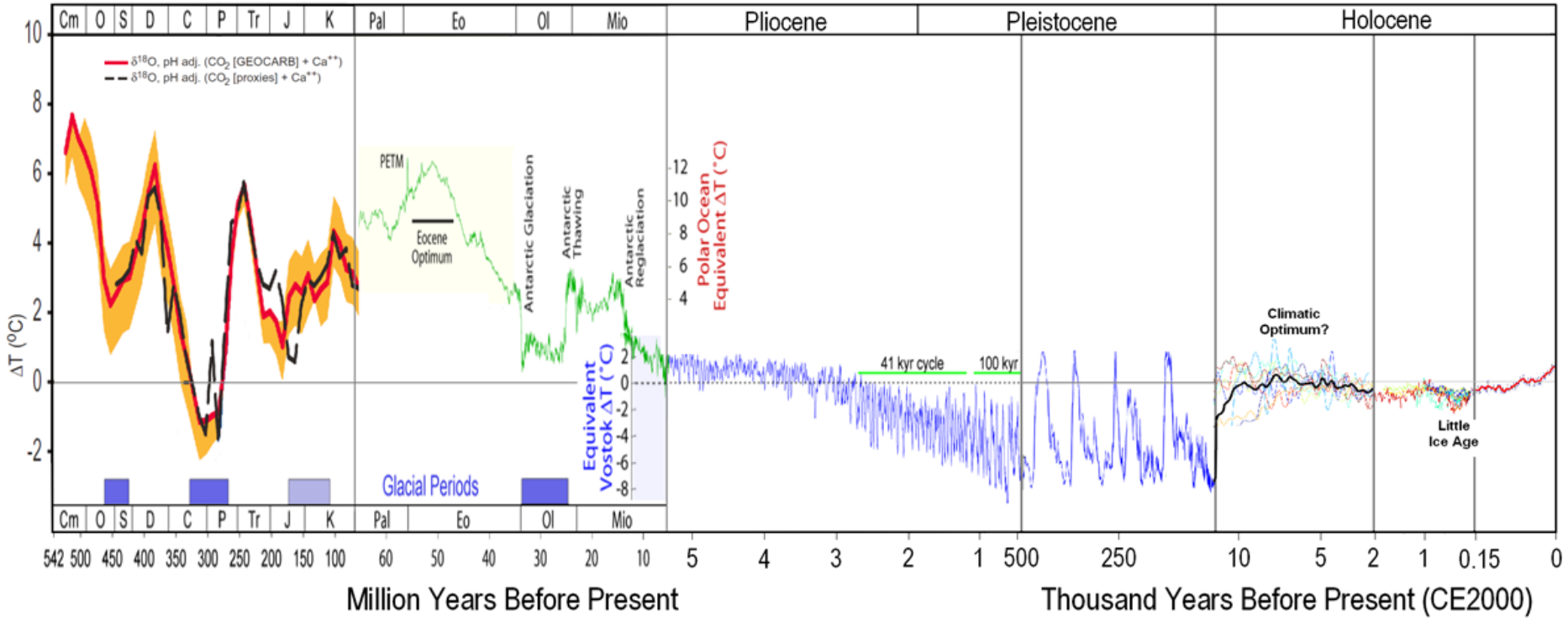
ZOOMING OUT...



The 800,000 year record of atmospheric CO2 from Antarctic ice cores, and a reconstruction of temperature based on hydrogen isotopes in the ice. The current CO2 concentration of 392 parts per million (ppm) is shown by the blue star. Credit: Jeremy Shakun/Harvard University

ZOOMING OUT...

Temperature of Planet Earth

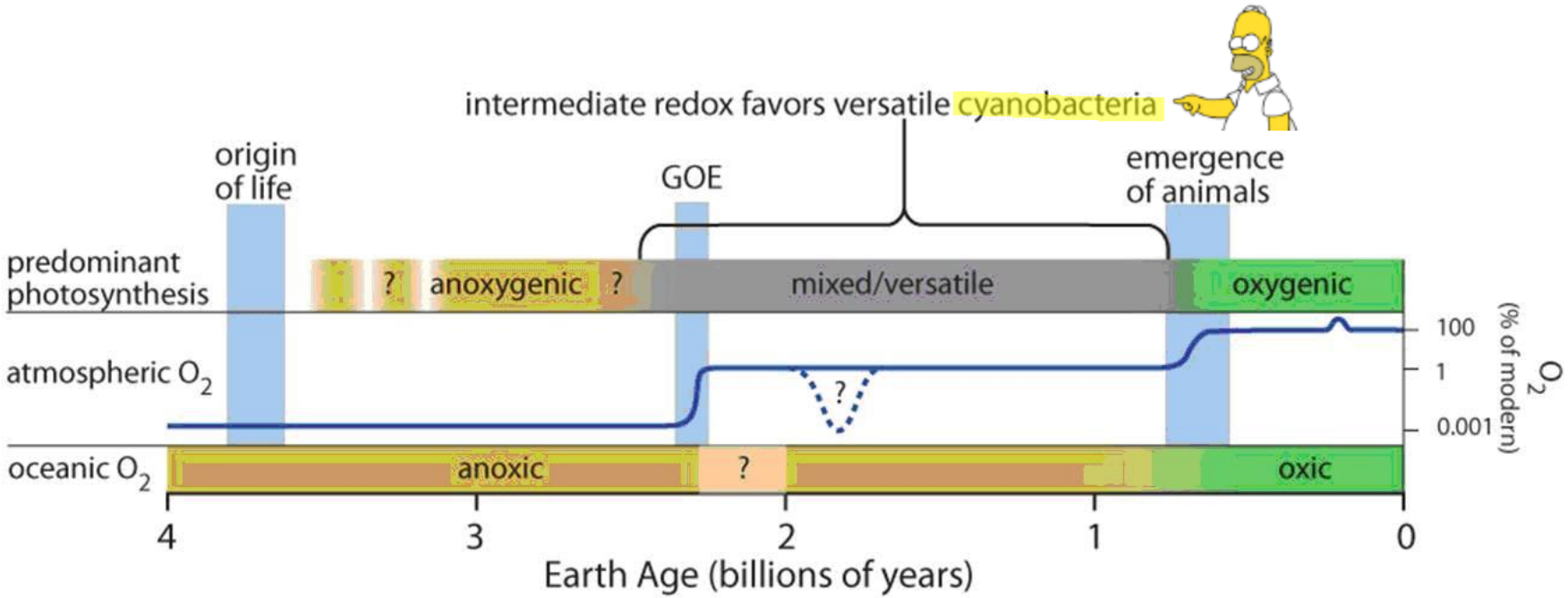


6 extinções em massa

agricultura e primeiras cidades

construção das primeiras pirâmides

Djoser (2648 AC)



Simplified schematic timeline of photosynthesis and the oxygenation of the atmosphere and oceans through Earth's history. Atmospheric oxygen concentrations are shown as a percentage of modern levels (from Lyons et al. 2009). GOE = Great Oxidation Event, ~2.4 bya. Although there is always uncertainty in chemical and biological data from the early Earth, time periods for which this information is especially uncertain are indicated with question marks. Three main phases are evident: (1) an early anoxic world in which there was very low oxygen and was dominated by anoxygenic photosynthesis; (2) an intermediate low-oxygen world in which significant contributions to photosynthesis were made by both oxygenic and anoxygenic phototrophs, or perhaps by organisms that could do both, such as those from Middle Island Sinkhole; and (3) the modern oxic world in which oxygenic photosynthesis predominates. Not until this later stage did complex plants and animals evolve.

FATOS

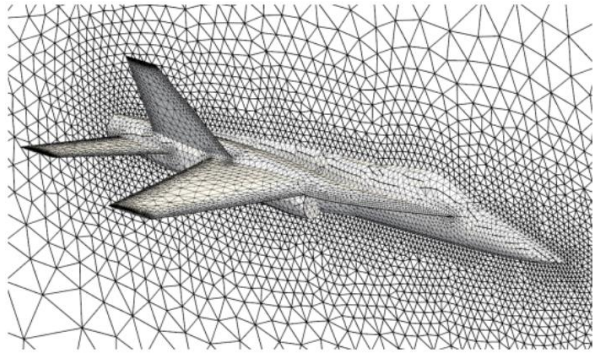
- A temperatura média do planeta está aumentando nos últimos 250 anos
- O pico na concentração de CO_2 se deve às emissões de GEE, sobretudo desde a revolução industrial

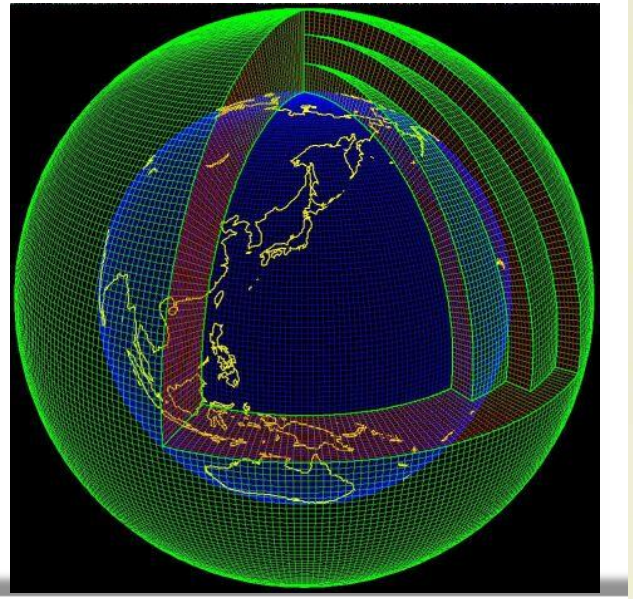
HIPÓTESE

- O aumento da temperatura é causado pelas emissões antropogênicas de GEE

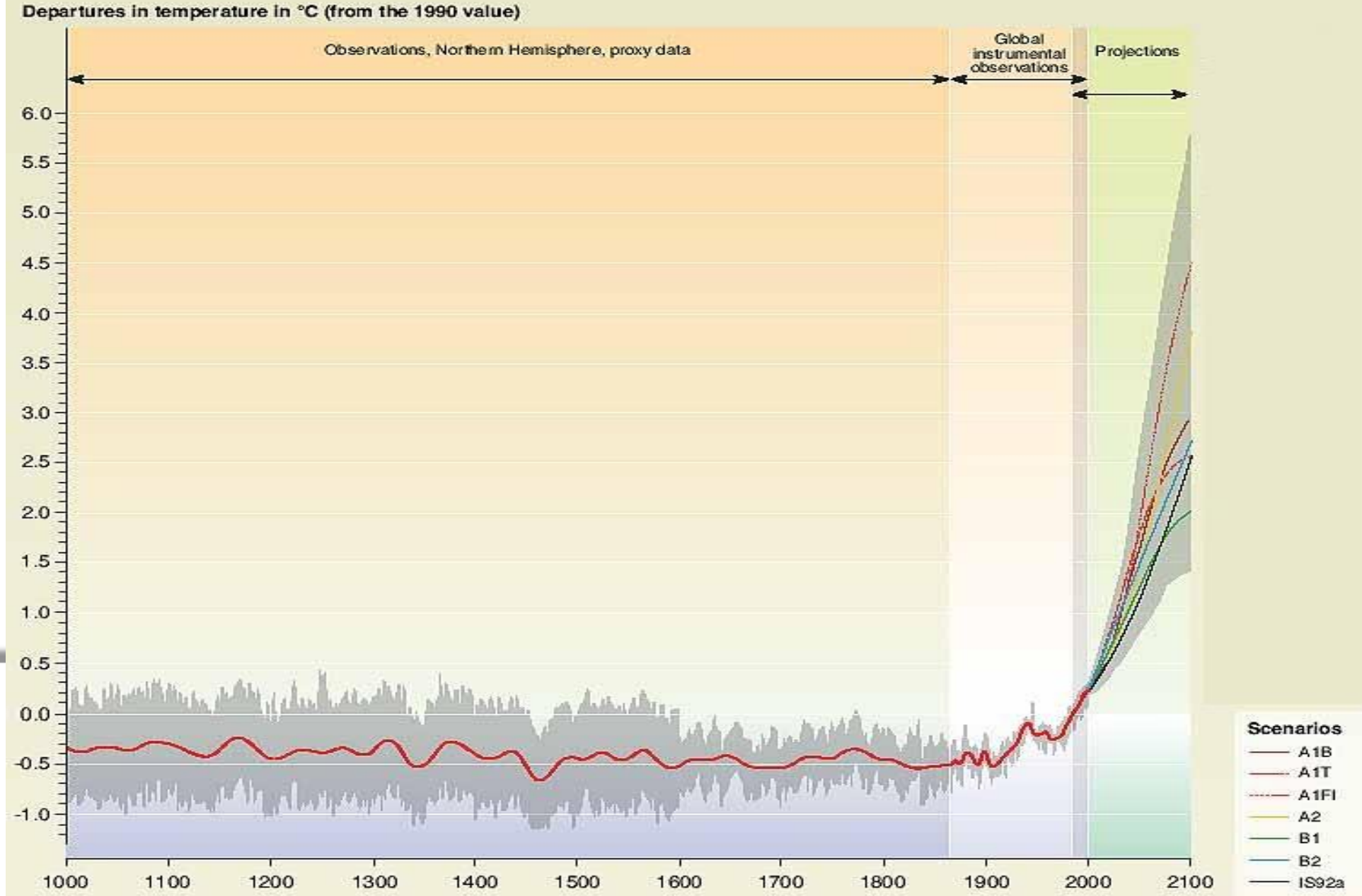
... porém os efeitos a curto e médio prazo são incertos.

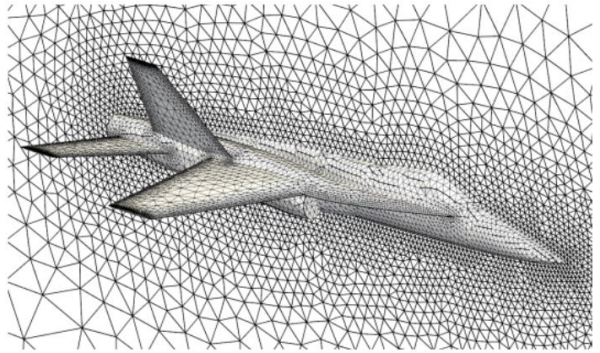
Testando a HIPÓTESE via modelos climáticos...

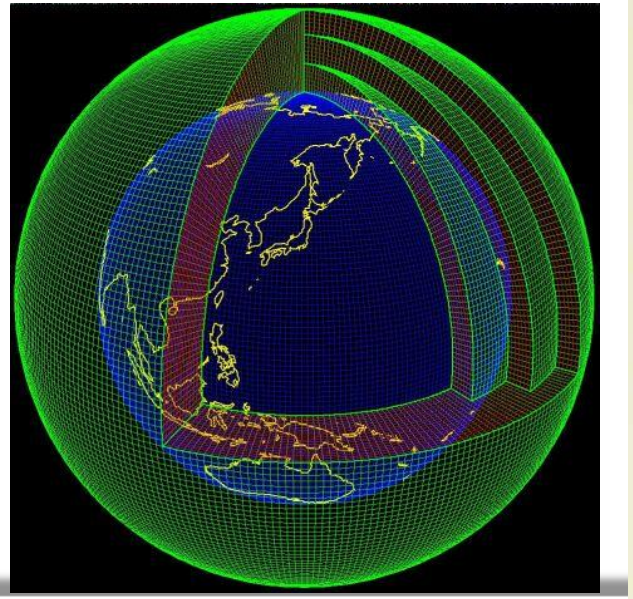




Variations of the Earth's surface temperature: years 1000 to 2100







Variations of the Earth's surface temperature: years 1000 to 2100

Departures in temperature in °C (from the 1990 value)

Observations, Northern Hemisphere, proxy data

Global instrumental observations

Projections

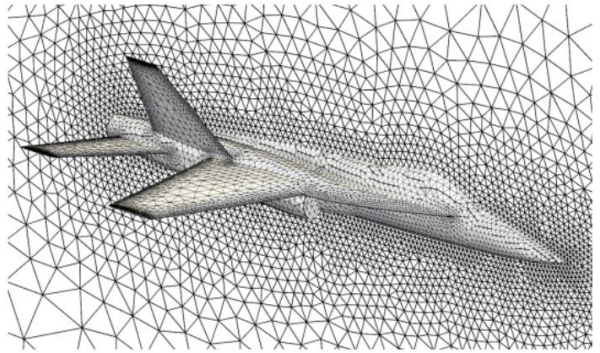
previsões até 2100 →

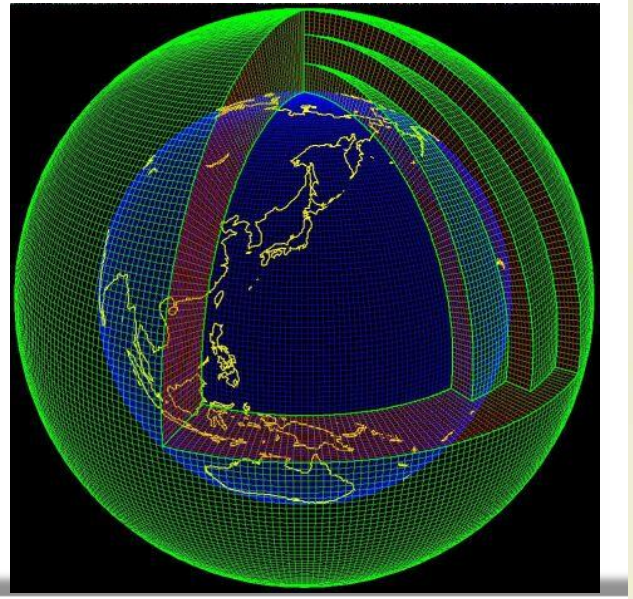
hoje →

6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
-1.0

1000 1100 1200 1300 1400 1500 1600 1700 1800 1900 2000 2100

Scenarios
A1B
A1T
A1FI
A2
B1
B2
IS92a





Variations of the Earth's surface temperature: years 1000 to 2100

Departures in temperature in °C (from the 1990 value)

Observations, Northern Hemisphere, proxy data

Global instrumental observations

Projections

previsões até 2100 →

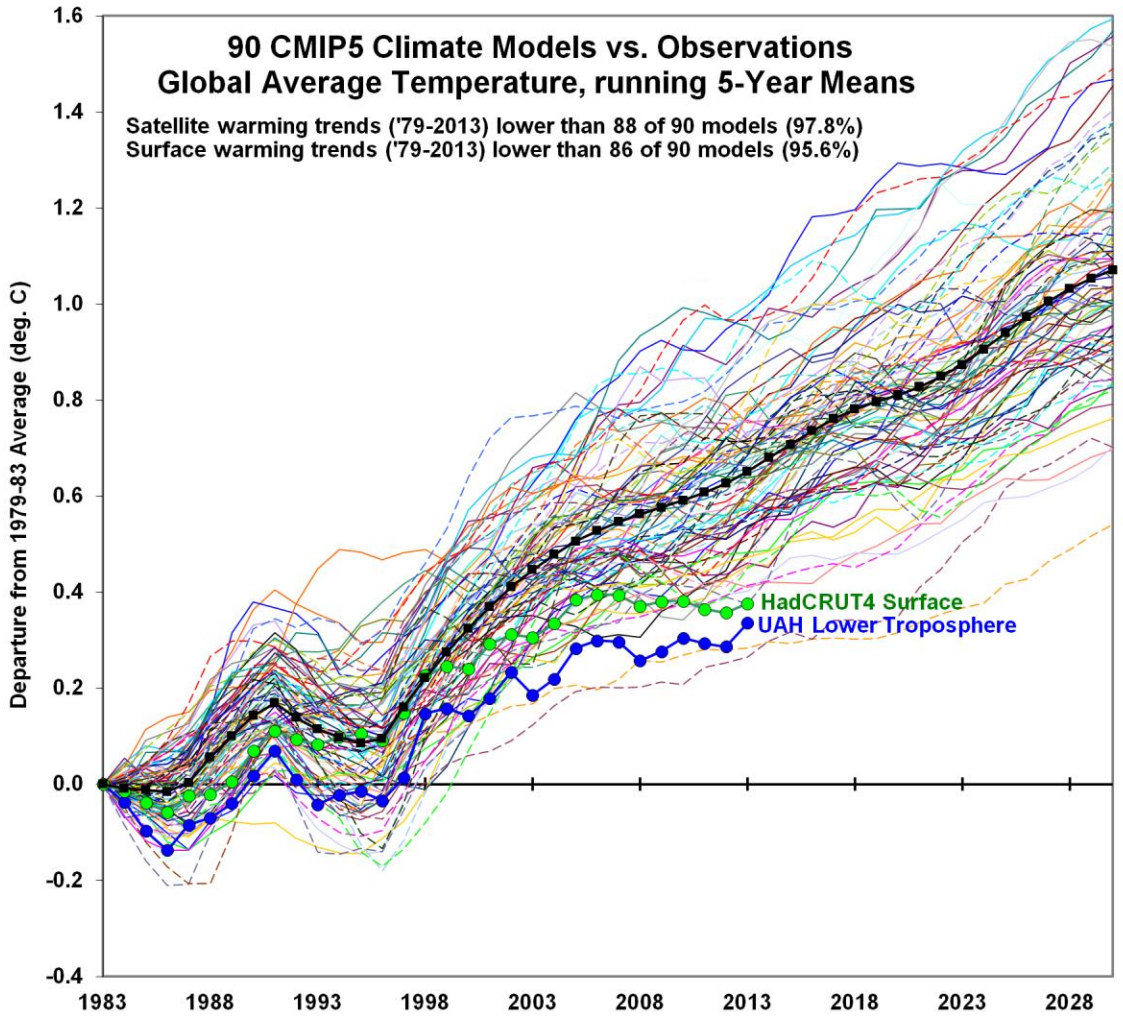
< 2,5ºC evita-se mudanças climáticas perigosas...

hoje →

ΔT

probabilidade

Scenarios
A1B
A1T
A1FI
A2
B1
B2
IS92a

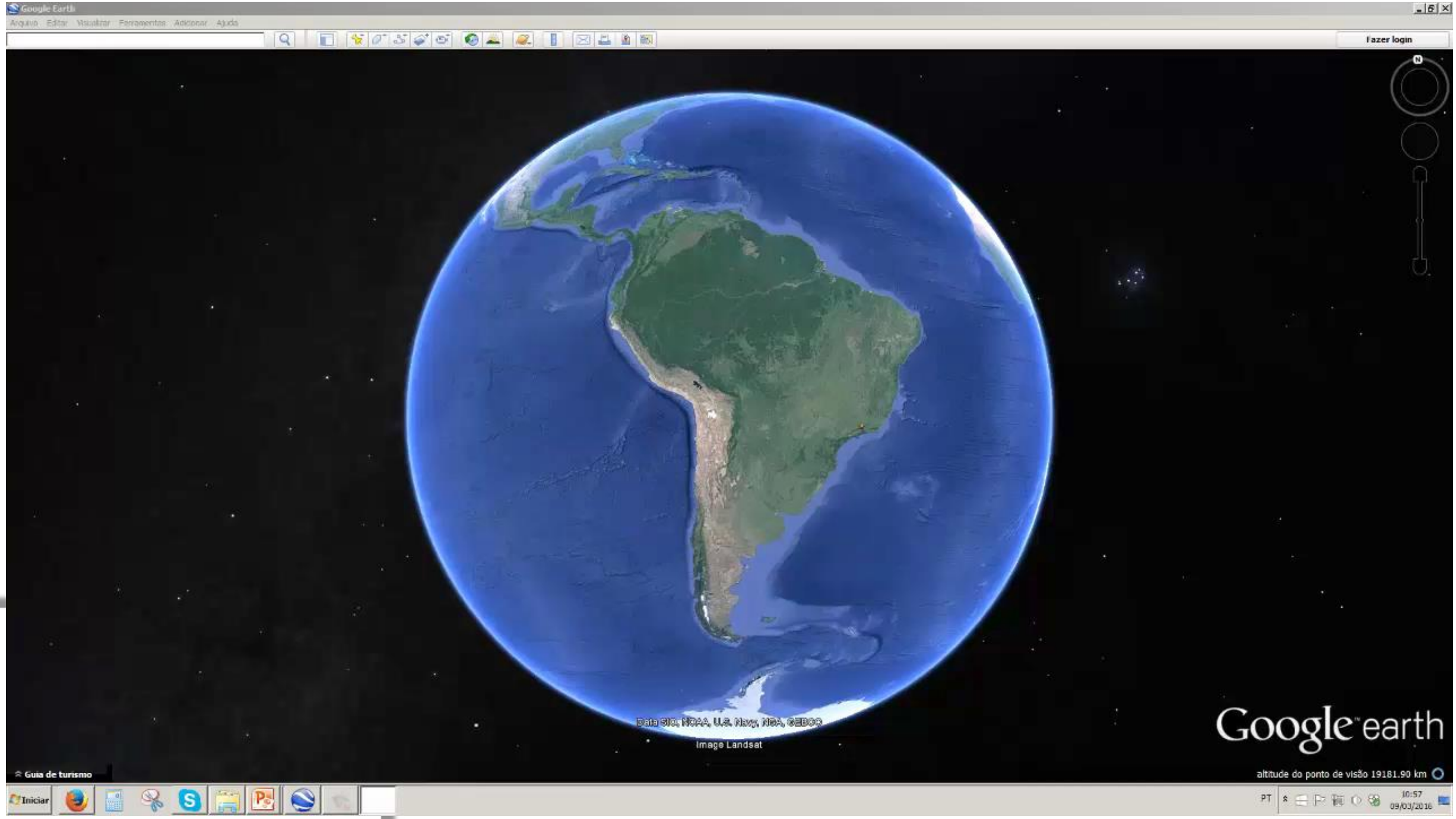


www.drroyspencer.com

CERCA DE 95% DOS MODELOS CLIMÁTICOS CONCORDAM ENTRE SI:

“OS FATOS DEVEM ESTAR ERRADOS !”

Testando a HIPÓTESE via proxies...

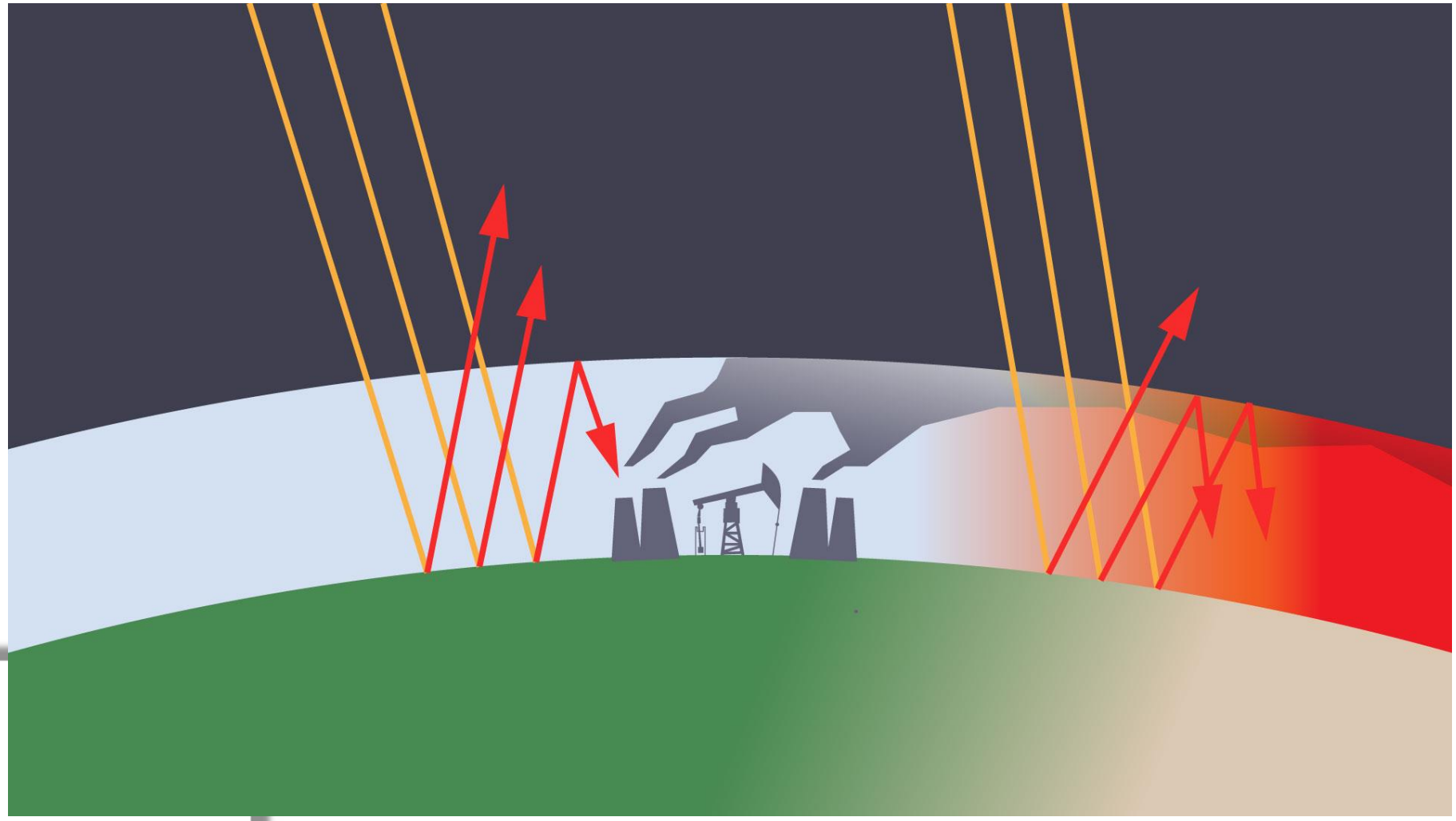

Google Earth
Arquivo Editar Visualizar Ferramentas Adicionar Ajuda
Fazer login
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Image Landsat
Guia de turismo
Google earth
altitude do ponto de visão 19181.90 km
Iniciar
PT
10:57
09/03/2016

Retração das Geleiras

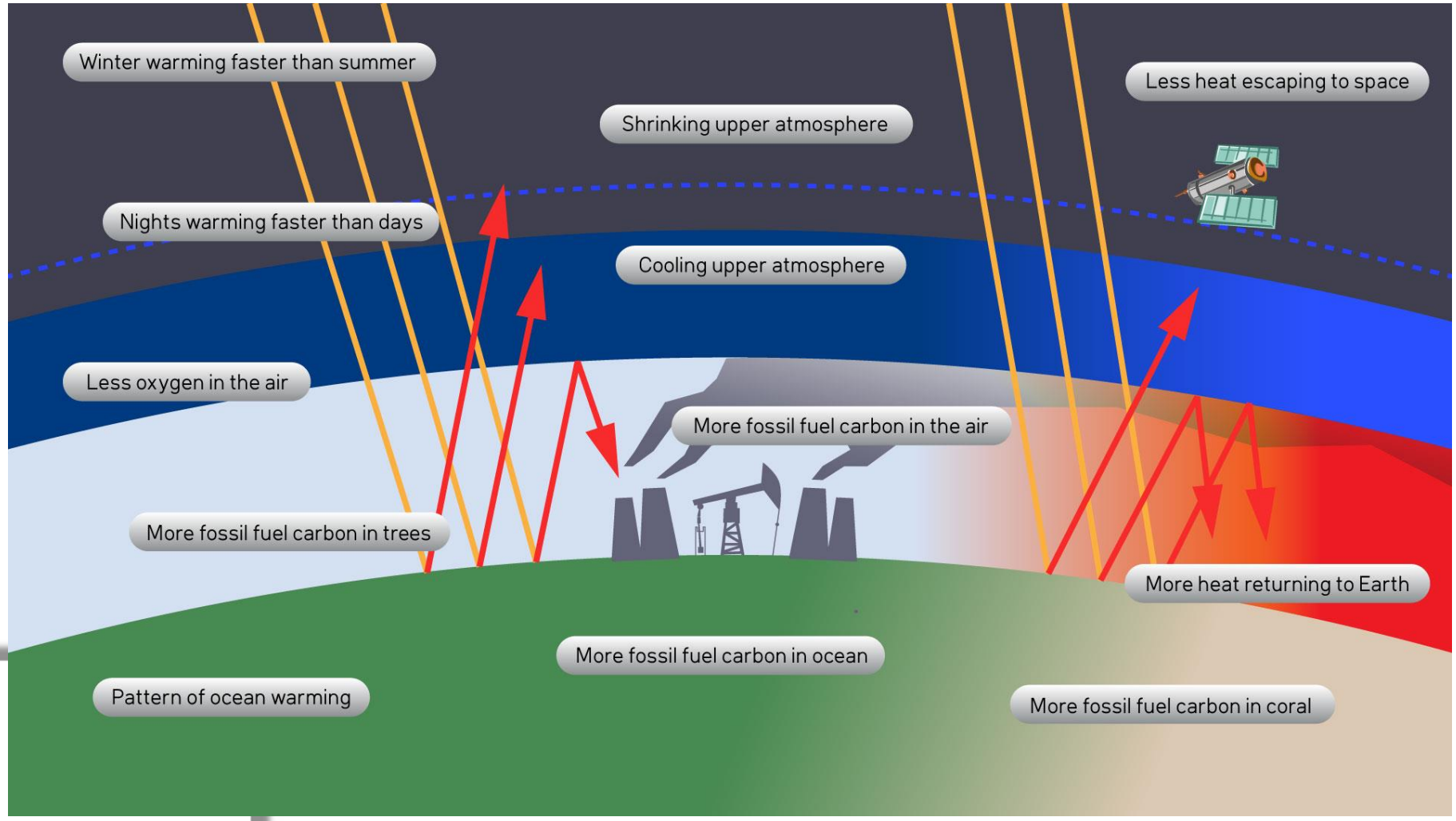
Glaciar Grey, Campo de Gelo Patagônico Sul

Retração das Geleiras

Glaciar Grey, Campo de Gelo Patagônico Sul



CONFIRMAÇÃO ATRAVÉS “PROXIES” (variável de inferência)



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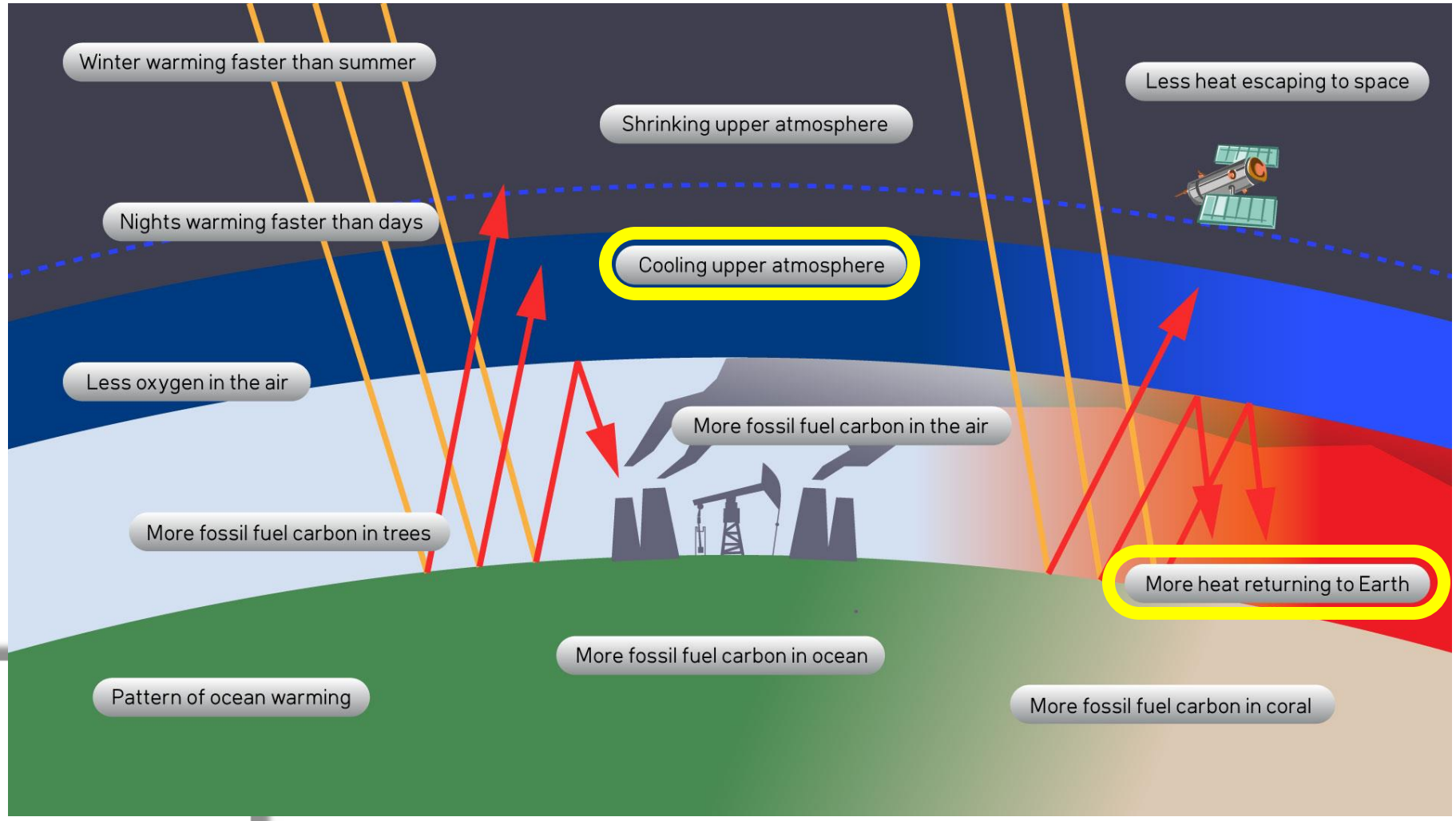
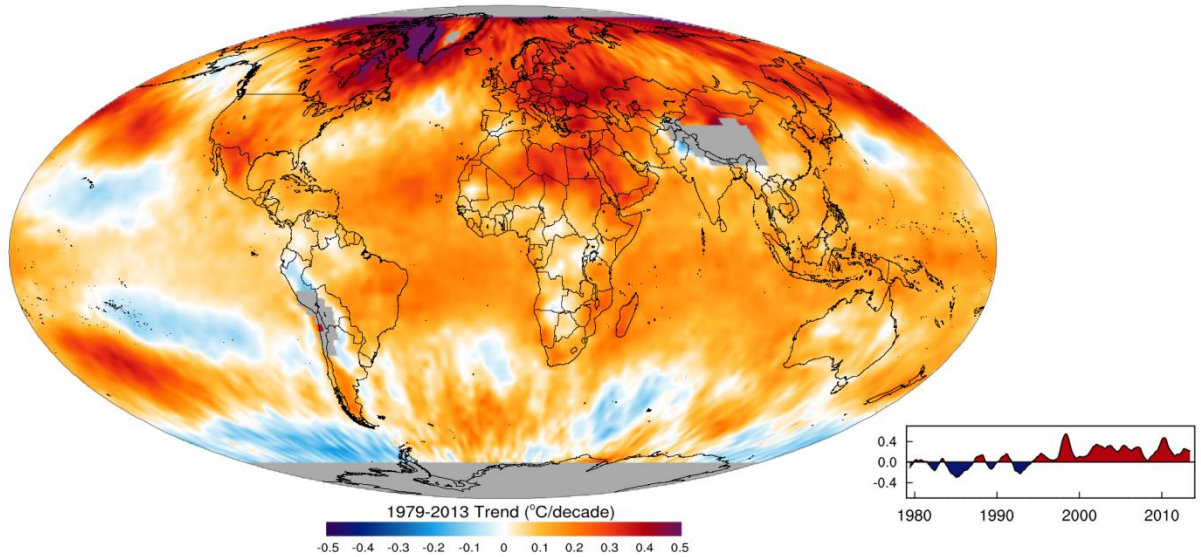
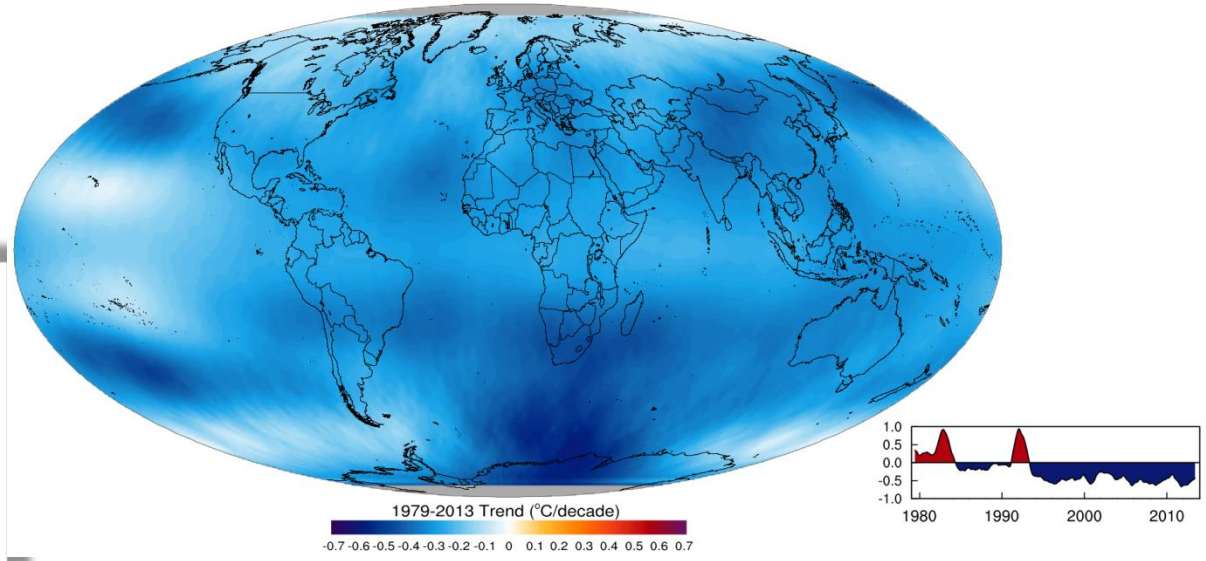


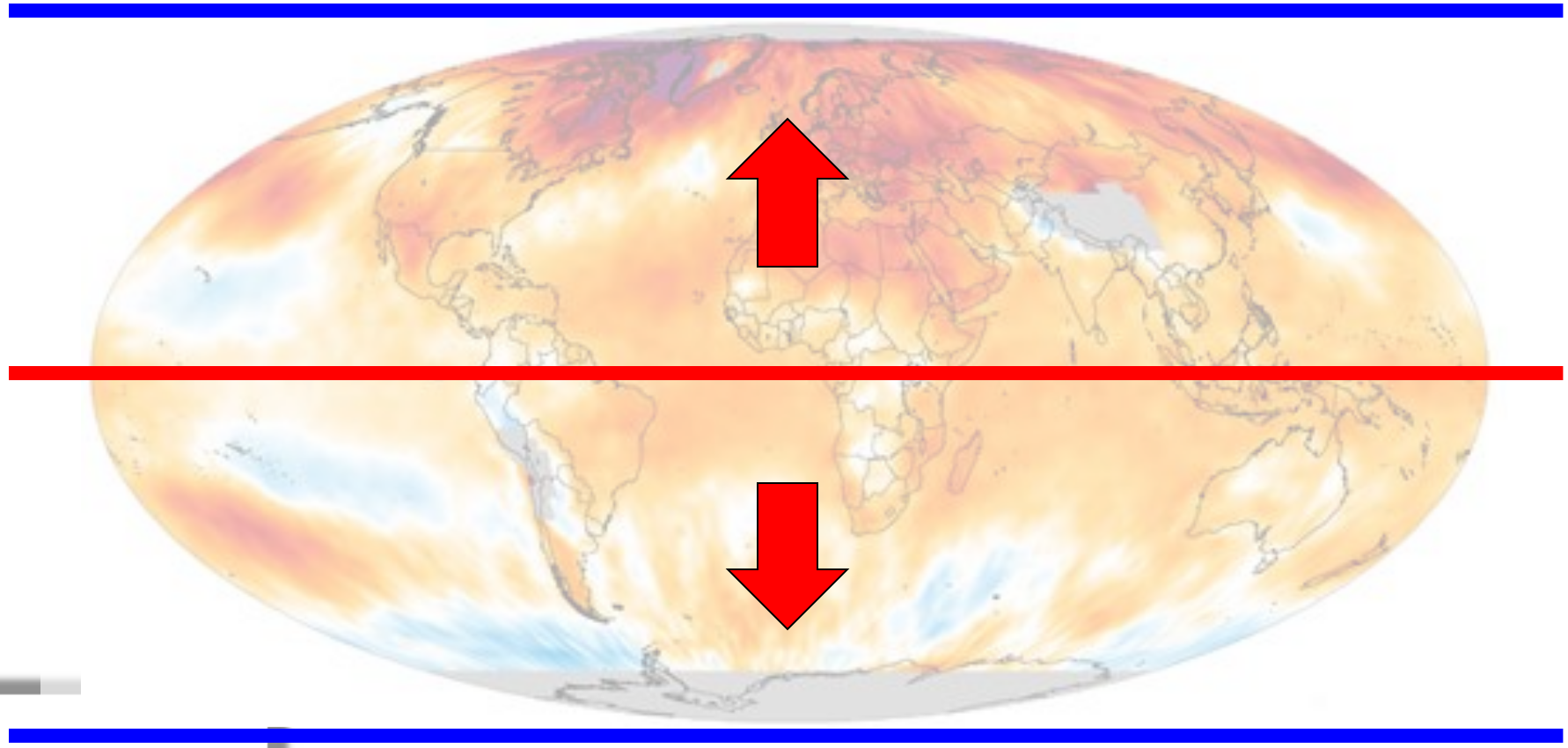
Lower Troposphere



Lower Stratosphere



EVENTOS CLIMÁTICOS EXTREMOS



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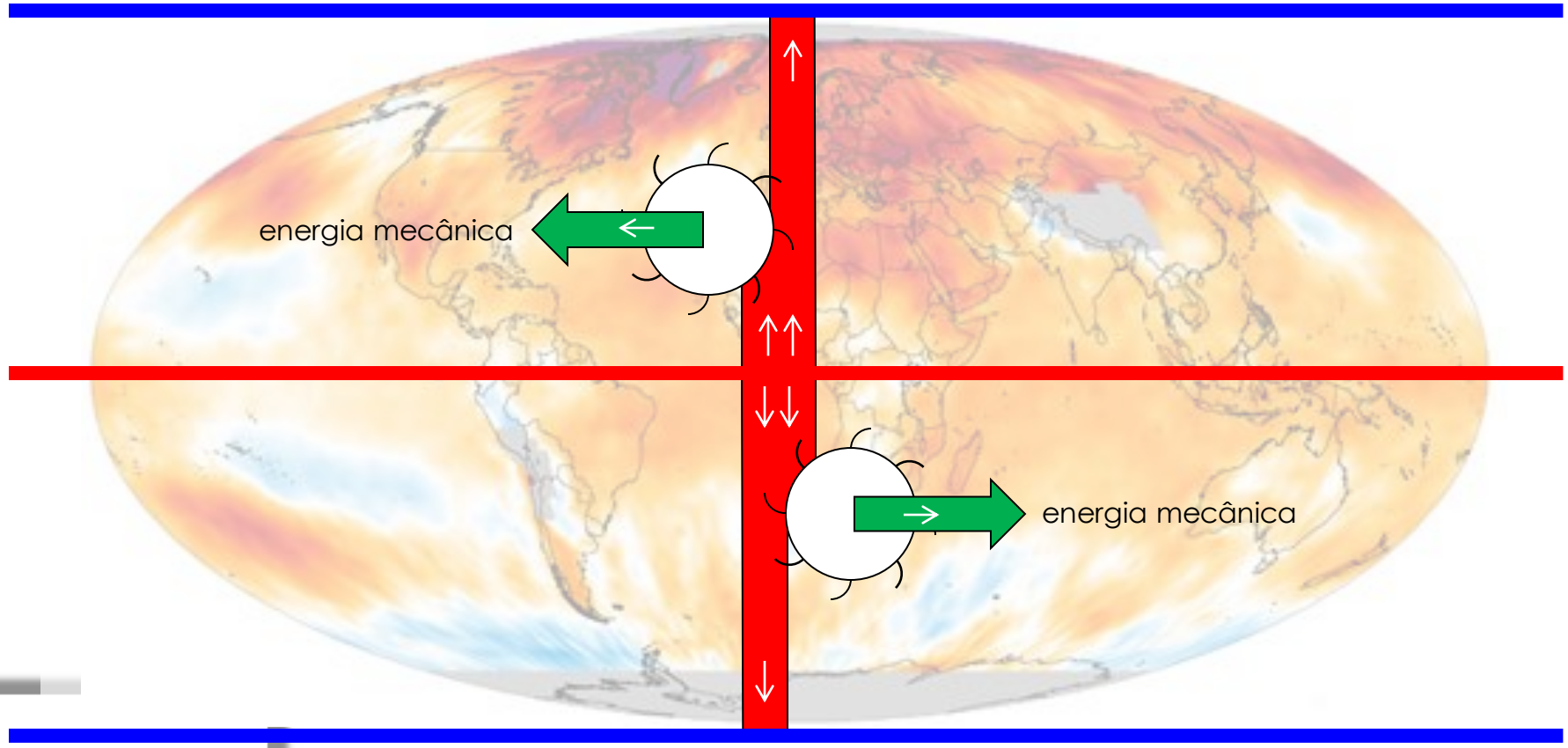

nature COMMUNICATIONS

ARTICLE

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Negative emissions physically needed to keep global warming below 2 °C

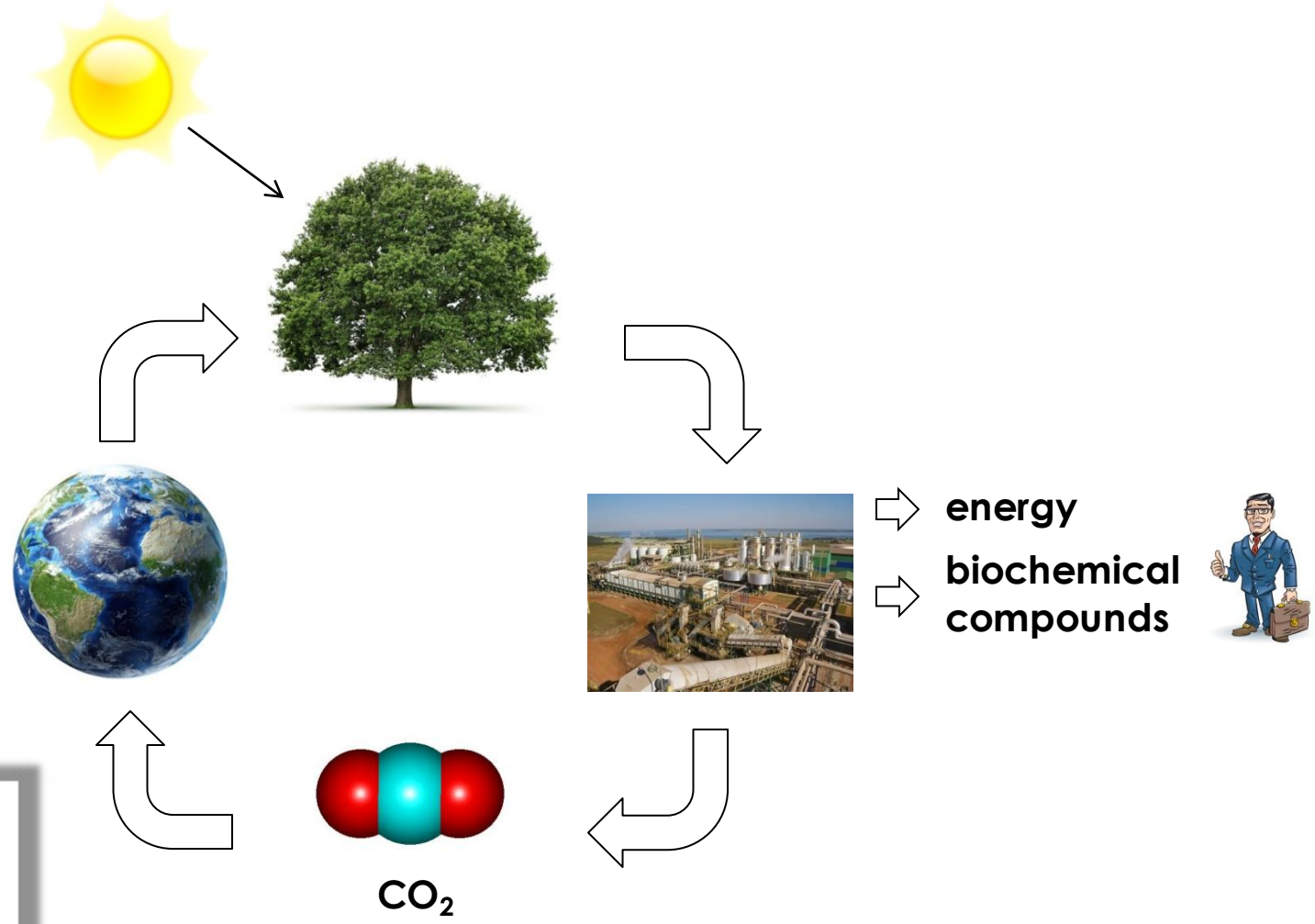
T. Gasser[1,2], C. Guivarch[2], K. Tachiiri[3], C.D. Jones[4] & P. Ciais[1]

To limit global warming to <2 °C we must reduce the net amount of CO_2 we release into the atmosphere, either by producing less CO_2 (conventional mitigation) or by capturing more CO_2 (negative emissions). Here, using state-of-the-art carbon–climate models, we quantify the trade-off between these two options in RCP2.6: an Intergovernmental Panel on Climate Change scenario likely to limit global warming below 2 °C. In our best-case illustrative assumption of conventional mitigation, negative emissions of 0.5–3 Gt C (gigatonnes of carbon) per year and storage capacity of 50–250 Gt C are required. In our worst case, those requirements are 7–11 Gt C per year and 1,000–1,600 Gt C, respectively. Because these figures have not been shown to be feasible, we conclude that development of negative emission technologies should be accelerated, but also that conventional mitigation must remain a substantial part of any climate policy aiming at the 2-°C target.

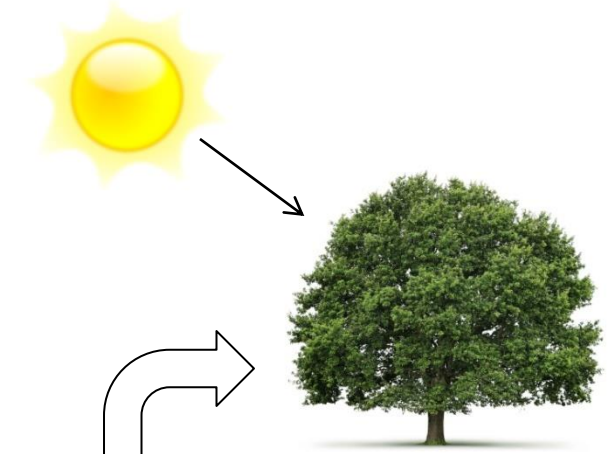
[1] Laboratoire des Sciences du Climat et de l'Environnement (LSCE), Institut Pierre-Simon Laplace (IPSL), CEA - CNRS - UVSQ, CEA l'Orme des Merisiers, 91191 Gif-sur-Yvette, France. [2] Centre International de Recherche sur l'Environnement et le Développement (CIRED), CNRS - Ecole des Ponts ParisTech - EHESS - AgroParisTech - CIRAD, Campus du Jardin Tropical, 45 bis avenue de la Belle Gabrielle, 94736 Nogent-sur-Marne, France. [3] Japan Agency for Marine-Earth Science and Technology, 3173-25 Showa-machi, Kanazawa-ku, Yokohama, Kanagawa 236-0001, Japan. [4] Met Office, Hadley Centre, FitzRoy Road, Exeter EX1 3PB, UK. Correspondence and requests for materials should be addressed to T.G. (email: tgasser@lsce.ipsl.fr).

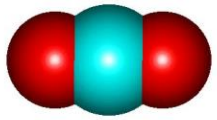
UMA POSSIBILIDADE...

Renewable negative carbon based economy



Renewable negative carbon based economy





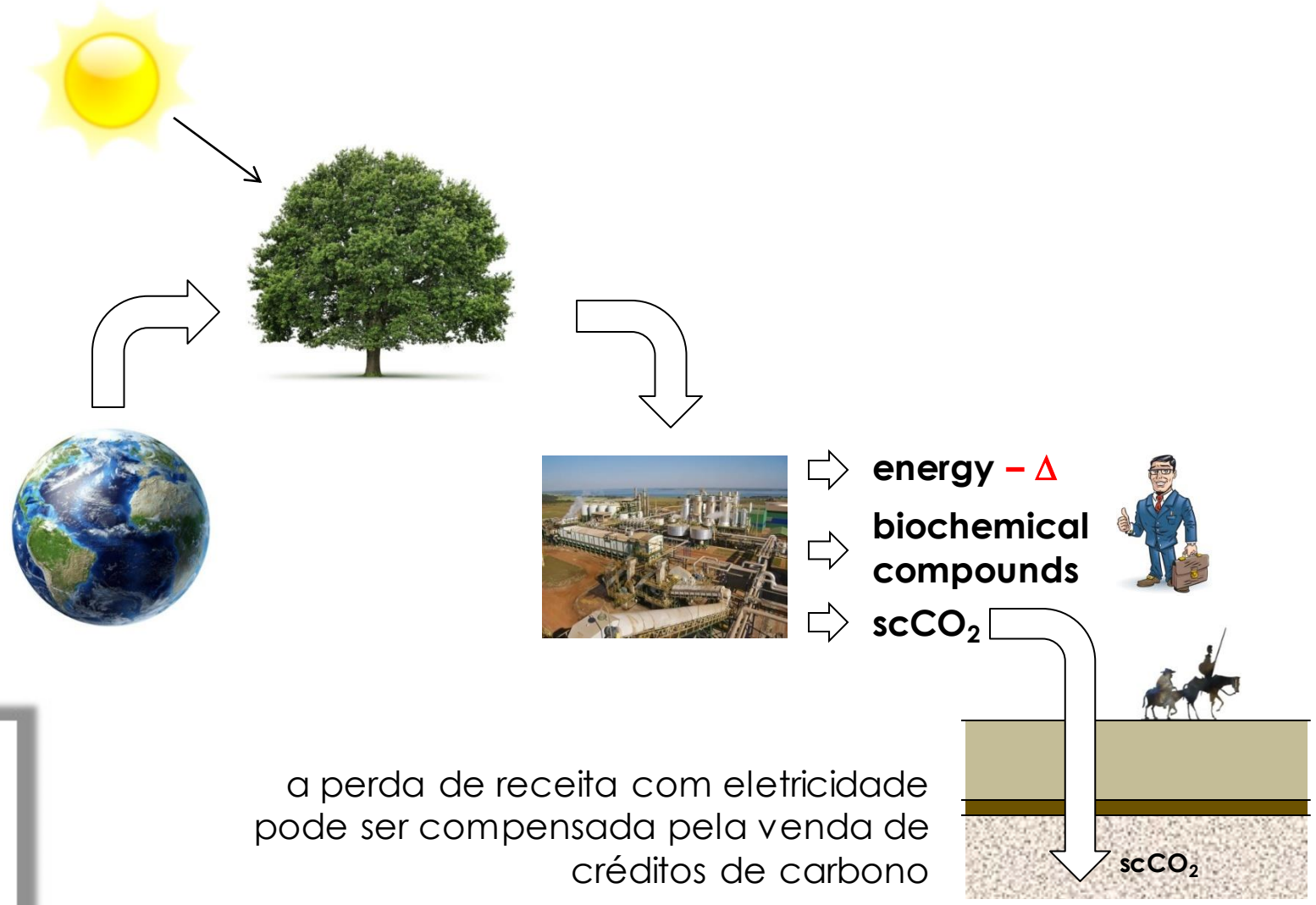
CO_2

separação
compressão

energy – Δ

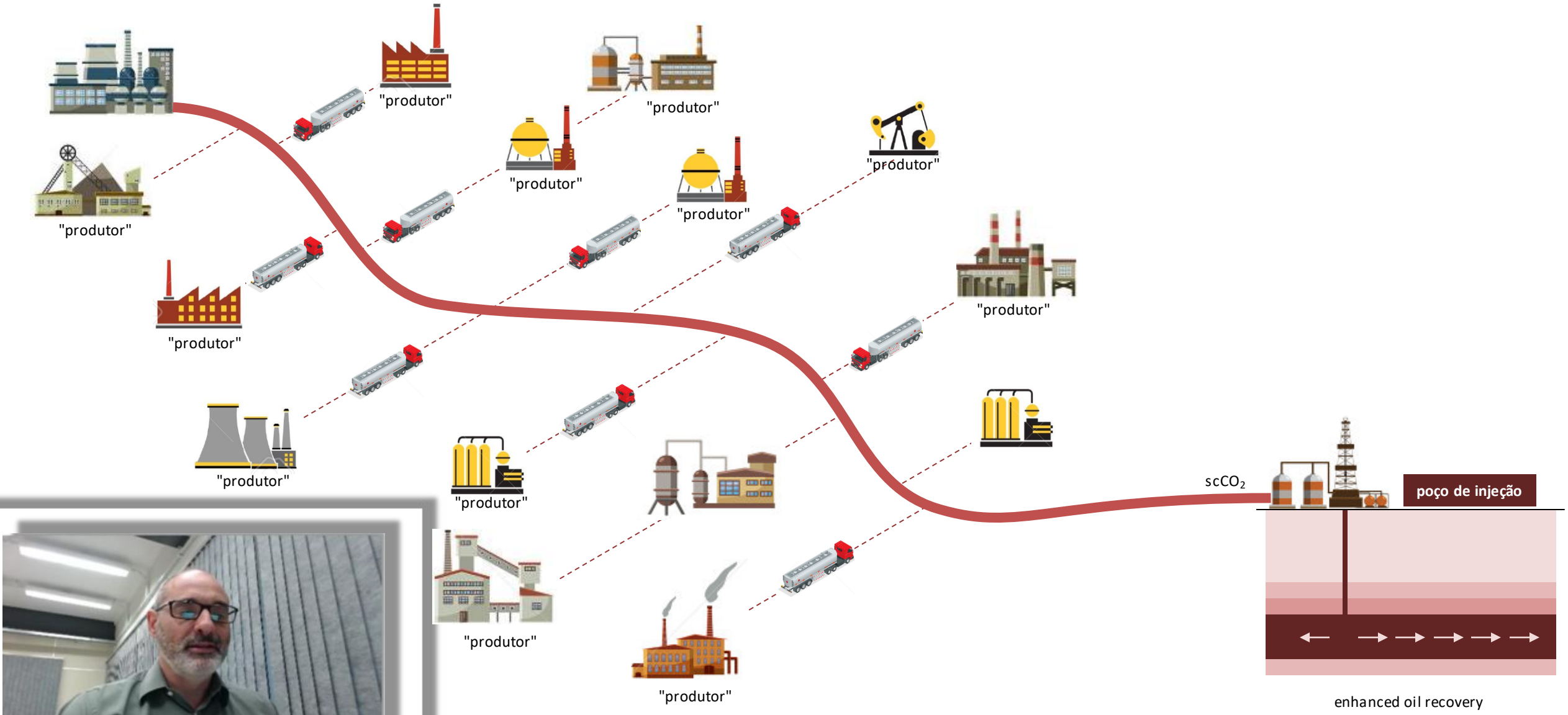
biochemical compounds

Renewable negative carbon based economy

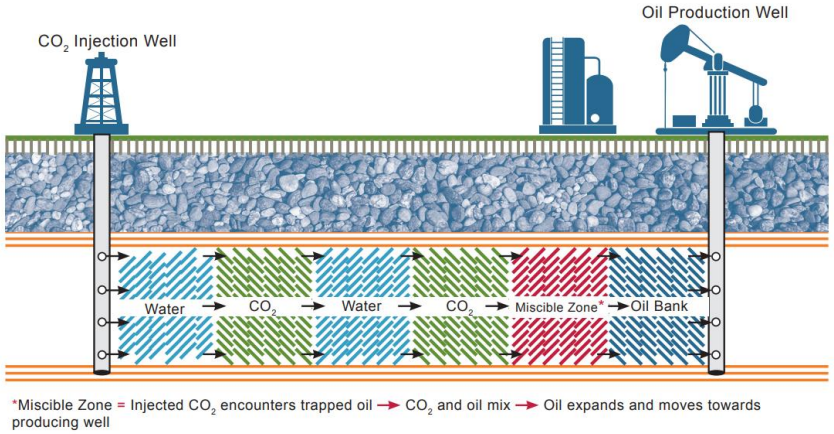


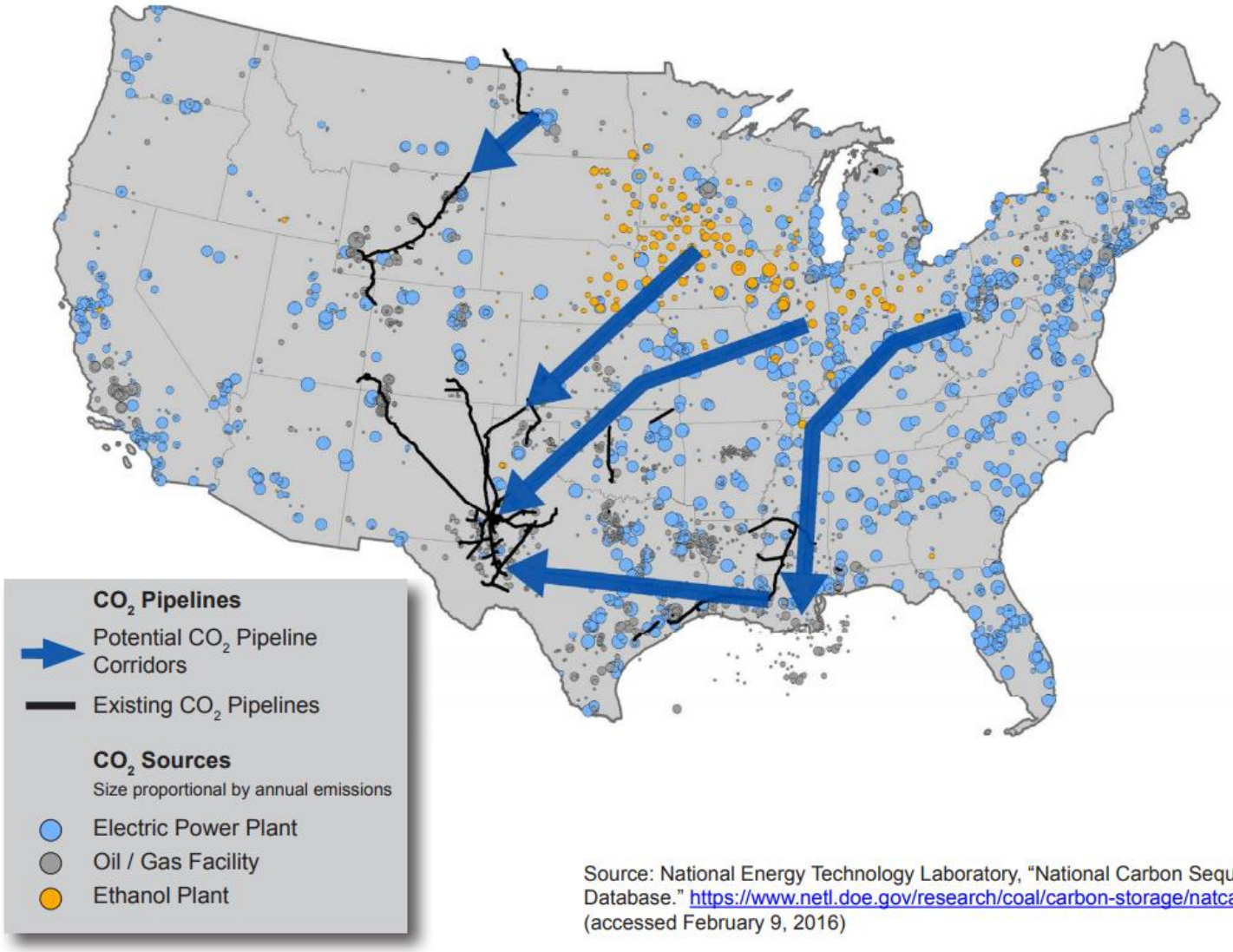
a perda de receita com eletricidade pode ser compensada pela venda de créditos de carbono

Carbon capture, transportation and geological storage



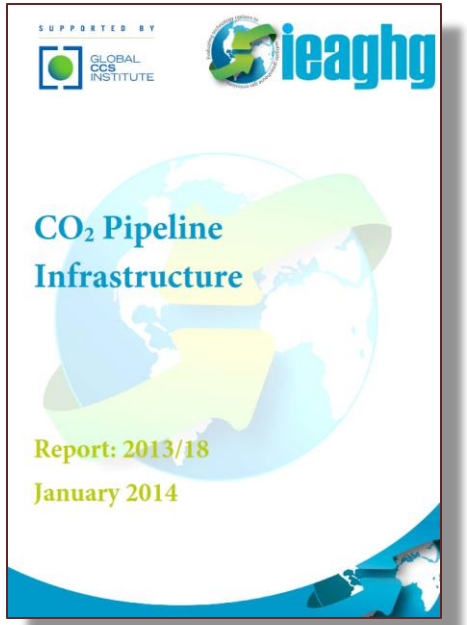
21st Century Energy Infrastructure:
Policy Recommendations for Development of American CO_2 Pipeline Networks





Source: National Energy Technology Laboratory, "National Carbon Sequestration Database." https://www.netl.doe.gov/research/coal/carbon-storage/natcarb-atlas (accessed February 9, 2016)

Prepared by the State CO_2-EOR Deployment Work Group



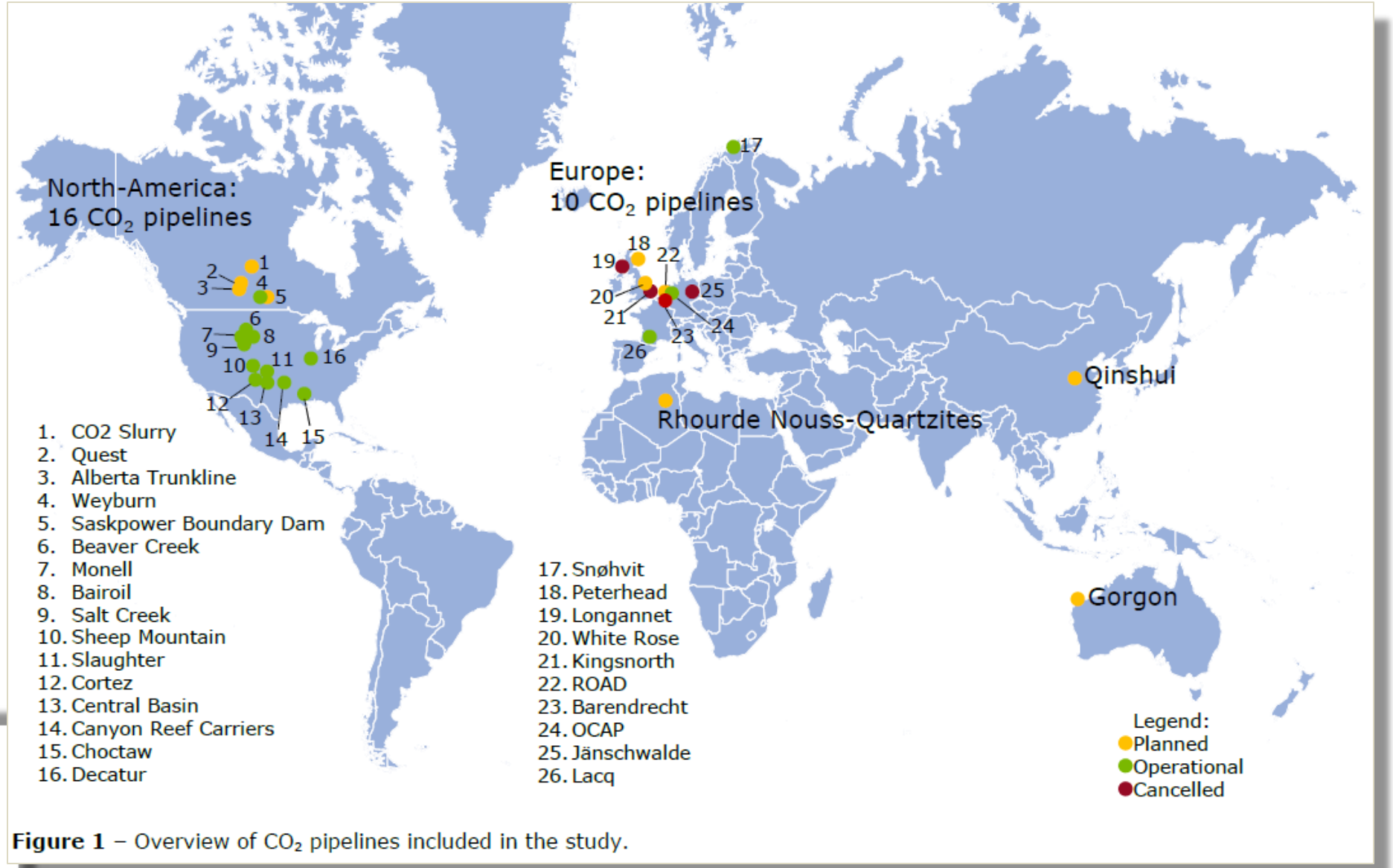


Figure 1 – Overview of CO_2 pipelines included in the study.

How to transform GHG emitting industrial units to producers of scCO2 for geological storage ?

CO2 atmosférico

⇩ FTST

Biomassa

⇩ Oxi Comb

CO2 supercrítico

⇩ EOR, etc.

Subsolo

CO2 atmosférico

⇩ FTST

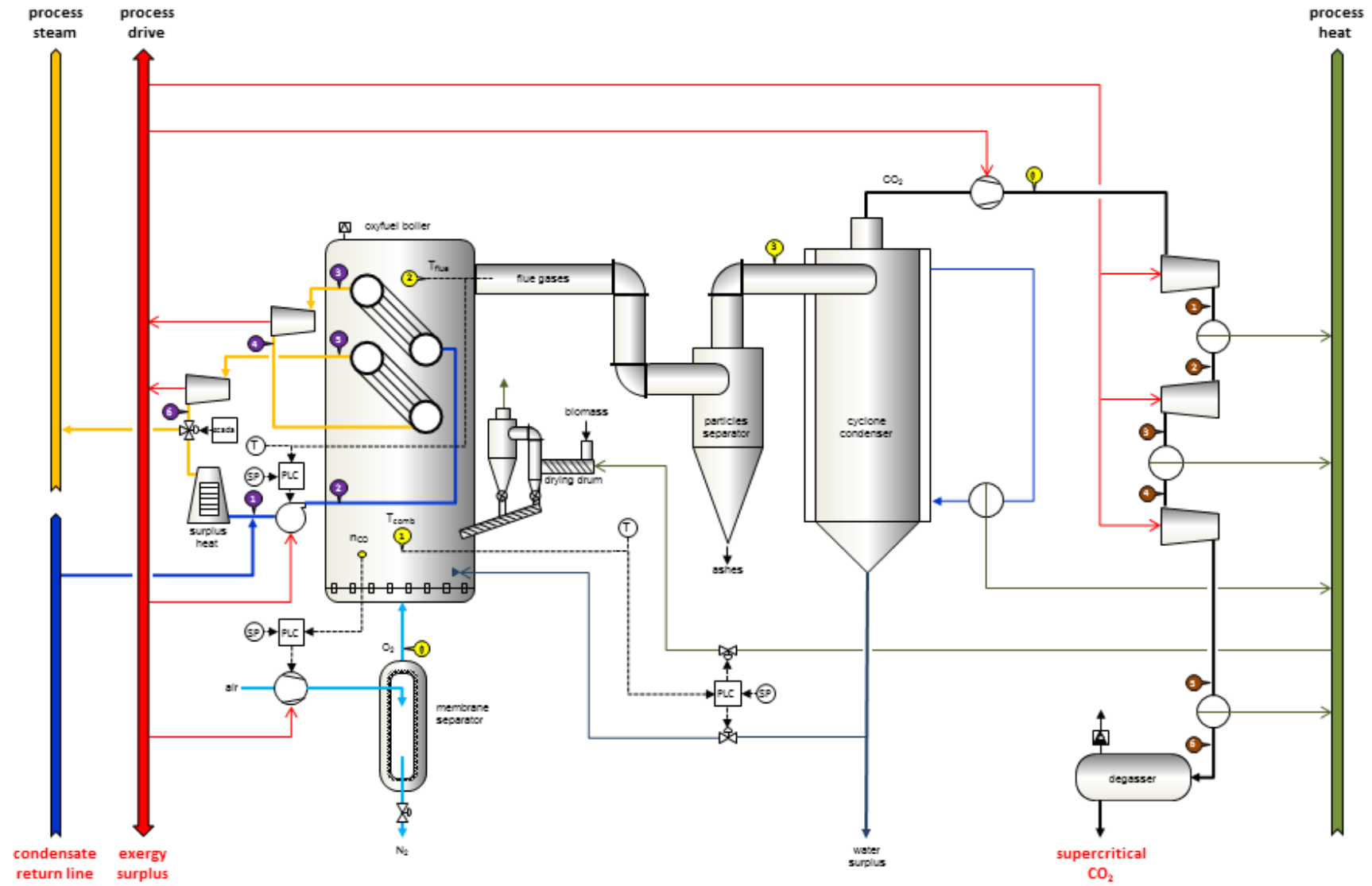
Biomassa

⇩ Oxi Comb

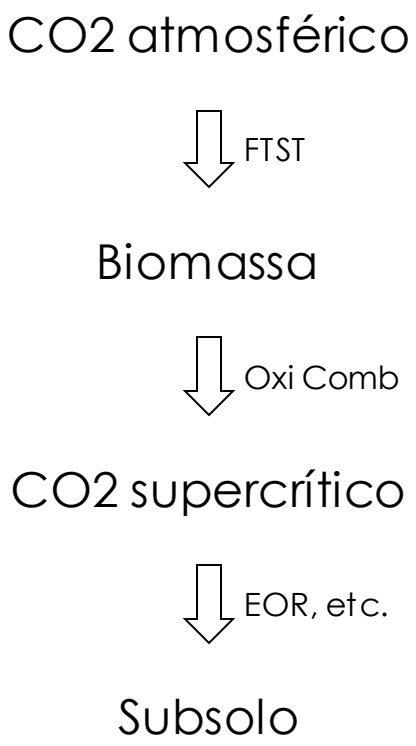
CO2 supercrítico

⇩ EOR, etc.

Subsolo



Potential capture from sugarcane processing in Brazil



CO_2 emissions from a reference sugar mill (500tsc/h)

- **Fermentation: 2 tCO_2/h**
- **Bagasse and straw combustion: 89 tCO_2/h**

Annual CO_2 capture and storage by the sugarcane sector

- **One mill: 0.43 $MtCO_2$/year**
- **Number of mills: 400 average proc. rate 500tsc/h**
- **Annual CCS: 292 $MtCO_2$/year**

Annual CO_2 Brazilian emissions

- **~ 400 $MtCo_2$/year**

OUTRAS FONTES DE ENERGIA PARA APLICAÇÕES NÃO VEICULARES...

Energia Eólica

Renovável de maior crescimento no mundo

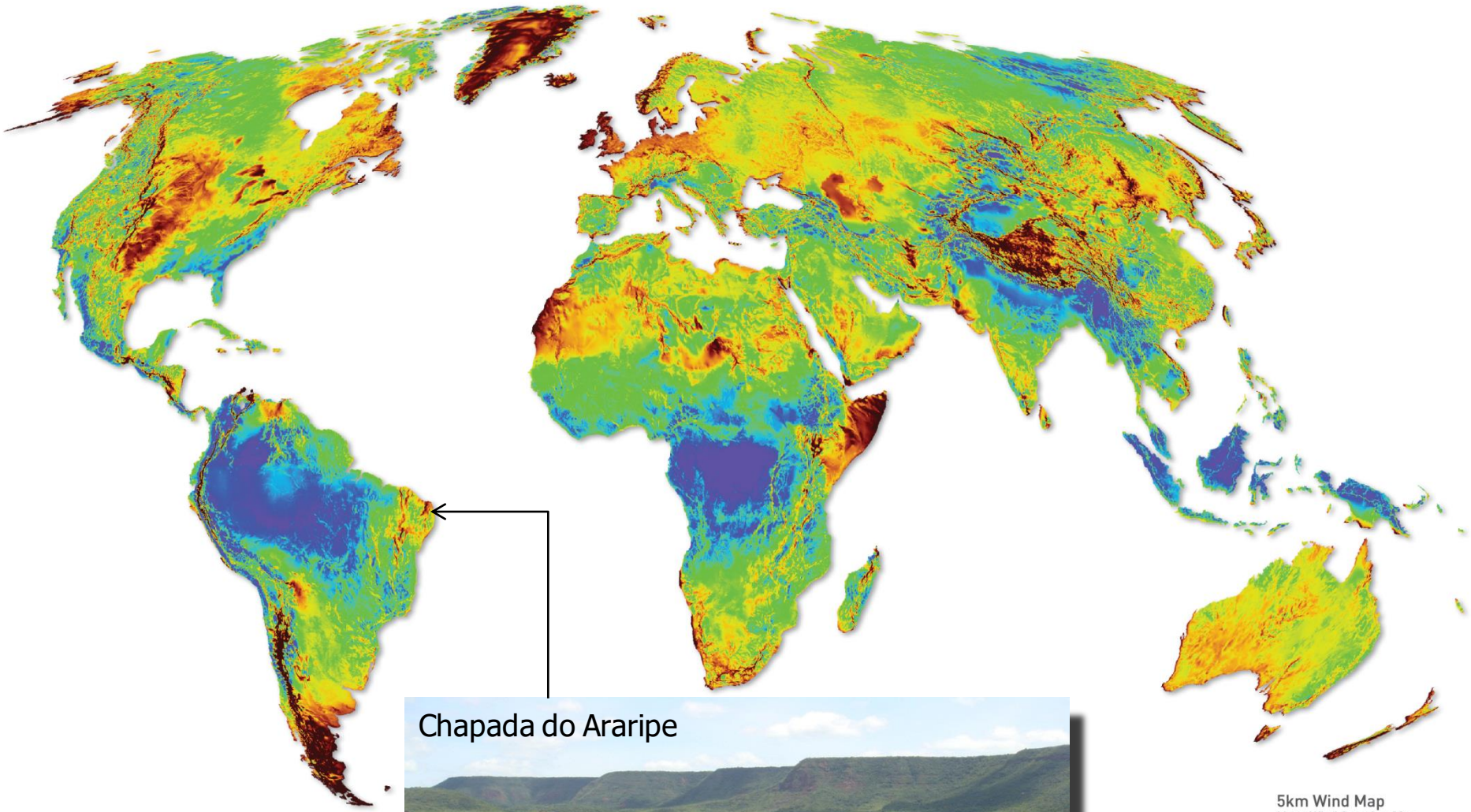
Brasil: 2008 = 341MW, 2009 = 606 MW, 2010 = 920MW

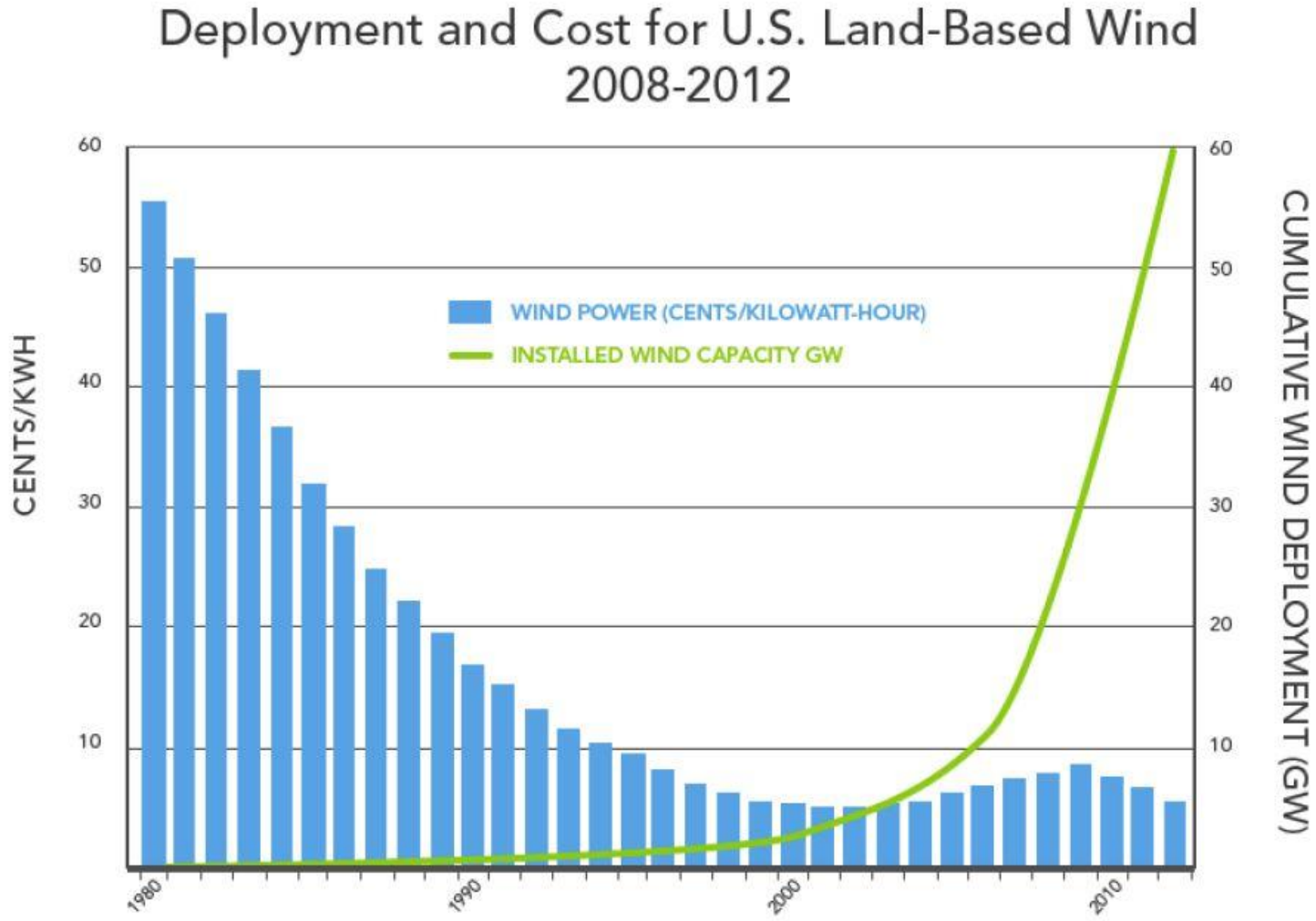
Potencial brasileiro = 300GW (demanda 2010 = 70GW)

Expectativa de contratar pelo menos 2,0 GW por ano até 2020

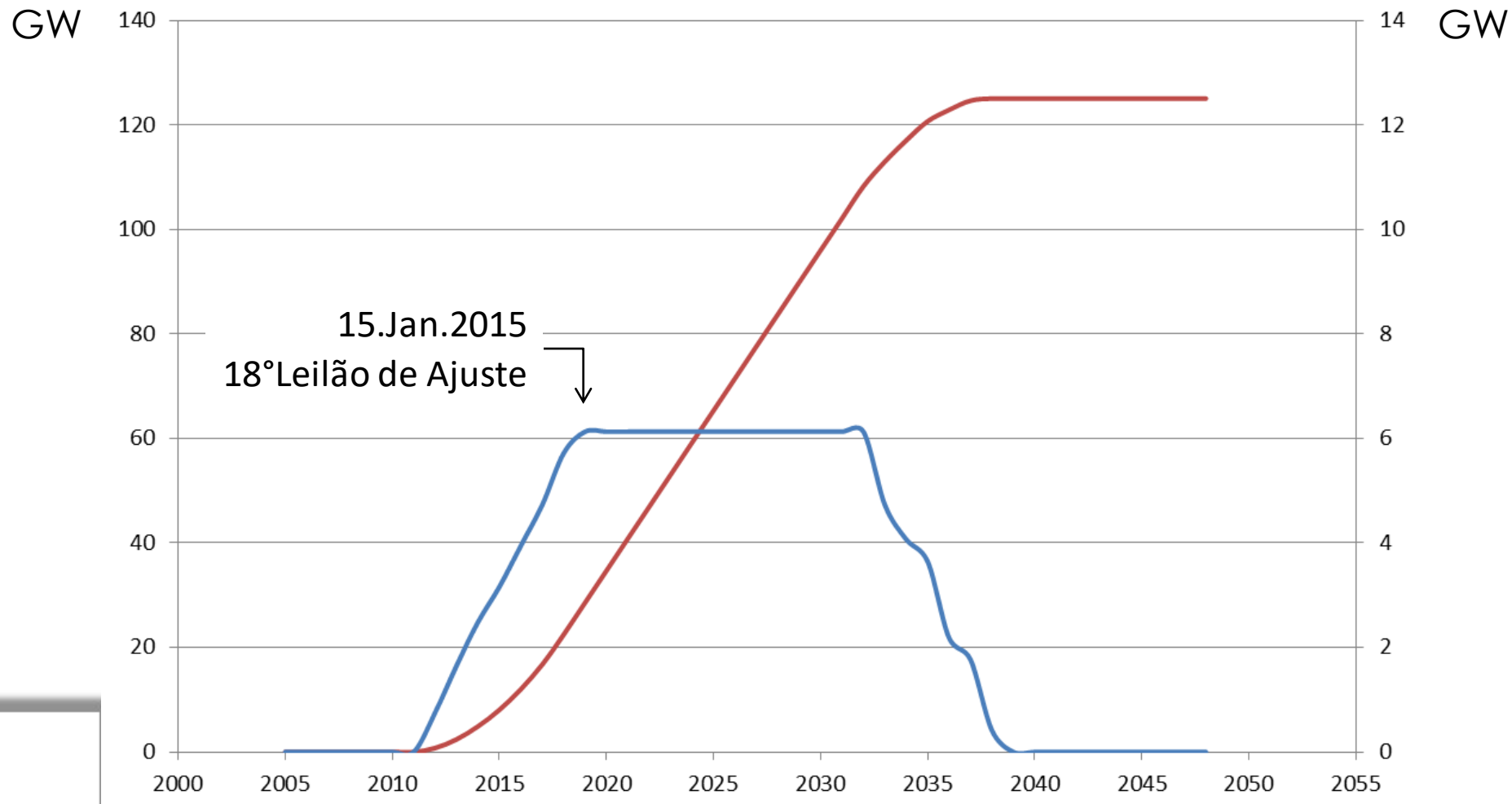
Global Mean Wind Speed at 80m

3TIER by Vaisala




Deployment and Cost for U.S. Land-Based Wind
2008-2012
CENTS/KWH
CUMULATIVE WIND DEPLOYMENT (GW)
WIND POWER (CENTS/KILOWATT-HOUR)
INSTALLED WIND CAPACITY GW
60
50
40
30
20
10
1980
1990
2000
2010

Evolução do fornecimento contratado no Brasil



Fator de Capacidade Médio = 35%

Energy generation investment contracts in Piauí until 01/2016

MENU G1 ECONOMIA

14/01/2013 09h25 - Atualizado em 14/01/2013 11h40

Governo publica lei que permite baratear conta de luz

Plano prevê que energia fique 20,2% mais barata a partir de fevereiro. Lei renova concessões e elimina encargos da conta de luz.

Fábio Amato
Do G1, em Brasília

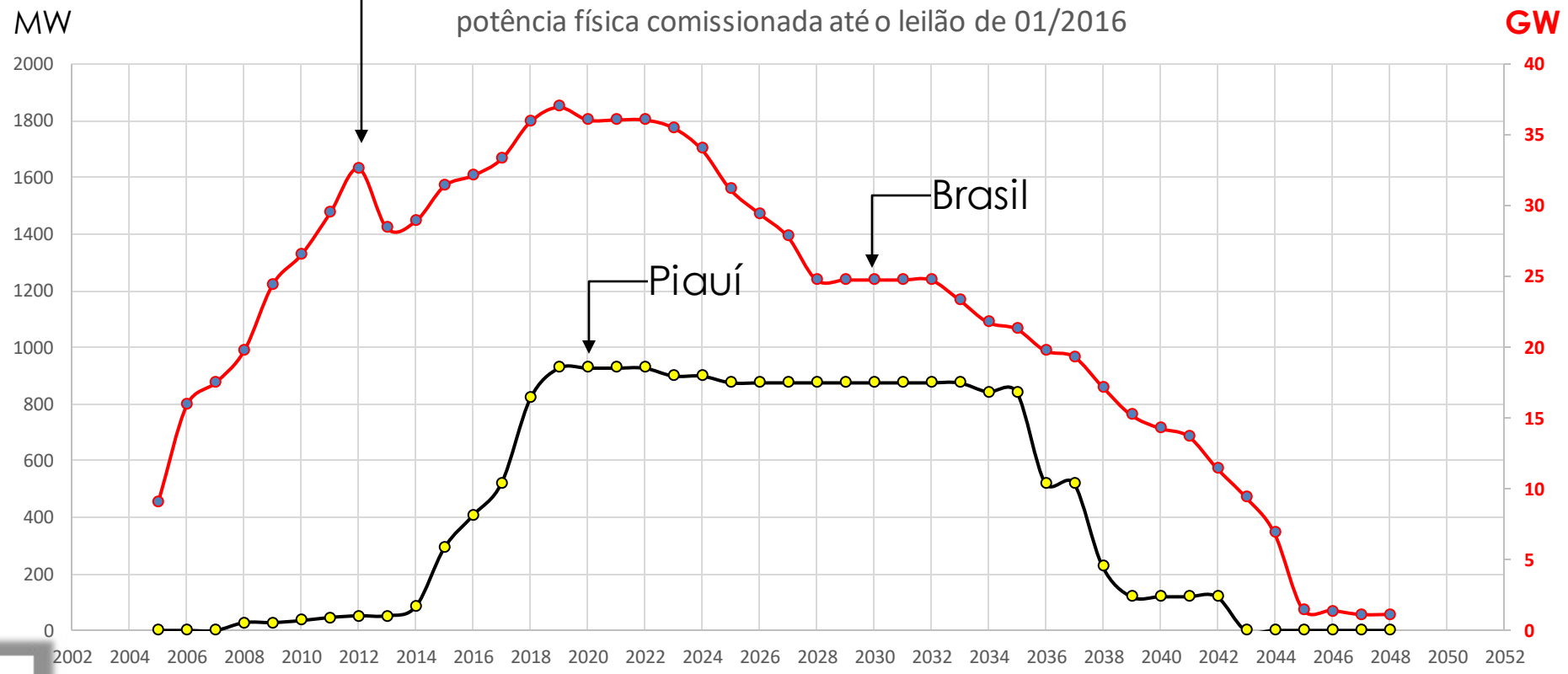
A presidente Dilma Rousseff sancionou a lei 12.783, que renova concessões do setor de energia e permite o barateamento da conta de luz dos brasileiros. A lei foi publicada na edição desta segunda-feira (14) do "Diário Oficial da União".

saiba mais

- Geração térmica não compromete queda na conta de luz, diz ministério
- Reservatórios voltam a baixar e nível fica abaixo do pré-racionamento
- Governo vai discutir situação dos reservatórios na quarta-feira
- Dilma diz que governo vai bancar plano de diminuição de energia

De acordo com cálculos do governo federal, as medidas previstas na lei vão levar a uma redução média de 20,2% na tarifa de energia a partir de fevereiro.

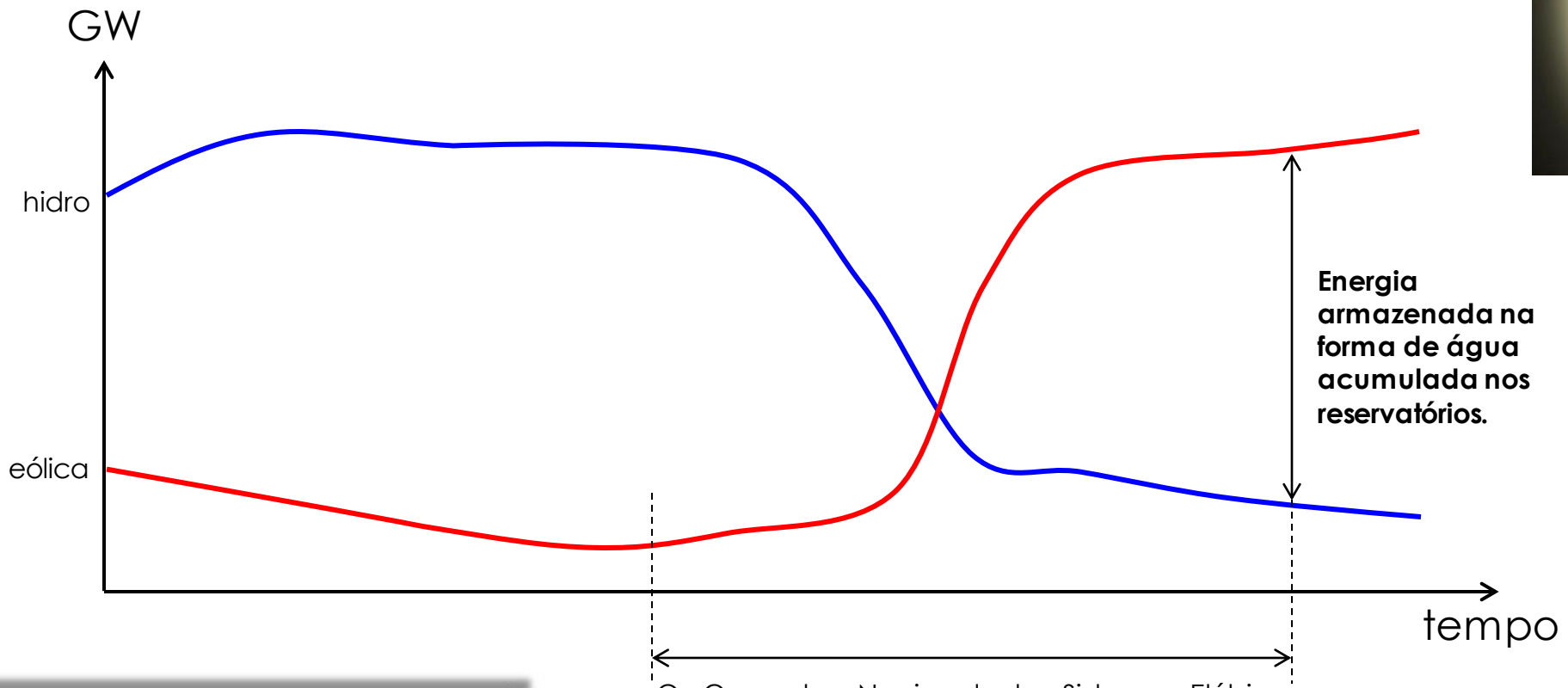
A lei permite ao governo prorrogar, por até 30 anos, concessões de geração (usinas hidrelétricas e térmicas), transmissão e distribuição de energia que vencem entre 2015 e 2017. Em troca, esses concessionários tiveram que aceitar receber, já a partir de 2013,



Piauí → electrical energy exporter

Brasil → depressed supply (opportunities !?)

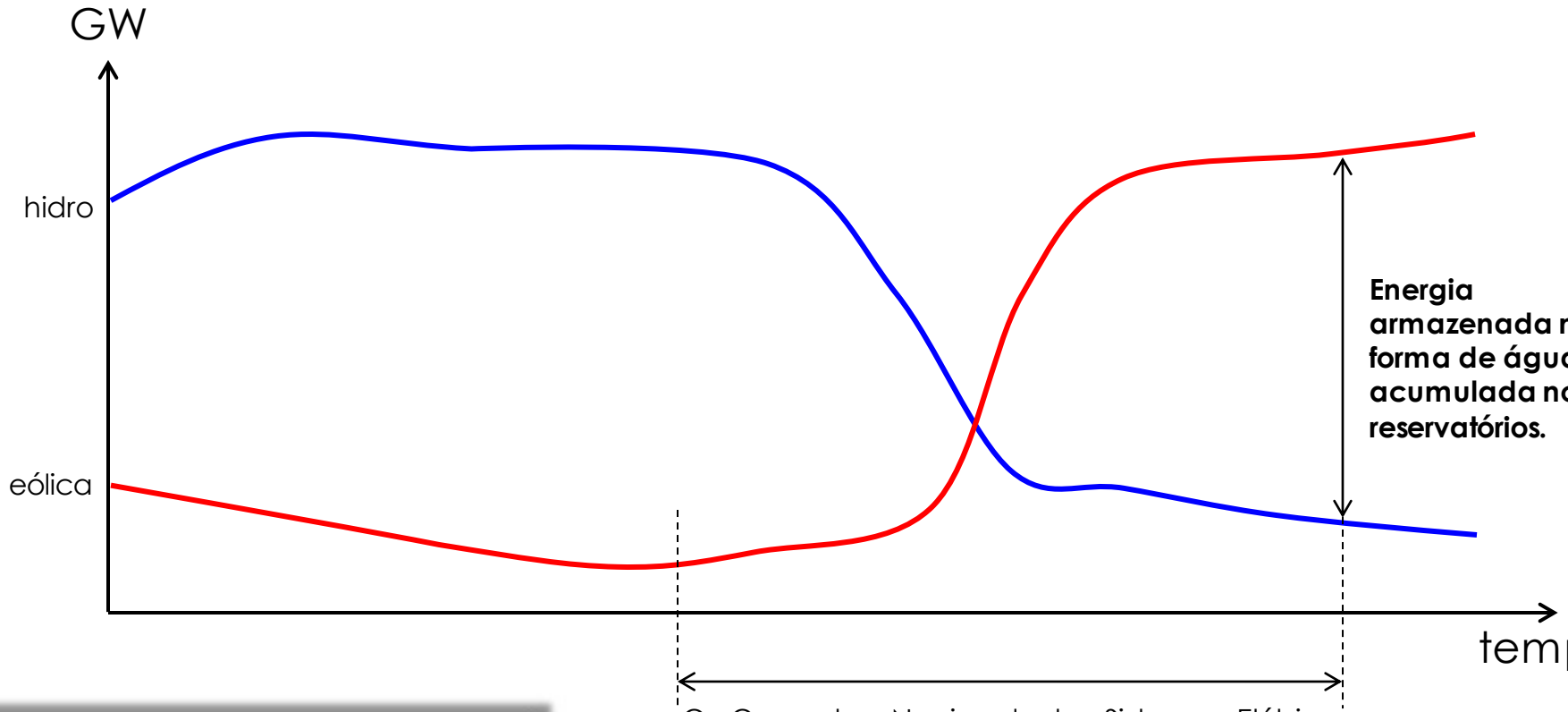
“Armazenando Vento...”



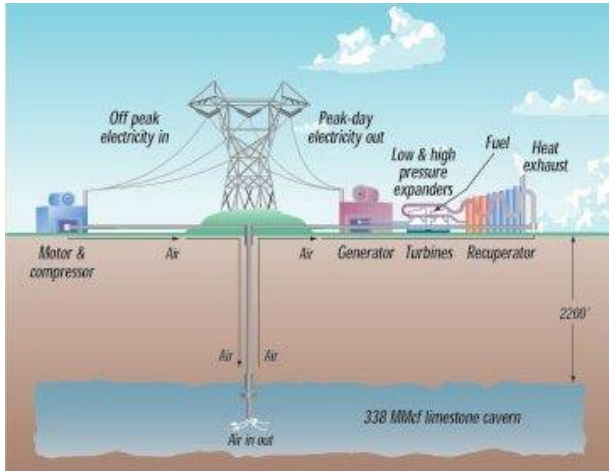
O Operador Nacional do Sistema Elétrico detecta o aumento da geração eólica e diminui a geração hidrelétrica para adequar a produção à demanda de energia.

O mesmo conceito se aplica aos outros modais de geração com característica intermitente

“Armazenando Vento...”



Energia armazenada na forma de água acumulada nos reservatórios.



O Operador Nacional do Sistema Elétrico detecta o aumento da geração eólica e diminui a geração hidrelétrica para adequar a produção à demanda de energia.

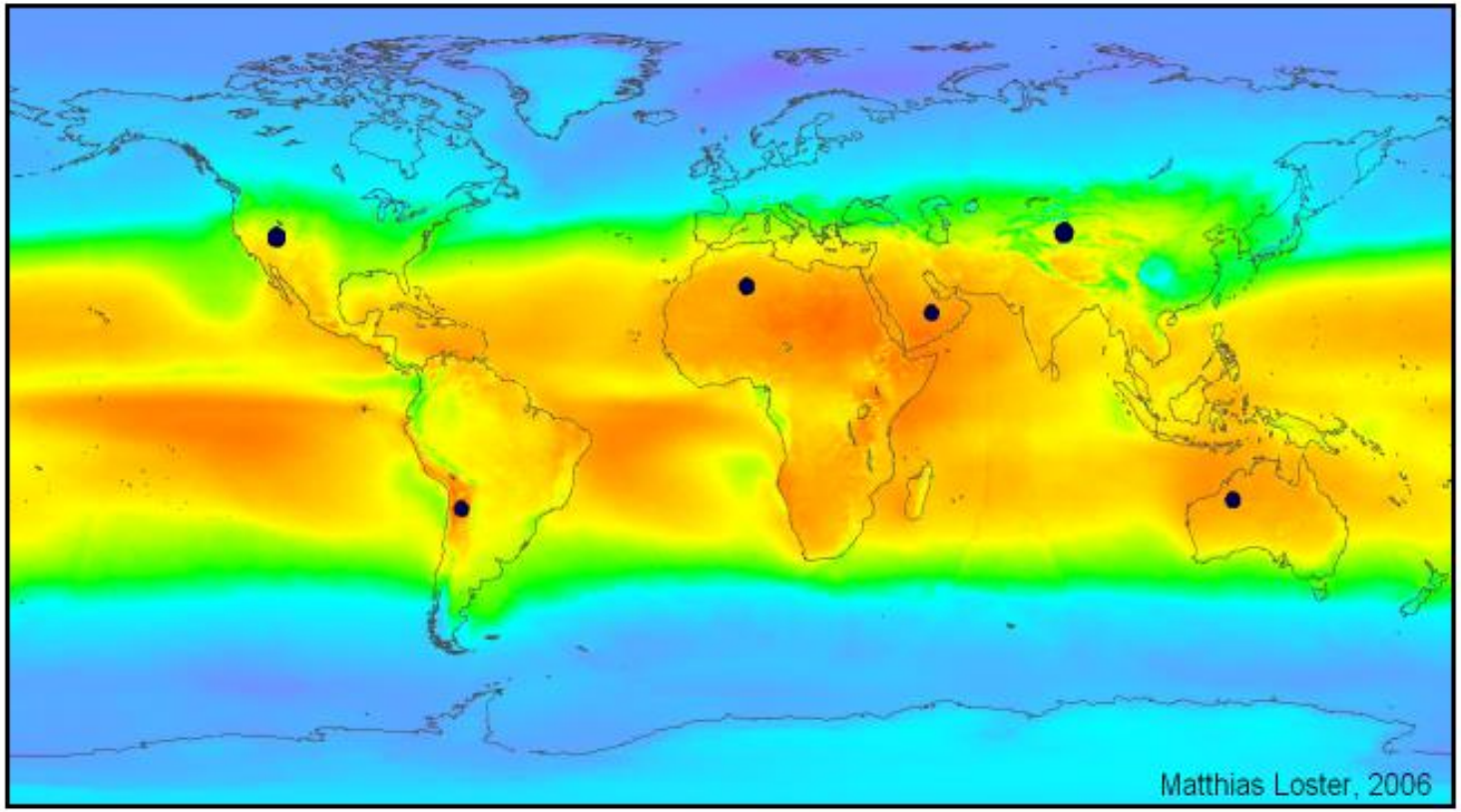
O mesmo conceito se aplica aos outros modais de geração com característica intermitente

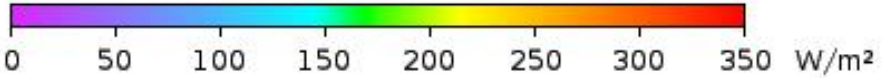
Energia Solar

89 mil TW

3,5 a 7,0 kWh/m2/dia

- Grande Bacia
- Atacama
- Saara
- Arábia
- Gobi
- Outback

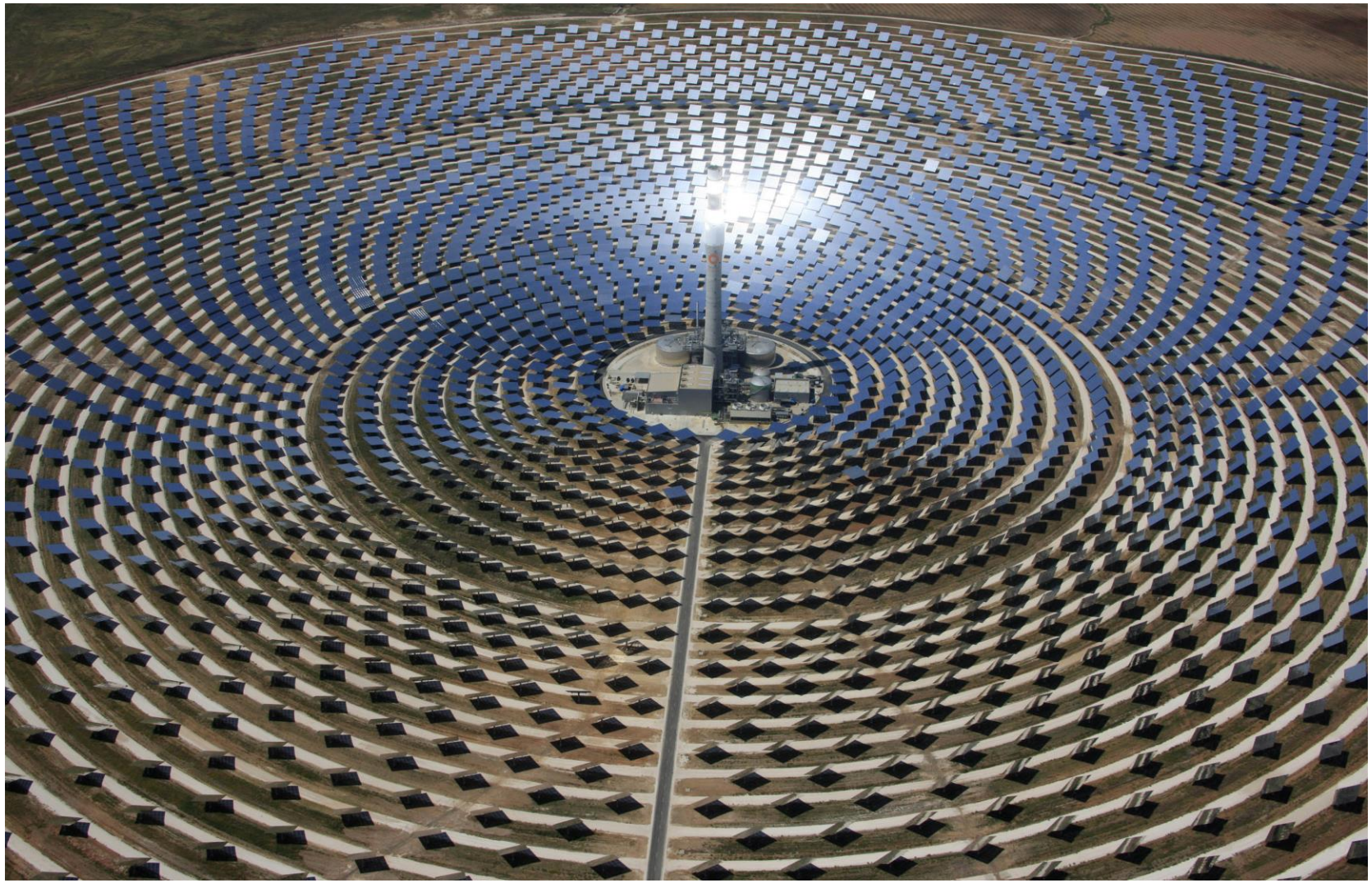




Σ● = 18 TWe

Σ● = 18 TWe

Energia Termosolar



© TORRESOL ENERGY

Ponto focal (T < 1000ºC) – 2D azimute/elevação

Energia Termosolar

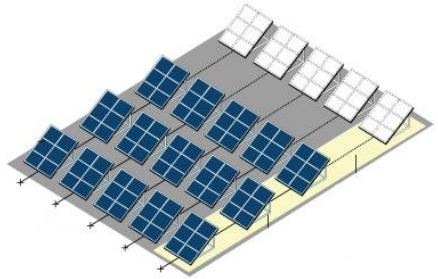
© TORRESOL ENERGY

Linha focal (T < 350ºC) – 1D leste/oeste

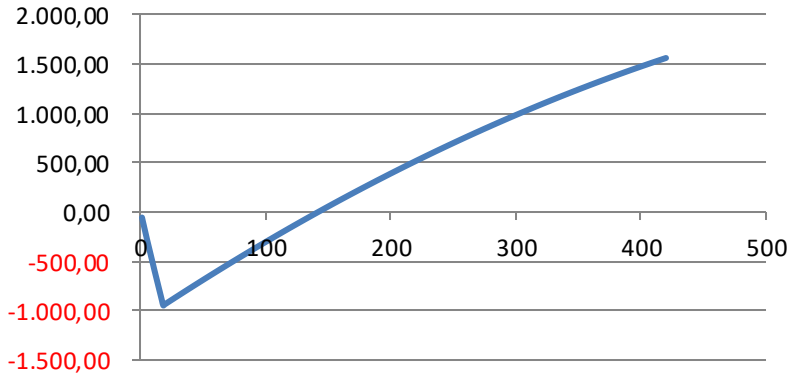
Energia Fotovoltaica

Pouco competitiva economicamente...

Análise dos projetos de investimento (Capital Budgeting)

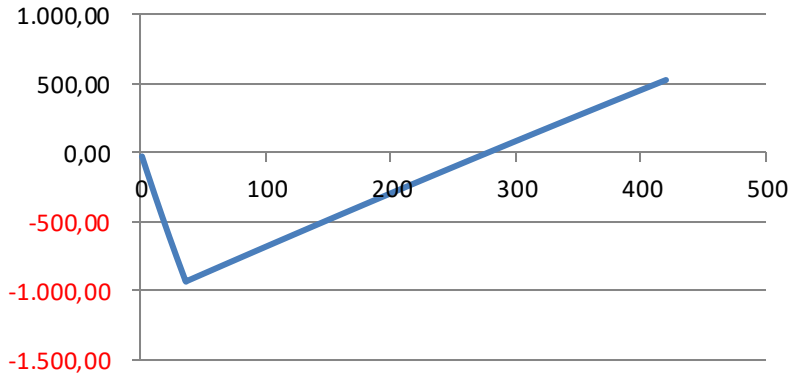


Acumulado (MR$)



depreciação	5	
taxa de desconto	0,54%	ao mês
VPL	42,20	MR$
TIR	0,65%	ao mês
TIR	7,81%	ao ano
Benefício/Custo	1,1274	R$/R$

Acumulado (MR$)



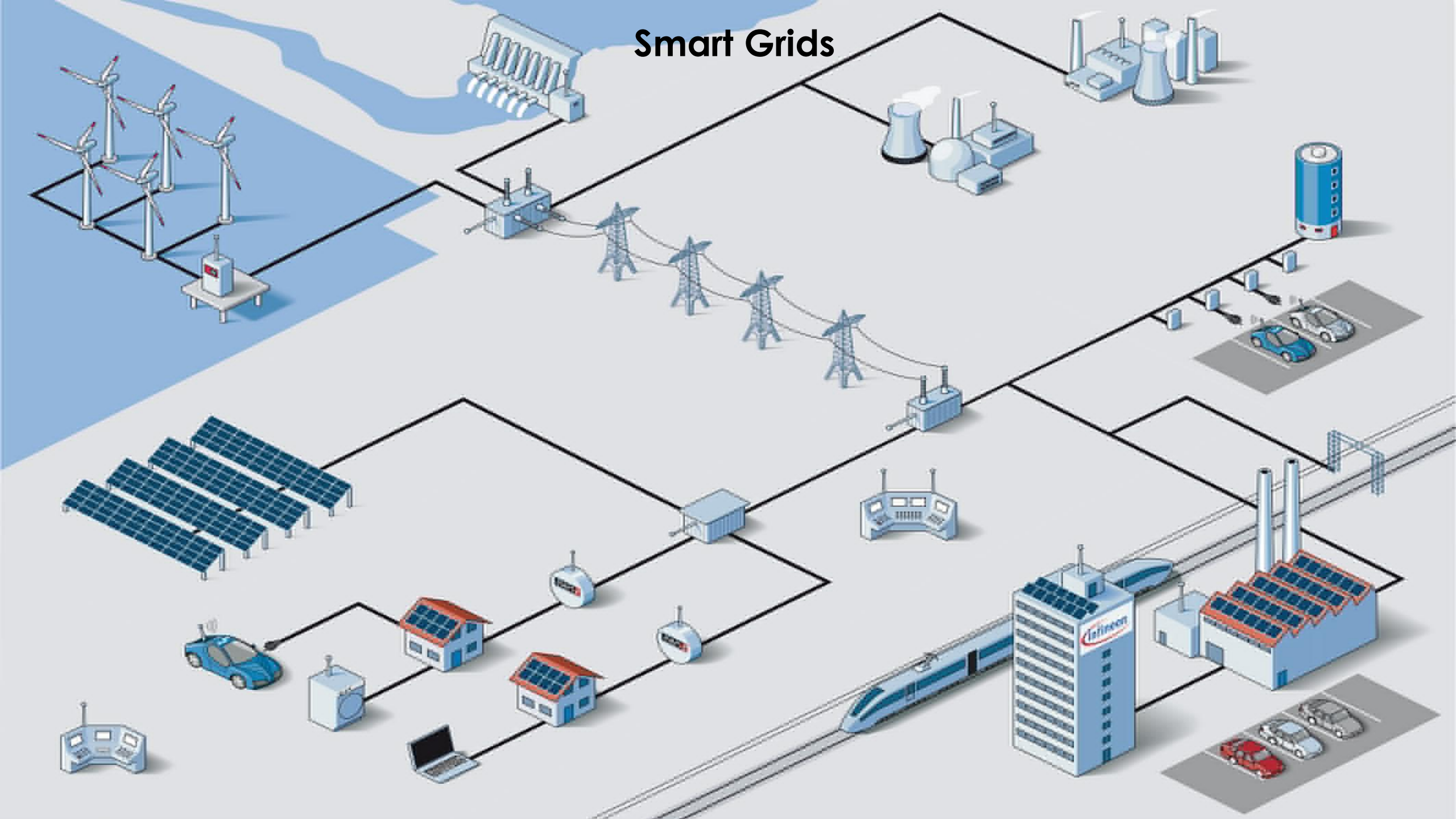
depreciação	2	
taxa de desconto	0,54%	ao mês
VPL	-401,50	MR$
TIR	0,23%	ao mês
TIR	2,77%	ao ano
Benefício/Custo	0,6632	R$/R$

DECISÃO: EÓLICA, MAS...

Geração Fotovoltaica Residencial

geradores / consumidores

Smart Grids



PERPECTIVAS...

lenha, tração animal, biomassa, etc.

lenha, tração animal, biomassa, etc.

⇩ revolução industrial

carvão, petróleo e gás

lenha, tração animal, biomassa, etc.

⇩ revolução industrial

carvão, petróleo e gás

⇩ revolução informacional

hidrelétricas, bioenergias, eólica, termosolar, fotovoltaica, ondas, marés, geotérmicas...

lenha, tração animal, biomassa, etc.

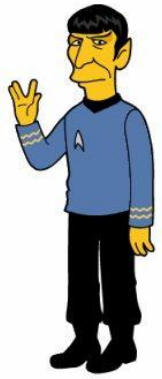
⇩ revolução industrial

carvão, petróleo e gás

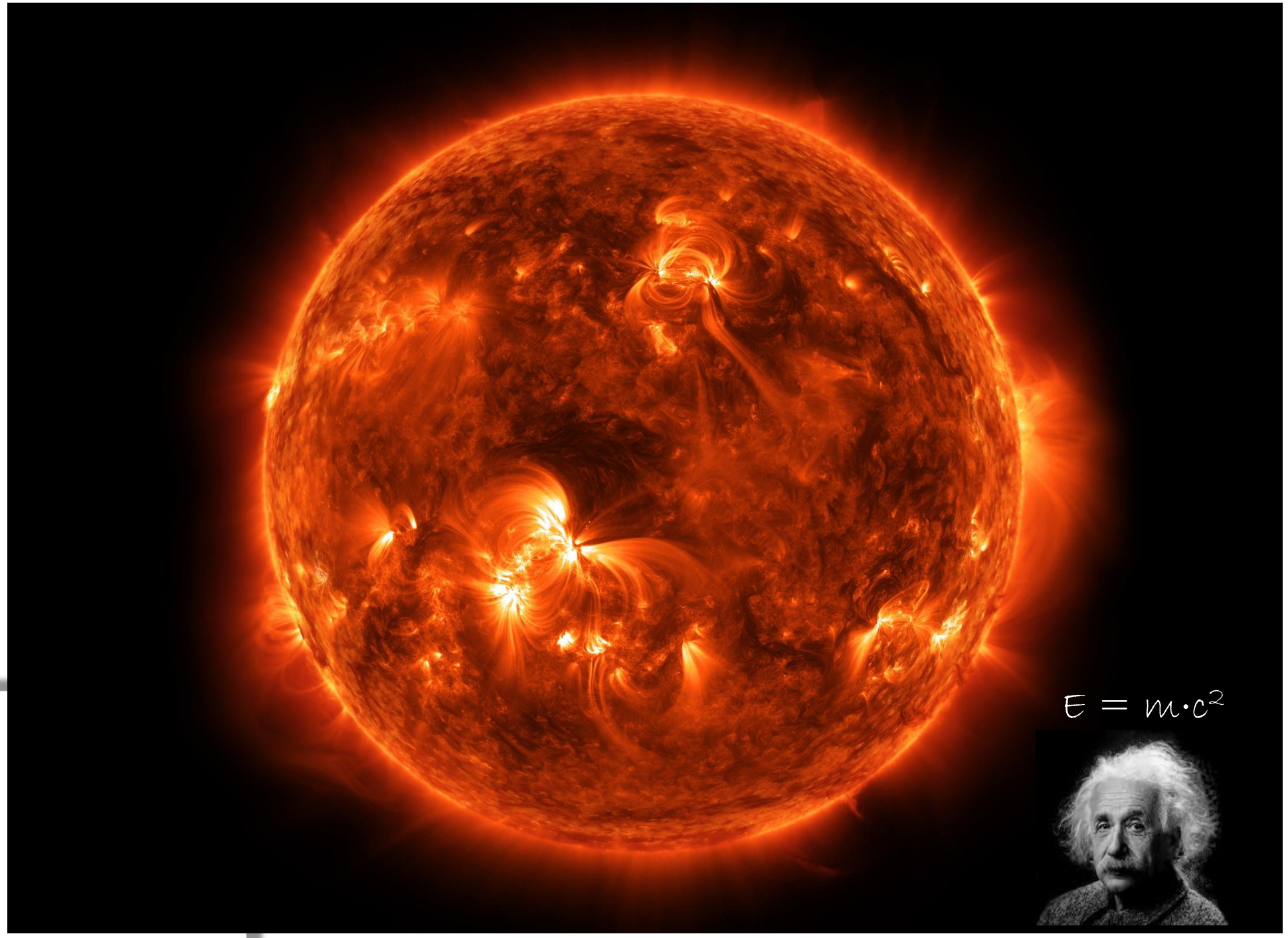
⇩ revolução informacional

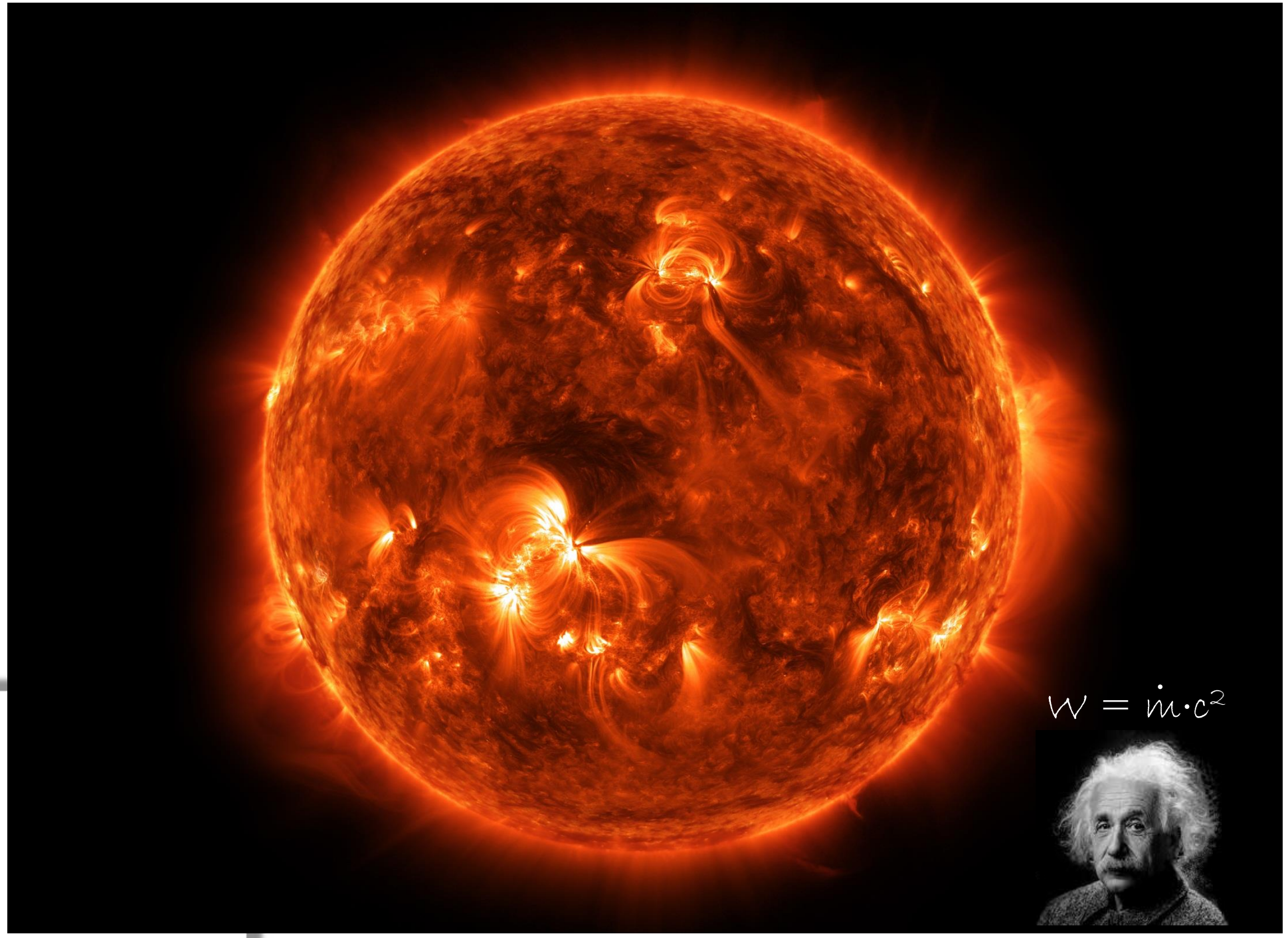
hidrelétricas, bioenergias, eólica, termosolar, fotovoltaica, ondas, marés, geotérmicas...

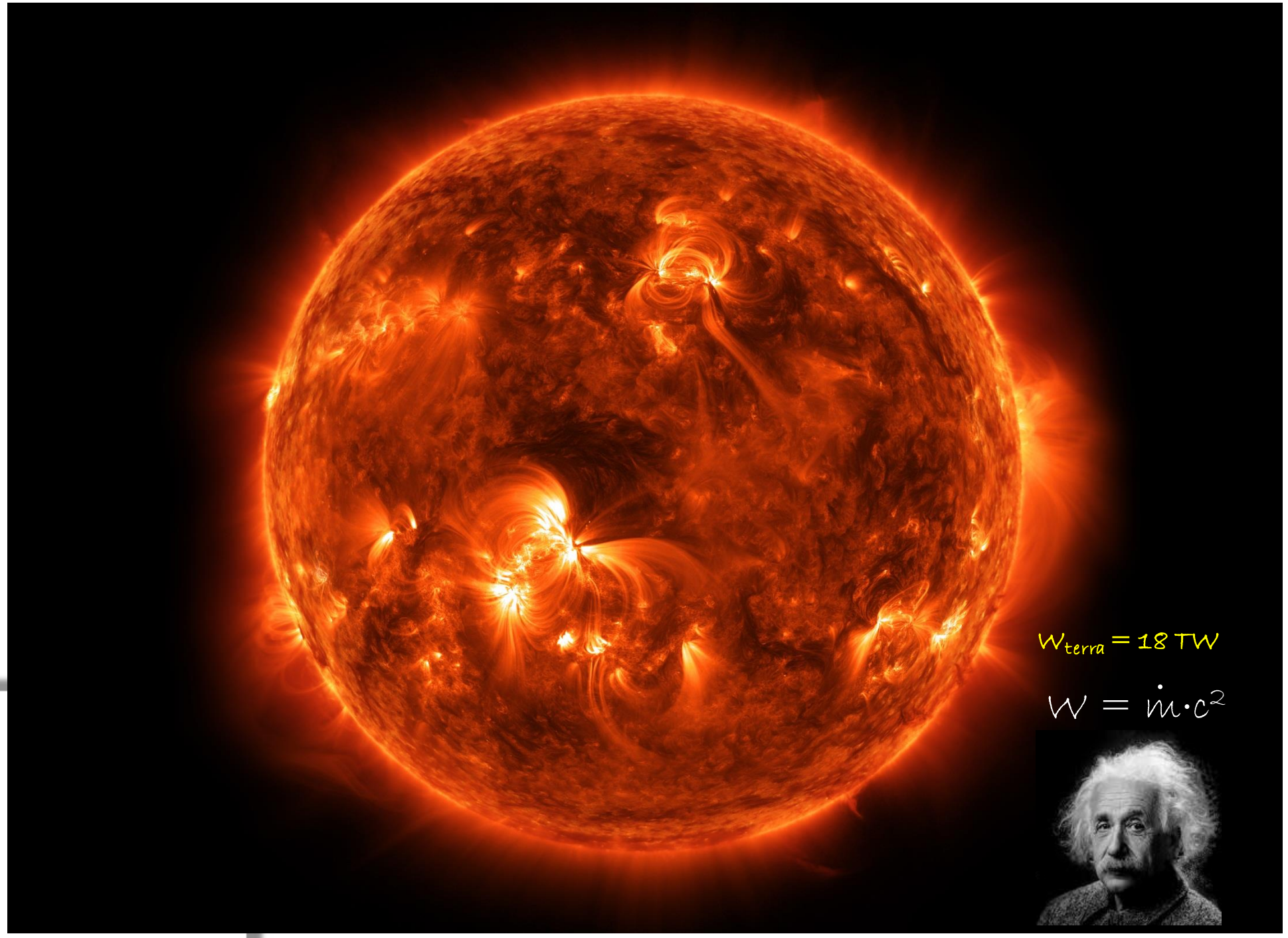
⇩ revolução energética (?)

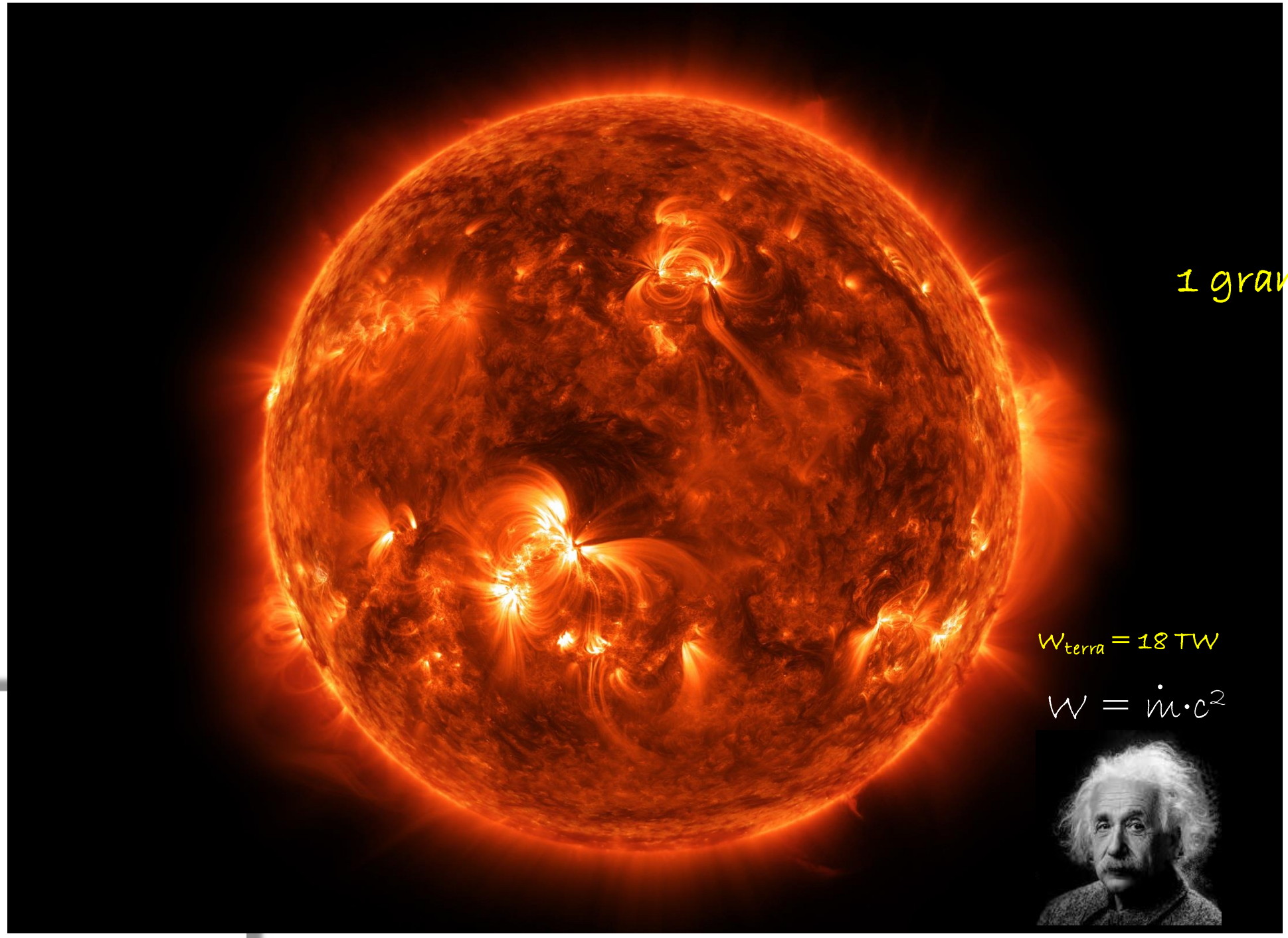


FUSÃO NUCLEAR


$E = m \cdot c^2$


$W = \dot{m} \cdot c^2$


$W_{terra} = 18\ TW$
$W = \dot{m} \cdot c^2$



1 grama/s

$W_{terra} = 18\ TW$

$W = \dot{m} \cdot c^2$

1 grama/s

↓

90 TW !!!!

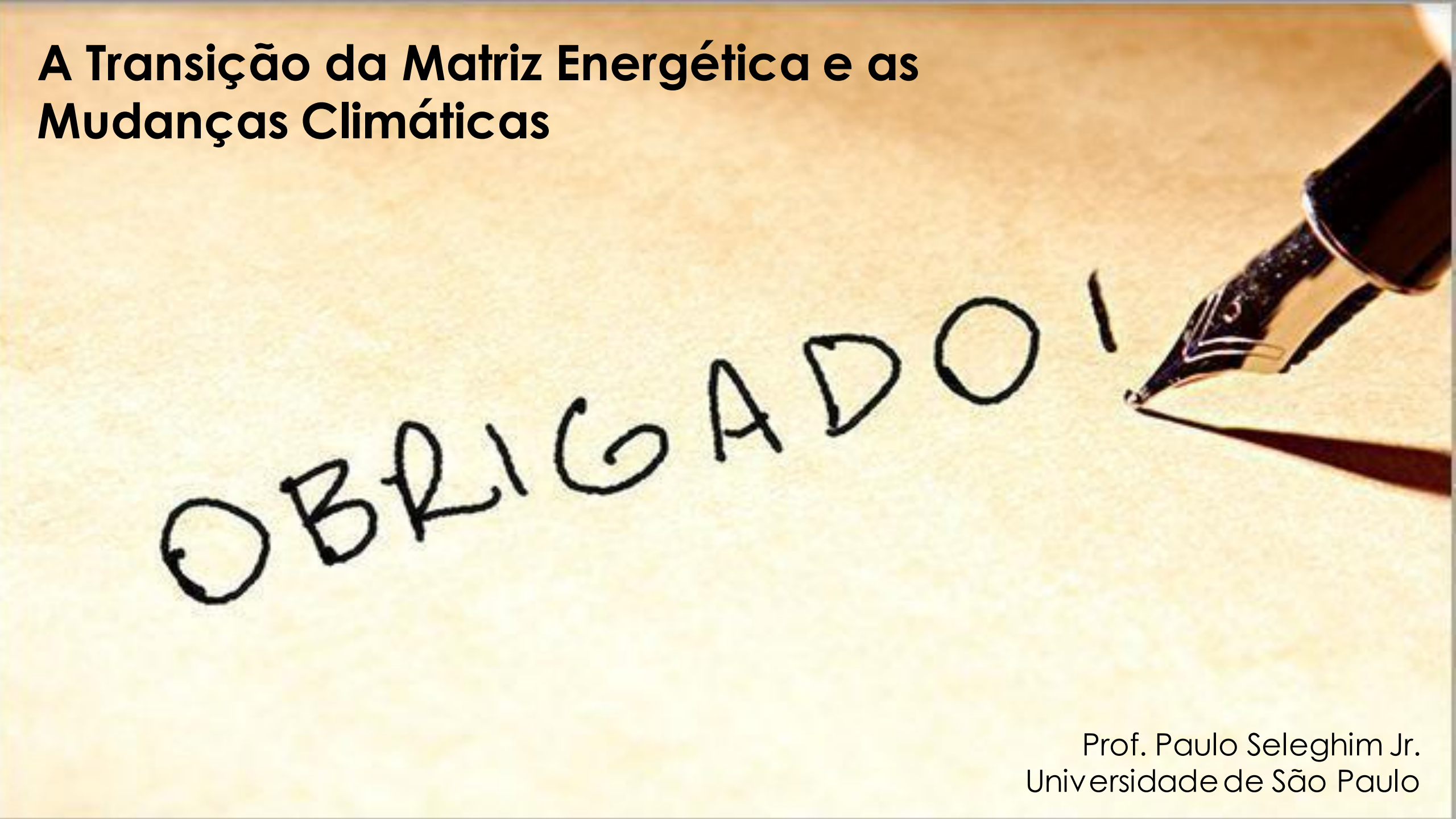
$W_{terra} = 18\ TW$

$$W = \dot{m} \cdot c^2$$

$$W = 10^{-3}\frac{kg}{s} \cdot \left(300 \cdot 10^{6}\frac{m}{s}\right)^2$$

$$W = 90\ TW$$

A Transição da Matriz Energética e as Mudanças Climáticas



Prof. Paulo Seleghim Jr.
Universidade de São Paulo

Paulo Seleghim - YouTube

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