

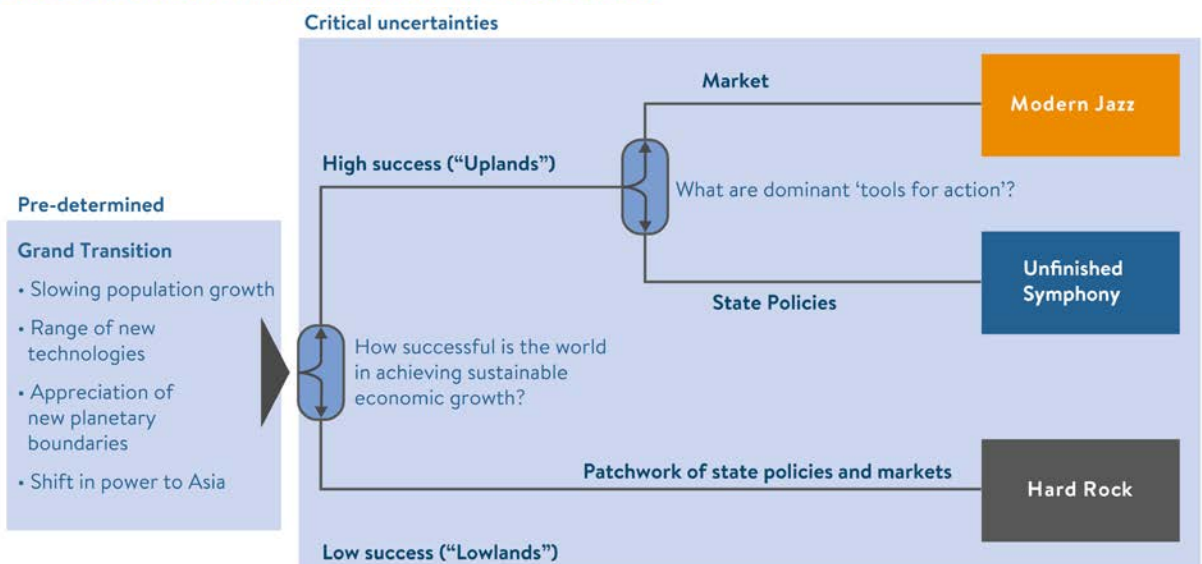
KEY FINDINGS

Since 1970, the world has seen rapid growth in energy demand, mainly satisfied by fossil fuels. The future will be different. Disruptive trends are emerging that will create a fundamentally new world for the energy industry, characterised by lower population growth, radical new technologies, greater environmental challenges, and a shift in economic and geopolitical power. These underlying drivers will re-shape the economics of energy. We call this uncertain journey into the new world of energy – *The Grand Transition*.

Over the past three years, the World Energy Council has explored the likely futures and outcomes for the *Grand Transition*. Our findings indicate:

- 1 THE WORLD'S PRIMARY ENERGY DEMAND GROWTH** will slow and per capita energy demand will peak before 2030 due to unprecedented efficiencies created by new technologies and more stringent energy policies.
- 2 DEMAND FOR ELECTRICITY** will double to 2060. Meeting this demand with cleaner energy sources will require substantial infrastructure investments and systems integration to deliver benefits to all consumers.
- 3 THE PHENOMENAL RISE OF SOLAR AND WIND ENERGY** will continue at an unprecedented rate and create both new opportunities and challenges for energy systems.
- 4 DEMAND PEAKS FOR COAL AND OIL** have the potential to take the world from “Stranded Assets” to “Stranded Resources”.
- 5 TRANSITIONING GLOBAL TRANSPORT** forms one of the hardest obstacles to overcome in an effort to decarbonise future energy systems.
- 6 LIMITING GLOBAL WARMING** to no more than a 2°C increase will require an exceptional and enduring effort, far beyond already pledged commitments, and with very high carbon prices.
- 7 GLOBAL COOPERATION, SUSTAINABLE ECONOMIC GROWTH, AND TECHNOLOGY INNOVATION** are needed to balance the Energy Trilemma.

FIGURE 8: THE GRAND TRANSITION AND THREE SCENARIOS



DATA TABLES

MODERN JAZZ

TABLE 21: MODERN JAZZ ECONOMIC INDICATORS

Indicator	2014	2020	2030	2040	2050	2060	CAGR (2014-60)
Population (million)	7,266	7,758	8,501	9,157	9,725	10,184	0.7%
GDP (trillion USD2010 MER)	70	87	122	170	233	312	3.3%
GDP per capita (USD2010 MER)	9,686	11,178	14,322	18,539	23,966	30,627	2.5%
Car ownership (cars/1000 people)	153	146	173	203	237	278	1.3%
Primary Energy Intensity (MTOE/ USD2010 MER)	194	171	132	98	72	55	-2.7%
Final Energy Intensity (MTOE/USD2010 MER)	133	122	96	73	55	42	-2.5%

TABLE 22: MODERN JAZZ PRIMARY ENERGY

Primary Energy Supply (MTOE)	2014	2020	2030	2040	2050	2060	CAGR (2014-60)
Total	13,652	14,793	16,085	16,649	16,847	17,013	0.5%
Coal	3,902	3,831	3,636	3,102	2,303	1,832	-1.6%
Oil	4,276	4,683	5,123	4,941	4,545	3,962	-0.2%
Gas	2,891	3,417	3,927	4,515	4,974	4,968	1.2%
Nuclear	659	815	856	947	1,085	1,262	1.4%
Biomass	1,408	1,415	1,580	1,768	2,106	2,671	1.4%
Hydro	334	375	413	461	515	562	1.1%
Other renewables	181	258	551	916	1,320	1,755	5.1%

TABLE 23: MODERN JAZZ TOTAL FINAL CONSUMPTION BY SECTOR AND BY FUEL SOURCE

Total Final Consumption (MTOE)	2014	2020	2030	2040	2050	2060	CAGR (2014-60)
Total	9,395	10,553	11,714	12,359	12,735	12,947	0.7%
Industry	2,743	3,399	3,780	3,975	4,087	4,092	0.9%
Transport	2,619	2,804	3,179	3,317	3,359	3,423	0.6%
Residential/ Commercial	3,209	3,386	3,636	3,816	3,930	3,986	0.5%
Non-energy uses	825	965	1,118	1,252	1,360	1,446	1.2%
Coal	1,072	1,303	1,288	1,184	1,064	910	-0.4%
Oil	3,749	4,117	4,530	4,377	4,085	3,648	-0.1%
Gas	1,416	1,601	1,819	2,096	2,235	2,261	1.0%
Electricity	1,701	1,968	2,353	2,790	3,214	3,649	1.7%
Heat	273	306	343	386	404	416	0.9%
Biomass & Biofuels	1,148	1,164	1,175	1,216	1,303	1,503	0.6%
Other	36	95	205	310	430	560	6.1%

TABLE 24: MODERN JAZZ TRANSPORT BY FUEL SOURCE

Fuels in Transport (MTOE)	2014	2020	2030	2040	2050	2060	CAGR (2014-60)
Total	2,619	2,805	3,179	3,317	3,359	3,423	0.6%
Electricity	26	35	70	115	166	277	5.3%
Hydrogen	0	0	4	15	40	86	29.2%
Liquid fuels – fossil	2,419	2,577	2,843	2,819	2,635	2,297	-0.1%
Liquid fuels – biogenous	74	90	146	206	301	482	4.2%
Gaseous fuels – fossil	98	96	105	142	182	224	1.8%
Gaseous fuels – biogenous	0	7	11	19	34	56	14.0%
Other (coal)	3	0	0	0	0	0	-100.0%

TABLE 25: MODERN JAZZ POWER BY FUEL SOURCE

Electricity Generation (TWh)	2014	2020	2030	2040	2050	2060	CAGR (2014-60)
Total	23,816	27,124	32,171	37,724	43,090	48,491	1.6%
Coal	9,697	9,468	8,960	7,358	4,152	2,634	-2.8%
Coal (with CCS)	0	0	20	119	338	665	NA
Oil	1,033	765	560	442	350	274	-2.8%
Gas	5,155	6,731	9,292	11,949	14,241	10,610	1.6%
Gas (with CCS)	0	0	0	81	762	4,853	NA
Nuclear	2,535	3,170	3,327	3,681	4,219	4,908	1.4%
Hydro	3,895	4,371	4,816	5,382	6,003	6,558	1.1%
Biomass	493	692	1,069	1,340	1,880	2,421	3.5%
Biomass (with CCS)	0	0	0	10	33	153	NA
Wind	717	1,316	2,540	4,257	6,433	8,818	5.6%
Solar	198	482	1,369	2,746	4,068	5,718	7.6%
Geothermal	77	129	210	323	481	638	4.7%
Other	15	0	8	36	127	239	6.2%

TABLE 26: MODERN JAZZ CARBON EMISSIONS

Carbon Emissions	2014	2020	2030	2040	2050	2060	CAGR (2014-60)
CO₂ emissions (GtCO ₂ /yr)	32.4	34.5	35.8	34.1	29.7	23.2	-0.7%
CO₂ capture (GtCO ₂)	0.0	0.0	0.0	0.1	1.0	3.6	NA
CO₂ per capita (tCO ₂)	4.46	4.4	4.2	3.7	3.1	2.3	-1.5%
CO₂ intensity (kgCO ₂ /USD2010)	0.46	0.4	0.3	0.2	0.1	0.1	-3.9%

TABLE 27: MODERN JAZZ COAL IN TPES BY REGION

Coal by Region (MTOE)	2014	2020	2030	2040	2050	2060	CAGR (2014-60)
Total	3,902	3,831	3,636	3,102	2,303	1,832	-1.6%
China	2,017	2,080	1,919	1,681	1,239	937	-1.7%
India	377	502	665	692	593	462	0.4%
Europe	454	357	290	208	148	145	-2.4%
Latin America	32	22	20	13	7	3	-5.3%
Middle East and Northern Africa	14	10	9	6	1	3	-3.6%
North America	462	399	276	172	84	56	-4.5%
Other Asia	438	373	368	243	149	132	-2.6%
Sub Saharan Africa	107	88	89	88	82	94	-0.3%

TABLE 28: MODERN JAZZ OIL IN TPES BY REGION

Oil by Region (mb/d)	2014	2020	2030	2040	2050	2060	CAGR (2014-60)
Total	86	94	103	99	91	80	-0.2%
China	11	14	19	17	14	12	0.2%
India	4	5	7	8	9	9	1.9%
Europe	18	17	16	15	13	10	-1.3%
Latin America	7	7	8	8	8	6	0.0%
Middle East and Northern Africa	9	10	11	11	11	9	0.0%
North America	20	23	22	18	15	11	-1.4%
Other Asia	15	16	16	17	16	15	-0.1%
Sub Saharan Africa	2	2	3	4	6	8	3.2%

TABLE 29: MODERN JAZZ GAS IN TPES BY REGION

Gas by Region (MTOE)	2014	2020	2030	2040	2050	2060	CAGR (2014-60)
Total	2,891	3,417	3,927	4,515	4,974	4,968	1.2%
China	155	238	322	475	692	703	3.3%
India	43	71	114	196	307	415	5.0%
Europe	818	961	939	917	915	887	0.2%
Latin America	142	165	220	294	350	379	2.2%
Middle East and Northern Africa	459	449	495	570	563	530	0.3%
North America	771	926	1,032	1,046	915	792	0.1%
Other Asia	480	579	746	894	1,013	949	1.5%
Sub Saharan Africa	24	26	60	121	217	313	5.7%

UNFINISHED SYMPHONY

TABLE 30: UNFINISHED SYMPHONY ECONOMIC INDICATORS

Indicator	2014	2020	2030	2040	2050	2060	CAGR (2014-60)
Population (million)	7,266	7,758	8,501	9,157	9,725	10,184	0.7%
GDP (trillion USD2010 MER)	70	84	114	152	199	256	2.9%
GDP per capita (USD2010 MER)	9,686	10,871	13,396	16,602	20,473	25,172	2.1%
Car ownership (cars/1000 people)	153	144	167	194	224	258	1.1%
Primary Energy Intensity (MTOE/ USD2010 MER)	194	172	134	100	76	59	-2.6%
Final Energy Intensity (MTOE/USD2010 MER)	133	123	98	76	58	45	-2.3%

TABLE 31: UNFINISHED SYMPHONY PRIMARY ENERGY

Primary Energy Supply (MTOE)	2014	2020	2030	2040	2050	2060	CAGR (2014-60)
Total	13,652	14,499	15,291	15,178	15,095	15,085	0.2%
Coal	3,902	3,509	3,062	2,058	1,063	724	-3.6%
Oil	4,276	4,589	4,671	4,378	3,862	3,261	-0.6%
Gas	2,891	3,375	3,554	3,637	3,822	3,604	0.5%
Nuclear	659	848	1,123	1,413	1,683	1,959	2.4%
Biomass	1,408	1,532	1,835	2,145	2,564	2,949	1.6%
Hydro	334	381	438	488	553	609	1.3%
Other renewables	181	265	609	1,059	1,548	1,980	5.3%

TABLE 32: UNFINISHED SYMPHONY TOTAL FINAL CONSUMPTION BY SECTOR AND BY FUEL SOURCE

Total Final Consumption (MTOE)	2014	2020	2030	2040	2050	2060	CAGR (2014-60)
Total	9,395	10,360	11,147	11,513	11,585	11,417	0.4%
Industry	2,743	3,297	3,489	3,545	3,518	3,444	0.5%
Transport	2,619	2,738	3,050	3,183	3,196	3,123	0.4%
Residential/ Commercial	3,209	3,374	3,513	3,609	3,617	3,543	0.2%
Non-energy uses	825	951	1,096	1,177	1,254	1,307	1.0%
Coal	1,072	1,189	1,022	833	643	440	-1.9%
Oil	3,749	4,055	4,169	4,005	3,614	3,072	-0.4%
Gas	1,416	1,567	1,813	1,937	1,984	2,003	0.8%
Electricity	1,701	1,902	2,258	2,625	2,977	3,328	1.5%
Heat	273	296	324	350	336	311	0.3%
Biomass & Biofuels	1,148	1,252	1,361	1,463	1,619	1,751	0.9%
Other	36	99	201	302	412	511	5.9%

TABLE 33: UNFINISHED SYMPHONY TRANSPORT BY FUEL SOURCE

Fuels in Transport (MTOE)	2014	2020	2030	2040	2050	2060	CAGR (2014-60)
Total	2,619	2,738	3,050	3,183	3,196	3,123	0.6%
Electricity	26	35	63	117	184	321	5.6%
Hydrogen	0	1	7	21	53	88	29.2%
Liquid fuels – fossil	2,419	2,480	2,644	2,577	2,331	1,878	-0.5%
Liquid fuels – biogenous	74	127	222	329	451	617	4.7%
Gaseous fuels – fossil	98	91	106	123	146	178	1.3%
Gaseous fuels – biogenous	0	5	8	16	31	41	13.2%
Other (coal)	3	0	0	0	0	0	-100.0%
Sub Saharan Africa	24	26	60	121	217	313	5.7%

TABLE 34: UNFINISHED SYMPHONY POWER BY FUEL SOURCE

Electricity Generation (TWh)	2014	2020	2030	2040	2050	2060	CAGR (2014-60)
Total	23,816	26,216	30,854	35,453	39,843	44,474	1.4%
Coal	9,697	8,791	7,741	4,483	547	86	-9.8%
Coal (with CCS)	0	0	95	530	981	982	NA
Oil	1,033	651	381	241	133	76	-5.5%
Gas	5,155	6,362	7,014	6,927	4,486	822	-3.9%
Gas (with CCS)	0	0	82	1,227	4,414	6,694	NA
Nuclear	2,535	3,299	4,367	5,496	6,546	7,617	2.4%
Hydro	3,895	4,440	5,109	5,695	6,447	7,100	1.3%
Biomass	493	710	1,187	1,663	2,150	2,339	3.4%
Biomass (with CCS)	0	0	0	30	77	169	NA
Wind	717	1,320	2,918	4,928	7,431	9,326	5.7%
Solar	198	501	1,694	3,760	5,802	7,943	8.4%
Geothermal	77	142	262	448	735	1,111	6.0%
Other	15	0	5	24	93	210	5.9%

TABLE 35: UNFINISHED SYMPHONY CARBON EMISSIONS

Carbon Emissions	2014	2020	2030	2040	2050	2060	CAGR (2014-60)
CO₂ emissions (GtCO ₂ /yr)	32.38	32.6	31.1	25.8	18.1	12.6	-2.0%
CO₂ capture (GtCO ₂)	0.0	0.0	0.1	0.8	3.2	4.8	NA
CO₂ per capita (tCO ₂)	4.46	4.2	3.7	2.8	1.9	1.2	-2.8%
CO₂ intensity (kgCO ₂ /USD2010)	0.46	0.4	0.3	0.2	0.1	0.0	-4.7%

TABLE 36: UNFINISHED SYMPHONY COAL IN TPES BY REGION

Coal by Region (MTOE)	2014	2020	2030	2040	2050	2060	CAGR (2014-60)
Total	3,902	3,509	3,062	2,058	1,063	724	-3.6%
China	2,017	1,912	1,648	1,158	602	384	-3.5%
India	377	407	456	349	212	141	-2.1%
Europe	454	340	264	136	82	76	-3.8%
Latin America	32	23	18	12	4	2	-5.9%
Middle East and Northern Africa	14	10	9	1	1	0	-8.4%
North America	462	387	291	168	68	54	-4.5%
Other Asia	438	348	304	179	69	41	-5.0%
Sub Saharan Africa	107	82	71	56	26	25	-3.1%

TABLE 37: UNFINISHED SYMPHONY OIL IN TPES BY REGION

Oil by Region (mb/d)	2014	2020	2030	2040	2050	2060	CAGR (2014-60)
Total	86	92	94	88	78	65	-0.6%
China	11	14	16	15	12	10	-0.2%
India	4	5	7	8	9	9	2.0%
Europe	18	17	16	14	11	8	-1.6%
Latin America	7	7	7	7	6	5	-0.8%
Middle East and Northern Africa	9	9	10	10	8	7	-0.7%
North America	20	23	21	17	13	9	-1.8%
Other Asia	15	15	15	14	13	11	-0.7%
Sub Saharan Africa	2	2	3	3	5	7	2.8%

TABLE 38: UNFINISHED SYMPHONY GAS IN TPES BY REGION

Gas by Region (MTOE)	2014	2020	2030	2040	2050	2060	CAGR (2014-60)
Total	2,891	3,375	3,554	3,637	3,822	3,604	0.5%
China	155	221	318	415	647	563	2.8%
India	43	71	134	226	295	340	4.6%
Europe	818	984	910	890	828	736	-0.2%
Latin America	142	160	190	209	212	220	0.9%
Middle East and Northern Africa	459	443	502	490	482	459	0.0%
North America	771	924	894	714	618	522	-0.8%
Other Asia	480	549	556	604	605	568	0.4%
Sub Saharan Africa	24	23	48	89	135	196	4.7%

HARD ROCK

TABLE 39: HARD ROCK ECONOMIC INDICATORS

Indicator	2014	2020	2030	2040	2050	2060	CAGR (2014-60)
Population (million)	7,266	7,758	8,501	9,157	9,725	10,184	0.7%
GDP (trillion USD2010 MER)	70	77	93	110	129	150	1.7%
GDP per capita (USD2010 MER)	9,686	9,923	10,901	12,004	13,239	14,684	0.9%
Car ownership (cars/1000 people)	153	145	169	197	229	268	1.2%
Primary Energy Intensity (MTOE/ USD2010 MER)	194	193	174	155	137	122	-1.0%
Final Energy Intensity (MTOE/USD2010 MER)	133	137	125	113	102	92	-0.8%

TABLE 40: HARD ROCK PRIMARY ENERGY

Primary Energy Supply (MTOE)	2014	2020	2030	2040	2050	2060	CAGR (2014-60)
Total	13,652	14,865	16,154	17,012	17,654	18,272	0.6%
Coal	3,902	3,932	3,923	4,044	3,524	3,194	-0.4%
Oil	4,276	4,578	5,044	5,180	5,176	5,139	0.4%
Gas	2,891	3,392	3,727	3,811	4,231	4,370	0.9%
Nuclear	659	840	994	1,160	1,391	1,713	2.1%
Biomass	1,408	1,498	1,631	1,742	1,960	2,098	0.9%
Hydro	334	377	414	459	511	563	1.1%
Other renewables	181	248	422	615	859	1,195	4.2%

TABLE 41: HARD ROCK TOTAL FINAL CONSUMPTION BY SECTOR AND BY FUEL SOURCE

Total Final Consumption (MTOE)	2014	2020	2030	2040	2050	2060	CAGR (2014-60)
Total	9,395	10,543	11,625	12,473	13,155	13,717	0.8%
Industry	2,743	3,367	3,592	3,850	4,041	4,221	0.9%
Transport	2,619	2,786	3,256	3,562	3,729	3,904	0.8%
Residential/ Commercial	3,209	3,427	3,669	3,808	4,001	4,053	0.5%
Non-energy uses	825	962	1,108	1,253	1,384	1,539	1.4%
Coal	1,072	1,468	1,482	1,501	1,523	1,552	0.8%
Oil	3,749	3,973	4,409	4,581	4,636	4,615	0.5%
Gas	1,416	1,540	1,740	1,935	2,013	2,132	0.9%
Electricity	1,701	1,939	2,229	2,608	2,974	3,357	1.5%
Heat	273	285	279	279	296	287	0.1%
Biomass & Biofuels	1,148	1,240	1,303	1,311	1,368	1,319	0.3%
Other	36	97	183	258	344	456	5.6%

TABLE 42: HARD ROCK TRANSPORT BY FUEL SOURCE

Fuels in Transport (MTOE)	2014	2020	2030	2040	2050	2060	CAGR (2014-60)
Total	2,619	2,786	3,256	3,562	3,730	3,904	0.9%
Electricity	26	32	59	86	111	151	3.9%
Hydrogen	0	1	4	13	22	41	27.1%
Liquid fuels – fossil	2,419	2,556	2,917	3,051	3,075	3,041	0.5%
Liquid fuels – biogenous	74	83	135	196	289	383	3.7%
Gaseous fuels – fossil	98	102	139	214	230	281	2.3%
Gaseous fuels – biogenous	0	3	0	1	3	7	9.1%
Other (coal)	3	8	1	1	0	0	-12.4%
Other	36	97	183	258	344	456	5.6%

TABLE 43: HARD ROCK POWER BY FUEL SOURCE

Electricity Generation (TWh)	2014	2020	2030	2040	2050	2060	CAGR (2014-60)
Total	23,816	26,728	30,605	35,559	40,191	44,914	1.4%
Coal	9,697	9,096	9,684	10,922	9,491	8,199	-0.4%
Coal (with CCS)	0	0	0	0	0	0	NA
Oil	1,033	974	733	585	488	421	-1.9%
Gas	5,155	6,501	7,740	8,680	10,984	11,781	1.8%
Gas (with CCS)	0	0	0	0	0	0	NA
Nuclear	2,535	3,267	3,864	4,510	5,411	6,661	2.1%
Hydro	3,895	4,395	4,825	5,361	5,958	6,573	1.1%
Biomass	493	667	844	1,066	1,389	1,870	2.9%
Biomass (with CCS)	0	0	0	0	0	0	NA
Wind	717	1,264	1,983	2,946	4,063	5,608	4.6%
Solar	198	472	793	1,262	2,037	3,270	6.3%
Geothermal	77	91	133	194	301	418	3.7%
Other	15	0	8	32	68	113	4.5%

TABLE 44: HARD ROCK CARBON EMISSIONS

Carbon Emissions	2014	2020	2030	2040	2050	2060	CAGR (2014-60)
CO₂ emissions (GtCO ₂ /yr)	32.38	34.4	36.2	37.2	35.7	34.1	0.1%
CO₂ capture (GtCO ₂)	0.0	0.0	0.0	0.0	0.0	0.0	NA
CO₂ per capita (tCO ₂)	4.46	4.4	4.3	4.1	3.7	3.3	-0.6%
CO₂ intensity (kgCO ₂ /USD2010)	0.46	0.4	0.4	0.3	0.3	0.2	-1.5%

TABLE 45: HARD ROCK COAL IN TPES BY REGION

Coal by Region (MTOE)	2014	2020	2030	2040	2050	2060	CAGR (2014-60)
Total	3,902	3,932	3,923	4,044	3,524	3,194	-0.4%
China	2,017	2,162	1,945	1,935	1,448	1,159	-1.2%
India	377	486	690	876	938	962	2.1%
Europe	454	396	350	298	209	158	-2.3%
Latin America	32	26	23	18	11	9	-2.7%
Middle East and Northern Africa	14	11	11	10	2	2	-4.5%
North America	462	335	268	197	117	72	-4.0%
Other Asia	438	422	519	555	593	580	0.6%
Sub Saharan Africa	107	95	116	154	206	253	1.9%

TABLE 46: HARD ROCK OIL IN TPES BY REGION

Oil by Region (mb/d)	2014	2020	2030	2040	2050	2060	CAGR (2014-60)
Total	86	92	101	104	104	103	0.4%
China	11	12	15	16	15	15	0.7%
India	4	4	6	7	8	9	1.9%
Europe	18	17	18	17	16	16	-0.3%
Latin America	7	7	8	9	8	9	0.6%
Middle East and Northern Africa	9	10	11	12	12	12	0.5%
North America	20	24	24	21	18	14	-0.8%
Other Asia	15	16	17	18	19	19	0.4%
Sub Saharan Africa	2	2	3	4	7	10	3.8%

TABLE 47: HARD ROCK GAS IN TPES BY REGION

Gas by Region (MTOE)	2014	2020	2030	2040	2050	2060	CAGR (2014-60)
Total	2,891	3,392	3,727	3,811	4,231	4,370	0.9%
China	155	217	252	259	453	426	2.2%
India	43	69	131	189	242	324	4.5%
Europe	818	867	935	934	944	953	0.3%
Latin America	142	163	190	229	303	324	1.8%
Middle East and Northern Africa	459	509	537	559	601	641	0.7%
North America	771	992	1,069	986	1,021	1,030	0.6%
Other Asia	480	552	567	595	594	572	0.4%
Sub Saharan Africa	24	24	45	61	73	101	3.2%