100% RENEWABLE ENERGY FOR ALL:

energy [r]evolution

A SUSTAINABLE WORLD ENERGY OUTLOOK 2015

EXECUTIVE SUMMARY

GREENPEACE

IMAGE GEMASOLAR, A 15 MW SOLAR POWER TOWER PLANT, SPAIN.

CONTEXT

This is the year when the fight against climate change could take a dramatic turn. The conference in Paris in December presents political and business leaders with the opportunity to take the critical decisions needed if we are to keep average temperature rises to no more than 1.5 or 2 degrees C. According to the IPCC, humankind cannot emit more than 1,000 giga-tonnes of CO_2 from now, if we are to stay within this limit. At the current and projected rate of consumption, this entire carbon budget will be used by 2040.

Dynamic change is happening in energy supply, but the change needs to happen faster. This Energy [R]evolution scenario proposes a pathway to a 100% sustainable energy supply, ending CO_2 emissions and phasing out nuclear energy, and making redundant new oil exploration in the Arctic and deep sea waters such as off the coast of Brazil. It also demonstrates that this transformation increases employment in the energy sector.

What is required is for the political will to be there.

Greenpeace has been publishing its Energy [R]evolution scenarios since 2005, more recently in collaboration with the scientific community, in particular the German Aerospace Centre (DLR). While our predictions on the potential and market growth of renewable energy may once have seemed fanciful or unrealistic, they have proved to be accurate. The US-based Meister Consultants Group concluded earlier this year that "*the world's biggest energy agencies, financial institutions and fossil fuel companies for the most part seriously under-estimated just how fast the clean power sector could and would grow*". It wasn't the IEA, Goldman Sachs or the US Department of Energy who got it right. It was Greenpeace's market scenario which was the most accurate.

CURRENT SITUATION

The energy sector is changing rapidly. Renewable energy technologies have become mainstream in most countries as a result of dramatically falling prices. A global renewable energy supply is no longer science-fiction, but work in progress.

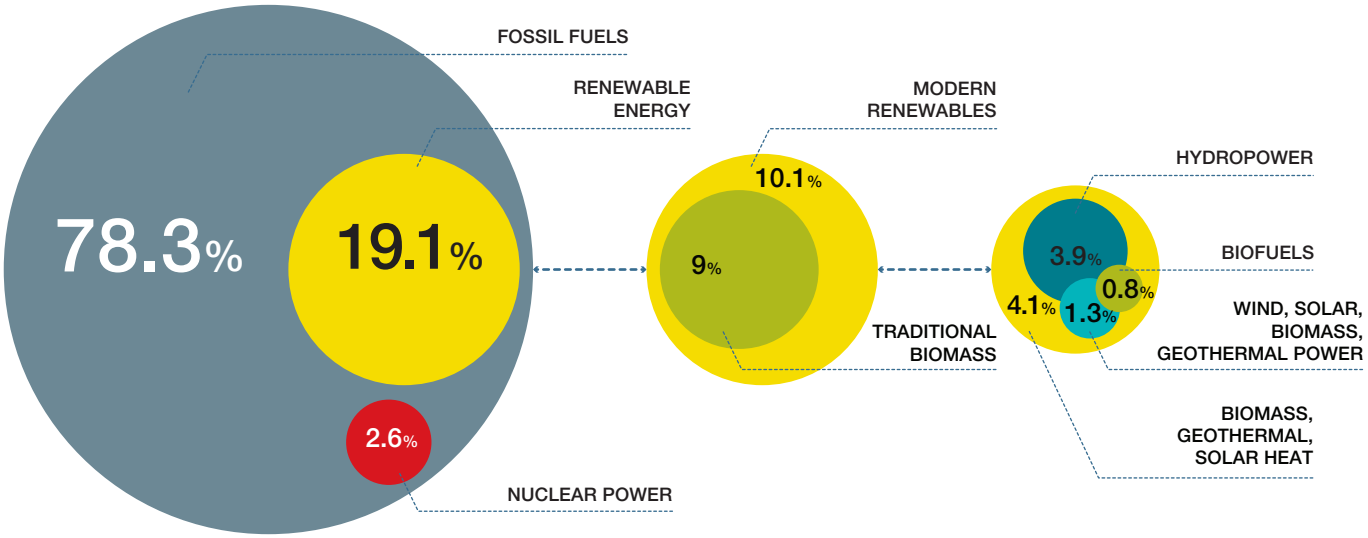
Renewables contributed 60% of new power generation worldwide in 2014, and in some countries the share was higher (REN21-2015). The three main power generation technologies (solar photovoltaics, wind and hydro) together added 127 GW of new power generation capacity worldwide in 2014.

This increase in market share has driven huge cost reductions, especially for solar PV and wind power, forcing other renewable energy technologies to reduce costs. All this has happened in an environment where subsidies are weighted heavily in favour of fossil fuels, which receive a global annual subsidy of $550 billion, more than double the subsidy for renewables (IEA WEO 2015).

The most dynamic sector is power generation. Renewable energy supplied 21% of electricity generation in 2012, with hydropower being the main renewable source. Heating and transport lag behind. The number of electric vehicles worldwide doubled year on year, but the number is still small at 665,000. E-mobility and recent developments in battery storage, including significant cost reductions, could herald a change in the role of renewable energy in the transport sector.

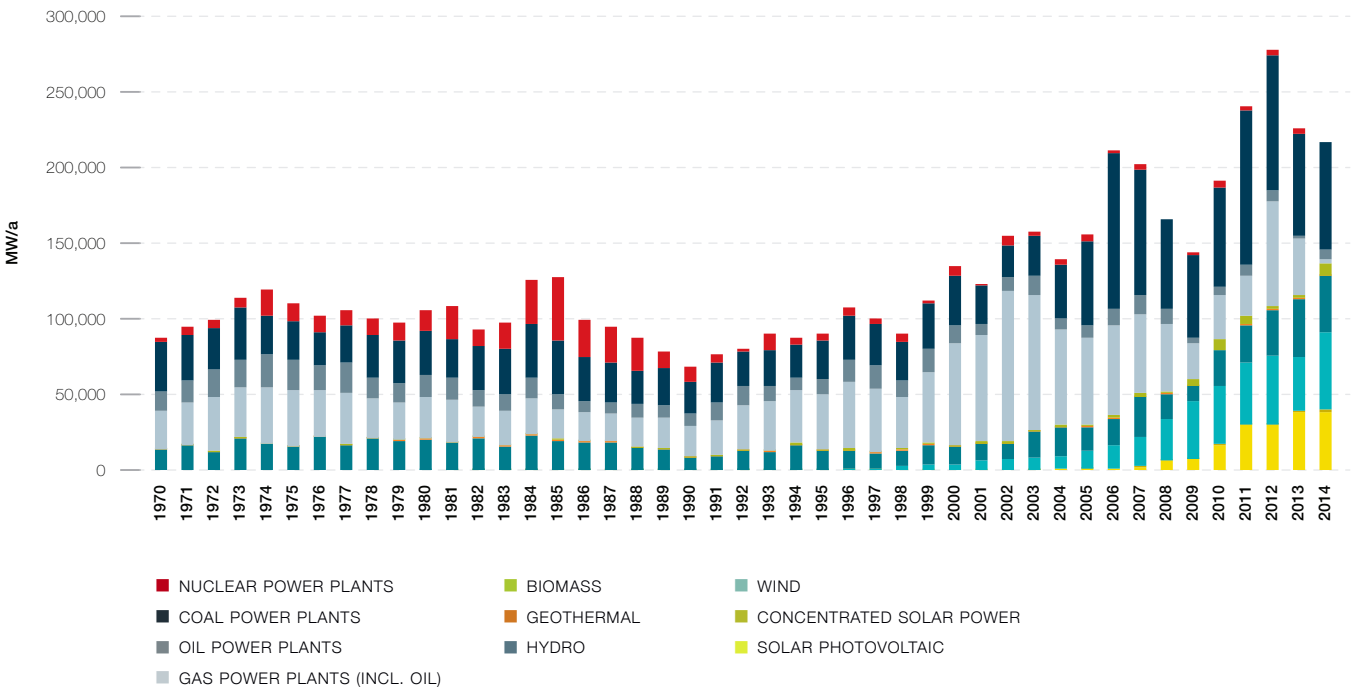
Even though the emissions landscape is changing rapidly, fossil fuels still provide 81.2% of the world's primary energy supply. In 2014, for the first time in 40 years, global energy-related CO_2 emissions remained stable in spite of continued economic growth, thanks mainly to declining coal consumption in China. If global mitigation efforts are strengthened, this trend will continue. But the transition to renewables needs to happen more quickly if it is to keep pace with the growth in energy demand and the necessary replacement of fossil fuel-based energy supply.

FIGURE 1 | GLOBAL FINAL ENERGY SHARES BY SOURCE IN 2013



source REN21-2015.

FIGURE 2 | ANNUAL GLOBAL POWER PLANT MARKET 1970 - 2014



source Platts, REN21, EWEA, GWEC, EPIA, National Statistics, IEA, Breyer.
data compilation Dr. Sven Teske/Greenpeace.

PEAK IN EMISSIONS

While the IEA "Current Policies" scenario[1], set out in its World Energy Outlook 2014, sees energy related CO_2 emissions increasing by 56% between 2012 and 2050, the Energy [R]evolution scenario decarbonizes the entire energy system by 2050. The combination of energy efficiency and renewable energy technologies leads to a stabilization of CO_2 emissions in the energy sector by 2020 and a steady reduction towards near zero CO_2 emissions in 2050.

By 2030, global CO_2 emissions are back to 1990 levels. Only a decade later, a further 60% reduction is achievable. The total carbon emissions between 2012 and 2050 add up to 667 gigatonnes – well within the IPCC's "safe" limit of 1,000 gigatonnes. Switching to 100% renewable energy is therefore a matter of humankind's survival.

The Energy [R]evolution scenario phases out coal, oil, gas and nuclear energy as fast as technically and economically possible, by expanding renewable energy and quickly rolling out efficient vehicles in the transport sector to replace oil-powered combustion engines. This leads to a renewable energy share of 42% in 2030, 72% in 2040 and 100% in 2050. The only remaining use for fossil fuels (mainly oil) is in the non-energy sector, such as petrochemicals and steel production.

Necessary steps

Bring down emissions before 2020, and agree on legally-binding greenhouse gas emission cuts to 2050.

Create a level playing field to increase cost competitiveness for renewables. Where energy or fuel subsidies focus on consumers, particularly in major economies, middle and low income countries, shift subsidies towards energy efficiency and renewable energy options.

MAKING THE TRANSITION

Global energy demand continues to grow due to economic growth and rising living standards. Taking into consideration population growth, GDP growth and improvements in energy intensity, peak energy demand will be reached in 2020, remaining at that level for about a decade. Overall demand will fall below the current levels by 2050, reaching about 453,000 PJ/a – 15% below current global primary energy demand.

The transport sector

Governments must introduce incentives for people to drive smaller cars using new, more efficient engines. Transport use must be shifted to more efficient areas like rail, light rail and buses, especially in large cities. If this is achieved, there are energy savings of 62% (92,000 PJ/a) in 2050 compared to the IEA scenario, in spite of population increase, GDP growth and higher living standards.

Highly efficient propulsion technology with hybrid, plug-in hybrid and battery-electric power trains will bring about large efficiency gains. Under the Energy [R]evolution scenario, 14% of road transport needs are met by electricity by 2030 compared to less than 1% today, and just over half by 2050. Hydrogen and synthetic fuels generated using renewable electricity further increase renewables' share in transport.

Necessary steps

Strengthen public transport and accelerate the transition towards electrification of transport, particularly of trains, light rail, trams and both two-and four-wheeled vehicles.

REFERENCES

1 THE IEA CURRENT POLICIES CASE IS A REFERENCE CASE FOR THE ENERGY [R]EVOLUTION SCENARIO. THE DATA FOR THIS REFERENCE CASE HAS BEEN IMPLEMENTED IN ENERGY-MODELLING SOFTWARE AND RECALCULATED, WHICH CAUSES SOME DEVIATION FROM THE ORIGINAL IEA RESULTS.

FIGURE 3 | CO_2 EMISSION DEVELOPMENT UNDER THE 100% ENERGY [R]EVOLUTION BY REGION, 2012 TO 2050

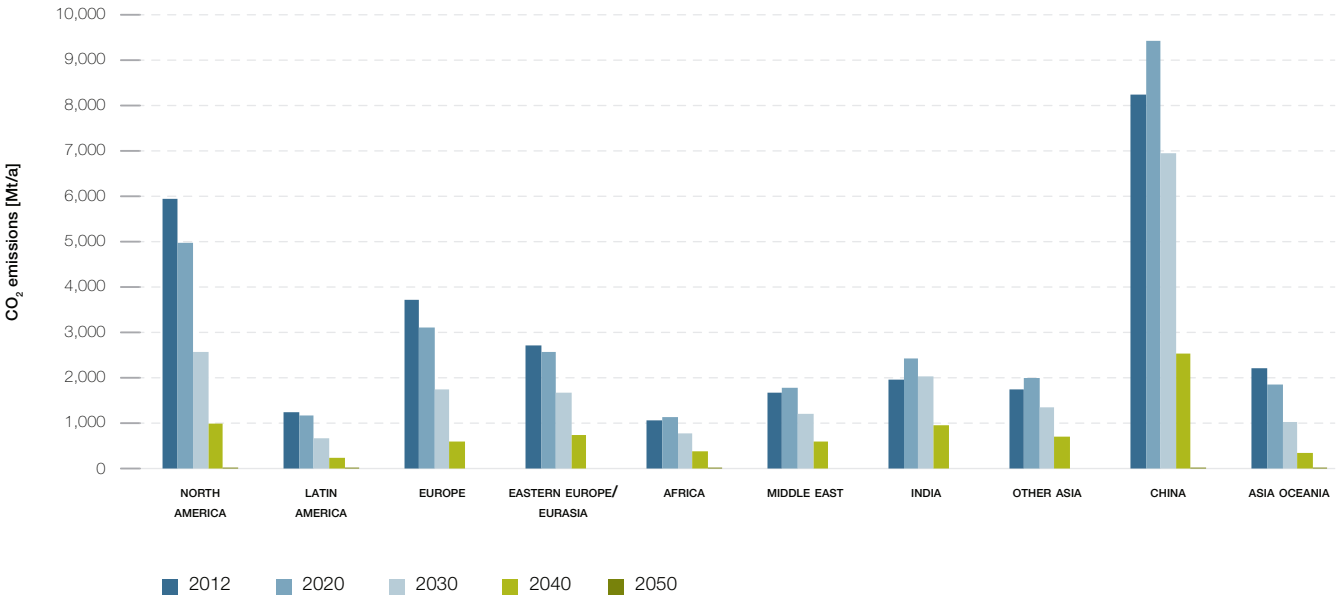
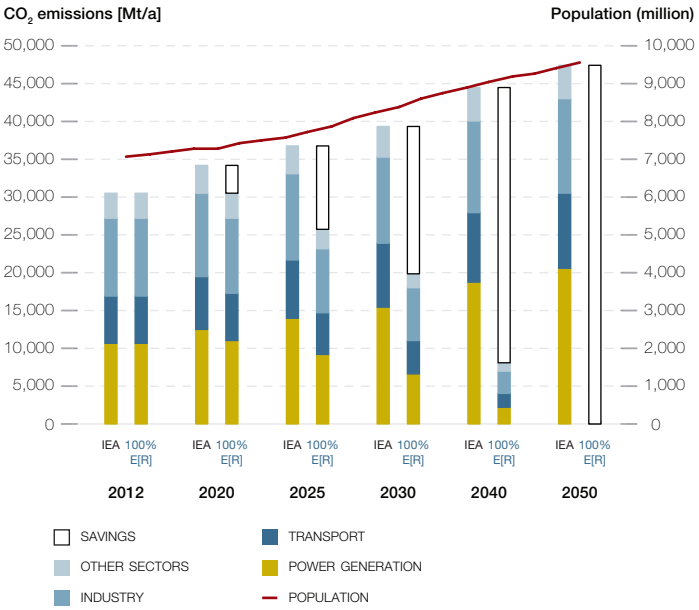


FIGURE 4 | DEVELOPMENT OF CO_2 EMISSIONS BY SECTOR UNDER THE 100% ENERGY [R]EVOLUTION

'SAVINGS' = REDUCTION COMPARED TO IEA CURRENT POLICIES



THE POWER INDUSTRY

Electricity replaces fuels, leading to a rise in electricity demand in all sectors. Technological advances and efficiency measures will limit demand in industry and homes, but there will be more demand overall because of the electrification of transport and the need to generate synthetic fuels to replace fossil fuels.

Electricity demand in the transport sector will double by 2020 and again increase by a factor of 5 in order to achieve decarbonisation by 2050. Furthermore hydrogen and synthetic fuels – both produced with renewable power - will add to increased electricity demand. But the energy-related renovation of existing housing, the introduction of low energy standards and highly efficient air conditioning systems, sharply reduces energy demand in the housing sector.

The electricity supply industry is transformed by a dynamically growing renewable energy market. This trend will more than compensate for the phasing out of nuclear power production. By 2050, 100% of global electricity supply comes from renewable energy sources, with 23,600 GW of installed generation capacity. By 2020, wind and PV are the main contributors to the growing market share, followed by solar thermal, geothermal and wave energy.

Smart grids, demand side management, energy storage capabilities and other options will need to be expanded to increase the flexibility of the power system for grid integration and a secure supply of electricity.

The cost of transition

The introduction of renewable technologies slightly increases the cost of electricity generation, compared to the IEA scenario, though the difference is marginal – only some 0.2 to 2 US cents/kWh (excluding integration costs for storage or other load-balancing measures) depending on the region. In some countries, such as China and India, the Energy [R]evolution scenario is economical from the beginning and cheaper than conventional power supplies by 2020. As prices rise for conventional fuels, these costs will become economically favourable across all world regions by 2030, and by 2050 the fuel cost savings will be 1.7 US cents/kWh.

While the IEA scenario leads to total electricity supply costs more than doubling to $5.35 trillion in 2050, the Energy [R]evolution scenario sees overall generation costs of $6.2 trillion by 2050 but huge savings in fuel supply costs, especially in transport and industry, with the phase-out of fossil fuels. Because renewable energy has no fuel costs, the cost savings amount to $42 trillion or $1.1 trillion/year. So the additional investment costs of the 100% Energy [R]evolution scenario are covered entirely (107%) by fuel cost savings. There are no further fuel costs in renewable energy beyond 2050. The Energy [R]evolution scenario not only meets global CO_2 reduction targets, it also helps stabilise energy costs for societies.

Investment required

Around $64.6 trillion needs to be invested by 2050, or $1.6 trillion/year, for this to become a reality including investments for replacement of out-of-date plants. This includes high levels of investment for additional power plants for the production of synthetic fuels. About 95% of total investment in the power sector must shift towards renewables and cogeneration. By 2030 the only investment in fossil fuels is in gas power plants which are switched from natural gas to renewable hydrogen between 2035 and 2050.

Necessary steps

Policymakers should work with utilities and grid system operators, in addition to major energy consumers like energy intensive industries, to define new policy mechanisms and regulatory structures.

KEY RESULT OF THE ENERGY [R]EVOLUTION CASE:

Renewable Energies are cost competitive and a transition towards 100% renewables can be entirely financed by fuel cost savings.

FIGURE 5 | WORLD DEVELOPMENT OF ELECTRICITY GENERATION UNDER THE IEA "CURRENT POLICIES" AND THE ENERGY [R]EVOLUTION CASE

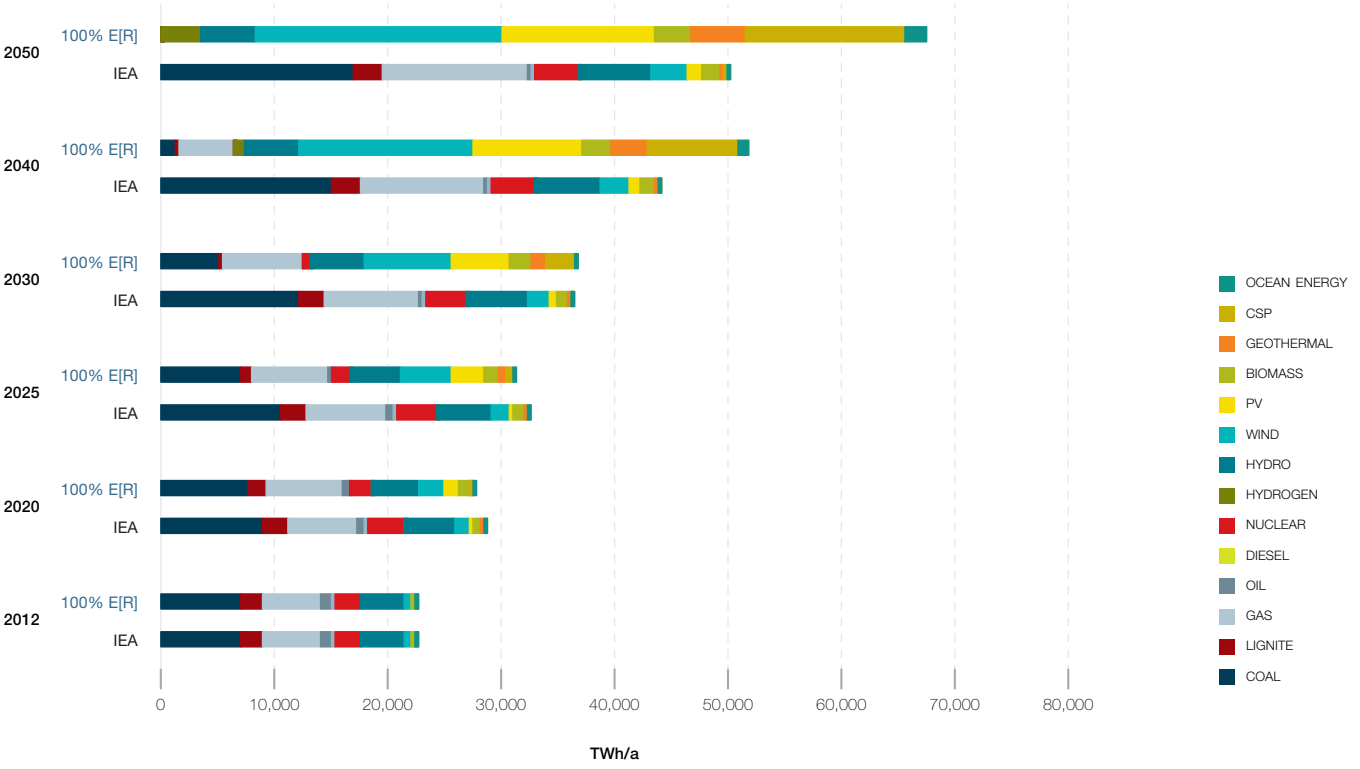


TABLE 1A | ACCUMULATED INVESTMENT COSTS FOR ELECTRICITY GENERATION AND FUEL COST SAVINGS UNDER THE 100% ENERGY [R]EVOLUTION SCENARIO COMPARED TO THE IEA "CURRENT POLICIES"

ACCUMULATED INVESTMENT COSTS DIFFERENCE IEA MINUS 100% E[R]	UNIT	2012-2020	2021-2030	2031-2040	2041-2050	2012-2050	2012 - 2050 AVERAGE PER YEAR
CONVENTIONAL (FOSSIL + NUCLEAR)	BILLION $	987.3	2,448.9	2,441.1	2,528.7	8,406.0	215.5
RENEWABLES (INCL. CHP)	BILLION $	-2,014.1	-11,835.8	-16,264.6	-18,555.9	-48,670.4	-1,248.0
TOTAL	BILLION $	-1,026.9	-9,386.9	-13,823.5	-16,027.1	-40,264.5	-1,032.4
ACCUMULATED FUEL COST SAVINGS SAVINGS CUMULATIVE 100% E[R] VERSUS IEA							
FUEL OIL	BILLION $	51.5	483.3	769.7	633.4	1,937.9	49.7
GAS	BILLION $	-113.0	1,502.4	6,057.6	12,315.0	19,761.9	506.7
HARD COAL	BILLION $	232.0	2,449.7	5,960.2	8,299.8	16,941.7	434.4
LIGNITE	BILLION $	32.5	253.7	442.3	562.2	1,290.8	33.1
NUCLEAR ENERGY	BILLION $	63.4	384.2	698.5	945.4	2,091.4	53.6
TOTAL	BILLION $	266.4	5,073.2	13,928.3	22,755.8	42,023.8	1,077.5

TABLE 1B | ACCUMULATED INVESTMENT COSTS FOR HEAT GENERATION UNDER THE 100% ENERGY [R]EVOLUTION SCENARIO COMPARED TO THE IEA CURRENT POLICIES

ACCUMULATED INVESTMENT COSTS DIFFERENCE IEA MINUS 100% E[R]	UNIT	2012-2020	2021-2030	2031-2040	2041-2050	2012-2050	2012 - 2050 AVERAGE PER YEAR
RENEWABLE	BILLION $	458.8	2,570.7	4,929.7	4,631.6	12,590.9	322.8

TABLE 2 | KEY PARAMETERS FOR RE MARKET EXPANSION UNDER THE IEA "CURRENT POLICIES" AND THE ENERGY [R]EVOLUTION CASE

	GENERATION [TWh/a]		INSTALLED CAPACITY [GW]		ANNUAL MARKET VOLUME [GW/a]		ANNUAL GROWTH RATE BASED ON GENERATION IN TWh/a [%/a]		ELECTRICITY SHARE	
	IEA	100% E[R]	IEA	100% E[R]	IEA	100% E[R]	IEA	100% E[R]	IEA	100% E[R]
2012	22,604	22,604	5,680	5,680						
2020	28,492	27,586	7,343	7,645						
2030	36,256	36,867	9,130	13,146						
2050	50,110	67,535	12,033	25,835						
PV										
2012	97	97	97	97	39	39				
2020	408	1090	332	844	29	93	23%	41%	1.4%	4.0%
2030	630	5067	494	3,725	16	288	5%	19%	1.7%	13.7%
2050	1096	13,613	803	9,295	15	279	3%	5%	2.2%	20.2%
CSP										
2012	5	5	3	3	1	1				
2020	34	131	11	42	1	5	33%	61%	0.1%	0.5%
2030	85	2552	26	635	1	59	11%	39%	0.2%	6.9%
2050	303	14,035	74	2,555	2	96	7%	9%	0.6%	20.8%
WIND ON+OFFSHORE										
2012	521	521	277	277	52	52				
2020	1,254	2,158	554	904	35	78	13%	23%	4.4%	7.8%
2030	1,962	7,737	807	3,064	25	216	5%	15%	5.4%	21.0%
2050	3,202	21,673	1217	8,040	21	249	3%	6%	6.4%	32.1%
GEOTHERMAL FOR POWER GENERATION										
2012	70	70	11	11	1	1				
2020	113	210	17	31	1	3	7%	17%	0.4%	0.8%
2030	188	1,149	28	171	1	14	6%	21%	0.5%	3.1%
2050	425	4,547	62	708	2	27	4%	8%	0.8%	6.7%
BIOENERGY FOR POWER GENERATION										
2012	379	379	87	87	8	8				
2020	740	979	150	200	8	14	10%	15%	2.6%	3.5%
2030	1,039	1,993	199	405	5	21	4%	8%	2.9%	5.4%
2050	1,577	3,193	293	742	5	17	2%	3%	3.1%	4.7%
OCEAN										
2012	1	1	0	0	0	0				
2020	3	32	1	11	0	1	29%	81%	0.0%	0.1%
2030	13	363	4	131	0	12	15%	31%	0.0%	1.0%
2050	76	2,010	28	738	1	30	11%	9%	0.2%	3.0%
HYDRO										
2012	3,672	3,672	1,099	1,099	37	37				
2020	4,458	4,349	1,331	1,316	29	27	3%	2%	15.6%	15.8%
2030	5,207	4,621	1,544	1,402	21	9	2%	1%	14.4%	12.5%
2050	6,431	4,966	1,878	1,536	17	7	1%	0%	12.8%	7.4%

THE HEATING SECTOR

Today renewables meet around 21% of global energy demand for heating, most coming from biomass. Energy efficiency measures help reduce the current growing demand for heating by 33% in 2050. Up to 2030, biomass retains the largest share of a growing market, while the share of renewable heating doubles to 43%. After 2030, solar collectors and geothermal and environmental heat, as well as heat from renewable hydrogen, further reduces dependence on fossil fuels. By 2050, hydrogen generated from renewable electricity replaces the remaining gas consumption.

Cost

A major revision of current investment strategies is required, with far more solar thermal, geothermal and heat pump technologies needed in the heating sector.

Renewable heating technologies are variable, from low-tech biomass stoves and unglazed solar collectors to sophisticated enhanced geothermal and solar arrays. The investment required is about $429 billion/year.

Necessary steps

Policymakers at all levels of government must support the development of renewable heat, given the large share of heat in final energy demand. Further development of integrated approaches for the heating and electricity sectors also can contribute to reducing grid pressure and will keep the amount of bio energy within sustainable limits.

FIGURE 6 | PROJECTION OF HEAT SUPPLY BY SOURCE. IEA "CURRENT POLICIES" VERSUS 100% ENERGY [R]EVOLUTION

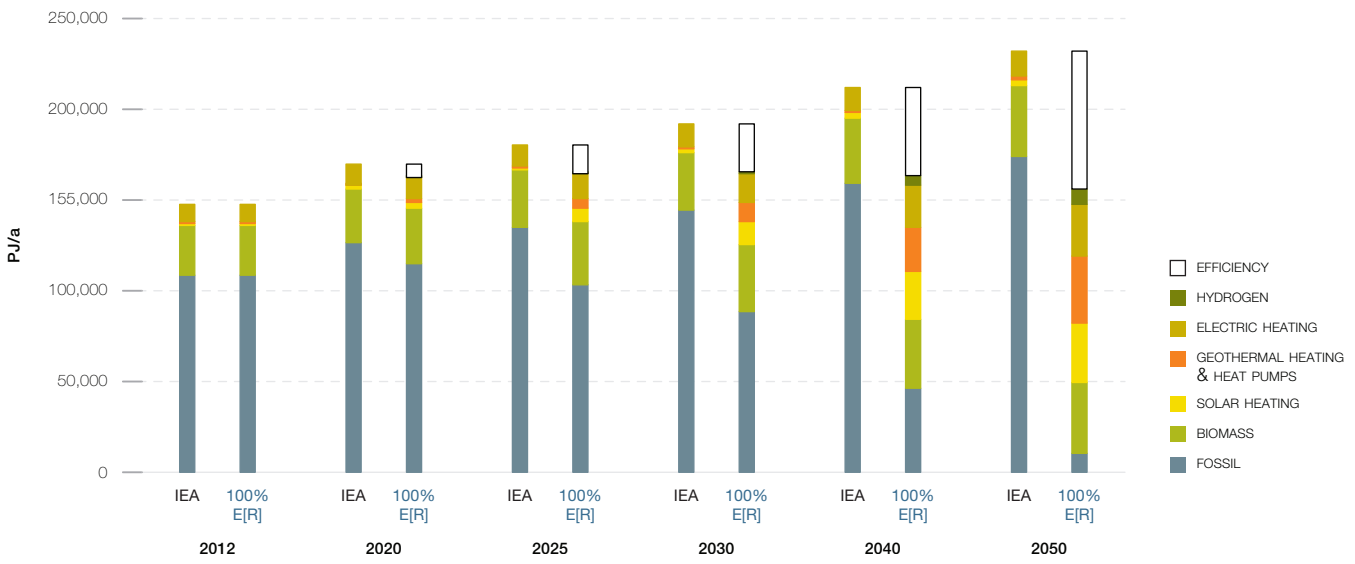
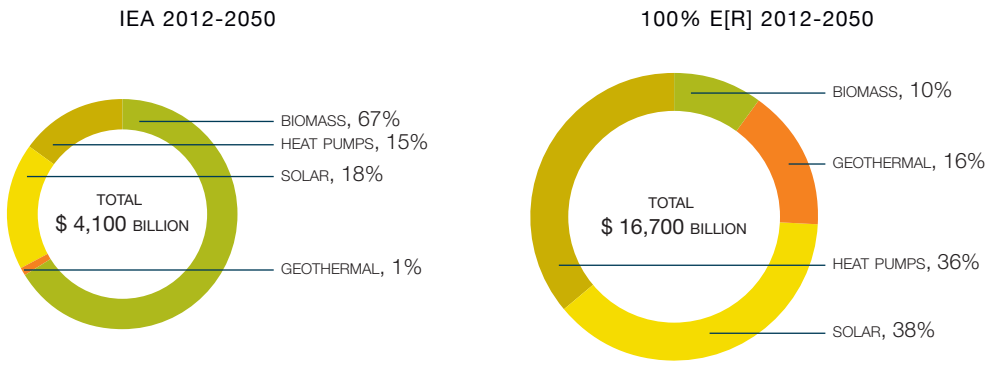


FIGURE 7 | DEVELOPMENT OF INVESTMENTS FOR RENEWABLE HEAT GENERATION TECHNOLOGIES UNDER THE SCENARIOS



THE IMPACT ON ENERGY SECTOR JOBS – A JUST TRANSITION FROM FOSSIL FUELS TO RENEWABLES

At every stage, the Energy [R]evolution scenario results in more energy sector jobs. While the IEA scenario sees energy sector jobs increase slightly to 2020, after which they decline, the Energy [R]evolution produces a 25% increase by 2020, and job numbers grow nearly 60% above 2015 levels in 2025. Job numbers continue to rise after 2025, reaching more than 46 million by 2030, driven by strong growth and investment in the renewable sector.

Renewable energy accounts for 86% of all energy jobs by 2030. Solar photovoltais will provide 9.7 million jobs, equal to the amount of coal jobs today. Employment in the wind sector will increase by a factor of 10 from 0.7 million today to over 7.8 million in 2030, twice asmany jobs as the current oil and gas industry.

Necessary steps

Stability and predictability of policy frameworks are both required to underpin the sustained deployment of renewable energy and the just transition from dirty to renewable. The renewable energy industry needs predictability in order to attract investment, build up production capacity, develop new technologies, and expand the number of sustainable jobs.

By 2030 the solar industry could employ the same number of people as the coal industry today, over 9.5 million. A "just transition" initiative is required, so no-one is left behind.

FIGURE 8 | GLOBAL PROPORTION OF FOSSIL FUEL AND RENEWABLE EMPLOYMENT IN 2015 AND 2030 UNDER THE IEA "CURRENT POLICIES" AND THE 100% ENERGY [R]EVOLUTION CASE

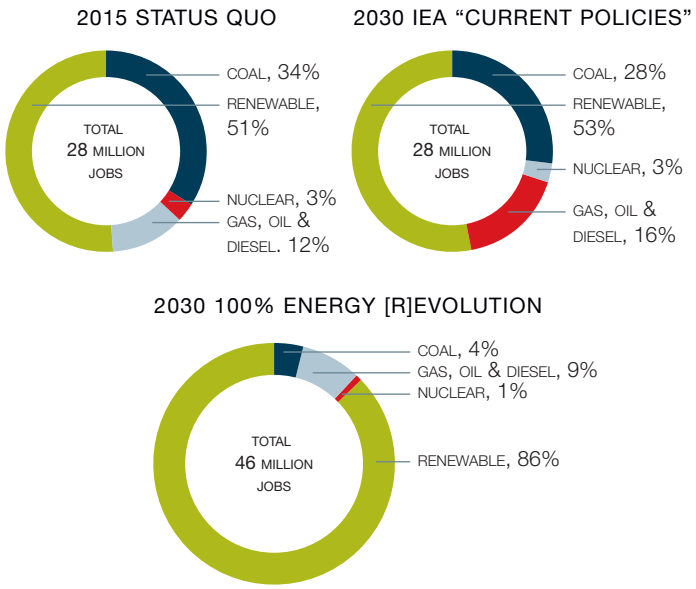


TABLE 3 | GLOBAL TOTAL EMPLOYMENT, ENERGY SECTOR WORKERS UNDER THE IEA "CURRENT POLICIES" AND THE 100% ENERGY [R]EVOLUTION CASE IN MILLION JOBS

		IEA CURRENT POLICIES			100% E[R]		
	2015	2020	2025	2030	2020	2025	2030
BY FUEL							
COAL	9.68	9.59	8.56	7.62	4.78	3.27	1.96
GAS, OIL & DIESEL	3.51	3.96	4.30	4.37	3.91	4.08	3.93
NUCLEAR	0.71	0.84	0.80	0.71	0.51	0.50	0.49
RENEWABLES	14.48	15.24	15.40	14.64	26.28	37.36	39.76
TOTAL JOBS	28.38	29.62	29.06	27.34	35.48	45.21	46.14
BY SECTOR							
CONSTRUCTION AND INSTALLATION	4.74	4.96	4.47	3.81	7.96	13.84	14.62
MANUFACTURING	2.33	2.38	2.18	1.85	5.37	8.59	9.18
OPERATIONS AND MAINTENANCE	3.10	3.79	4.13	4.09	4.62	6.64	8.54
FUEL SUPPLY (DOMESTIC)	17.60	17.83	17.60	16.91	17.08	15.75	13.43
COAL AND GAS EXPORT	0.61	0.66	0.67	0.69	0.45	0.39	0.37
TOTAL JOBS (MILLION)	28.38	29.62	29.06	27.34	35.48	45.21	46.14
BY TECHNOLOGY							
COAL	9.68	9.59	8.56	7.62	4.78	3.27	1.96
GAS, OIL & DIESEL	3.51	3.96	4.30	4.37	3.91	4.08	3.93
NUCLEAR	0.71	0.84	0.80	0.71	0.51	0.50	0.49
BIOMASS	10.93	11.80	12.00	11.71	11.94	12.38	11.35
HYDRO	1.39	1.39	1.39	1.22	0.96	0.79	0.68
WIND	0.69	0.71	0.75	0.64	4.10	6.65	7.82
PV	1.00	0.84	0.81	0.63	6.46	10.52	9.69
GEOTHERMAL POWER	0.03	0.03	0.03	0.03	0.18	0.29	0.37
SOLAR THERMAL POWER	0.02	0.04	0.05	0.07	0.42	1.58	2.50
OCEAN	0.00	0.00	0.00	0.01	0.22	0.43	0.63
SOLAR - HEAT	0.36	0.37	0.33	0.30	1.54	3.78	5.33
GEOTHERMAL & HEAT PUMP	0.07	0.05	0.04	0.04	0.46	0.95	1.40
TOTAL JOBS (MILLION)	28.38	29.62	29.06	27.34	35.48	45.21	46.14

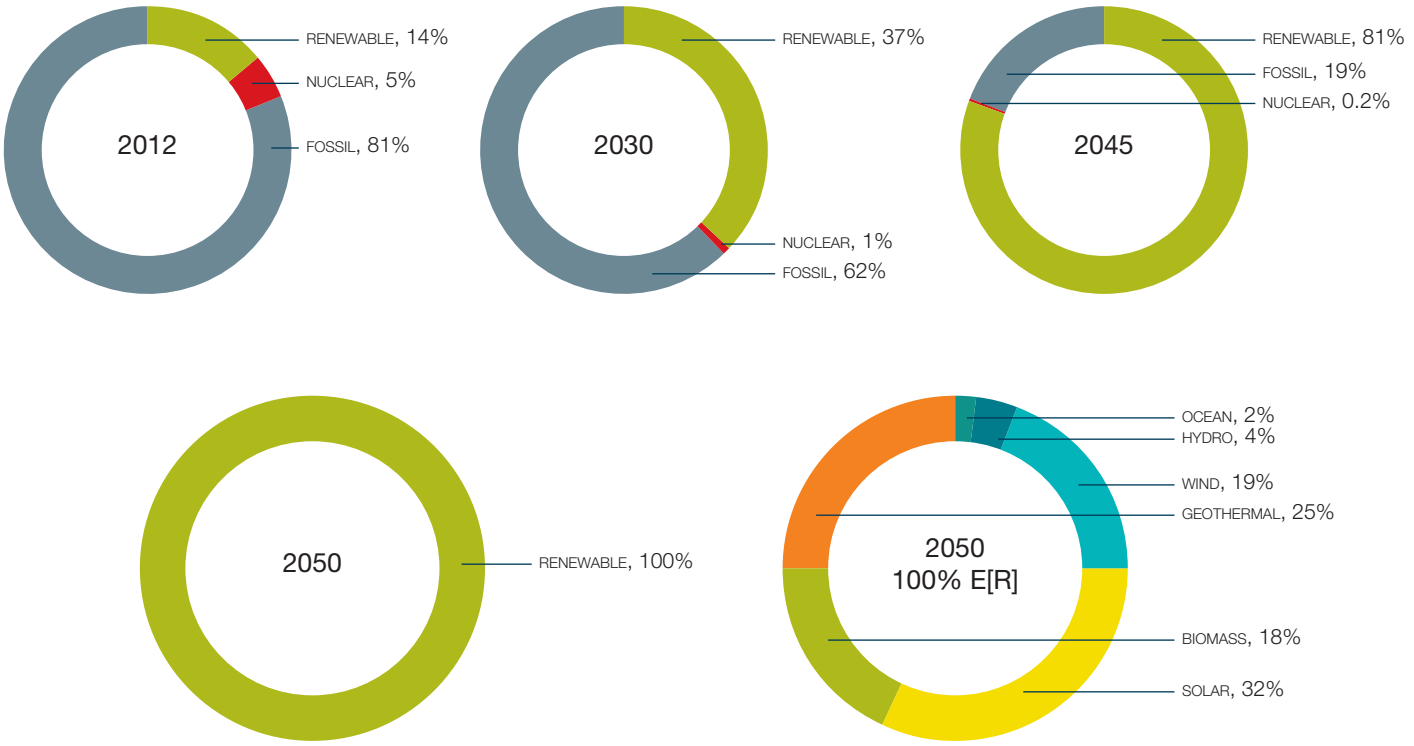
THE REQUIREMENTS FOR THE TRANSITION

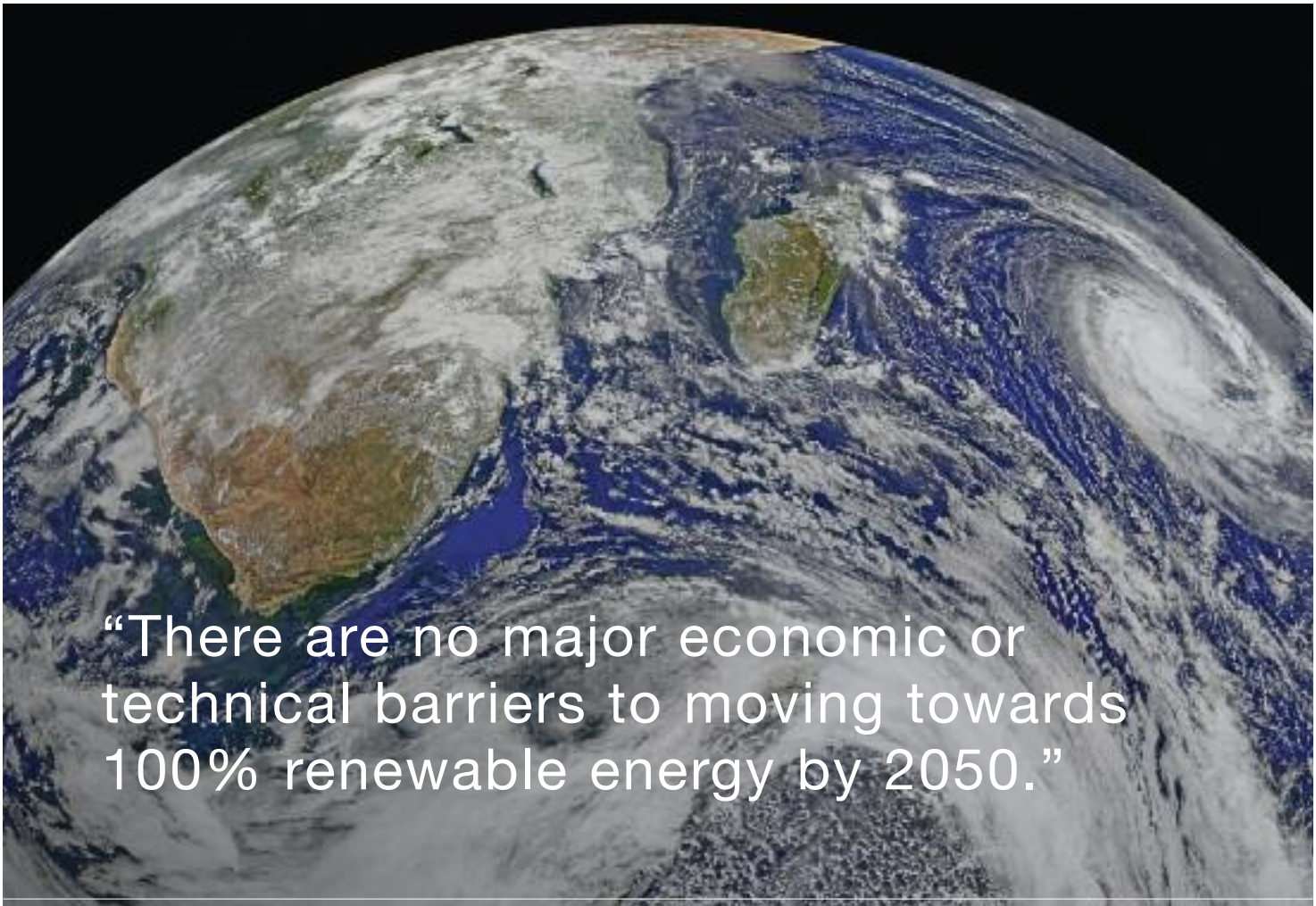
Immediate political action is required to make this Energy [R]evolution scenario a reality. There are no major economic or technical barriers to moving towards 100% renewable energy by 2050. The renewable energy sector is delivering change, but political action is needed to ensure it happens in time. It is up to political and business leaders to steer industry, influence consumers and stimulate markets towards renewable energy and energy efficiency. A starting point is to agree on further binding emissions reductions at the Paris conference under the UNFCCC process.

An effective climate agreement should include strong short-term action and set out a clear long-term pathway. It needs to include the following:

- A strong long-term goal, phasing out fossil fuels and nuclear power by 2050 through a just transition to 100% renewable energy, as well as the protection and restoration of forests.
- A 5-year commitment cycle for countries, starting in 2020, to encourage countries to deepen their commitments and discourage back-sliding.
- A legally-binding agreement, including common accounting rules for mitigation and finance, to encourage leaders to act boldly.
- A shifting of subsidies away from fossil fuels by 2020.
- A strong commitment for adaptation, finance and loss and damage, $100 billion annually by 2020 for the Energy [R]evolution and adaptation.
- A commitment to bring down emissions before 2020, in order to keep global warming below 2/1.5 degrees C°.

FIGURE 9 | DEVELOPMENT OF GLOBAL ENERGY INVESTMENTS UNDER THE 100% ENERGY [R]EVOLUTION CASE





“There are no major economic or technical barriers to moving towards 100% renewable energy by 2050.”

GREENPEACE

UMWELTSTIFTUNG | GREENPEACE

Greenpeace is a global organisation that uses non-violent direct action to tackle the most crucial threats to our planet’s biodiversity and environment. Greenpeace is a non-profit organisation, present in 40 countries across Europe, the Americas, Africa, Asia and the Pacific. It speaks for 2.8 million supporters worldwide, and inspires many millions more to take action every day. To maintain its independence, Greenpeace does not accept donations from governments or corporations but relies on contributions from individual supporters and foundation grants. Greenpeace has been campaigning against environmental degradation since 1971 when a small boat of volunteers and journalists sailed into Amchitka, an area west of Alaska, where the US Government was conducting underground nuclear tests. This tradition of ‘bearing witness’ in a non-violent manner continues today, and ships are an important part of all its campaign work.

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