UQEI Energy Perspectives

Meeting the two degrees scenario – the carbon budget and emissions reduction constraints

20 November, 2014

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What is (should be) a Scenario ?

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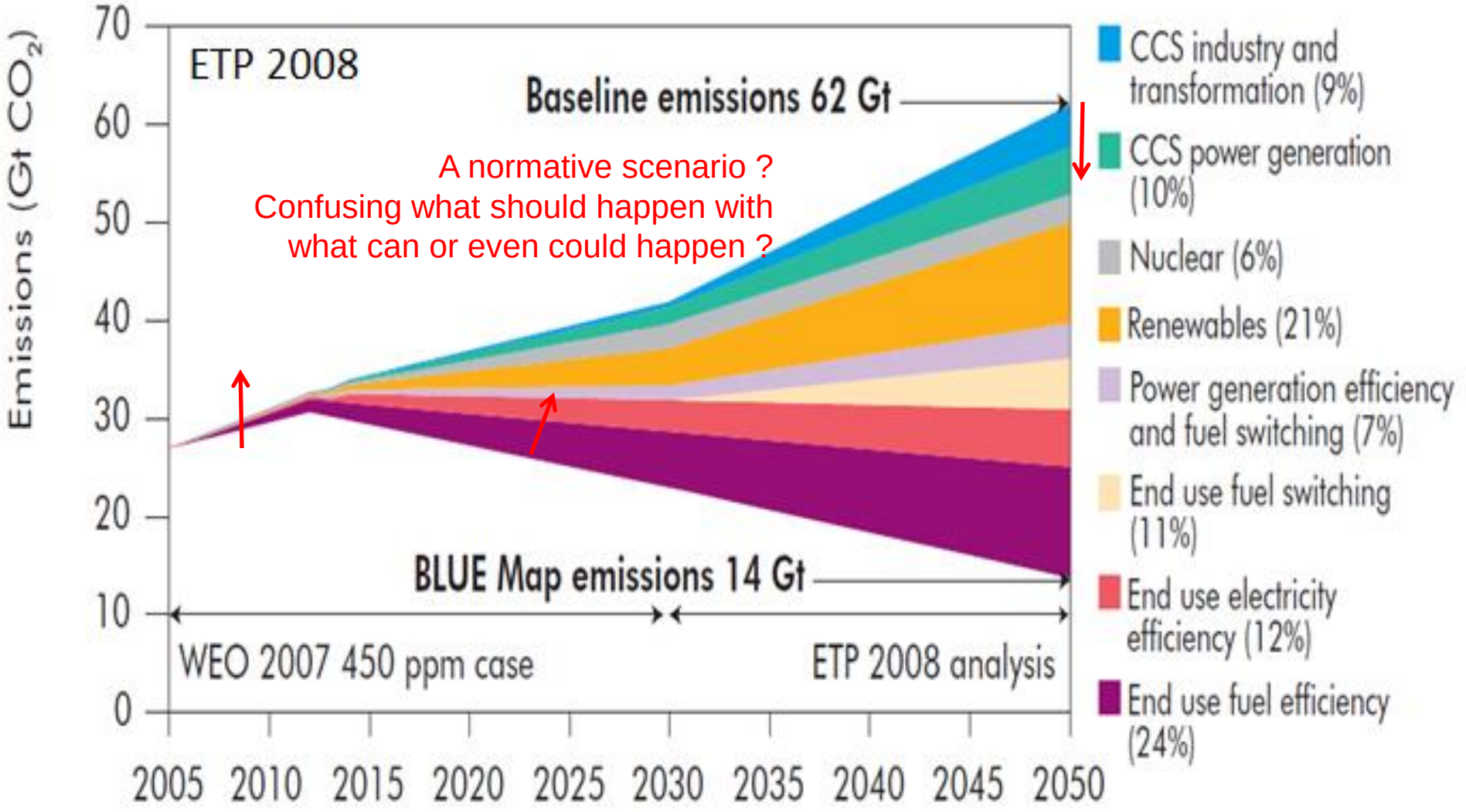
- Emerged from military planning via the RAND Corp (post WWII).
- Evolved (largely but not only in Shell) to help deal with uncertainty by creating discretely and significantly different futures.
  - see. “The Art of Strategic Conversation”. Kees van der Heijden (1996)

Scenarios

- Discrete, significantly different, yet *plausible and credible* futures.
- Should have enough ‘hooks’ into current organisational mental models to make them plausible to a ‘critical mass’
- Should provide tangible real-world context **to illustrate rather than espouse** (descriptive rather than normative)
  - *How things could be (and how they got there), not ‘ideally should be’*
  - *Employs causal modes of thinking; rich, granular narratives*.

ETP 2008 onwards – Evolution



Source: IEA - www.iea.org/

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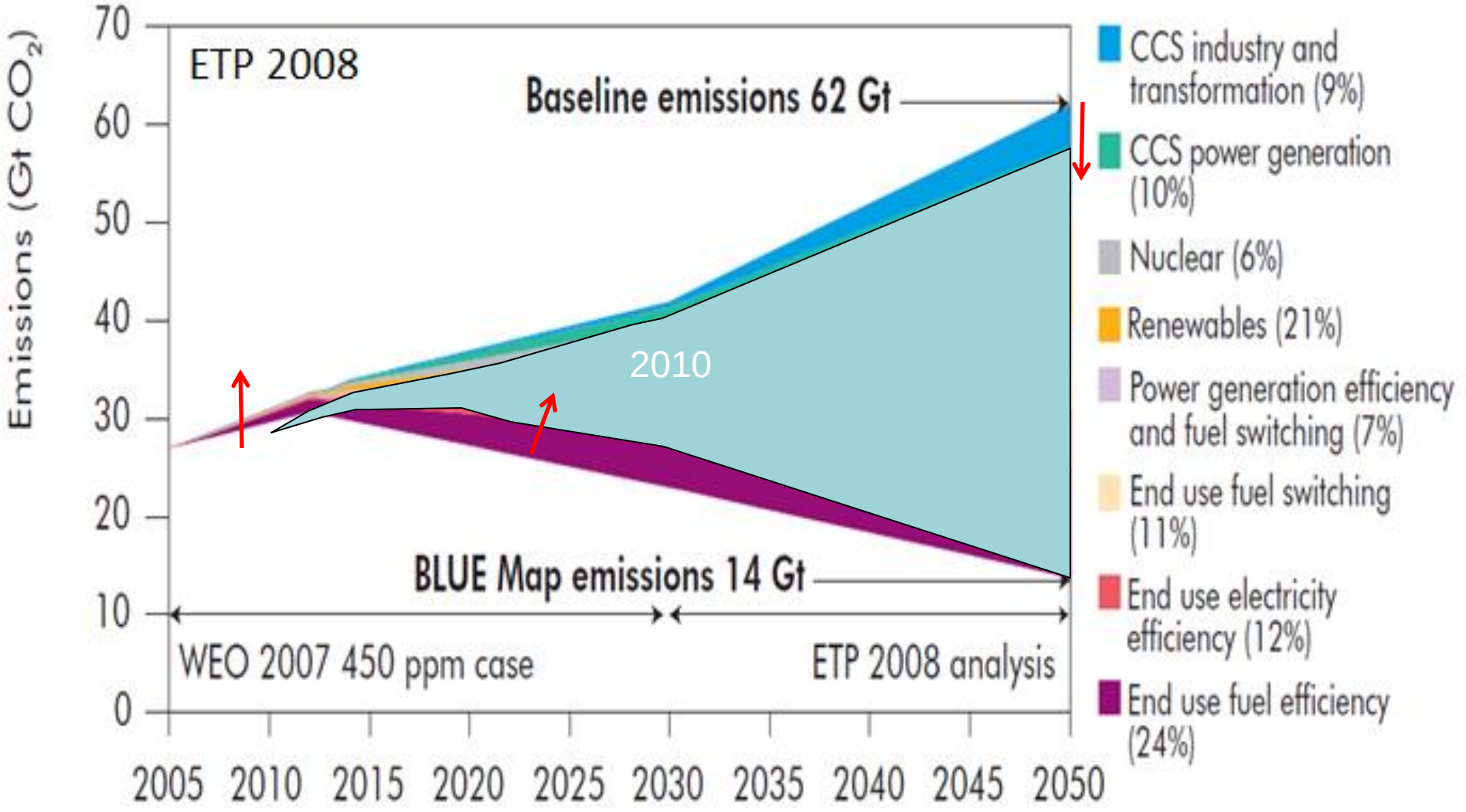

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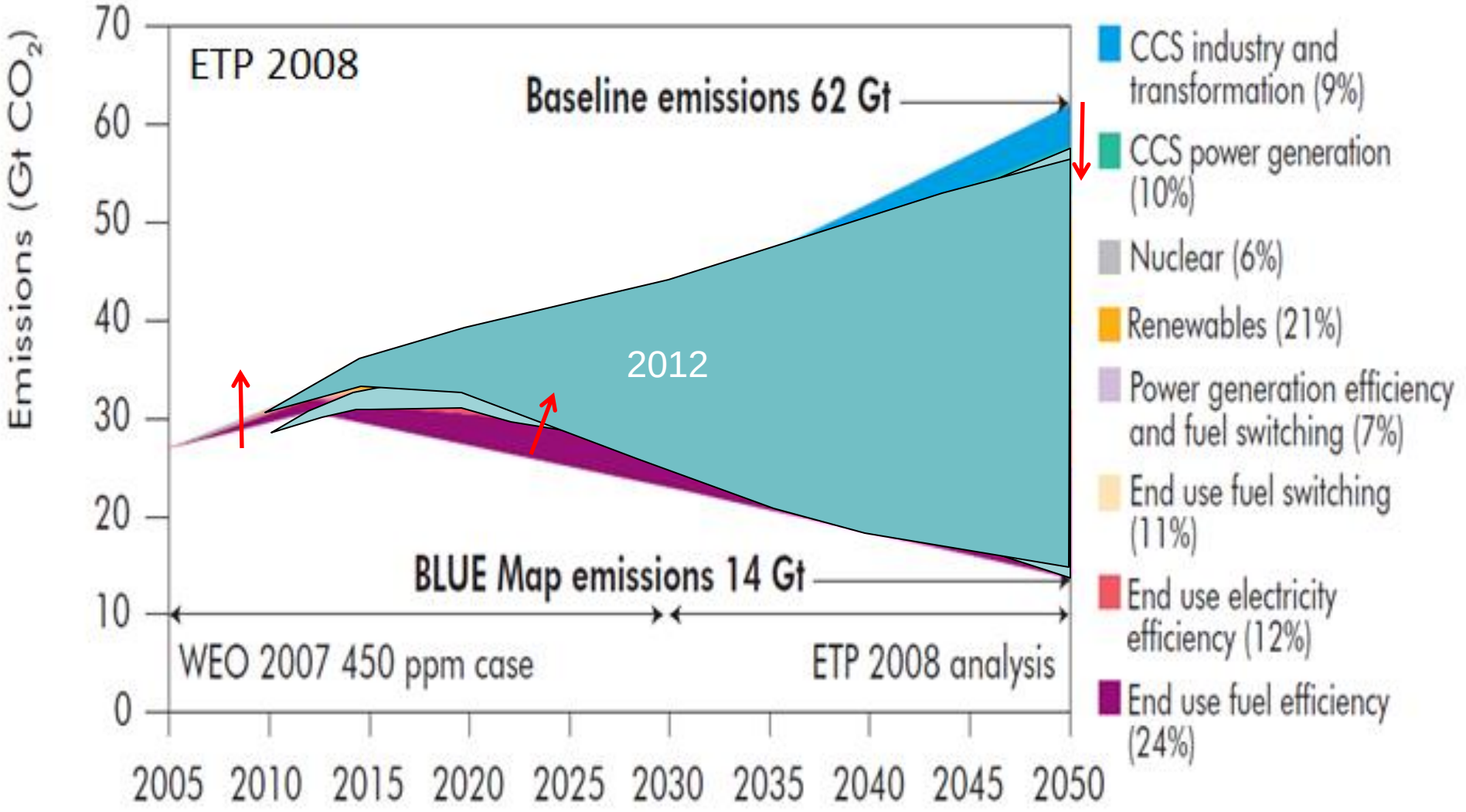

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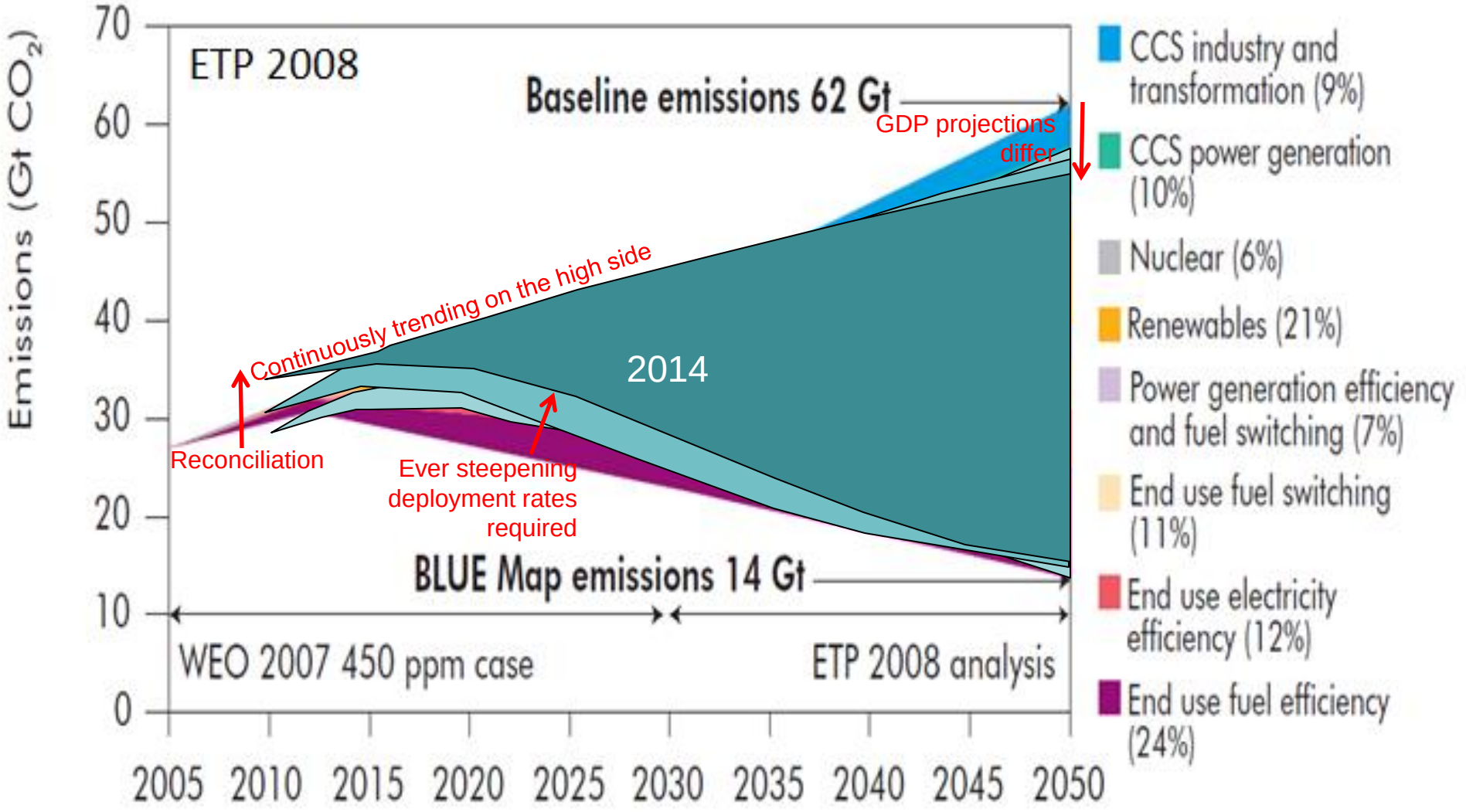

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Terminology & the Famous '2DS'

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World Energy Outlook Scenario.

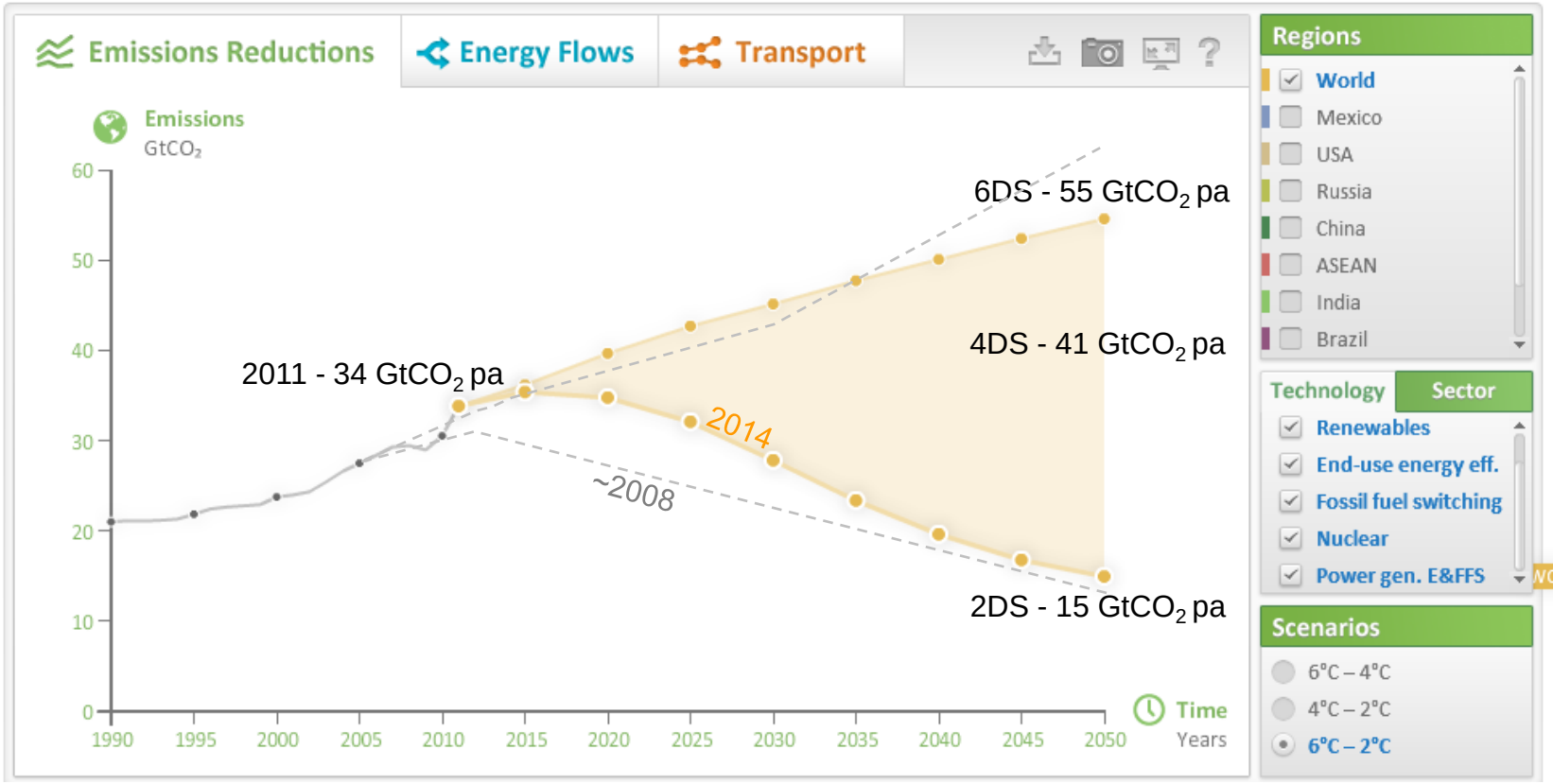
- **Current Policies Scenario:** assumes no changes in policies from today (prev. *Reference Scenario*).
- **New Policies Scenario** includes broad policy commitments, plans and pledges to reduce GHGs and phase out FF subsidies "*even if the measures to implement these commitments have yet to be identified or announced*" !
- Several other interesting scenarios …
- **450 Scenario** an energy pathway consistent with $\Delta T<2$deg & <450ppm atmospheric concentration.

Energy Technology Perspectives

- **6DS** is largely an extension of current trends **Current Policy Scenario …**
- **4DS** is largely consistent with the **New Policy Scenario** (to 2035)
- **2DS** broadly consistent with **450 Scenario** (to 2035). It requires an energy system consistent with an emissions trajectory to give an 80% chance of limiting average global temperature increase to 2°C incl. a 50% cut in emissions by 2050 (c.f. 2009) & falling thereafter. Only achieved if CO_2 and GHG emissions in non-energy sectors are also reduced.

Ref: IEA - www.iea.org/

Those Bloody Wedges – ETP-2014



Source: IEA, ETP, 2014

The Energy Choices Now Being Made

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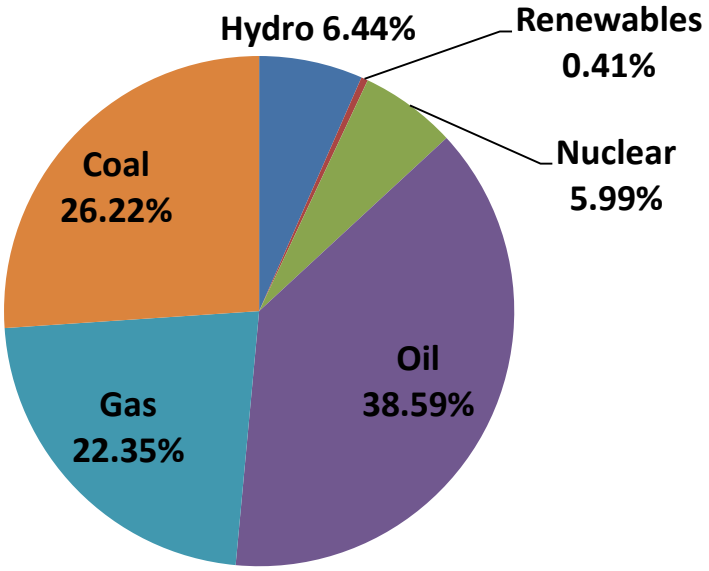
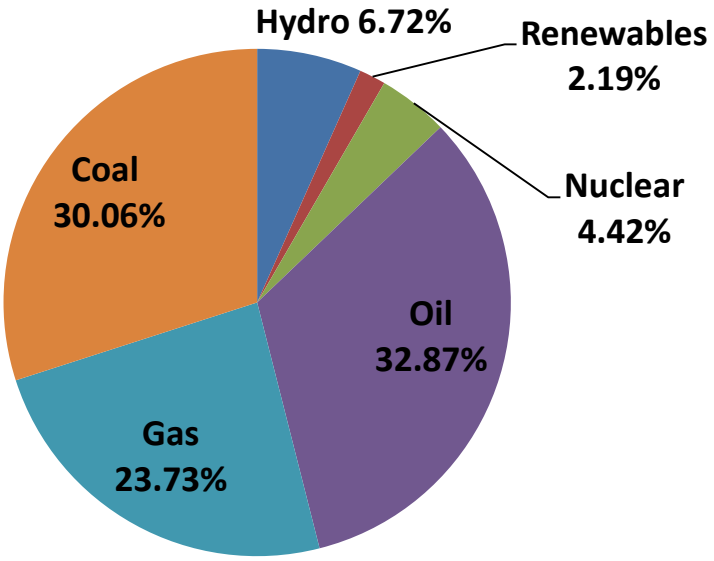
- Globally we currently consume about **12.7 billion tonnes of oil equivalent**
- Fossil fuels are used for power generation, transportation and industrial applications (cement, steel, fertilisers, plastics etc.)





1993 (8.3 Btoe) **vs** **2013 (12.7 Btoe)**

- Our energy sources **<u>have hardly changed</u>** over the last 20 years - the vast majority of energy consumed is still supplied by oil, coal and gas...

Source: BP Statistical Review of World Energy 2014

Good news but not *very*

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- Preferences in action evidenced by usage & growth

SOURCE	2003 Mtoe	2013 Mtoe	('03 – '13) Δ Mtoe	*Preference in action*	('03 – '13) %
Oil					**12%**
Coal					**47%**
Gas					**29%**
Hydro					**43%**
Nuclear					**-6% !**
Renewables					**317%**
Total World					**28%**
Fossil fuels (87% in 2013)					*21%*

Source: BP Statistical Review of World Energy 2014

Good news but not *very*

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- Preferences in action evidenced by usage & growth

SOURCE	2003 Mtoe	2013 Mtoe	('03 – '13) Δ Mtoe	*Preference in action*	('03 – '13) %
Oil	3725	4185	**460**	*3rd*	**12%**
Coal	2612	3827	**1215**	*1st*	**47%**
Gas	2345	3020	**675**	*2nd*	**29%**
Hydro	597	856	**259**	*4th*	**43%**
Nuclear	598	563	**-35**	*6th*	**-6% !**
Renewables	67	279	**212**	*5th*	**317%**
Total World	9944	12730	**2786**		**28%**
Fossil fuels (87% in 2013)	*8682*	*11032*	*2350*		*21%*

Source: BP Statistical Review of World Energy 2014

GHG Reduction *Rates*

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2050 scen.	6 DS – 2 DS			6 DS – 4 DS			4 DS – 2 DS		
Emissions in 2050 Gt pa	55 - 15			55 - 41			41 - 15		
Reduction	%	Gt pa in 2050	Install Mt/yr pa	%	Gt pa in 2050	Install Mt/yr pa	%	Gt pa in 2050	Install Mt/yr pa
CCS (power & ind)	17%	6.8	174	11%	1.54	39	21%	5.46	140
Renewables (all)	28%	11.2	287	28%	3.92	101	28%	7.28	187
End-use energy efficiency	38%	15.2	390	51%	7.14	183	31%	8.06	207
Fossil fuel switching	10%	4	103	4%	0.56	14	14%	3.64	93
Nuclear	6%	2.4	62	6%	0.84	22	6%	1.56	40
Power Gen. E&FFS	0%	0	0	0%	0	0	0%	0	0

The CCS Challenge – 174 Mt/yr

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ETP 2012

- Goal 1 - 50 Mt/yr by 2020

Global CCS Inst: 2013

- **Operating**
  - 26.6 Mt/yr (25 are EOR)
    - 9.0 Mt Pre-1990 (all EOR)
    - 19.9 MT/yr (nat. gas proc - EOR)
    - 1.0 Mt/yr (power gen - EOR)
    - 1.6 Mt/yr (geol. Storage)
- **Execution**
  - 13.53 Mt/yr (7.8 are EOR)
    - 3.7 MT/yr (nat. gas proc. Gorgon)
    - 4.4 MT/yr (power gen - EOR)
    - 5.8 MT/yr (geol. storage)

- What does installing 174 Mt/yr look like ?
  - 58 x Kemper County IGCC (power)
  - 47 x Gorgon LNG (nat. gas)
    - 33 built in over 50 years
      - 14 globally under construction – not CCS
- Or infrastructure which moves 3-4 mln bl/d
- The oil industry of…
  - Venezuela 3.0
  - Iraq 3.4
  - China 4.1

IEA, ETP 2014 – 2DS

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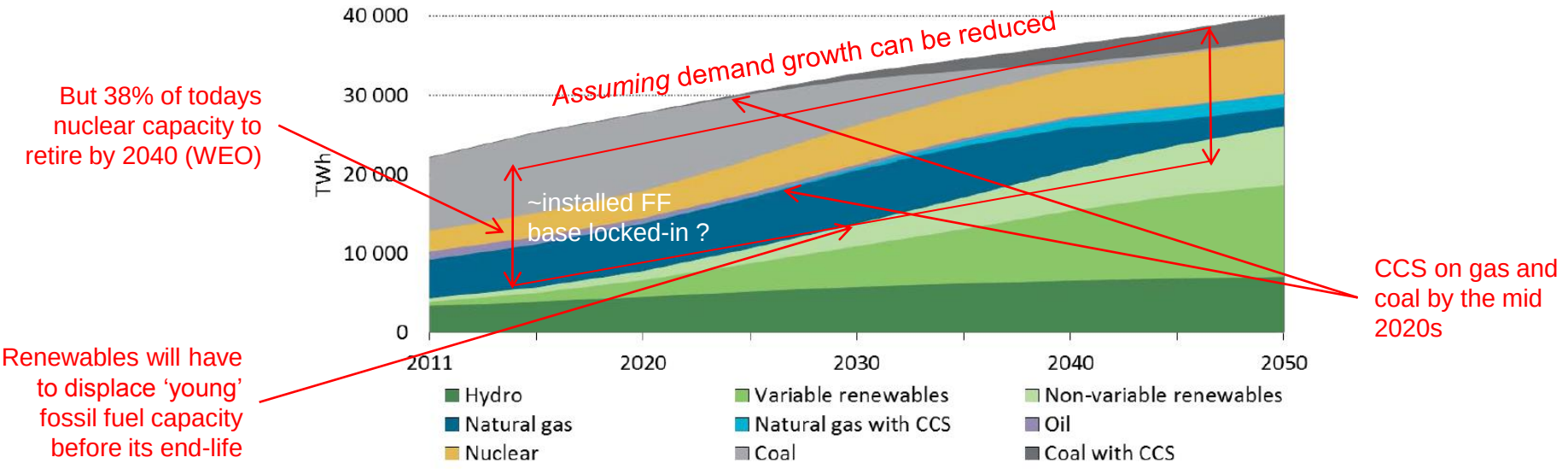
Electricity Generation: a share reversal

ETP 2014



- Generation today:
  - Fossil fuels: 68%
  - Renewables: 20%
- Generation 2DS 2050:
  - Renewables: 65%
  - Fossil fuels: 20%

International Energy Agency

Power Generation Growth (for 2DS)

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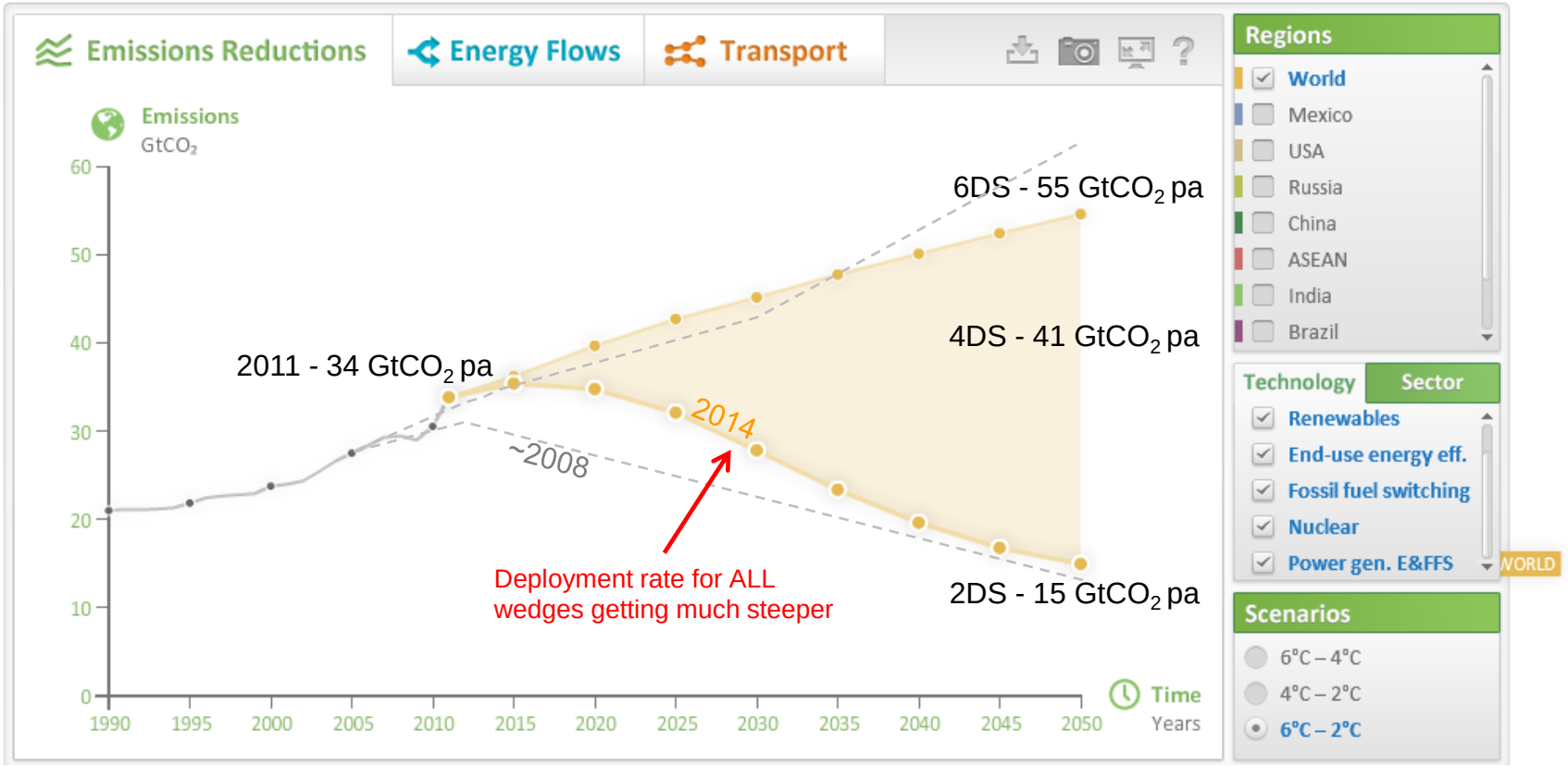
6DS = 150 EJ

Electricity	2011 : 66 EJ				(2050 @ 2 DS) : 119 EJ			
	%	Global EJ	Installed base GW	Recent installation GW pa	%	Global EJ	Required installed base GW	Ramp up installation rate GW pa (39yrs)
Fossil fuels	**68%**	44.9	4,030	> 230	**20%**	23.8	2,136	-48 GW (requires CCS & early retirement of plants now being built & planned)
Renewables	**20%**	13.2			**65%**	77.4		
Solar PV	0.33%	0.22	140	29	12%	14.00	8,769	221 GW (or 300 yr at current rate)
Wind (on. & off.)	2.39%	1.58	283	40	22%	25.78	4,334	104 GW (or 100 yr at current rate or 650 x 3MW / wk)

ETP 2014 – share reversal

Remember the Wedges ...



Source: IEA, ETP, 2014

Rough example: solar ramp-up needed

- ~ 8,800 GW needed in 2050
  - Current installed 140GW
  - Ramp-up needed 220 GW pa for 35-40 yrs

- Historic 'exponential'
  - 2000 - 2011 1.5 to 70 GW
  - Ramp up avg. 6 GW pa

Impressive manufacturing ramp-up
But materials & resource and build-rate limitations will set in

- But in 2013 ramp up was 29GW (c.f. >230 GW fossil fuel)
  - Heavily subsidised
  - 7-8 x installation rate needed
  - *From now*

Resource limits *may* play a part

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Source: Tao et al, 2011: Electro Chemical Society Transactions, 33 (17) 3-11 (2011)

Table1. The estimated, best-scenario maximum wattages for various solar cell technologies based on reserve base of the limiting material.

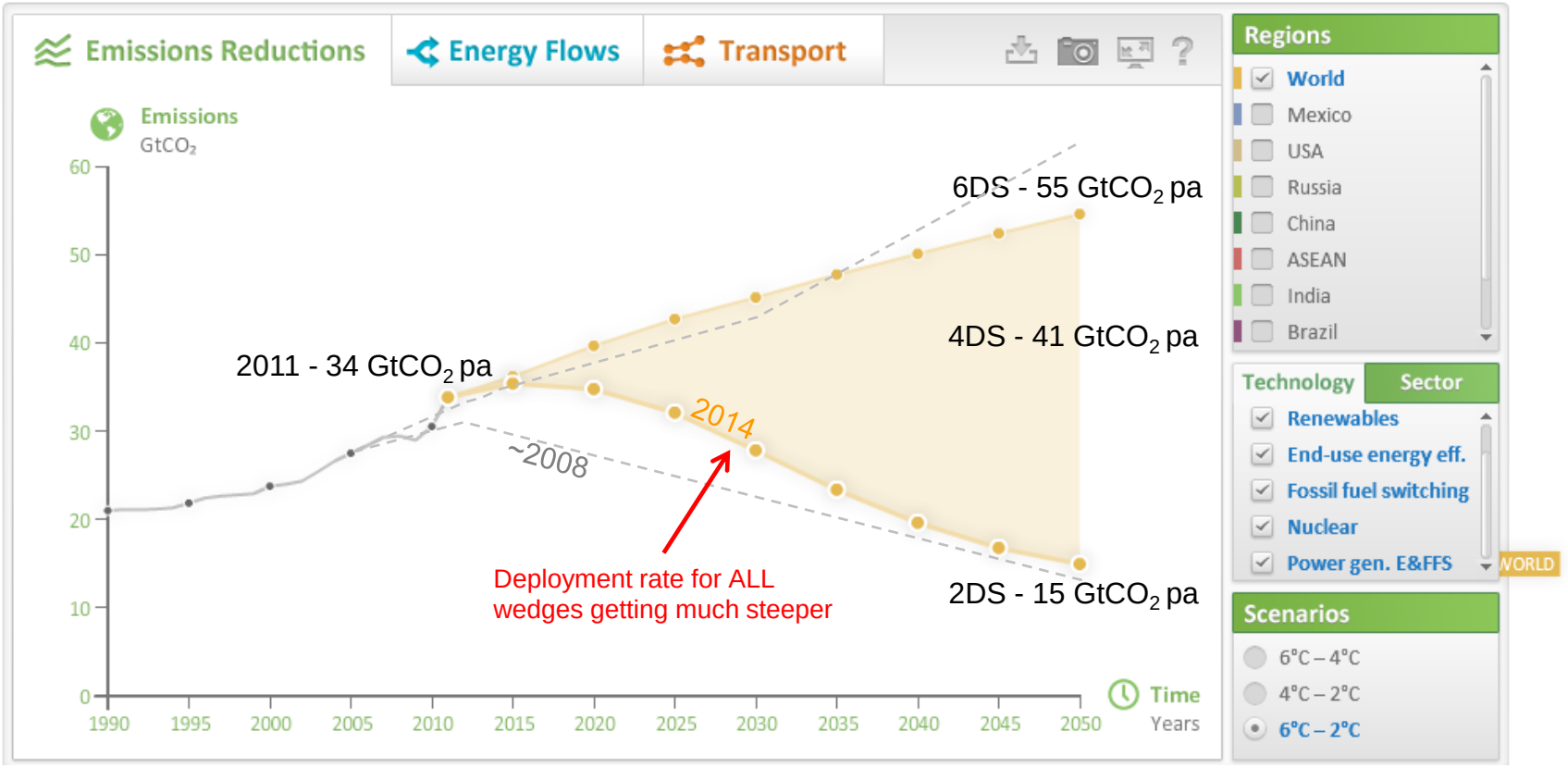
Solar Cell Technology	Efficiency Used	Limiting Material	Reserve Base (metric ton)	Maximum Wattage	Averaged Output (GW)
CdTe	10.6%	Tellurium	48,000	816 GW_p	120 – 1 60
CIGS	11.5%	Indium	16,000	1.3 TW_p	100 – 130
Dye-Sensitized	7%	Ruthenium	5,000	890 GW_p	135 – 180
Crystalline-Si	15%	Silver	400,000	5.7 TW_p	860 – 1150

Ball-park needed -- 8.8 TW in 2050

But resource = f(demand, price) – though with a resource & supply-chain development lag

And … will new technologies win (they'd better hurry up) ?

Resource *and* Supply Chain Limitations



Just how fast can you build this stuff *and* the supporting resource *and* supply chain capacity ?

Source: IEA, ETP, 2014

THE END - THANK YOU