

Il fabbisogno mondiale di energia e il ruolo delle diverse fonti energetiche primarie: criticità, evoluzione, prospettive

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Domanda mondiale di energia primaria

Fattori di equivalenza

1 tep = 10^7 kcal (energia di 1.000 kg di petrolio)

1 barile = 159 litri

densità convenzionale $\cong 0,88$ t/m³

1 tonnellata di petrolio $\cong 1/(0,159*0,88)= 7,15$ barili

1 tep $\cong 1.111$ m³ di gas $\cong 2$ t di carbone (medio)

World demand of primary energy by source (Mtoe)

New Policies Scenario (NPS) - IEA-WEO 2018

	2000	2016	2017e	2025	2030	2035	2040
Total demand	10 027	13 708	13 972	15 388	16 167	16 926	17 715
Coal	2 308 (23.0%)	3 720 (27.1%)	3 750 (26.8%)	3 768 (24.5%)	3 783 (23.4%)	3 793 (22.4%)	3 809 (21.5%)
Oil	3 665 (36.5%)	4 364 (31.8%)	4 435 (31.7%)	4 754 (30.9%)	4 830 (29.9%)	4 842 (28.6%)	4 894 (27.6%)
Gas	2 071 (20.7%)	3 022 (22.0%)	3 107 (22.2%)	3 539 (23.0%)	3 820 (23.6%)	4 132 (24.4%)	4 436 (25.0%)
Total fossil fuels	8 045 (80.2%)	11 107 (81.0%)	11 293 (80.8%)	12 062 (78.4%)	12 434 (76.9%)	12 767 (75.4%)	13 139 (74.2%)
Nuclear	675 (6.7%)	679 (5.0%)	688 (4.9%)	805 (5.2%)	848 (5.2%)	918 (5.4%)	971 (5.5%)
Hydro	225 (2.2%)	348 (2.5%)	353 (2.5%)	415 (2.7%)	458 (2.8%)	496 (2.9%)	531 (3.0%)
Bioenergy	1 022 (10.2%)	1 350 (9.8%)	1 384 (9.9%)	1 590 (10.3%)	1 691 (10.5%)	1 776 (10.5%)	1 851 (10.4%)
Other renewables	60 (0.6%)	224 (1.6%)	254 (1.8%)	516 (3.4%)	736 (4.6%)	968 (5.7%)	1 223 (6.9%)

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About 14 800 VLCC over the year

About 40.5 VLCC per day on average



Supertanker class VLCC, 300 000 tons



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IEA Scenarios on policies for E&E development

- 1. Current Policies Scenario.** Policies and implementing measures that had been enacted or formally adopted by mid-2017 continue unchanged.
The **CPS** is useful to evaluate the evolution of energy consumption and CO₂ emissions in absence of further actions. It is a benchmark for measuring the impact of new policies.
- 2. New Policies Scenario.** It considers the implementation of new policies and measures, in addition to those already adopted by mid-2017, in part already planned and initiated (renewable energy, energy saving, national targets on CO₂ emissions, etc.).
The **NPS** is still rather conservative since it takes into account institutional, political and economic obstacles relative to the implementation of new commitments.
- 3. Sustainable Development Scenario.** The new **SDS**, sets out a pathway to achieve the key energy-related components of the **United Nations Sustainable Development Agenda**:
 - universal access to modern energy by 2030
 - urgent action to tackle climate change in line with the Paris Agreement
 - measures to improve poor air quality.

World demand of primary energy by source (Mtoe)

Scenarios to 2040 - IEA-WEO 2018

	2016	New Policies		Current Policies		Sustainable Dev.	
		2040	r%	2040	r%	2040	r%
Total demand	13 708	17 715	1,0	19 328	1,3	13 715	0,0
Coal	3 720 (27,1%)	3 809 (21,5%)	0,1	4 769 (24,7%)	0,9	1 597 (11,6%)	-3,1
Oil	4 364 (31,8%)	4 894 (27,6%)	0,4	5 570 (28,8%)	0,9	3 156 (23,0%)	-1,2
Gas	3 022 (22,0%)	4 436 (25,0%)	1,4	4 804 (24,9%)	1,7	3 433 (25,0%)	0,5
Total fossil fuels	11 107 (81,0%)	13 139 (74,2%)	0,6	15 144 (78,4%)	1,2	8 186 (59,7%)	-1,1
Nuclear	679 (5,0%)	971 (5,5%)	1,3	951 (4,9%)	1,3	1 293 (9,4%)	2,4
Hydro	348 (2,5%)	531 (3,0%)	1,6	514 (2,7%)	1,5	601 (4,4%)	2,0
Bioenergy	1 350 (9,8%)	1 851 (10,4%)	1,2	1 771 (9,2%)	1,0	1 504 (11,0%)	0,4
Other renewables	224 (1,6%)	1 223 (6,9%)	6,5	948 (4,9%)	5,5	2 132 (15,5%)	8,7

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Domanda mondiale di energia primaria per produzione di energia elettrica

World demand of primary energy for electricity production (Mtoe) - New Policies Scenario (NPS) - IEA-WEO 2018

	2000	2016	2017e	2025	2030	2035	2040
Total demand	3 660 (36,5%)	5 208 (38,0%)	5 357 (38,3%)	5 826 (37,9%)	6 215 (38,4%)	6 668 (39,4%)	7 137 (40,3%)
Coal	1 565 (42,7%)	2 316 (44,5%)	2 390 (44,6%)	2 339 (40,1%)	2 342 (37,7%)	2 346 (35,2%)	2 353 33,0%)
Oil	341 (9,3%)	247 (4,8%)	252 (4,7%)	205 (3,5%)	179 (2,9%)	158 (2,4%)	141 (2,0%)
Gas	746 (20,4%)	1 241 (23,8%)	1 256 (23,5%)	1 341 (23,0%)	1 426 (22,9%) %	1 532 (23,0%)	1 642 (23,0%)
Total fossil fuels	2 652 (72,4%)	3 805 (73,1%)	3 899 (72,8%)	3 885 (66,7%)	3 947 (63,5%)	4 036 (60,5%)	4 136 (58,0%)
Nuclear	675 (18,5%)	679 (13,0%)	688 (12,8%)	805 (13,8%)	848 (13,6%)	918 (13,8%)	971 (13,6%)
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Bioenergy	57 (1,6%)	194 (3,7%)	211 (3,9%)	283 (4,9%)	329 (5,3%)	380 (5,7%)	433 (6,1%)
Other renewables	51 (1,4%)	181 (3,5%)	206 (3,9%)	438 (7,5%)	633 (10,2%)	838 (12,6%)	1 065 (14,9%)

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Produzione mondiale di energia elettrica

ORDINI DI GRANDEZZA

- 1 KWh = energia prodotta da una macchina da 1 KW che funziona per 1 ora
- 1 GWh = energia prodotta da un impianto da 1 GW che funziona per 1 ora
- 1 TWh = energia prodotta da un impianto di potenza pari a 1 GW che funziona per 1.000 ore
- 7,5 TWh = energia prodotta da un impianto di potenza pari a 1 GW che funziona per 7.500 ore (in 1 anno ci sono 8.760 ore)
- 22.500 TWh possono rappresentare l'energia prodotta in un anno da 3.000 impianti da 1.000 MW che funzionano per 7.500 ore/anno
- Oppure:
- 24.000 TWh possono rappresentare l'energia prodotta in un anno da 4.000 impianti da 1.000 MW che funzionano per 6.000 ore/anno

Electricity production (TWh)

New Policies Scenario (NPS) - IEA-WEO 2018

	2000	2016	2017e	2025	2030	2035	2040
Total	15 441	24 919	25 679	30 253	33 510	36 919	40 443
Coal	6 001	9 575	9 858	9 896	10 016	10 172	10 335
Oil	1 212	926	940	763	676	597	527
Gas	2 747	5 781	5 855	6 829	7 517	8 265	9 071
Total fossil fuels	9 960	16 282	16 653	17 488	18 209	19 035	19 933
Nuclear	2 591	2 605	2 637	3 089	3 253	3 520	3 726
Hydro	2 618	4 049	4 109	4 821	5 330	5 774	6 179
Bioenergy	164	569	623	890	1 057	1 238	1 427
Wind	31	957	1 085	2 304	3 157	3 960	4 690
Geothermal	52	82	87	129	190	261	343
Solar PV	1	328	435	1 463	2 197	2 935	3 839
CSP	1	10	11	34	75	138	222
Marine	1	1	1	3	12	27	52
Total renew	2 868	5 997	6 351	9 645	12 017	14 333	16 753

Electricity production percentage

New Policies Scenario (NPS) - IEA-WEO 2018

	2000	2016	2017e	2025	2030	2035	2040
Total	100,00	100,00	100,00	100,00	100,00	100,00	100,00
Coal	38,87	38,42	38,39	32,71	29,89	27,55	25,55
Oil	7,85	3,71	3,66	2,52	2,02	1,62	1,30
Gas	17,79	23,20	22,80	22,57	22,43	22,39	22,43
Total fossil fuels	64,50	65,34	64,85	57,81	54,34	51,56	49,29
Nuclear	16,78	10,45	10,27	10,21	9,71	9,53	9,21
Hydro	16,96	16,25	16,00	15,94	15,90	15,64	15,28
Bioenergy	1,06	2,28	2,42	2,94	3,15	3,35	3,53
Wind	0,20	3,84	4,22	7,62	9,42	10,73	11,60
Geothermal	0,34	0,33	0,34	0,43	0,57	0,71	0,85
Solar PV	0,01	1,32	1,69	4,83	6,56	7,95	9,49
CSP	0,00	0,04	0,04	0,11	0,22	0,37	0,55
Marine	0,00	0,00	0,00	0,01	0,03	0,07	0,13
Total renew	18,57	24,06	24,73	31,88	35,86	38,82	41,42

Electricity production (TWh)

Scenarios to 2040 - IEA-WEO 2018

	2016	New Policies		Current Policies		Sustainable Dev.	
		2040	r%	2040	r%	2040	r%
Total	24 919	40 443	1,8	42 755	2,0	37 114	1,5
Coal	9 575	10 335	0,3	13 910	1,4	1 982	-5,7
Oil	926	527	-2,1	610	-1,5	197	-5,6
Gas	5 781	9 071	1,7	10 295	2,2	5 358	-0,3
Total fossil fuels	16 282	19 933	0,8	24 815	1,6	7 537	-2,8
Nuclear	2 605	3 726	1,3	3 648	1,3	4 960	2,4
Hydro	4 049	6 179	1,6	5 973	1,5	6 990	2,0
Bioenergy	569	1 427	3,5	1 228	2,9	1 968	4,7
Wind	957	4 690	6,1	3 679	5,1	7 730	8,0
Geothermal	82	343	5,5	277	4,6	555	7,4
Solar PV	328	3 839	9,5	2 956	8,5	6 409	11,6
CSP	10	222	12,0	119	9,4	855	17,7
Marine	1	52	15,6	29	13,2	78	17,4
Total renew	5 997	16 753	3,9	14 261	3,3	24 585	5,4

Electricity production percentage Scenarios to 2040 - IEA-WEO 2018

	2016	New Policies		Current Policies		Sustainable Dev.	
		2040	r%	2040	r%	2040	r%
Total	100,00	100,00	1,8	100,00	2,0	100,00	1,5
Coal	38,42	25,55	0,3	32,53	1,4	5,34	-5,7
Oil	3,71	1,30	-2,1	1,43	-1,5	0,53	-5,6
Gas	23,20	22,43	1,7	24,08	2,2	14,44	-0,3
Total fossil fuels	65,34	49,29	0,8	58,04	1,6	20,31	-2,8
Nuclear	10,45	9,21	1,3	8,53	1,3	13,37	2,4
Hydro	16,25	15,28	1,6	13,97	1,5	18,83	2,0
Bioenergy	2,28	3,53	3,5	2,87	2,9	5,30	4,7
Wind	3,84	11,60	6,1	8,60	5,1	20,83	8,0
Geothermal	0,33	0,85	5,5	0,65	4,6	1,49	7,4
Solar PV	1,32	9,49	9,5	6,91	8,5	17,27	11,6
CSP	0,04	0,55	12,0	0,28	9,4	2,30	17,7
Marine	0,00	0,13	15,6	0,07	13,2	0,21	17,4
Total renew	24,06	41,42	3,9	33,36	3,3	66,24	5,4

Capacità di generazione elettrica

Power generation capacity (GW)

New Policies Scenario (NPS) - IEA-WEO 2018

	2000	2016	2017e	2025	2030	2035	2040
Total capacity		6 690	6 961	8 845	10 073	11 244	12 466
Coal		2 025	2 067	2 130	2 143	2 184	2 238
Oil		446	447	350	307	278	246
Gas		1 644	1 695	2 113	2 334	2 526	2 740
Total fossil fuels		4 115	4 209	4 593	4 784	4 988	5 224
Nuclear		414	412	448	464	495	518
Hydro		1 244	1 270	1 462	1 604	1 728	1 839
Bioenergy		129	136	186	216	247	278
Wind		467	515	953	1 250	1 498	1 707
Geothermal		13	14	20	29	39	51
Solar PV		300	398	1 109	1 589	2 033	2 540
CSP		5	5	13	25	44	68
Marine		1	1	1	5	11	21
Totale rinnovabili		2 159	2 339	3 744	4 718	5 600	6 504

Power generation capacity percentage

New Policies Scenario (NPS) - IEA-WEO 2018

	2000	2016	2017e	2025	2030	2035	2040
Total capacity		100,00	100,00	100,00	100,00	100,00	100,00
Coal		30,27	29,69	24,08	21,27	19,42	17,95
Oil		6,67	6,42	3,96	3,05	2,47	1,97
Gas		24,57	24,35	23,89	23,17	22,47	21,98
Total fossil fuels		61,51	60,47	51,93	47,49	44,36	41,91
Nuclear		6,19	5,92	5,07	4,61	4,40	4,16
Hydro		18,59	18,24	16,53	15,92	15,37	14,75
Bioenergy		1,93	1,95	2,10	2,14	2,20	2,23
Wind		6,98	7,40	10,77	12,41	13,32	13,69
Geothermal		0,19	0,20	0,23	0,29	0,35	0,41
Solar PV		4,48	5,72	12,54	15,77	18,08	20,38
CSP		0,07	0,07	0,15	0,25	0,39	0,55
Marine		0,01	0,01	0,01	0,05	0,10	0,17
Total renew		32,27	33,60	42,33	46,84	49,80	52,17

Power generation capacity (GW)

Scenarios to 2040 - IEA-WEO 2018

	2016	New Policies		Current Policies		Sustainable Dev.	
		2040	r%	2040	r%	2040	r%
Total capacity	6 690	12 466	2,3	11 981	2,2	14 655	2,9
Coal	2 025	2 238	0,4	2 693	1,1	1 119	-2,2
Oil	446	246	-2,2	264	-1,9	228	-2,5
Gas	1 644	2 740	1,9	2 930	2,2	2 406	1,4
Total fossil fuels	4 115	5 224	0,9	5 887	1,3	3 753	-0,3
Nuclear	414	518	0,8	498	0,7	678	1,8
Hydro	1 244	1 839	1,5	1 769	1,3	2 096	2,0
Bioenergy	129	278	2,9	241	2,3	379	4,1
Wind	467	1 707	4,9	1 345	4,0	2 819	6,9
Geothermal	13	51	5,2	41	4,3	82	7,1
Solar PV	300	2 540	8,2	1 951	7,2	4 240	10,3
CSP	5	68	10,1	36	7,6	267	15,9
Marine	1	21	11,9	11	9,3	31	13,6
Total capacity	2 159	6 504	4,2	5 394	3,4	9 914	5,8

Power generation capacity percentage Scenarios to 2040 - IEA-WEO 2018

	2016	New Policies		Current Policies		Sustainable Dev.	
		2040	r%	2040	r%	2040	r%
Total capacity	100,00	100,00	2,3	100,00	2,2	100,00	2,9
Coal	30,27	17,95	0,4	22,48	1,1	7,64	-2,2
Oil	6,67	1,97	-2,2	2,20	-1,9	1,56	-2,5
Gas	24,57	21,98	1,9	24,46	2,2	16,42	1,4
Total fossil fuels	61,51	41,91	0,9	49,14	1,3	25,61	-0,3
Nuclear	6,19	4,16	0,8	4,16	0,7	4,63	1,8
Hydro	18,59	14,75	1,5	14,77	1,3	14,30	2,0
Bioenergy	1,93	2,23	2,9	2,01	2,3	2,59	4,1
Wind	6,98	13,69	4,9	11,23	4,0	19,24	6,9
Geothermal	0,19	0,41	5,2	0,34	4,3	0,56	7,1
Solar PV	4,48	20,38	8,2	16,28	7,2	28,93	10,3
CSP	0,07	0,55	10,1	0,30	7,6	1,82	15,9
Marine	0,01	0,17	11,9	0,09	9,3	0,21	13,6
Total capacity	32,27	52,17	4,2	45,02	3,4	67,65	5,8

Produzione mondiale di CO₂ da combustibili fossili

CO₂ emissions from fossil fuels (Mt)

New Policies Scenario (NPS) - IEA-WEO 2018

	2000	2016	2017e	2025	2030	2035	2040
Total	23 123	32 053	32 580	33 902	34 576	35 157	35 881
Coal	8 951 (38,7%)	14 233 (44,4%)	14 448 (44,3%)	14 284 (42,1%)	14 235 (41,2%)	14 182 (40,3%)	14 170 (39,5%)
Oil	9 620 (41,6%)	11 204 (35,0%)	11 339 (34,8%)	11 862 (35,0%)	11 949 (34,6%)	11 904 (33,9%)	11 980 (33,4%)
Gas	4 551 (19,7%)	6 616 (20,6%)	6 794 (20,9%)	7 757 (22,9%)	8 393 (24,3%)	9 072 (25,8%)	9 731 (27,1%)
Electricity gen.	9 305 (40,2%)	13 247 (41,3%)	13 587 (41,7%)	13 384 (39,5%)	13 480 (39,0%)	13 652 (38,8%)	13 855 (38,6%)
Coal	6 458 (69,4%)	9 515 (71,8%)	9 822 (72,3%)	9 574 (71,5%)	9 553 (70,9%)	9 543 (69,9%)	9 542 (68,9%)
Oil	1 093 (11,7%)	796 (6,0%)	805 (5,9%)	651 (4,9%)	571 (4,2%)	503 (3,7%)	448 (3,2%)
Gas	1 754 (18,9%)	2 937 (22,2%)	2 961 (21,8%)	3 159 (23,6%)	3 357 (24,9%)	3 606 (26,4%)	3 865 (27,9%)

CO₂ emissions from fossil fuels

Scenarios to 2040 - IEA-WEO 2018

	2016	New Policies		Current Policies		Sustainable Dev.	
		2040	r%	2040	r%	2040	r%
Total	32 053	35 881	0,4	42 475	1,0	17 647	-2,2
Coal	14 233 (44,4%)	14 170 (39,5%)	0,0	17 930 (42,2%)	0,9	3 855 (21,8%)	-4,7
Oil	11 204 (35,0%)	11 980 (33,4%)	0,2	13 984 (32,9%)	0,8	6 886 (39,0%)	-1,8
Gas	6 616 (20,6%)	9 731 (27,1%)	1,4	10 561 (24,9%)	1,7	6 906 (39,1%)	0,2
Electricity gen.	13 247 (41,3%)	13 855 (38,6%)	0,2	17 610 (41,5%)	1,1	3 292 (18,7%)	-5,0
Coal	9 515 (71,8%)	9 542 (68,9%)	0,0	12 758 (72,4%)	1,1	930 (28,3%)	-8,3
Oil	796 (6,0%)	448 (3,2%)	-2,1	510 (2,9%)	-1,6	202 (6,1%)	-5,0
Gas	2 937 (22,2%)	3 865 (27,9%)	1,0	4 342 (24,7%)	1,5	2 160 (65,6%)	-1,1

CONSISTENZA DELLE RISERVE/RISORSE

	Petrolio	Gas	Carbone	Totale
Gtep (Gbarili/Tm³/Mt)	234 (1.653)	188 (209)	455 (861)	877
R/P (anni)	54	64	112	84
Gt CO₂	706	396	2.002	3.104
Δ[CO₂] (ppmv)	44	24	124	192

RISERVE ACCERTATE DI COMBUSTIBILI FOSSILI

	Petrolio	Gas	Carbone	Totale
Gtep (Gbarili/Tm³/Mt)	480 (3.400)	380 (422)	7.050	7.910
Gt CO₂	1.443	807	31.050	33.300
Δ[CO₂] (ppmv)	90	50	1.925	2.065

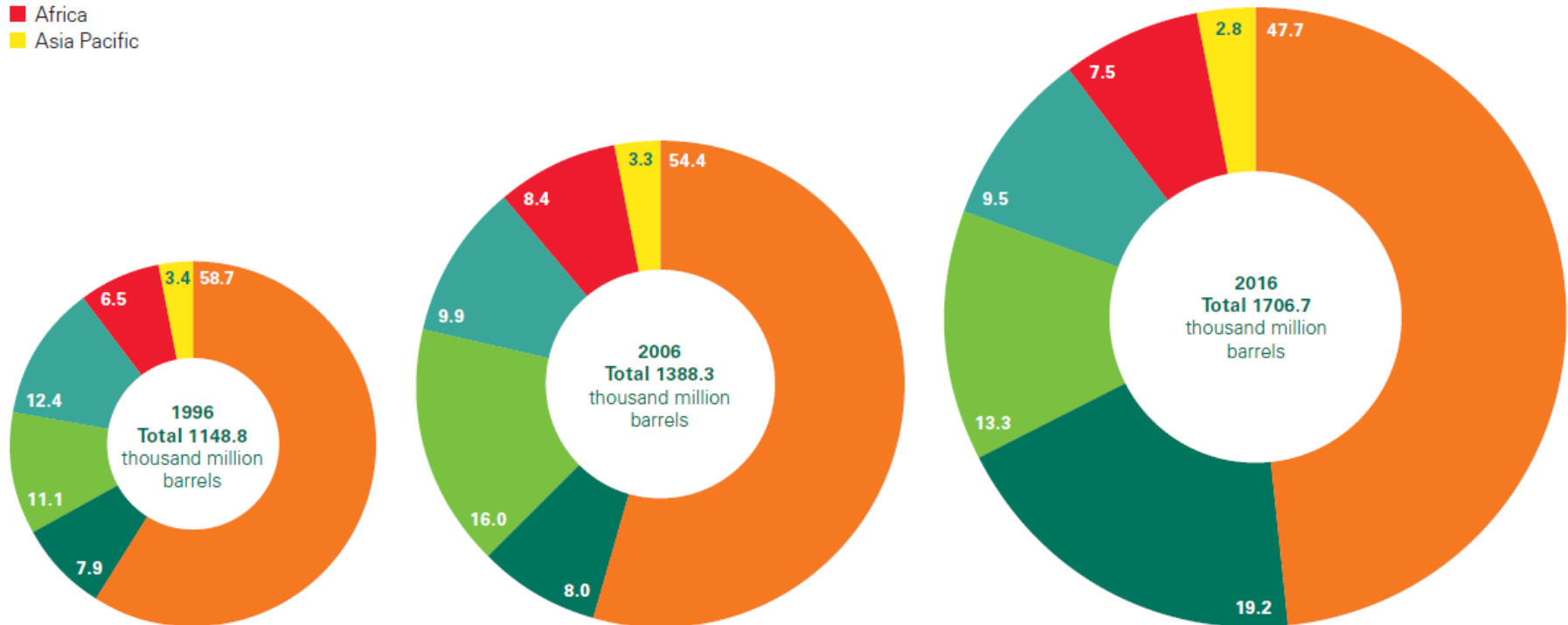
RISORSE PRESUNTE DI COMBUSTIBILI FOSSILI

RISERVE ACCERTATE DI PETROLIO 1996-2006-2016

Distribution of proved reserves in 1996, 2006 and 2016

Percentage

- Middle East
- S. & Cent. America
- North America
- Europe & Eurasia
- Africa
- Asia Pacific



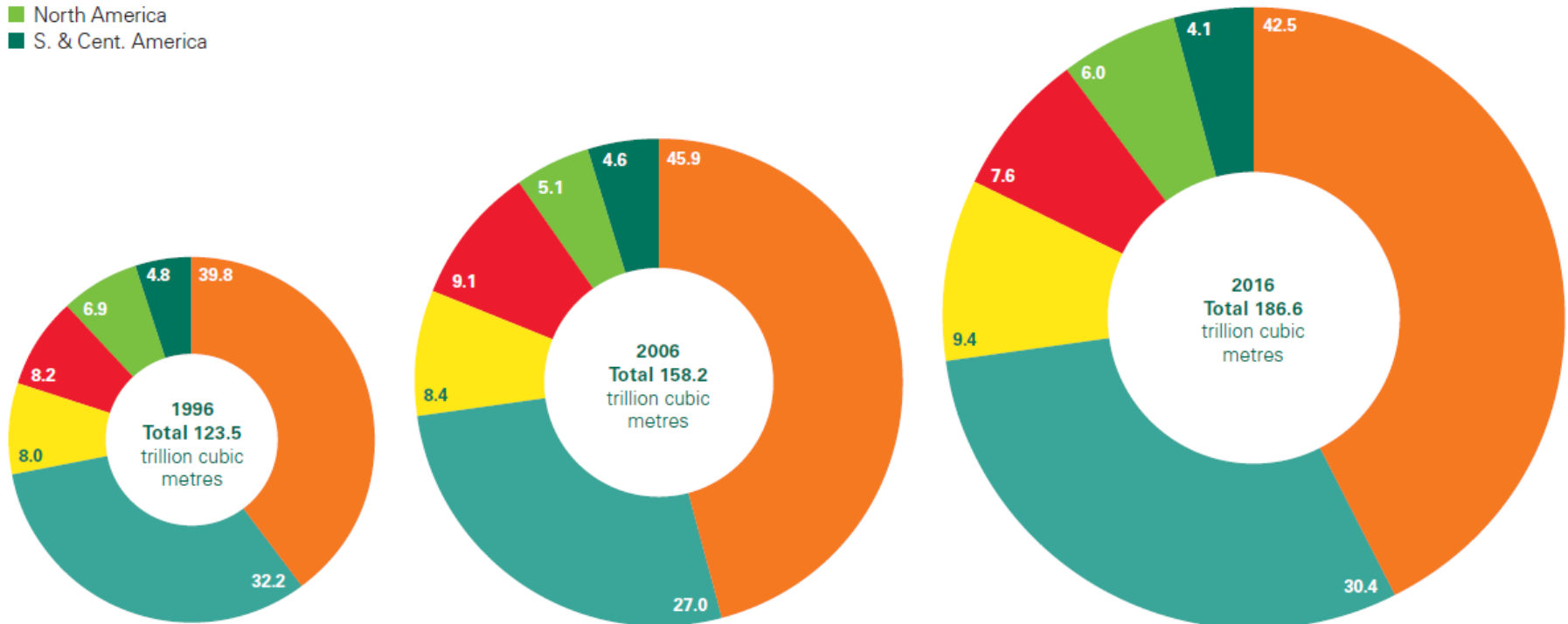
Fonte: BP Statistical Review of World Energy 2017

RISERVE ACCERTATE DI GAS 1996-2006-2016

Distribution of proved reserves in 1996, 2006 and 2016

Percentage

- Middle East
- Europe & Eurasia
- Asia Pacific
- Africa
- North America
- S. & Cent. America



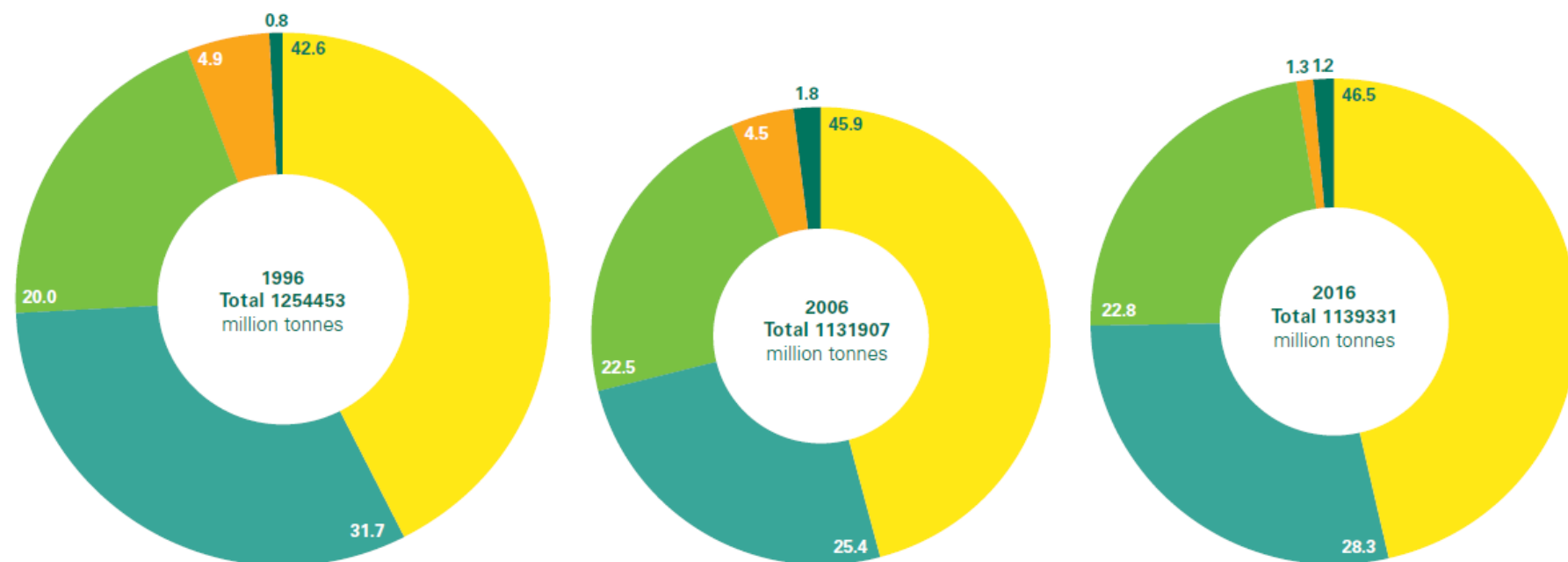
Fonte: BP Statistical Review of World Energy 2017

RISERVE ACCERTATE DI CARBONE 1996-2006-2016

Distribution of proved reserves in 1996, 2006 and 2016

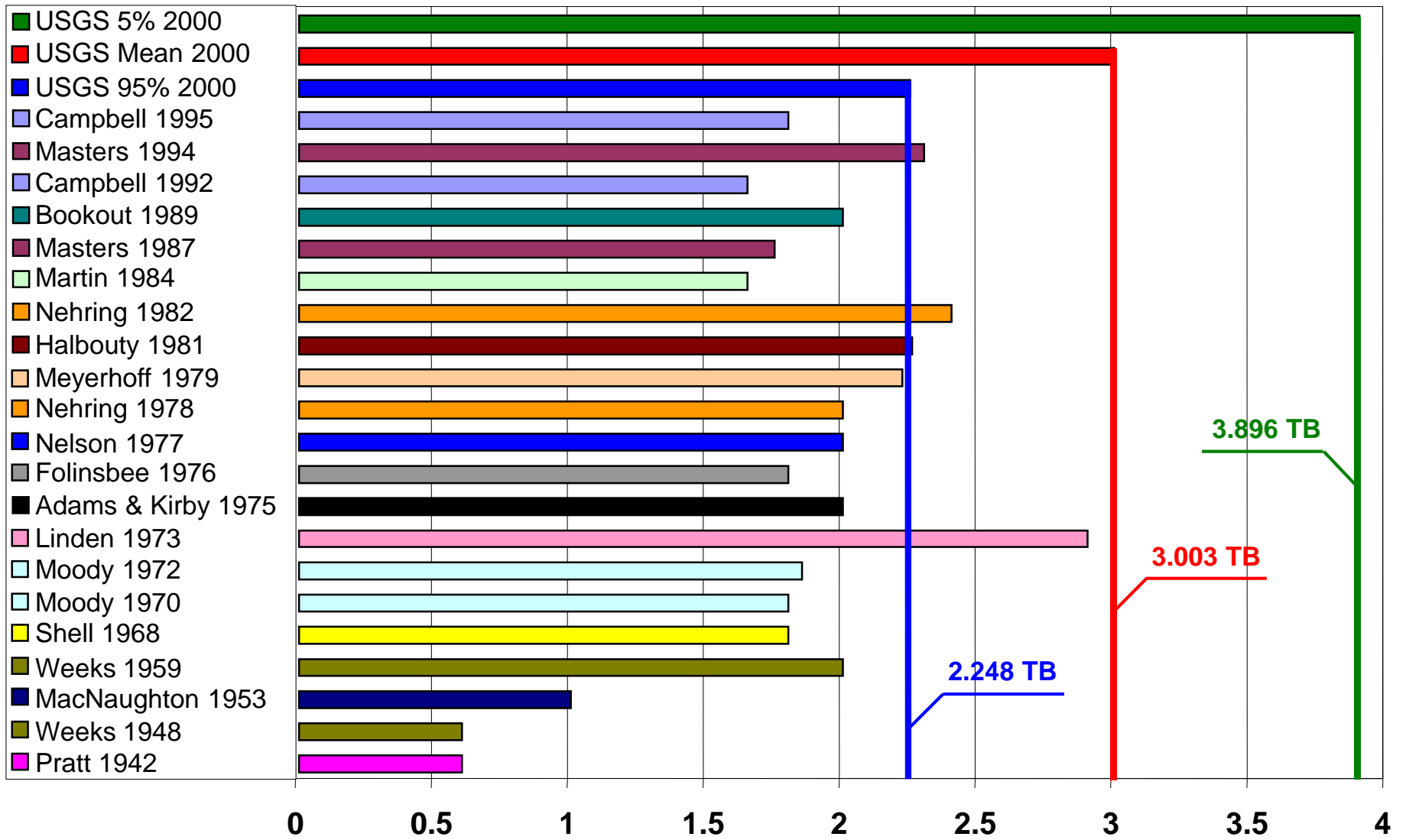
Percentage

- Asia Pacific
- Europe & Eurasia
- North America
- Middle East & Africa
- S. & Cent. America



Fonte: BP Statistical Review of World Energy 2017

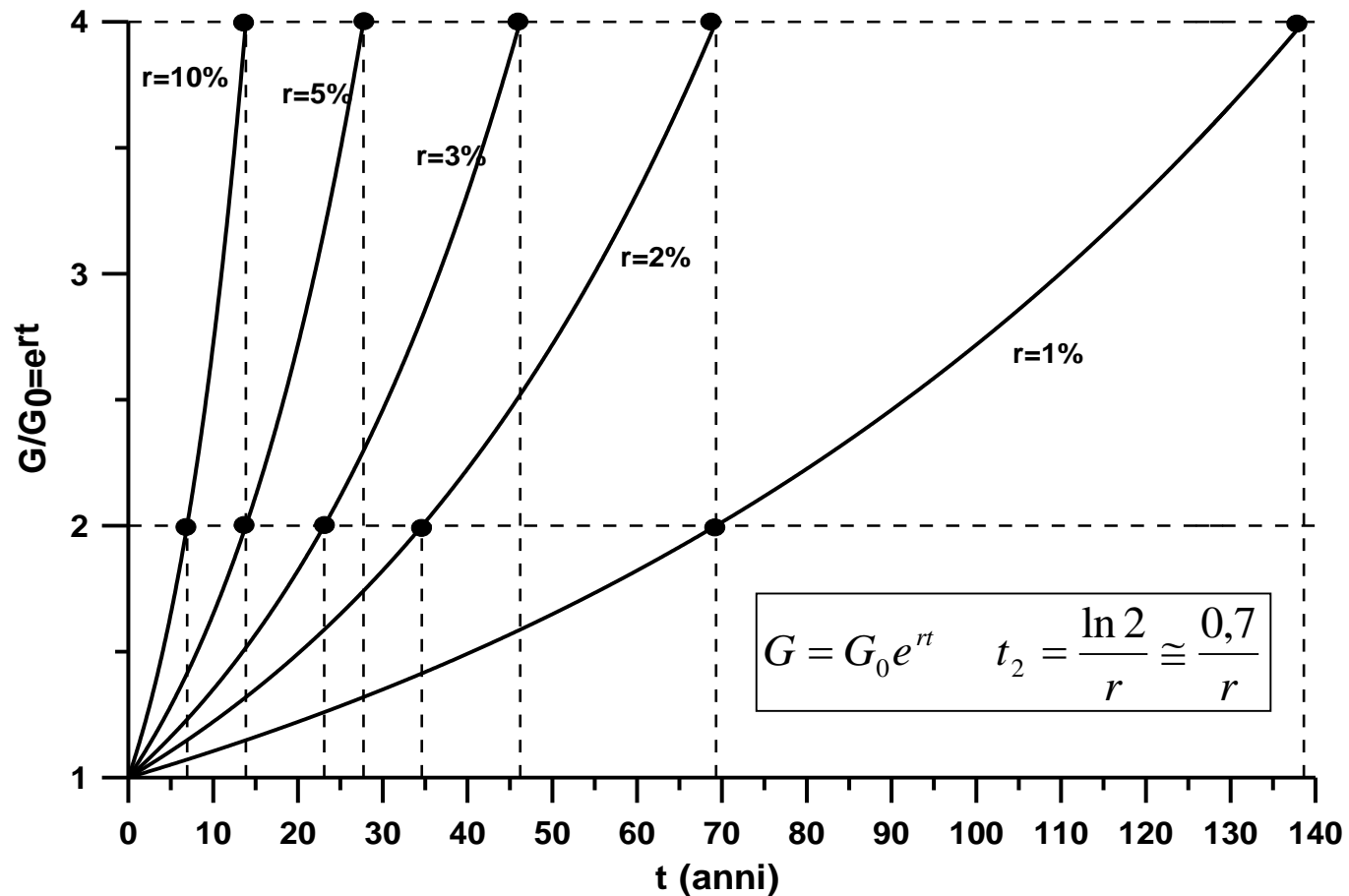
Published Estimates of World Oil Ultimate Recovery



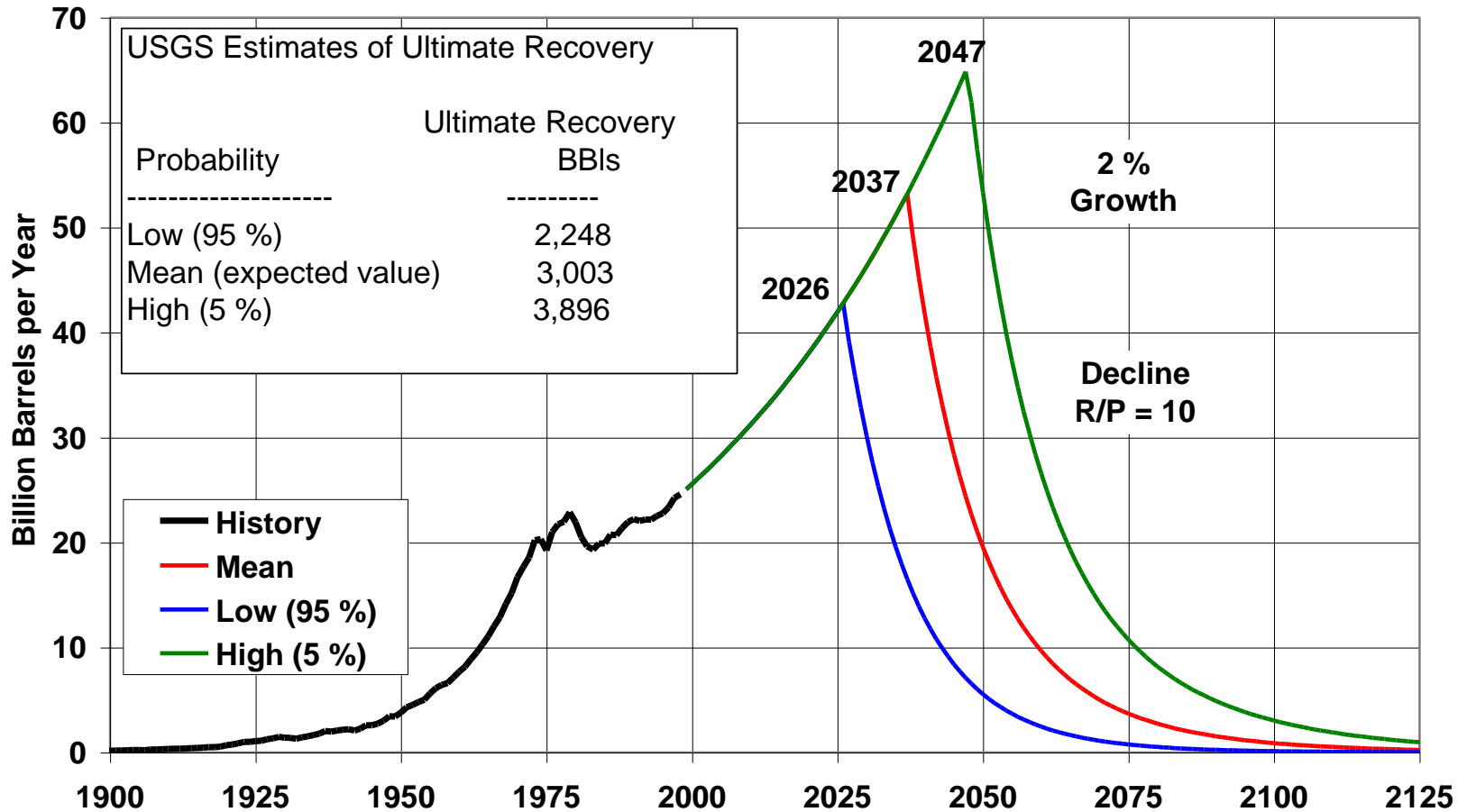
Source: USGS and Colin Campbell

Trillions of Barrels

LEGGE DI SVILUPPO ESPONENZIALE (tasso di crescita costante)

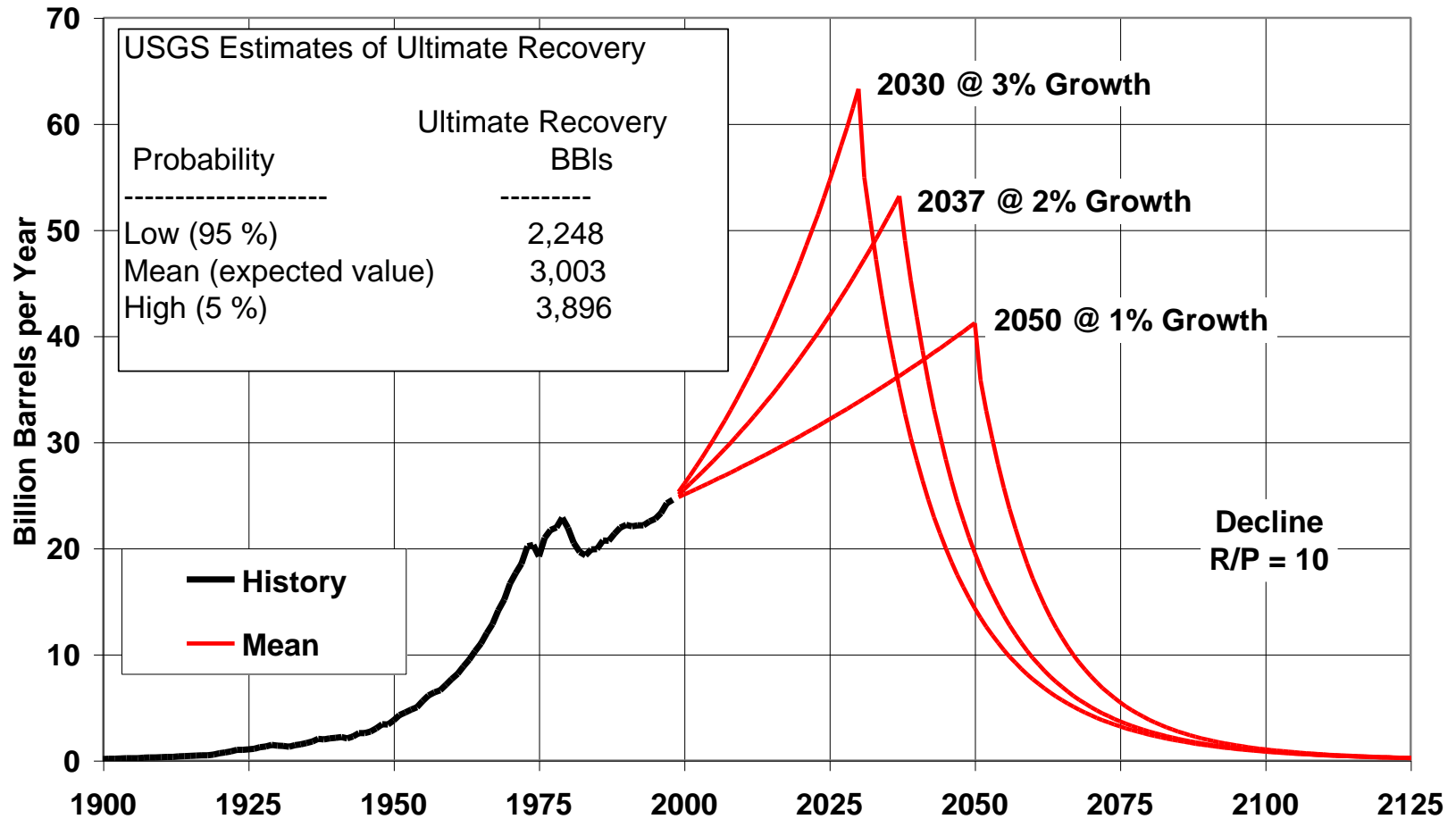


Annual Production Scenarios with 2 Percent Growth Rates and Different Resource Levels (Decline R/P = 10)



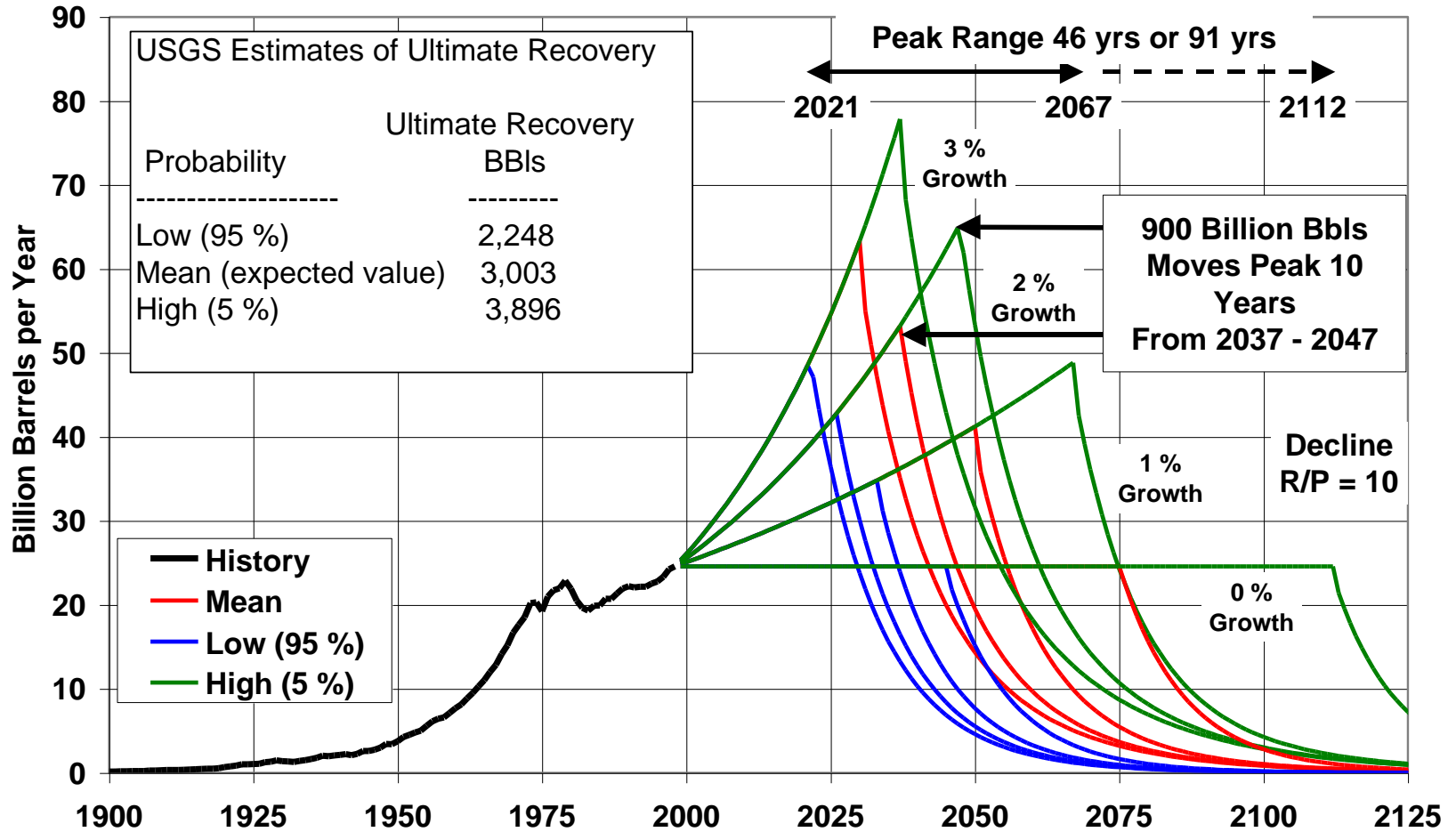
Note: U.S. volumes were added to the USGS foreign volumes to obtain world totals.

Annual Production Scenarios for the Mean Resource Estimate and Different Growth Rates (Decline R/P = 10)



Note: U.S. volumes were added to the USGS foreign volumes to obtain world totals.

12 EIA World Conventional Oil Production Scenarios



Note: U.S. volumes were added to the USGS foreign volumes to obtain world totals.

WORLD OIL PRODUCTION SCENARIOS

Probability of Ultimate Recovery	Ultimate Recovery (Billion barrels)	Annual Production Growth Rate (Percent)	Estimated Peak Year	Estimated Peak Production Rate	
				(Million barrels per year)	(Million barrels per day)
95 Percent	2,248	0.0	2045	24,580	67
	2,248	1.0	2033	34,820	95
	2,248	2.0	2026	42,794	117
	2,248	3.0	2021	48,511	133
Mean (expected value)	3,003	0.0	2075	24,580	67
	3,003	1.0	2050	41,238	113
	3,003	2.0	2037	53,209	146
	3,003	3.0	2030	63,296	173
5 Percent	3,896	0.0	2112	24,580	67
	3,896	1.0	2067	48,838	134
	3,896	2.0	2047	64,862	178
	3,896	3.0	2037	77,846	213

CONSISTENZA DELLE RISERVE/RISORSE

	Petrolio	Gas	Carbone	Totale
Gtep	234	188	455	877
R/P (anni)	54	64	112	84
Gt CO₂	706	396	2.002	3.104
Δ[CO₂] (ppmv)	44	24	124	192

RISERVE ACCERTATE DI COMBUSTIBILI FOSSILI

	Petrolio	Gas	Carbone	Totale
Gtep	480	380	7.050	7.910
Gt CO₂	1.443	807	31.050	33.300
Δ[CO₂] (ppmv)	90	50	1.925	2.065

RISORSE PRESUNTE DI COMBUSTIBILI FOSSILI

Correlazione caratteristica della produzione di CO₂

$$\text{produzione di CO}_2 = \left(\frac{\text{produzione di CO}_2}{\text{consumo di energia}} \right) \cdot \left(\frac{\text{consumo di energia}}{PIL} \right) \cdot \left(\frac{PIL}{\text{popolazione}} \right) \cdot \text{popolazione}$$

popolazione

È un fattore determinante della produzione di CO₂; la popolazione mondiale aumenta attualmente con un tasso di crescita dell'1.1%, con un rilevante contributo dei paesi non OCSE

$\frac{PIL}{\text{popolazione}}$

Prodotto Interno Lordo pro-capite, è un indice di benessere; tanto più evoluto è il sistema produttivo tanto maggiore è tale indice

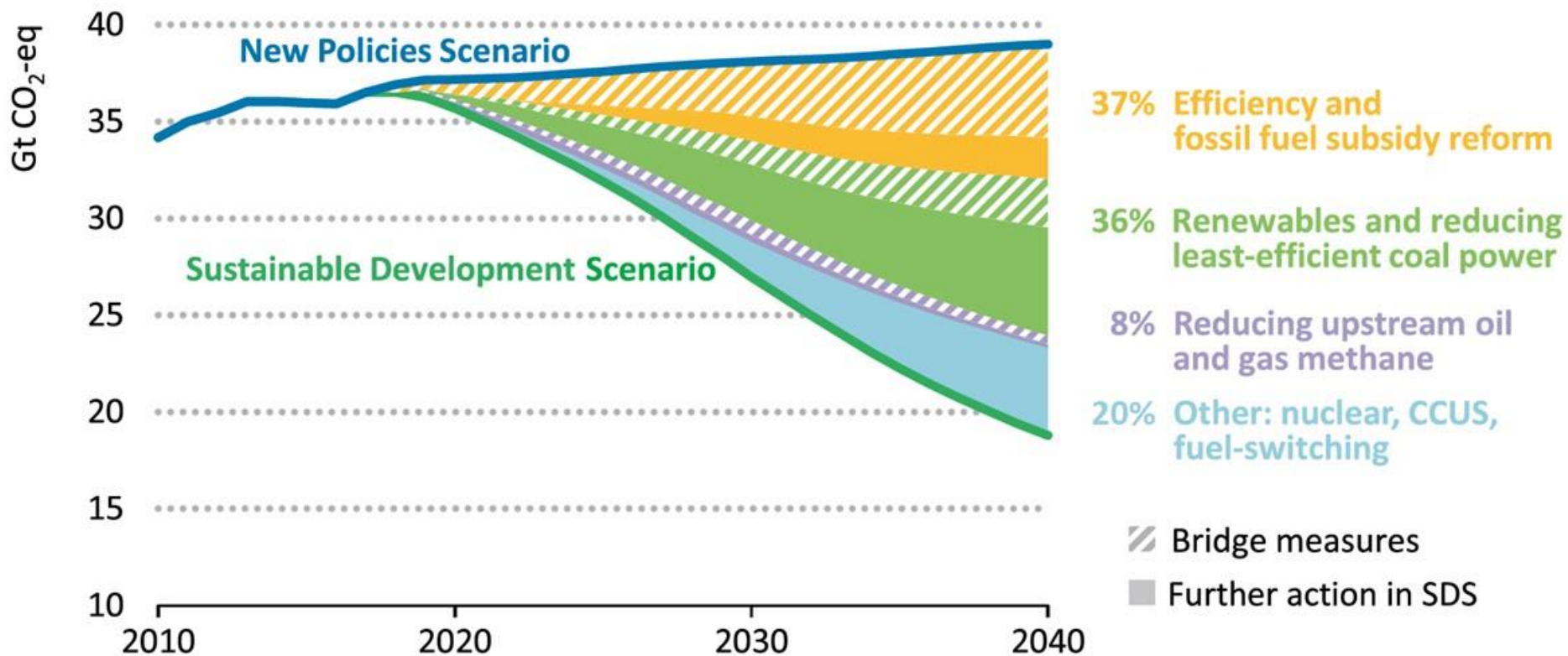
$\frac{\text{consumo di energia}}{PIL}$

È un indice di efficienza del sistema produttivo, quindi un indice di sviluppo tecnologico. Il sistema produttivo è tanto più efficiente quanto minore è il suo fabbisogno energetico a parità di ricchezza prodotta

$\frac{\text{produzione di CO}_2}{\text{consumo di energia}}$

È un indice caratteristico della diversificazione delle fonti di energia, nonché indice indiretto di sviluppo tecnologico in relazione alle diverse tecnologie di sfruttamento delle diverse fonti

NPS and SDS Scenarios on total CO₂-eq emissions (IEA-WEO 2018)



Note: 100-year GWP of methane = 30

Source: IEA-WEO 2018

Total CO₂-eq (CO₂ and methane) emissions reduction by measure in the Sustainable Development Scenario relative to the New Policies Scenario

Tecnologie **CCS** per la separazione e il “sequestro” della CO₂

- **CCS: “Carbon Capture and Storage”**
- Modalità di separazione (cattura) della CO₂
 - Dopo la combustione, dai prodotti della combustione
 - Prima della combustione, dal combustibile trasformato
 - Combustione con ossigeno puro

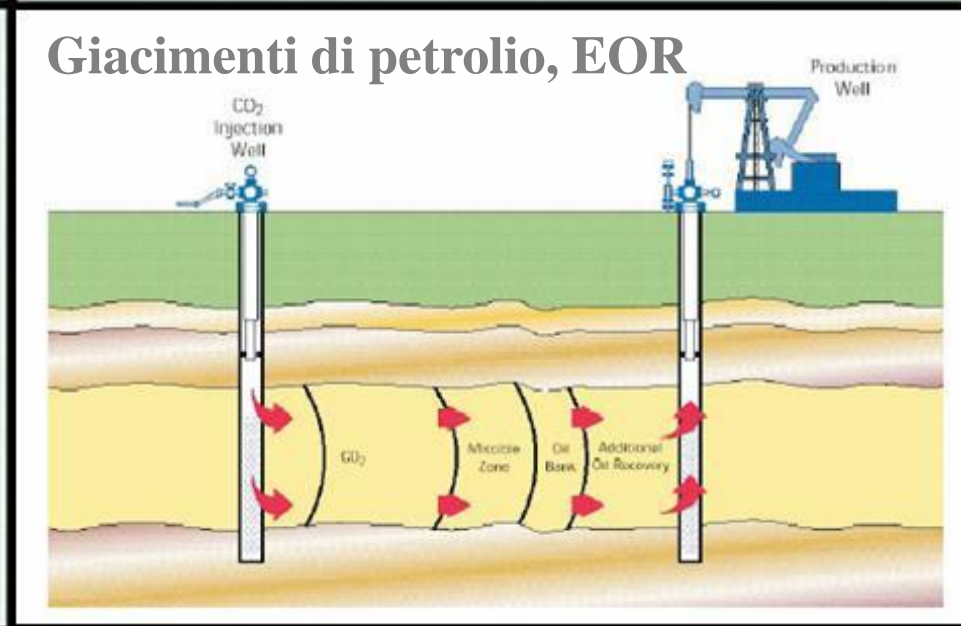
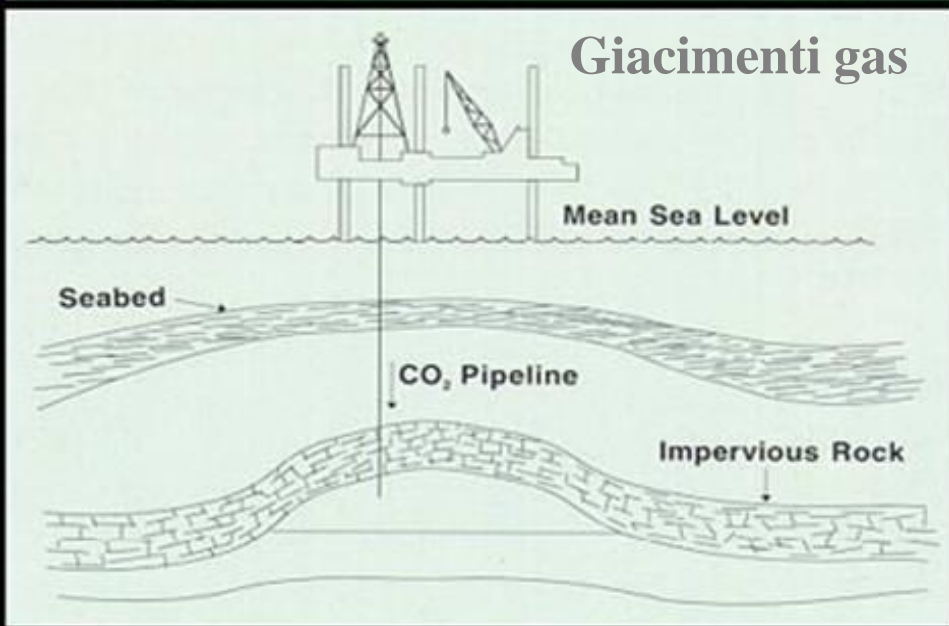
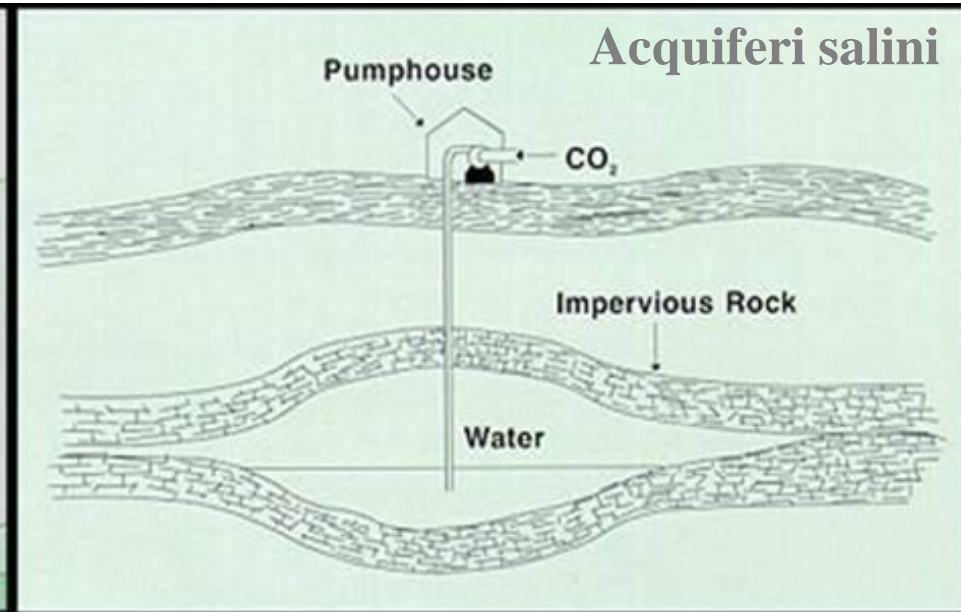
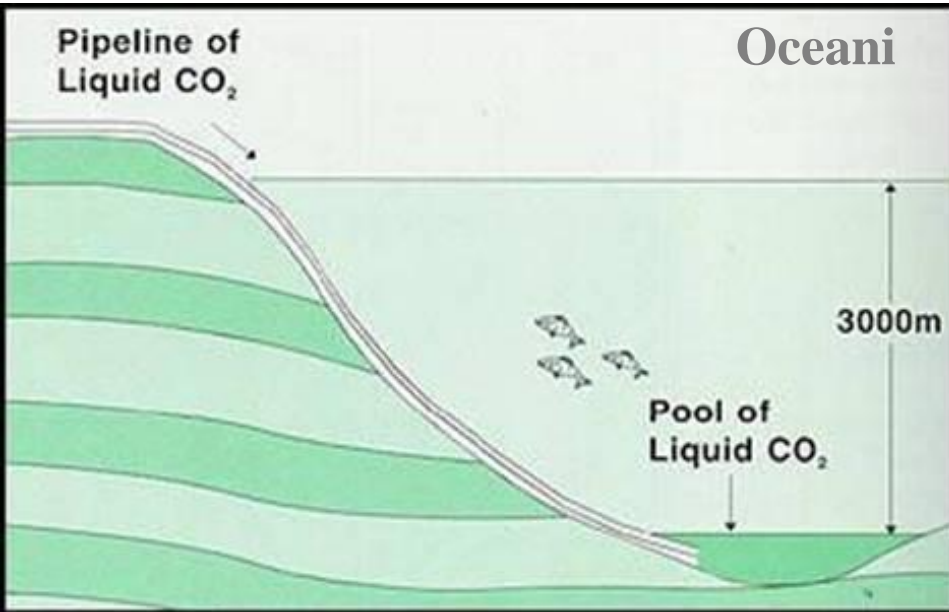
Tecnologie **CCS** per la separazione e il “sequestro” della CO₂

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 - Prima della combustione, dal combustibile trasformato
 - Combustione con ossigeno puro
- Modalità di sequestro (stoccaggio) della CO₂
 - Oceani
 - Strutture geologiche (acquiferi salini, formazioni sedimentarie, ecc.)
 - Giacimenti di petrolio, gas e carbone

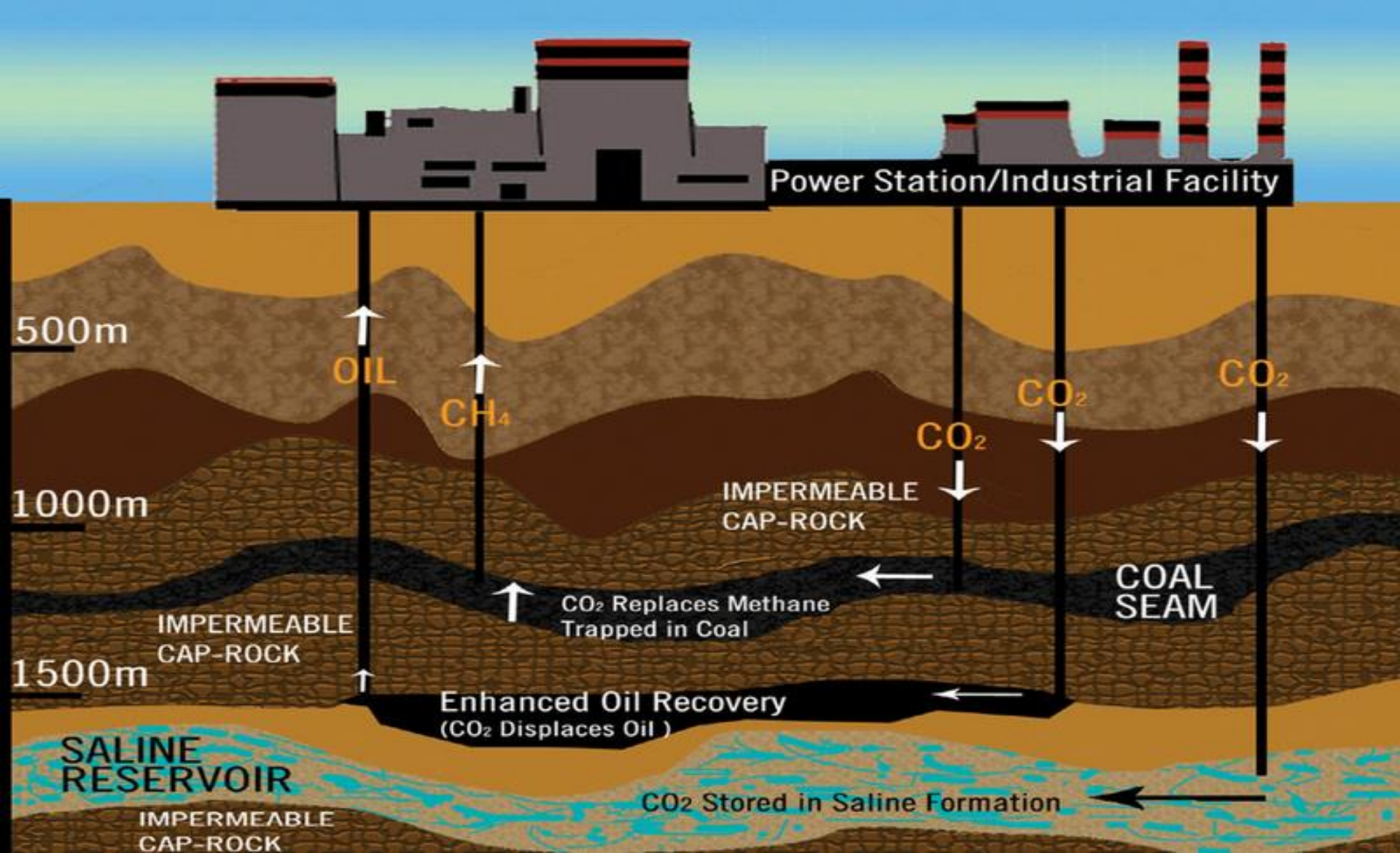
Segregazione della CO₂

- ❑ **Oceani**. Gli oceani costituiscono un enorme e naturale contenitore per la CO₂. L'impatto della segregazione della CO₂ negli oceani è praticamente trascurabile su scala globale. Su scala locale potrebbe incidere sullo sviluppo della vita nel mare.
- ❑ **Acquiferi salini**. Costituiscono anch'essi un notevole potenziale di stoccaggio della CO₂. La CO₂ può essere iniettata nelle falde mediante pozzi realizzati con le stesse tecniche di perforazione applicate per l'estrazione del petrolio e del gas.
- ❑ **Giacimenti di petrolio e gas**. La CO₂ può essere iniettata nei giacimenti di petrolio e gas in esercizio per aumentarne la resa (Enhanced Oil Recovery, EOR, ed Enhanced Gas Recovery, EGR), al posto di CO₂ prodotta ad hoc.
- ❑ **Giacimenti di carbone**. La CO₂ separata dai combustibili fossili può essere iniettata nei giacimenti di carbone profondi non coltivabili con contestuale estrazione di metano (Enhanced coal-bed methane, ECBM).

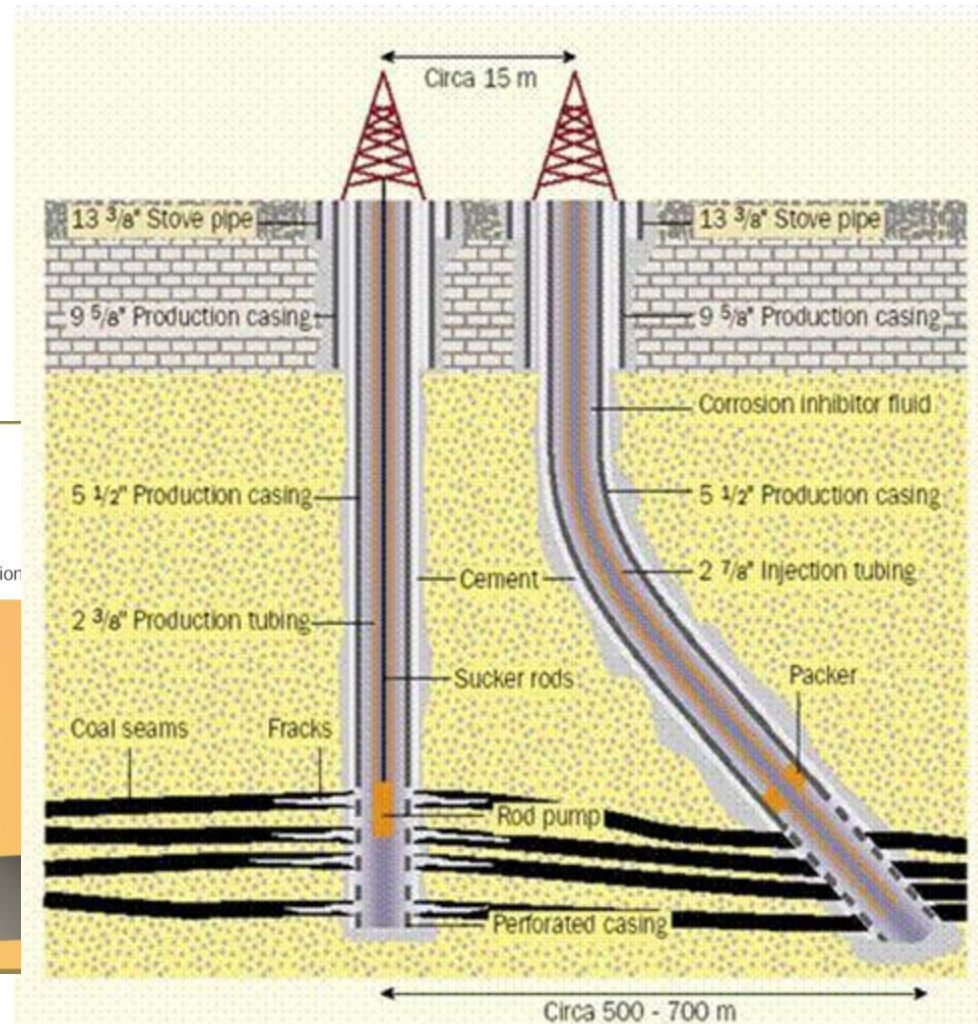
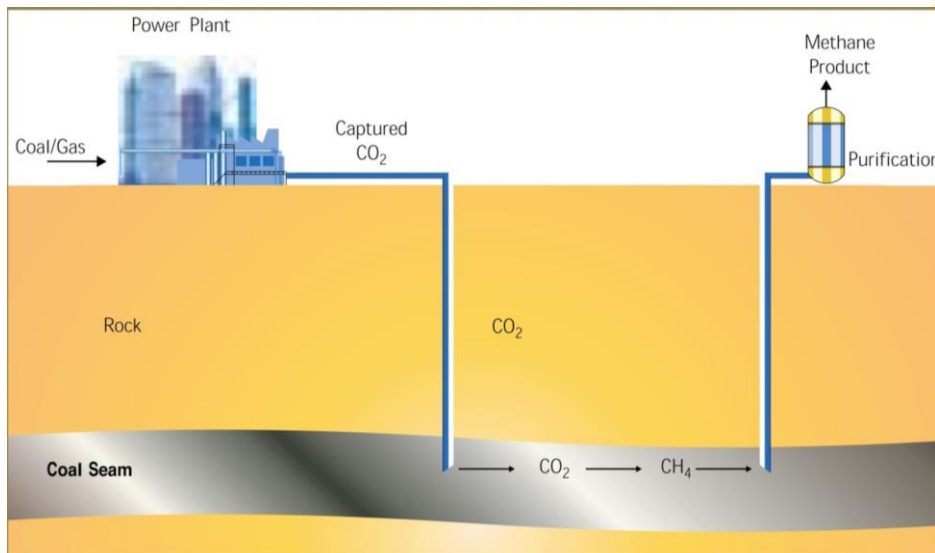
Segregazione della CO₂



Confinamento geologico della CO₂



Sequestro in giacimenti profondi di carbone, ECBM



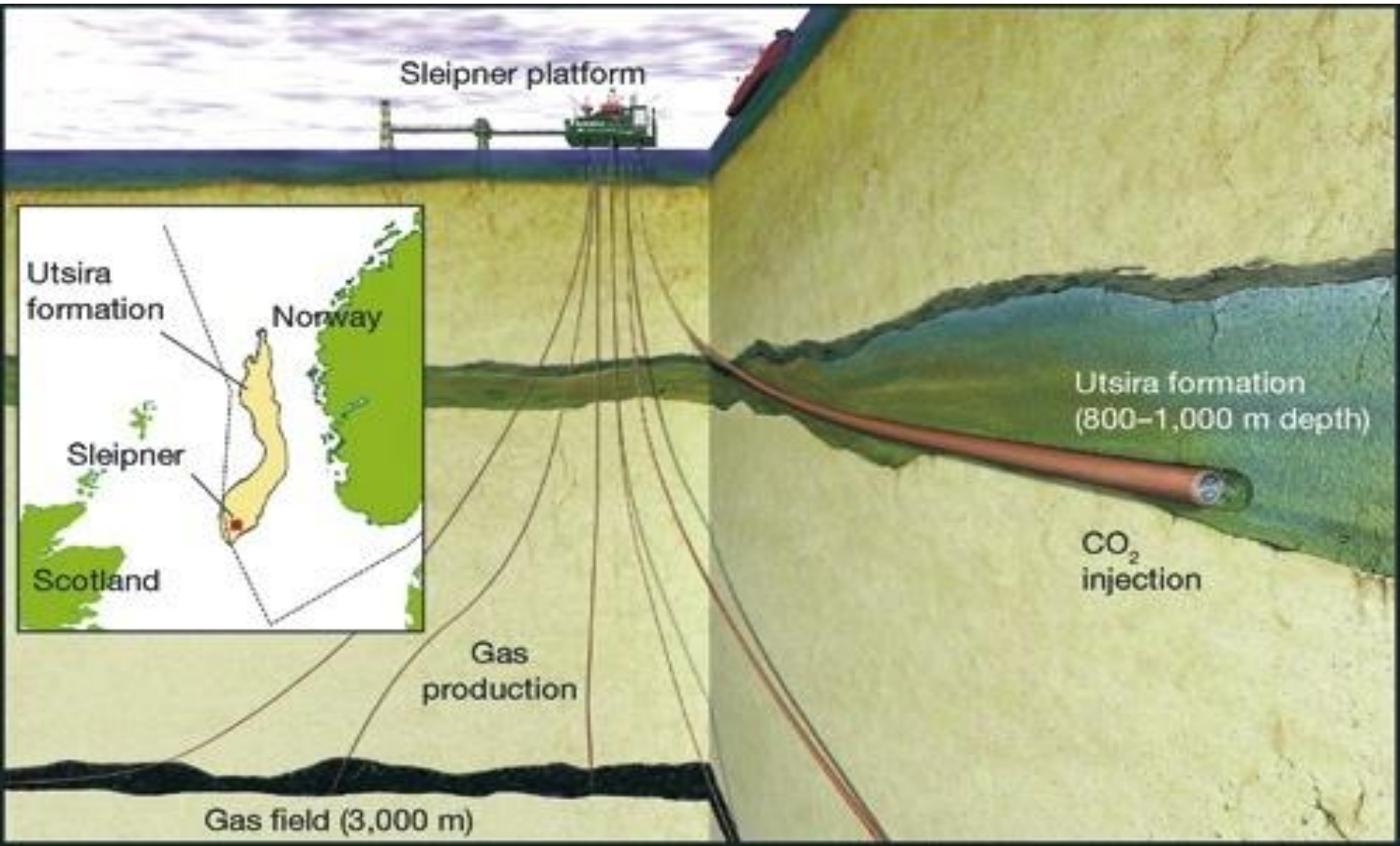
Sequestro off-shore della CO₂

Piattaforma Sleipner (Statoil)

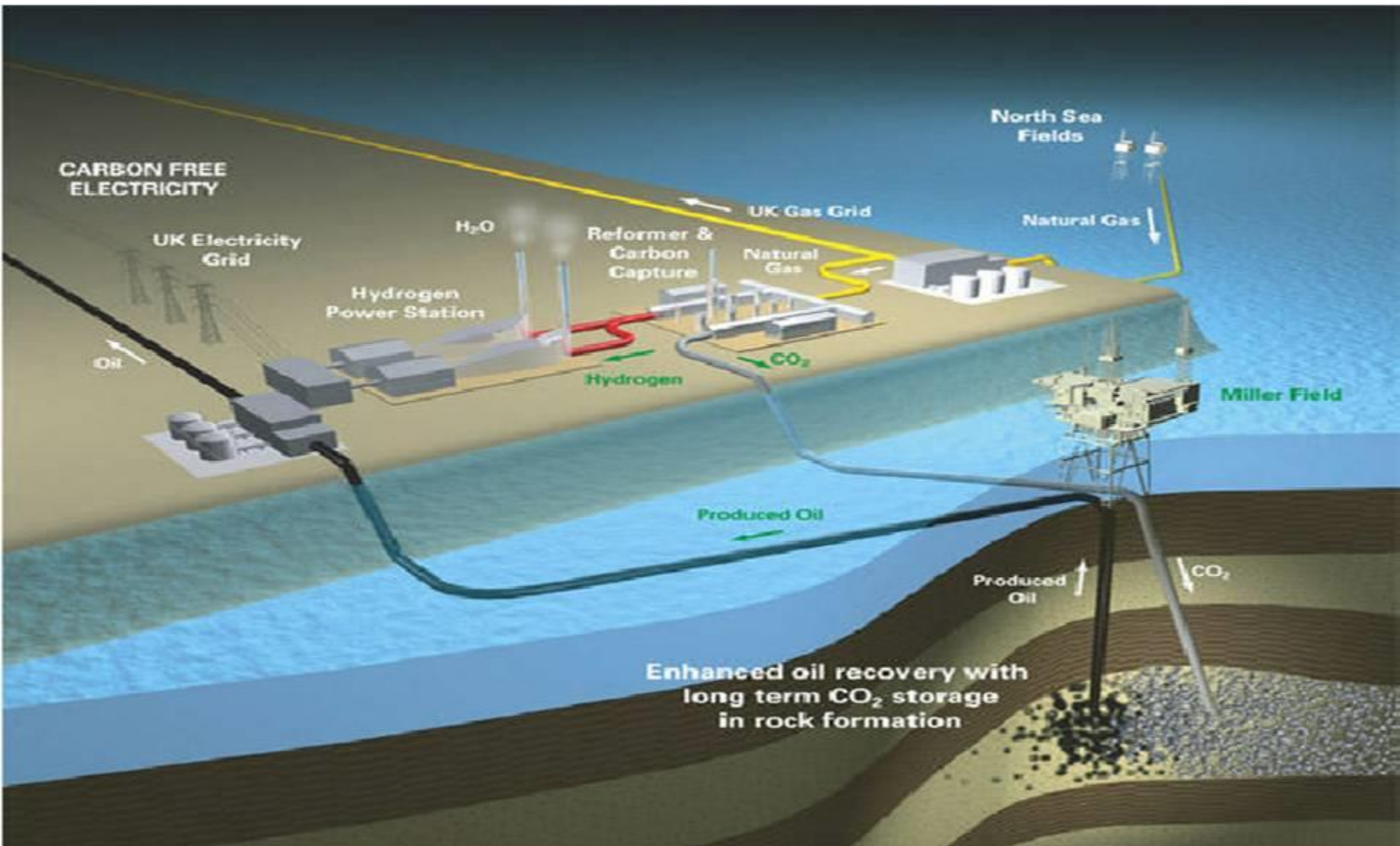


Sequestro off-shore della CO₂

Piattaforma Sleipner (Statoil)



Sistema integrato centrale a idrogeno da gas naturale con sequestro EOR della CO₂



Progetti dimostrativi di sequestro geologico della CO₂

