INTEGRATED ENERGY SYSTEMS ASSESSMENT
– how to ‘invent’ the future? –

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CONSUMERS – Lifestyle: small cars or no cars, less flights …

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TECHNOLOGY – power production, insulation materials, electric vehicles, LEDs, …

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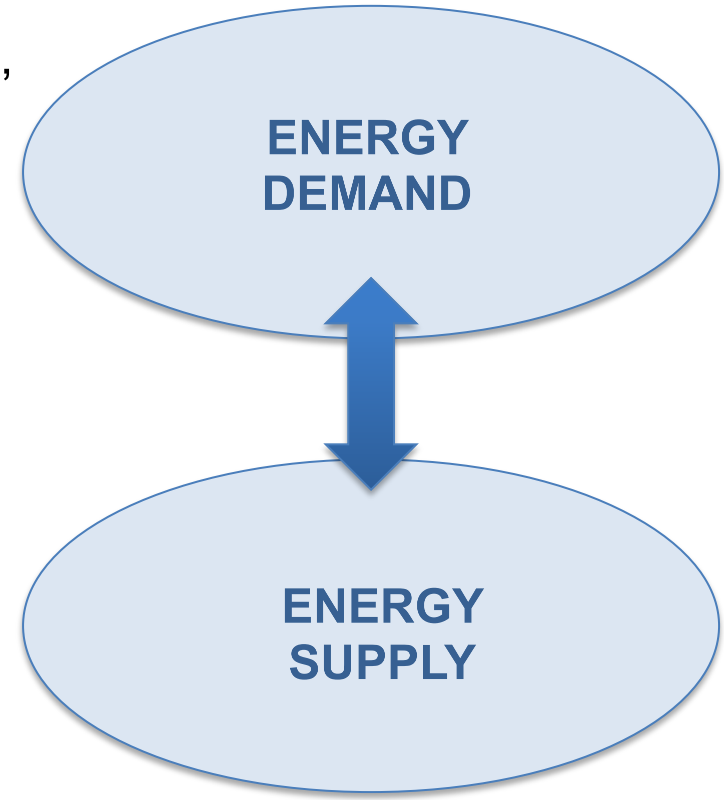
RESOURCES – coal, shale gas, sun, water …



1) HOW TO THINK FOR THE FUTURE? 2030 – 2040 – 2050 ?

2) 1 + UNDER A SEVERE CONSTRAINT OF GREENHOUSE GAS EMISSIONS?

3) 2 + WITHOUT LOOSING COMPETITIVENESS?

1st step: How to project energy needs for the future?

ENERGY DEMAND = Population * GDP per Capita * Energy/GDP

(final energy)

GDP per Capita: development index
Energy/GDP: energy intensity of the economy

Limitations?

1st step: Project energy needs for the future

Recall the Class *Energy Demand for Medium to Long Term Decisions*
15th March 2019, João Pedro Gouveia

From storylines to quantitative models

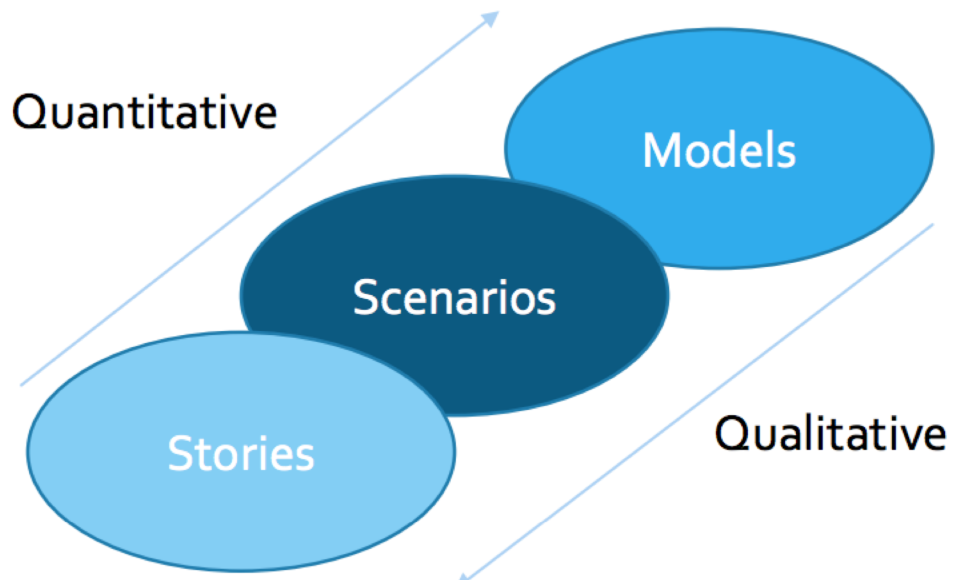
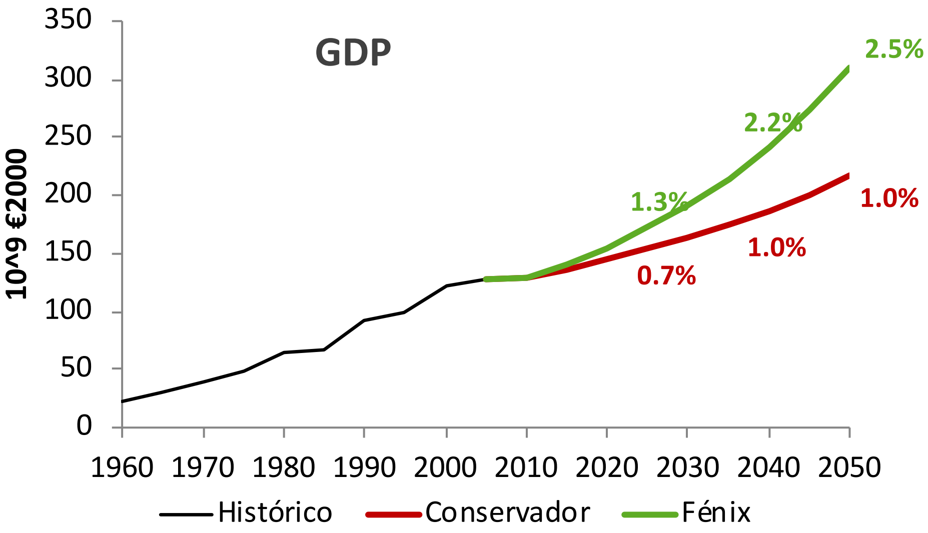


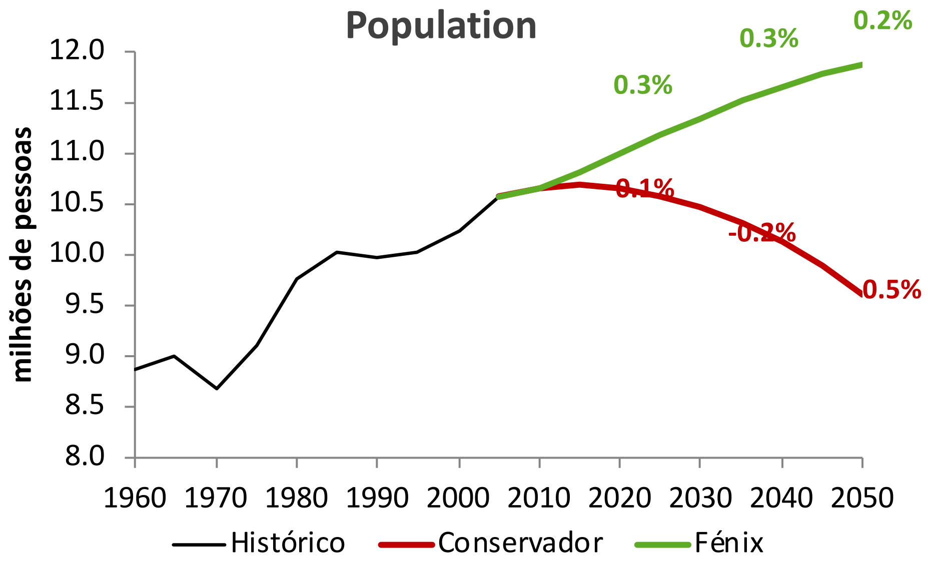
Fig. 4 - Schematic illustration of alternative scenario formulations, from narrative storylines to quantitative formal models (IPCC)

1st step: Project energy needs for the future

Energy Demand

Socio-economic scenarios 2050

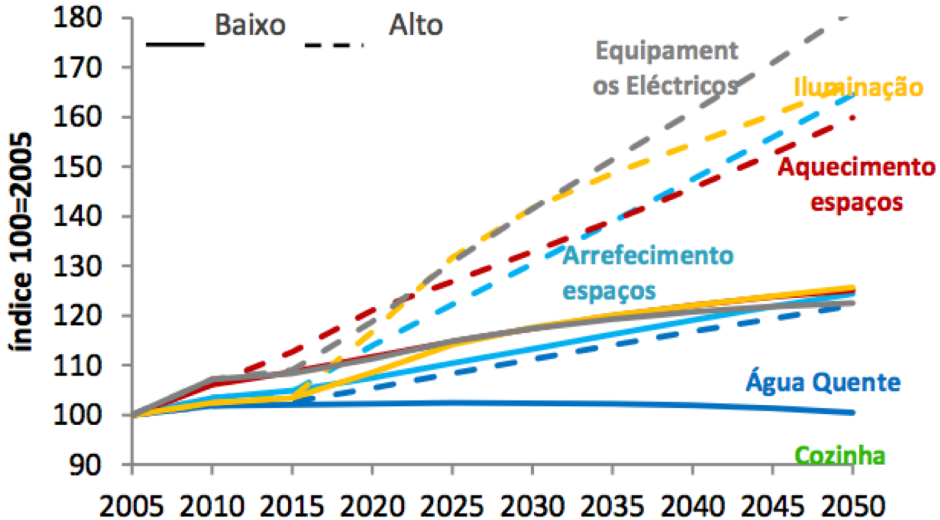


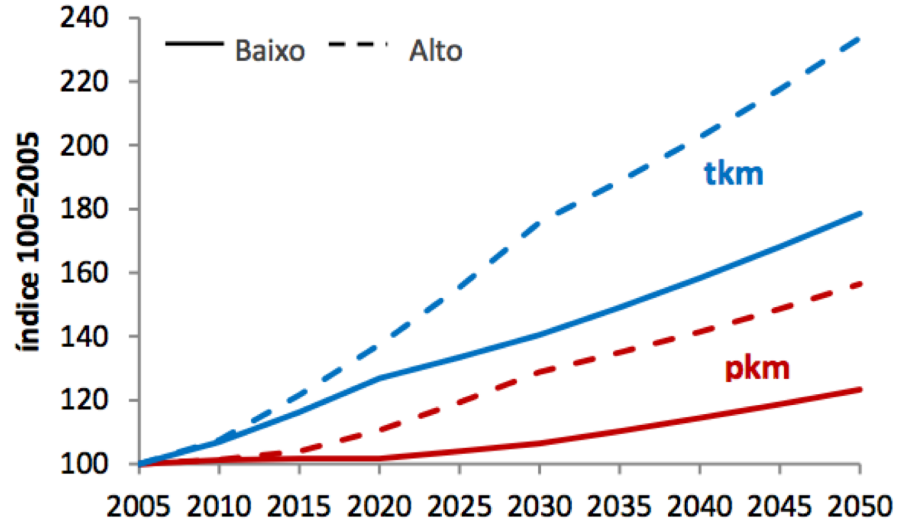


Indicator	Unit	2005	2010	2020	2030	2040	2050
GDP/capita	1000€$_{2000}$/inhab	12.80	12.1	13.4	15.1	17.2	20.1
			12.1	14.1	16.9	20.7	26.1

1st step: Project energy needs for the future

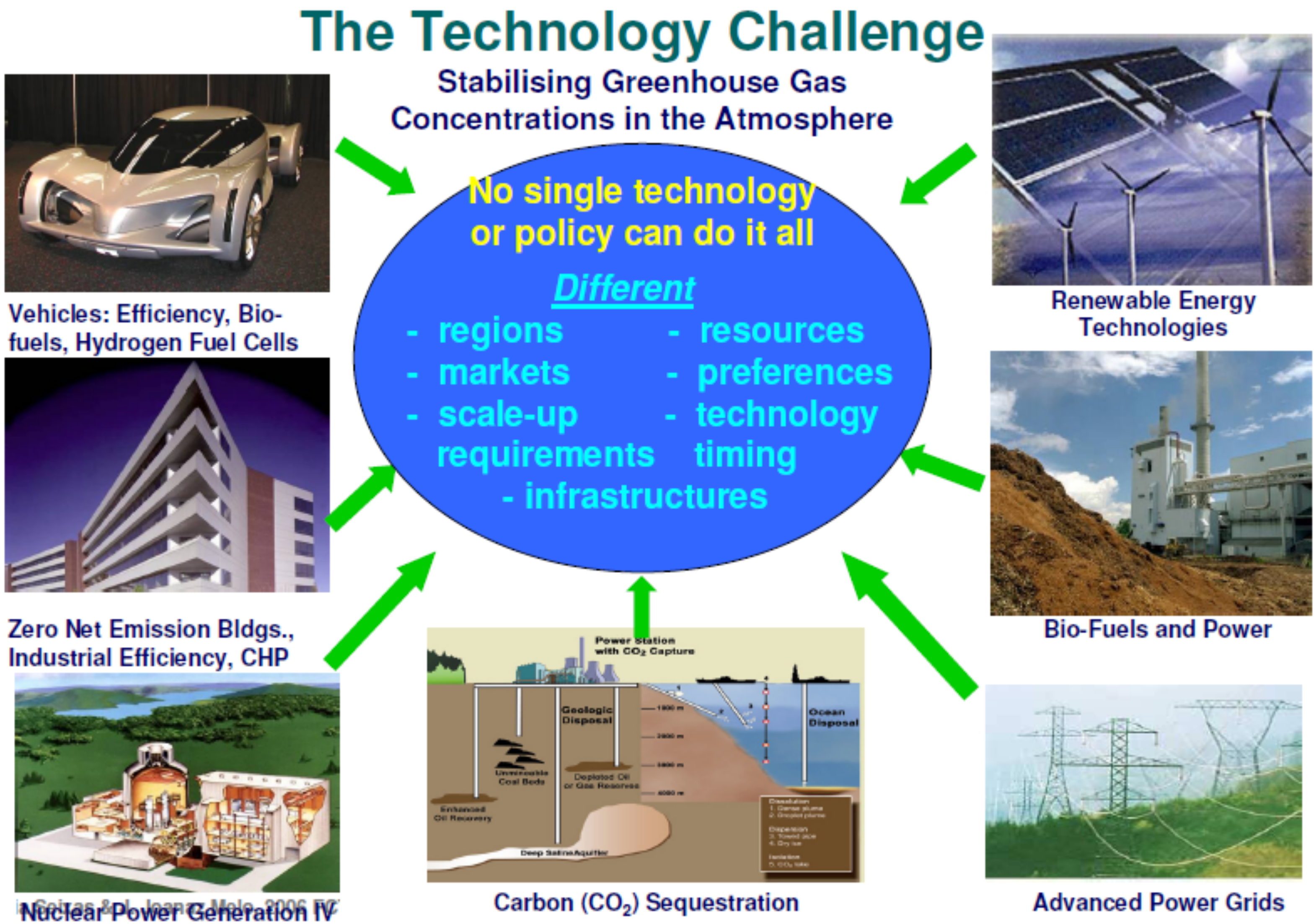
Examples of projections of energy services demand for buildings (households and services) and mobility





Why projecting energy services and not final energy?

3rd step: Project energy technologies available in the future



3rd step: Project energy technologies available in the future

Technological development

- is crucial to reach long-term climate goals
- is not autonomous, but partly induced by market incentives and policy measures
- is characterised by market failures (spillovers)

Optimal climate policy

- may involve both carrot (subsidies) and stick (taxes)
- has an important time dimension
- requires lots of information, e.g. about the future

Three questions:

- How should the optimal technology subsidy evolve over time?
- What are the costs of simpler policy rules?
- Under what conditions can lock-in of the wrong technology become important?

Source: K. Rosendahl, 2004

Source: IEA 2017

to read!

Solar PV and onshore wind ↗

Solar PV and onshore wind electricity generation are expected to grow by 2.5 times and by 1.7 times respectively, over 2015–20. This growth trend is on track with the 2DS target, providing a solid launching pad for the further 2 times increase in solar PV and 1.7 times increase in onshore wind respectively, required over the 2020–25 period.

Strong capacity growth continued for both solar PV and onshore wind, and record-low contract prices were announced in 2016.

Recommendation for 2017: Implement system-friendly solar PV and wind deployment and address market design challenges to improve grid integration of renewables.

Offshore wind and hydropower ↘

Offshore wind generation has grown fivefold over 2010–15 and is expected to double over 2015–20. However, over 2020–25, offshore wind generation needs to triple to be fully on track with its 2DS target.
For hydropower, the trend of capacity and generation growth is expected to slow down over the 2015–20 period compared with the previous five years. To be on track with 2DS 2025 targets, an increase in capacity growth rates is required.

Offshore wind additions in 2016 declined by a quarter year on year (y-o-y).
Hydropower additions decreased for the third consecutive year in 2016.

Recommendations for 2017: Ensure timely grid connection of offshore wind plants, and continue implementing policies that spur competition to achieve further cost reductions for offshore wind. Improve market design to better value the system flexibility of hydropower.

Bioenergy, concentrated solar power (CSP), ocean energy and geothermal ~

Progress in renewable technologies at earlier technology development stages remains behind the performance needed to get on track to reach their 2DS targets.

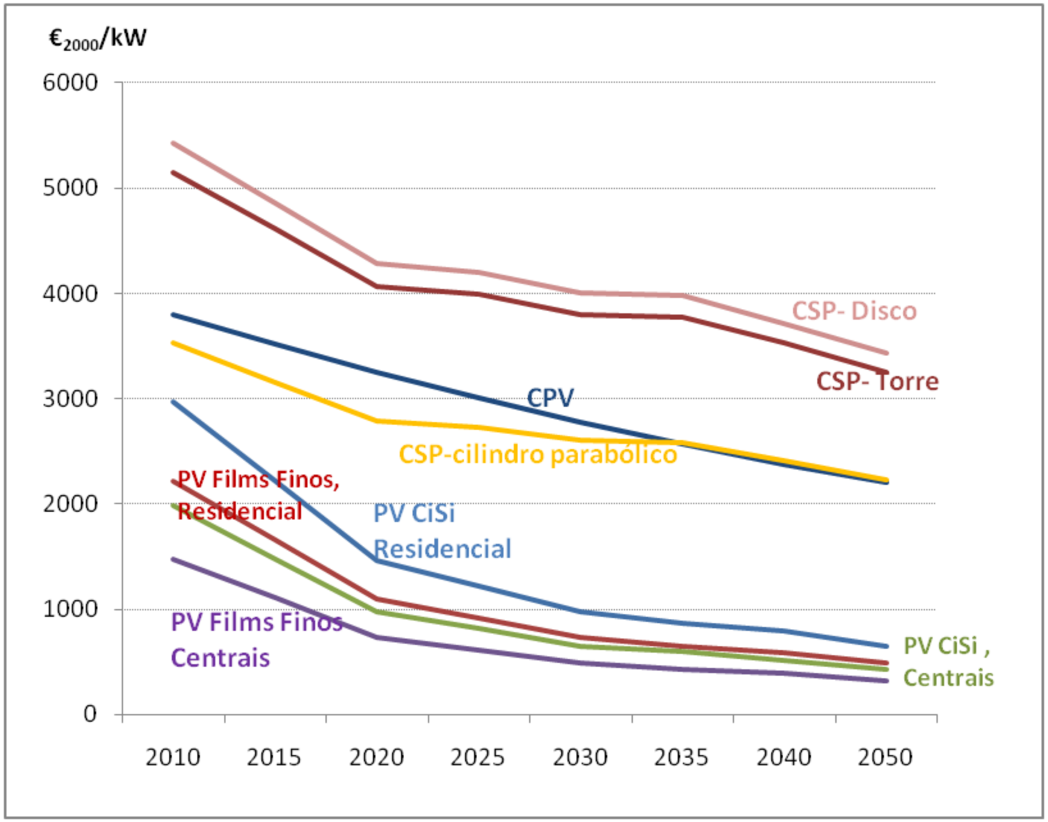
Generation costs and project risks remain higher than conventional alternatives, preventing faster deployment.

Recommendations for 2017: Devise plans to address technology-specific challenges to achieve faster growth. Strategies could include: better remuneration of the market value of storage for CSP; improved policies tackling pre-development risks for geothermal energy; facilitating larger demonstration projects for ocean technologies; complementary policy drivers for sustainable bioenergy.

3rd step: Project energy technologies available in the future

Technology assumptions

Technology cost curve: the solar case



Source PV and CPV: IEA- Technology Roadmap Solar photovoltaic energy 2010; Magpower;
Fonte CSP: Valores 2010 - IEA, 2010 “Technology Roadmap, Concentrating Solar Power” -International Energy Agency, 2010.

Technology efficiency

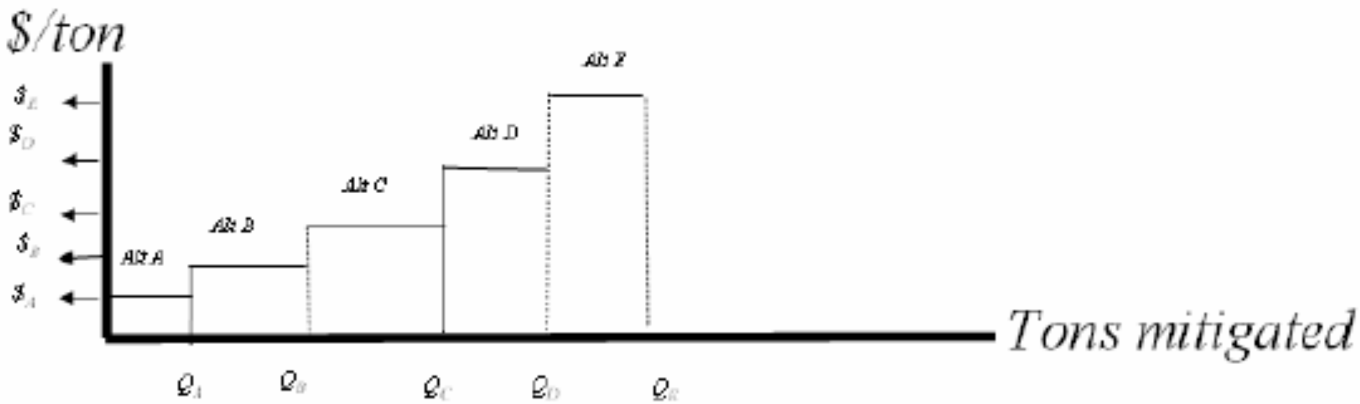
		'10 – '15	'15 – '20	'20 – '50
	PV	17%	19%	21%
	Thin films	12%	14%	16%
	CPV	23%		30%
CSP	Tower	20%		
	Parabolic cilinder	15%		
	Discs	25%		

Recall: Learning Curves

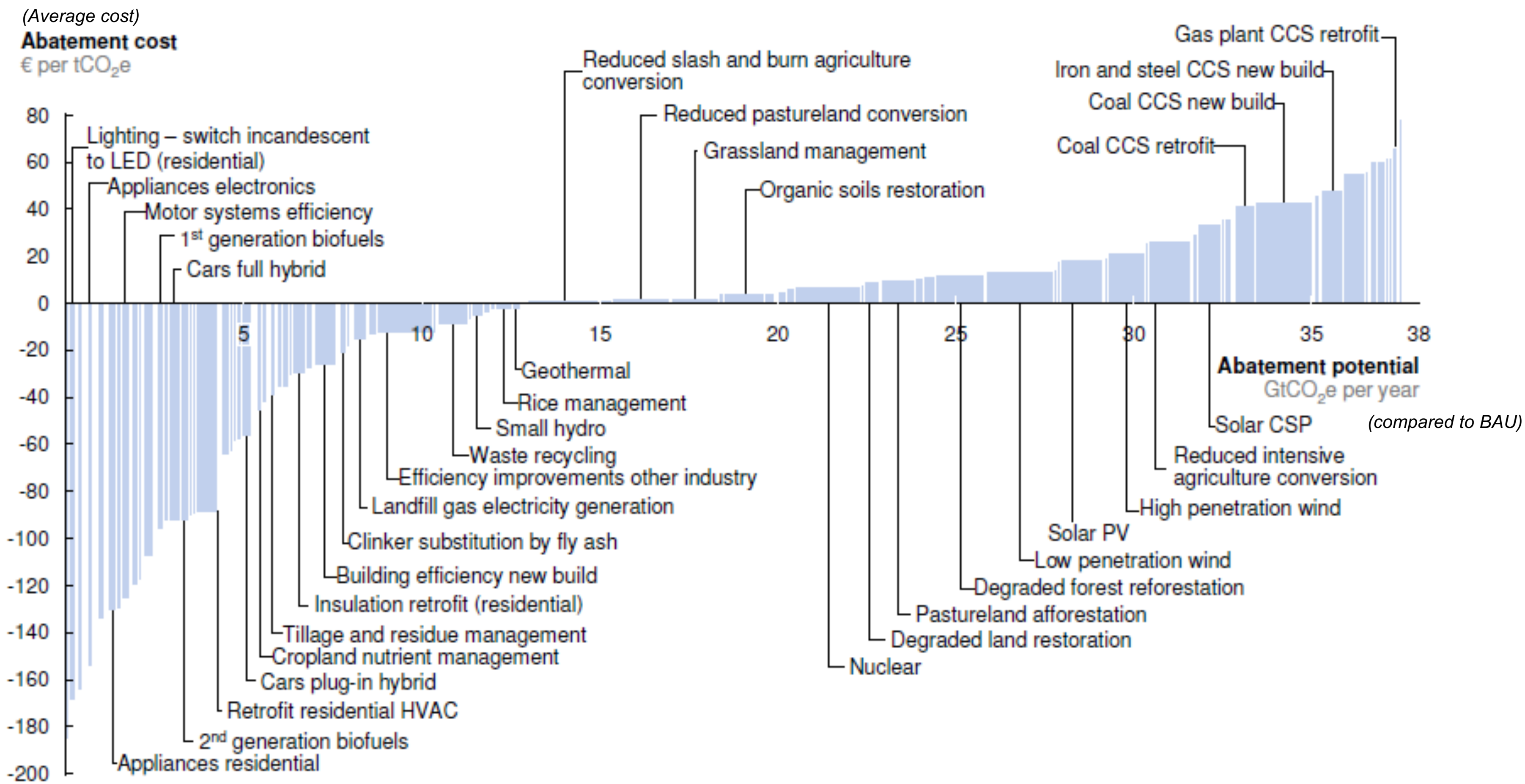
2nd step: Project energy technologies available in the future

How to assess technological options?
The usefulness of Marginal Abatement Curves

- Identify alternative mitigation technologies
- Obtain data on mitigation effectiveness and cost
  - Vary by technology and location
- Estimate cost per ton mitigated for each technology
- Rank order from cheapest to most expensive



V2.1 Global GHG abatement cost curve beyond BAU – 2030



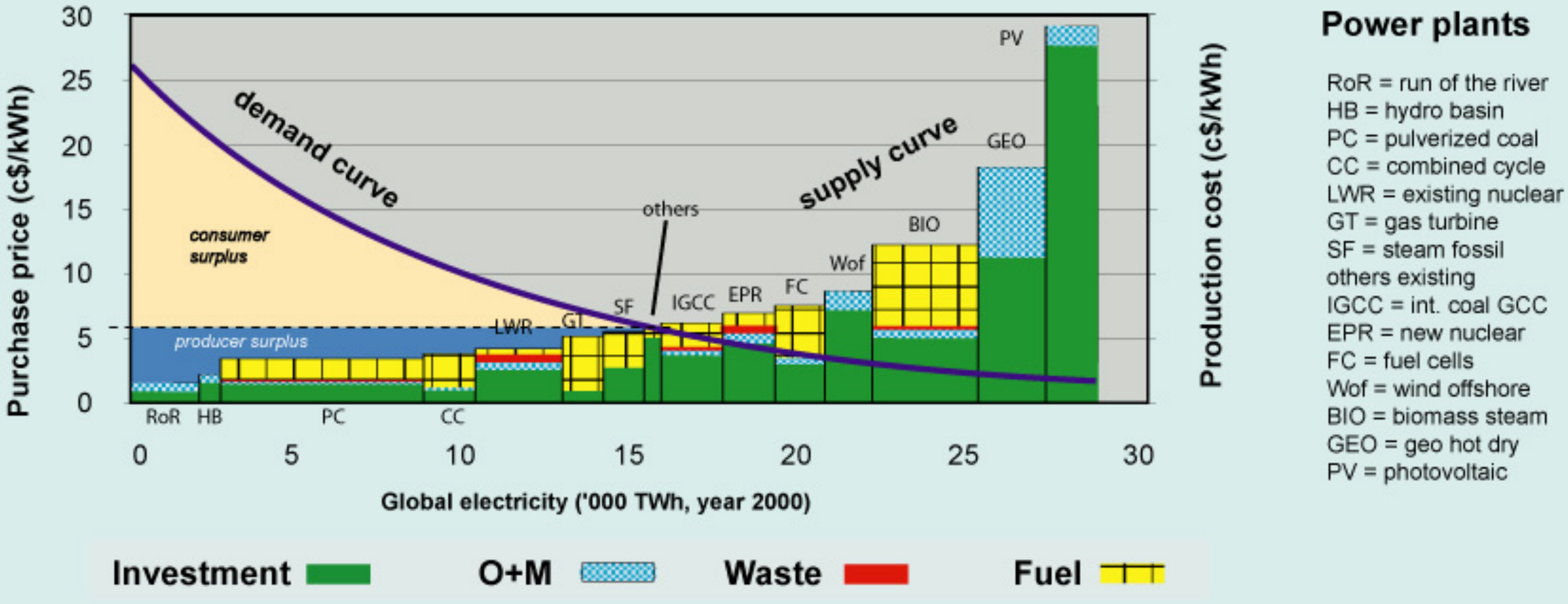
Note: The curve presents an estimate of the maximum potential of all technical GHG abatement measures below €80 per tCO_2e if each lever was pursued aggressively. It is not a forecast of what role different abatement measures and technologies will play.
Source: Global GHG Abatement Cost Curve v2.1

Impact of financial crisis in carbon economics (McKinsey 2010)
http://www.mckinsey.com/clientservice/sustainability/pdf/Impact_Financial_Crisis_Carbon_Economics_GHGcostcurveV2.1.pdf **a ler!**

2nd step: Project energy technologies available in the future

What are the most competitive technologies to supply energy demand?

Supply – demand curves for energy technologies.

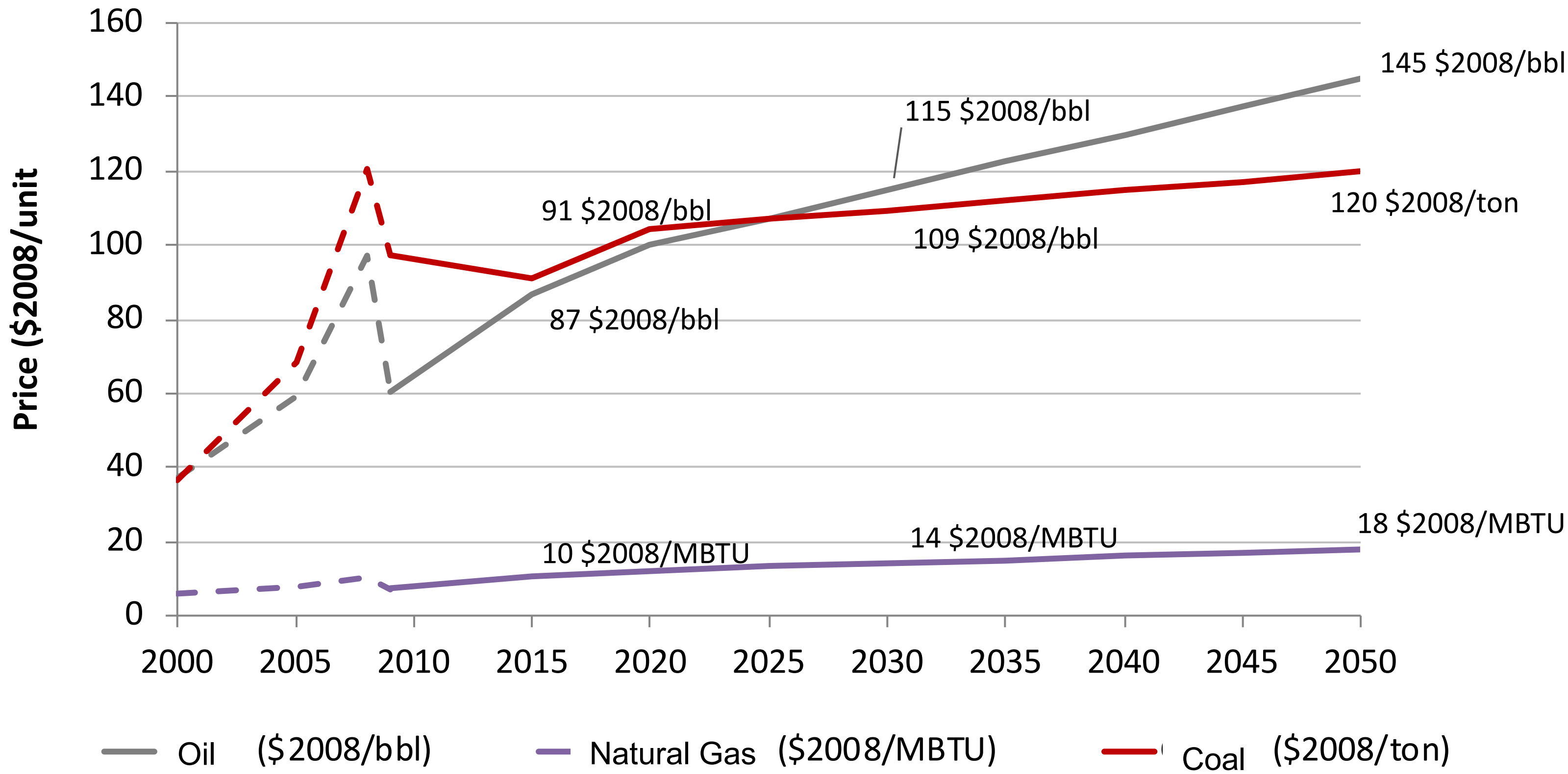


Typical representation of an energy commodity in MARKAL - TIMES.
The algorithm maximises the global surplus over thousands such markets.

Note: adapted from G. Tosato - IEA (April, 2006)

2nd step: Project energy technologies available in the future

Future Fuel prices are importante for the competitiveness of energy technologies



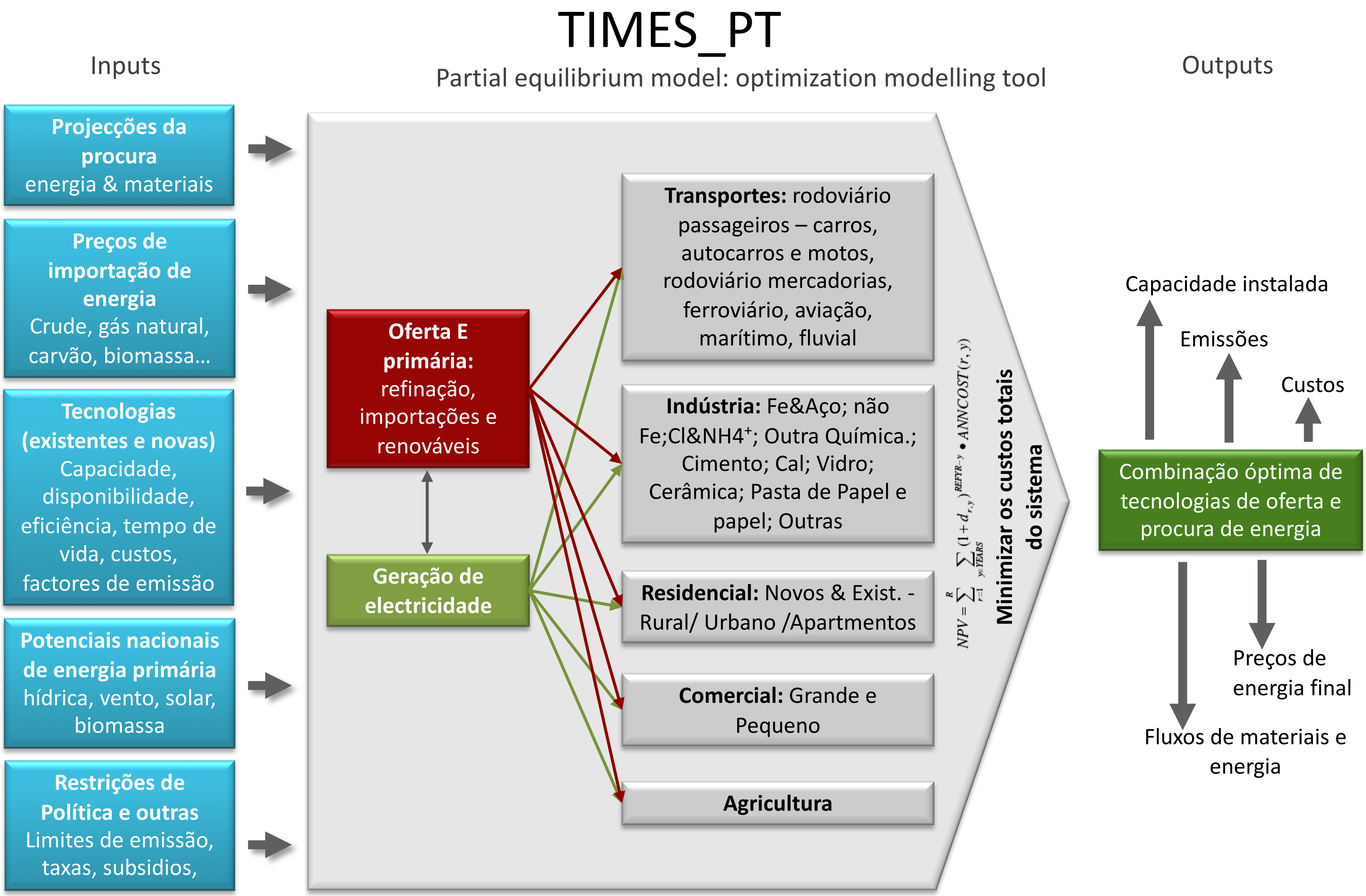
Source: reference Scenario. **World Energy Outlook**. International Energy Agency. 2009. Paris

2nd step: Project energy technologies available in the future

Availability of Endogenous Resources potential is crucial for its adoption in the future

Resource	Unit	Current use	MAximun technical Potential			Source
		2009	2020	2030	2050	
Hydro power	GW	4.497	9.08			Plano Nacional de Barragens com Elevado Potencial Hidroeléctrico. 2009.
Mini-hydro power	GW	0.324	0.70	0.81		
Windonshore	GW	3.566	6.50	7.00	7.50	Comunicação pessoal de Ana Estanqueiro. LNEG. 16 Junho 2010.
Windoffshore	GW	0	0.075	4.00	10.00	Estimativa com base em estudo do INETI
Waves/Tide	GW	0.004	5.00		7.70	Comunicação pessoal de Alex Raventos. Wave Energy Center. 23 Abril 2010
Rooftop PV	GW	0.019	1.50	9.30		DGEG (MEID) – Montra Tecnológica Solar (Lisboa, 16 Março de 2010); REN (comunicação pessoal)
PV utility scale	GW	0.077				
Urban waste	PJ	0.088 GW	9.83	9.99	10.43	Extrapolação com base em indicador de RSU incinerado per capita e cenários de RSU elaborados no âmbito do PORTUGAL CLIMA2020.
Biogas	PJ	0.02 GW	17.46	6.90	5.89	Extrapolação PNAC 2006 e GPPAA- MADRP. 2005.
Geothermal	GW	0.023	0.045	0.077	0.23	Comunicação pessoal de Luís Neves. Faculdade de Ciências e Tecnologia da Universidade de Coimbra. Junho 2010.
Geothermal (Hot Dry Rock)	GW	0	0.038	0.102	0.750	
Biomass from forest	PJ	0.46 GW	17.67	30.87		Grupo de trabalho-Direcção Nacional das Fileiras Florestais, Junho, 2010. Comunicação pessoal de Armando Goes. CELPA.
Biomass (agriculture waste+ wood industry)			5.93			INR, 2006.PERAGRI - Plano Estratégico dos Resíduos Agrícolas. Relatório Técnico, Vol 1 - Sumáro Executivo. Abril de 2006. Universidade do Minho GPPAA- MADRP. 2005. Biomassa e Energias Renováveis na Agricultura Pescas e Florestas.
Bioetanol	PJ	-	19.50			GPPAA- MADRP. 2005. Biomassa e Energias Renováveis na Agricultura Pescas e Florestas.
Biodiesel	PJ	-	9.99			

3st step: Matching energy needs and energy technologies



3st step: Matching energy needs and energy technologies

Scenarios (uncertainities) analysed until the modeling time horizon:

- **Different caps of GHG emissions;**
- **Different paces of cost reductions of energy technologies;**
- **Different energy services demand;**
- **Different energy prices of fossil fuels;**
- **Different policies (e.g. renewables targets, waste for energy goals)**

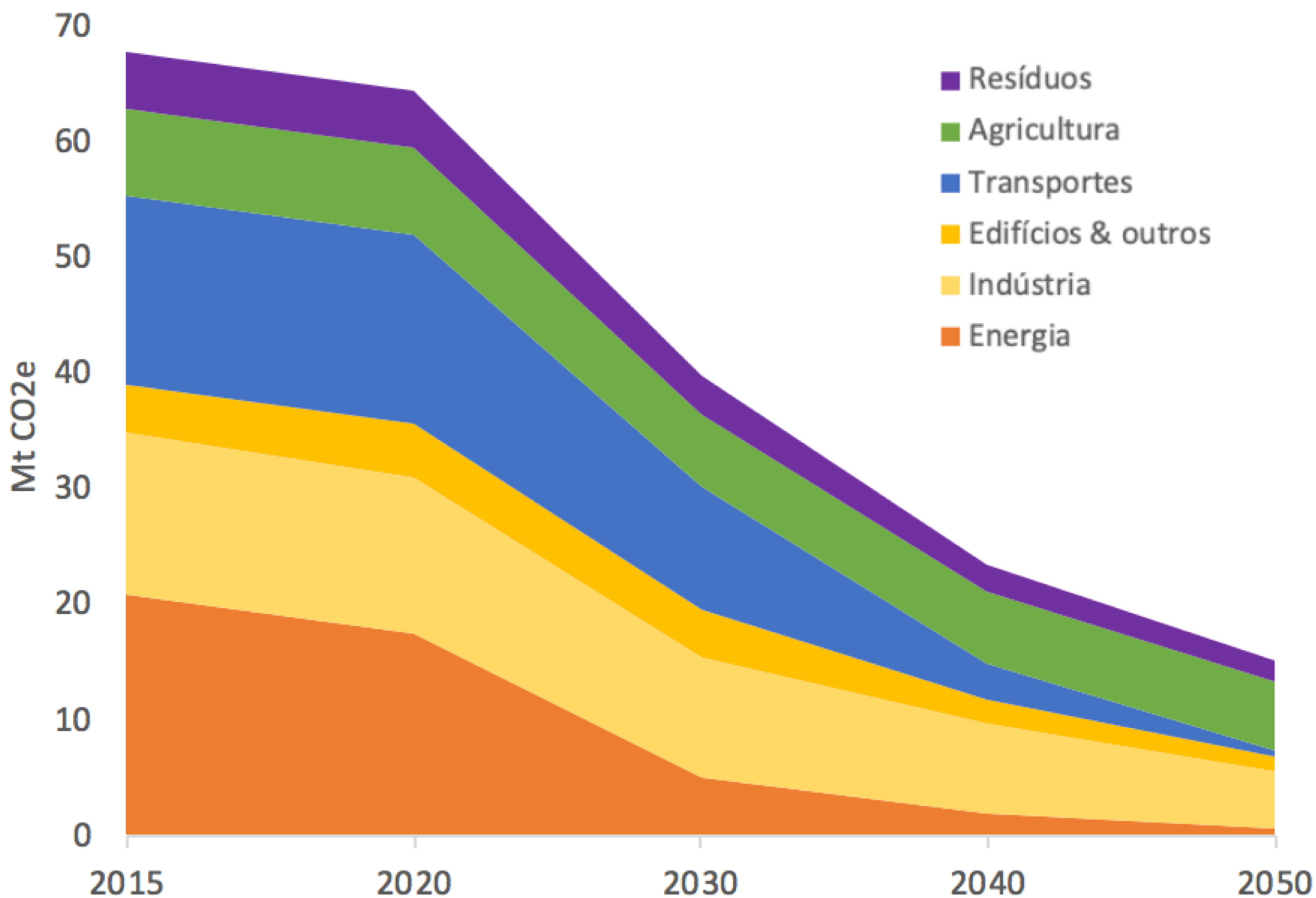
↓

Different future pathways of national/ regional energy systems:

- Portfolio of energy technologies
- Primary energy (import vs endogenous)
- Costs of energy production (e.g. electricity)
- GHG emissions

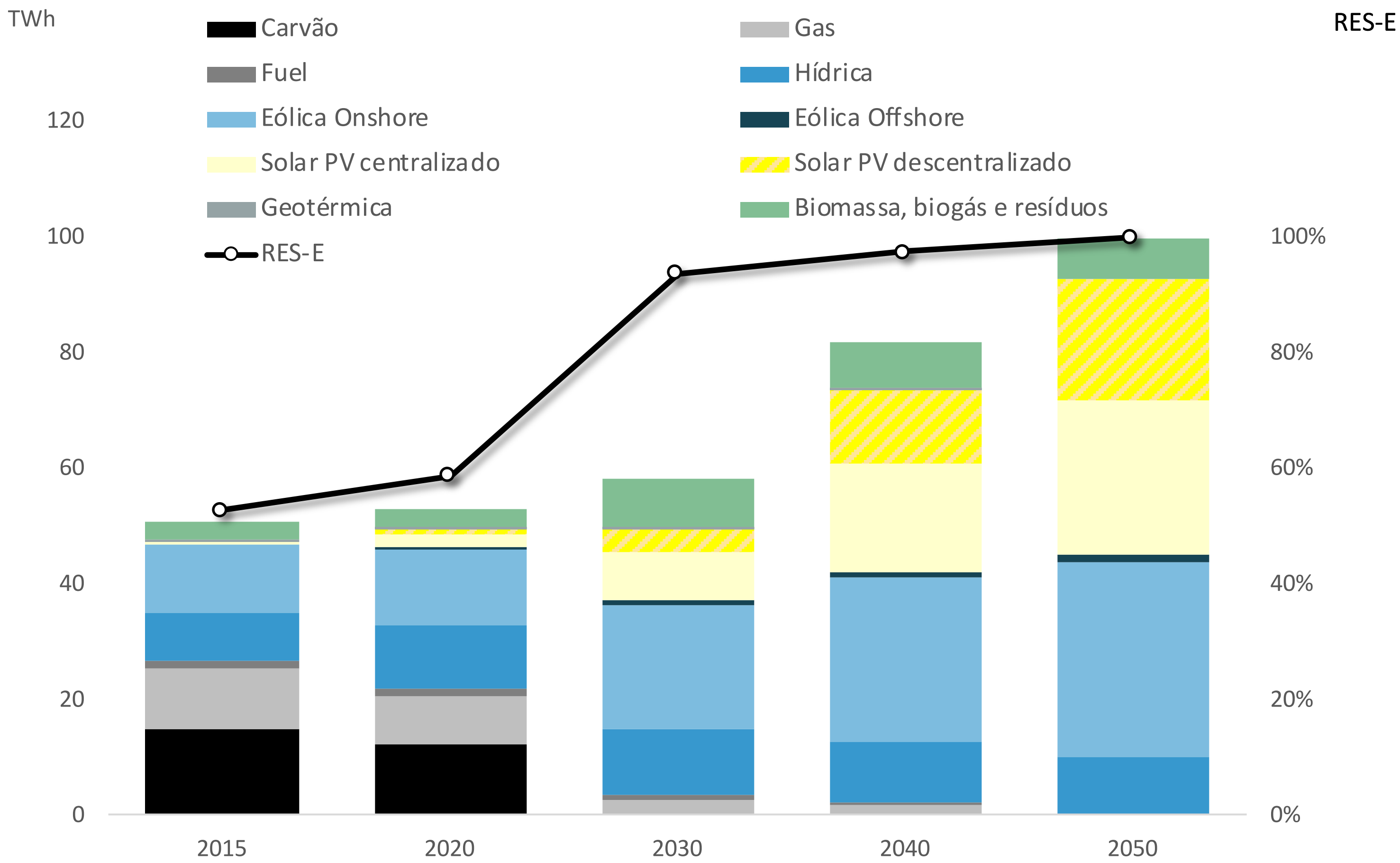
4th step: Analyzing results to support decision

Global assessment



4th step: Analyzing results to support decision

Focused on a specific sector: power sector



4th step: Analyzing results to support decision

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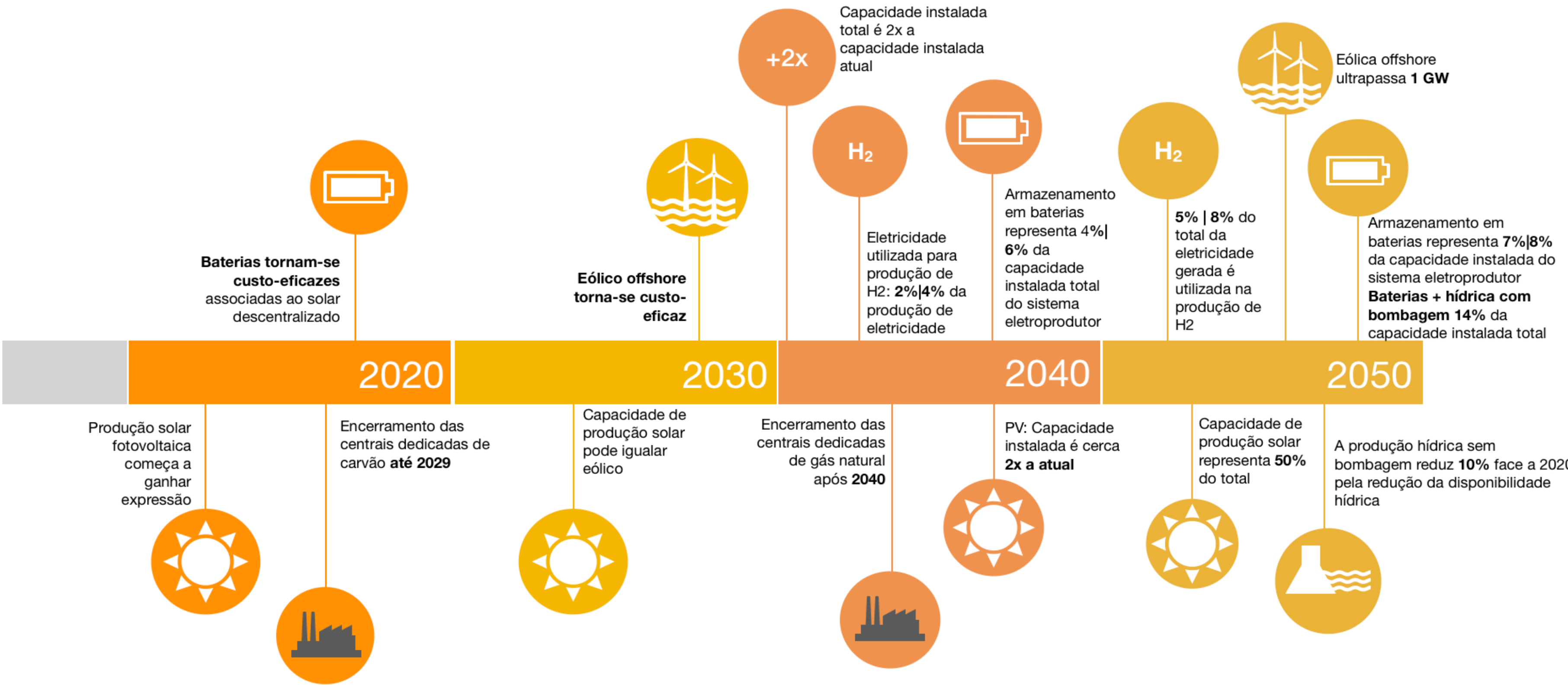


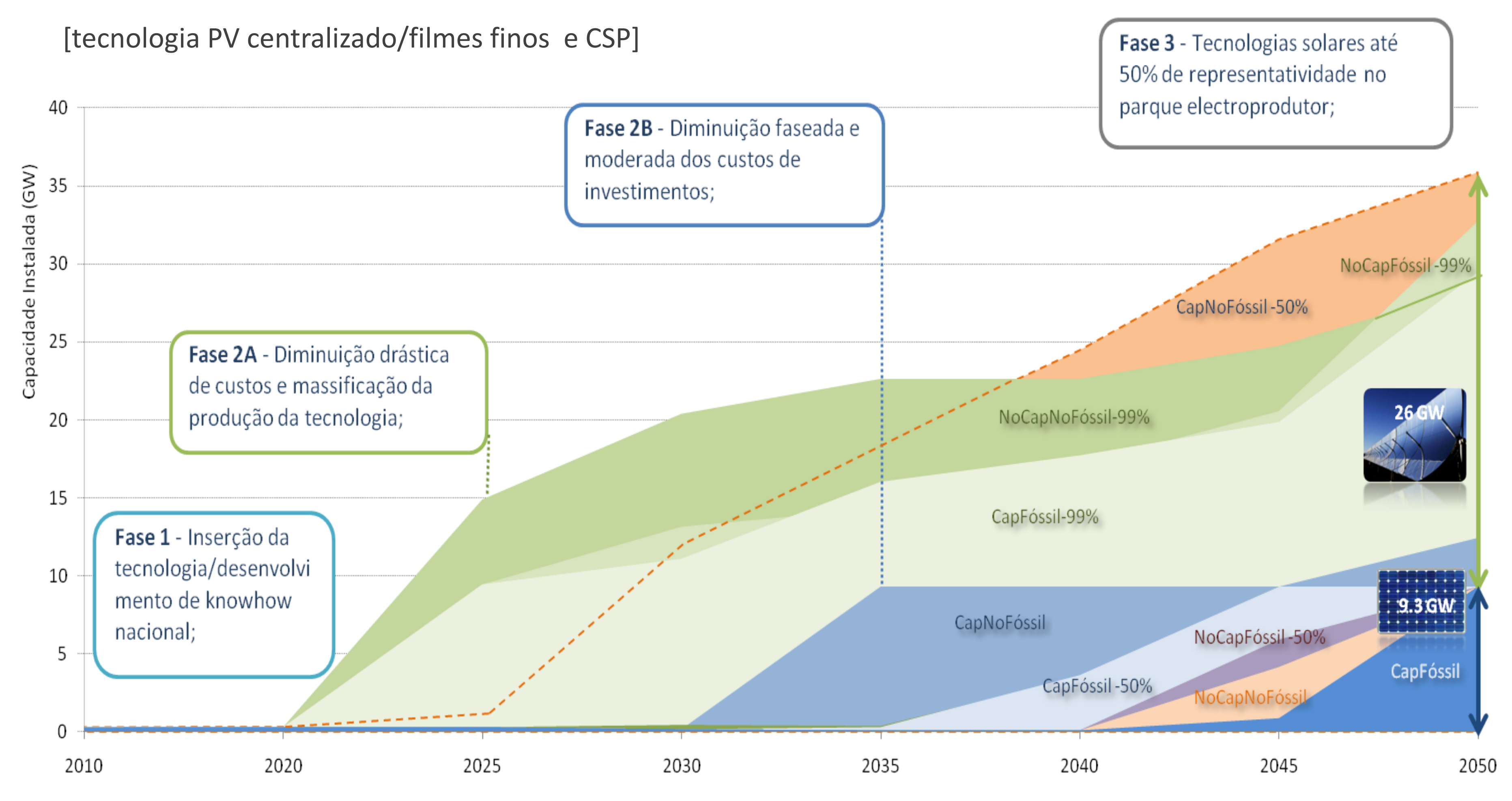
	2020	2030	2040	2050
% de FER	59	88 | 86	97	100
% Redução de GEE (face 2005)	-38	-83 | -84	-93 | -94	-98

CO_2

4th step: Analyzing results to support decision

Focused on a specific technology: solar power

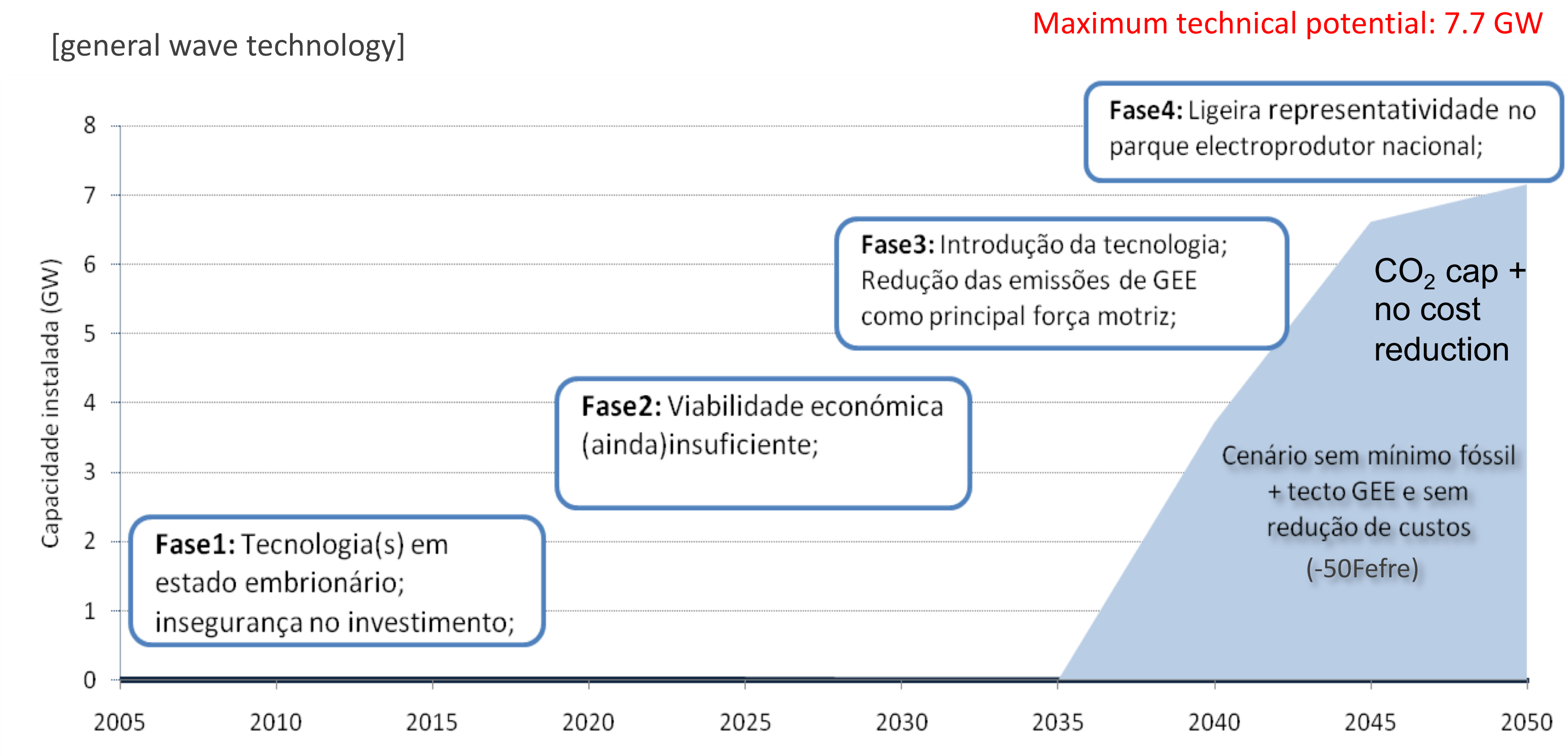
Maximum technical potential: 9.3 GW PV e n.d. CSP



Em 2050 até 51% GW totais e até 34% TWh totais

4th step: Analyzing results to support decision

Focused on a specific technology: wave power

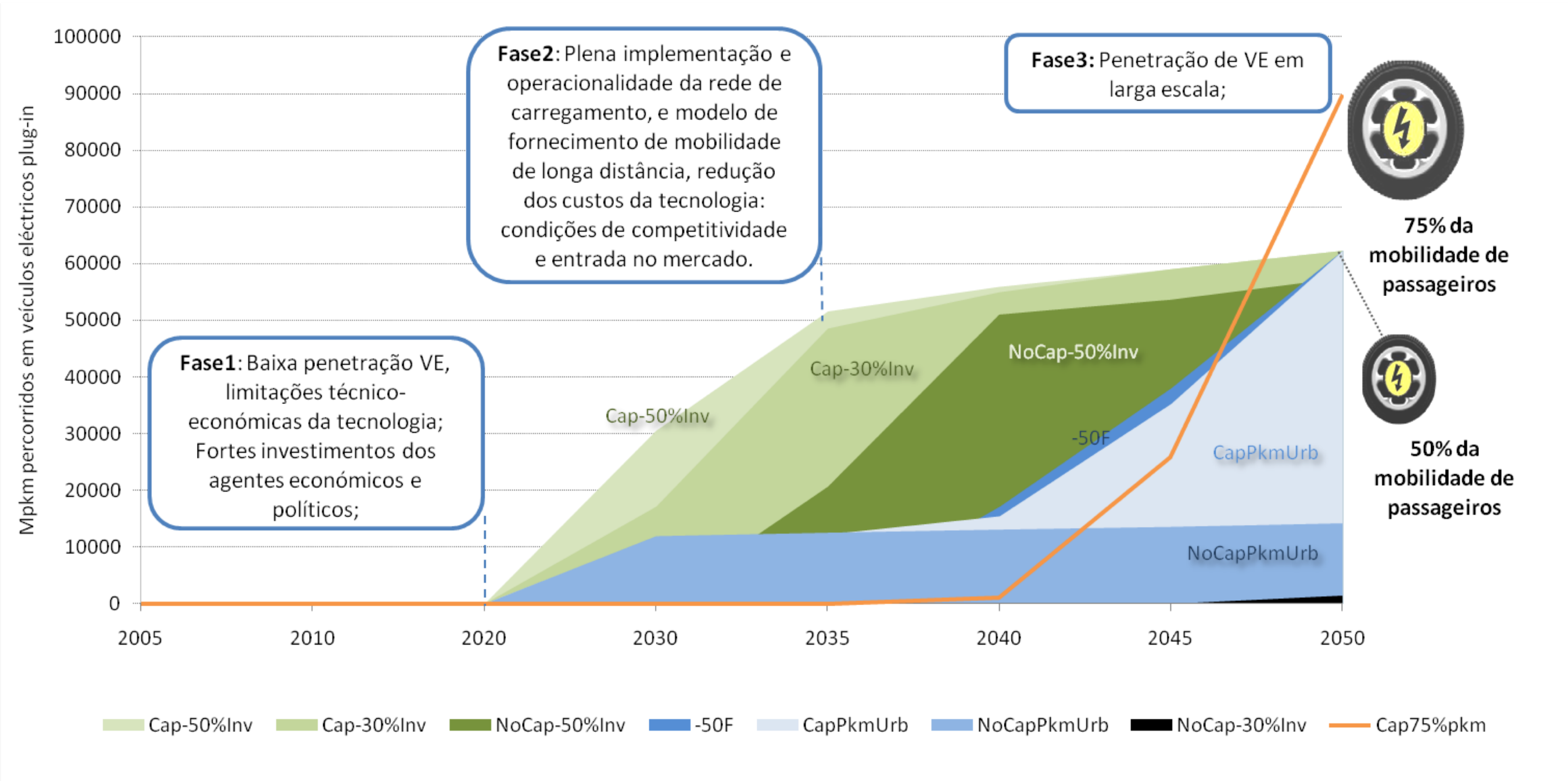


2050: up to 15% of total instaled capacity and 16% totalproduction

Fonte: Roadmap Portugal 2050: análise das novas tecnologias energéticas nacionais e cenarização do seu impacto no sistema energético nacional. E.Value SA. Lisboa 2010. (http://evalue.na-rede.net/publicacoes/D3_Analise_Competitividade_Novas_Tecnologias_Energeticas_12.2010.pdf)

4th step: Analyzing results to support decision

Focused on a specific technology: electric vehicles

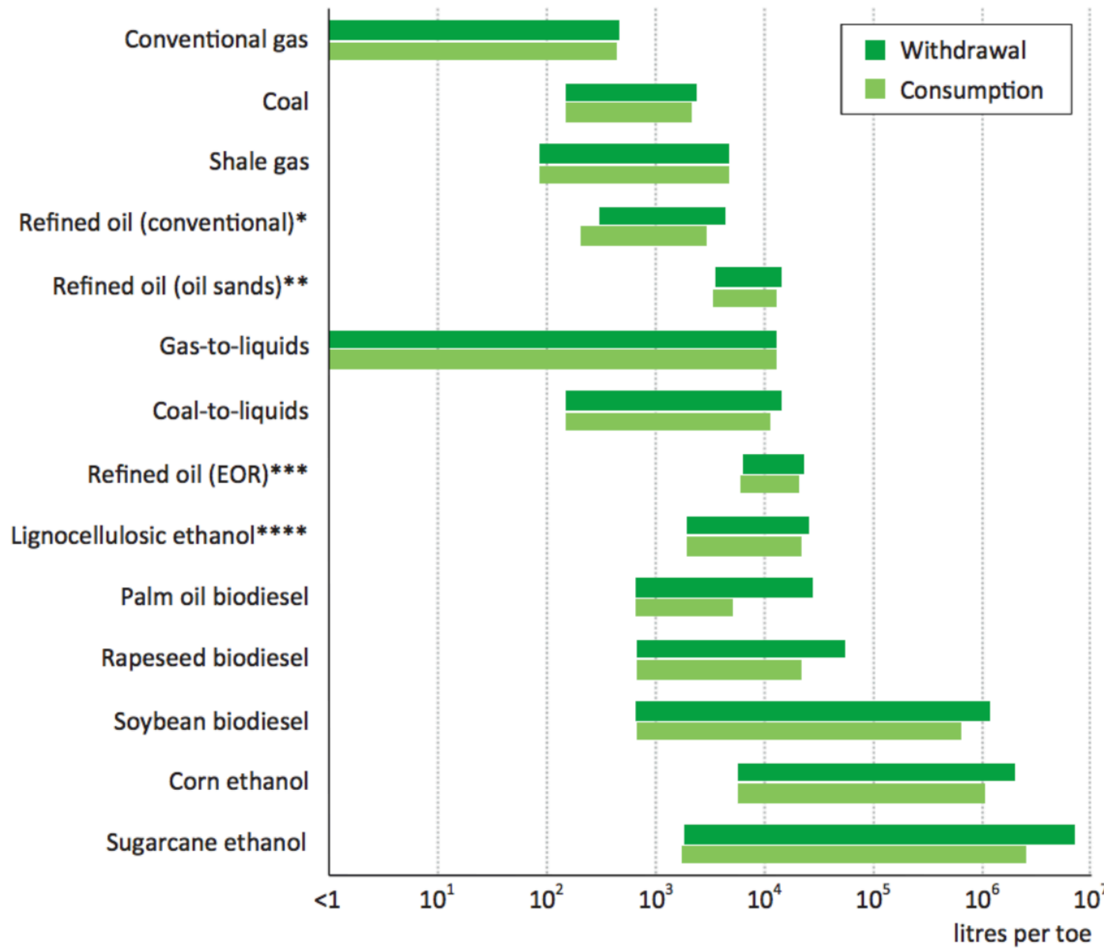


Fonte: Roadmap Portugal 2050: análise das novas tecnologias energéticas nacionais e cenarização do seu impacto no sistema energético nacional. E.Value SA. Lisboa 2010. (http://evalue.na-rede.net/publicacoes/D3_Analise_Competitividade_Novas_Tecnologias_Energeticas_12.2010.pdf)

5th step: Analyzing the sustainability of the cost-effective solutions (because models have limitations)

Energy - water nexus:

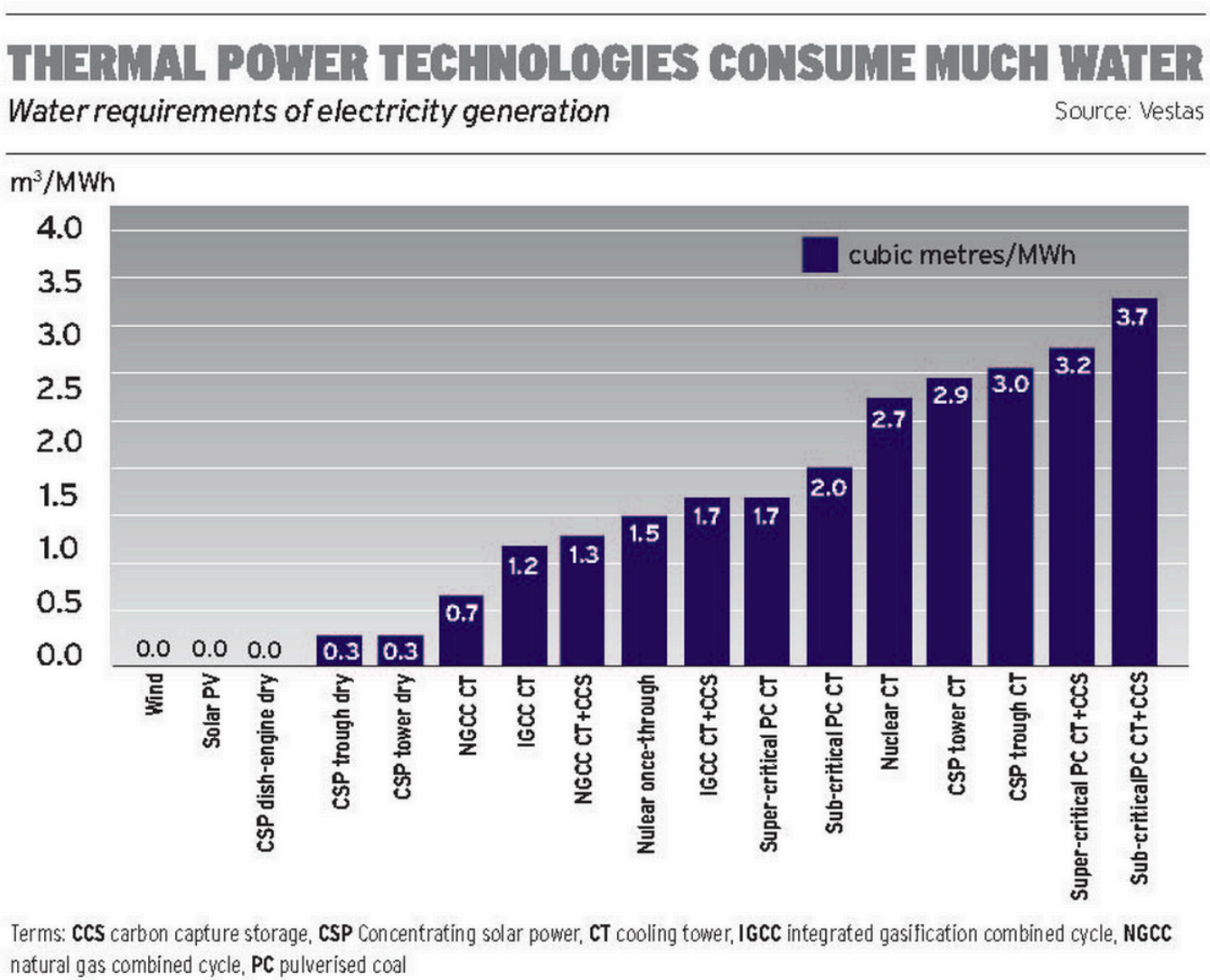
Figure 17.3 ▷ Water use for primary energy production



IEA (2012). WEO, Water for Energy: Is energy becoming a thirstier resource? (Ch 17)

5th step: Analyzing the sustainability of the cost-effective solutions (because models have limitations)

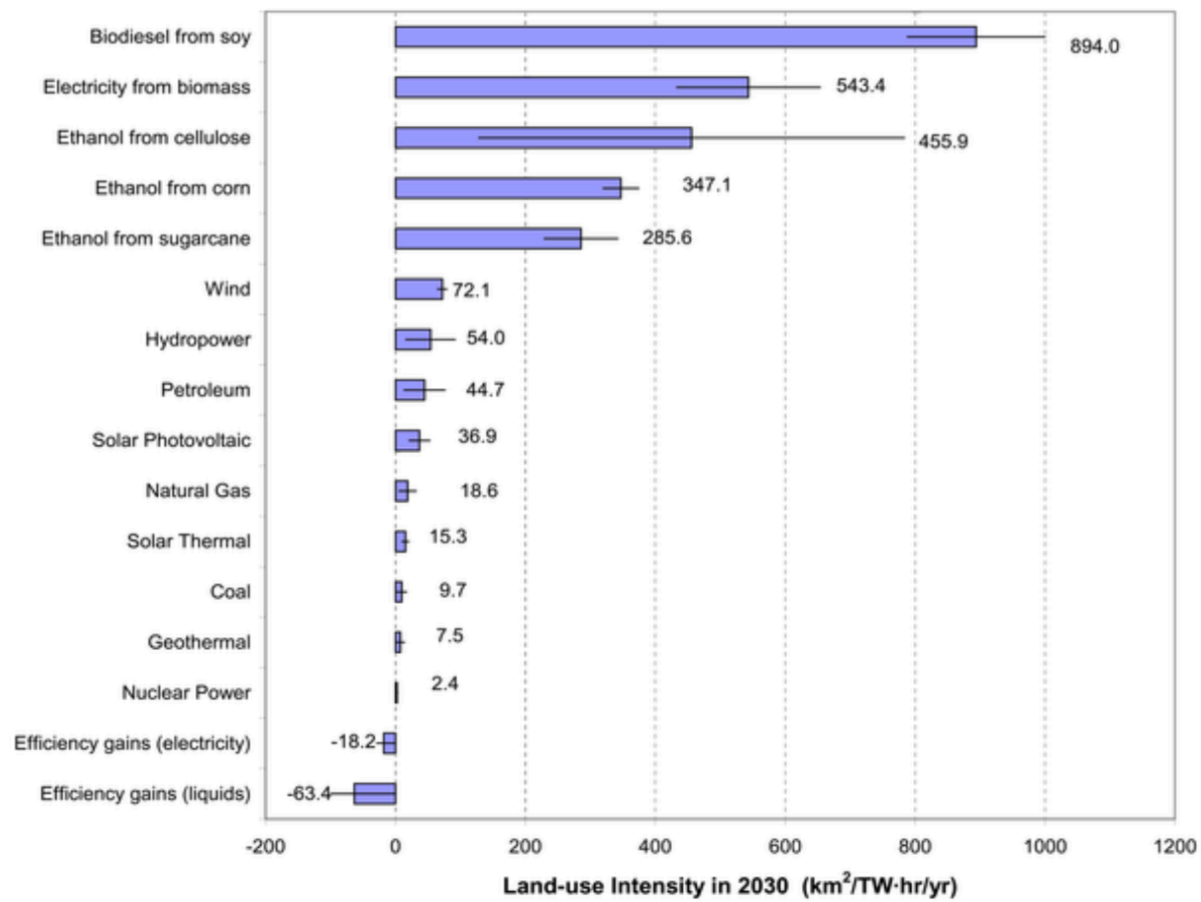
Energy - water nexus:



5th step: Analyzing the sustainability of the cost-effective solutions (because models have limitations)

Energy - land nexus:

Land-use intensity for energy production/conservation techniques.



McDonald RI, Fargione J, Kiesecker J, Miller WM, Powell J (2009) Energy Sprawl or Energy Efficiency: Climate Policy Impacts on Natural Habitat for the United States of America. PLoS ONE 4(8): e6802. doi:10.1371/journal.pone.0006802
http://127.0.0.1:8081/plosone/article?id=info:doi/10.1371/journal.pone.0006802

5th step: Analyzing the sustainability of the cost-effective solutions (because models have limitations)

Energy - water - land nexus:

QUESTIONS:

- How much water resources become available for energy production, due competition with other purposes? Recall climate change expectation scenarios on water cycle (e.g. Mediterranean)
- How much land will be available (at what cost?) for land intensive renewables production, in face of expected competition with food and livestock production?
- **What will be the energy options for future decarbonization pathways if water scarcity and land intensity will be taken into account?**