Cost-effectiveness of Clean Energy R&D policy research

	Pessimistic	Realistic	Optimistic	Notes	Source	Further notes
Annual Clean Energy R&D budget in $billion to increase	$7.1bn [1]	$11.1bn	$15.0bn [2]	Pessimistic assumption: **only** the $7.1bn/year U.S. public clean energy R&D budget will increase. Optimistic assumption: clean energy R&D budget of all Mission Innovation signatory countries will double from $15bn/year in 2016	ITIF analysis based on International Energy Agency data	
Counterfactual percentage increase by 2021	1% [3]	10%	50% [4]	Pessimistic assumption: Assumes just a 1% increase in the U.S. clean energy R&D budget. Optimistic assumption: Mission Innovation countries committed to double clean energy R&D funding from $15 billion in 2016 to $30 billion by 2021, but will only meet 50% of their targets based on current trends. The optimistic case assumes that they will meet their targets i.e. the other 50% — this is equal to $7.5bn counterfactual increase	ITIF report based on data from the International Energy Agency	"[...] MI members committed to double clean energy RD&D funding within 5 years from a baseline of $15 billion in 2016 to $30 billion by 2021. [citation ink]
Chance of ITIF's policy research leading to spending increase	1%	5%	10%	Intuition: a grant to a leading US think tank to intensify their work might result in budget increases, especially given the tractability and public support of clean energy R&D	Subjective input	"If the member countries stay on their current feeble growth trajectory, MI will reach only 50 percent of its target. Based
Cost: project expenses in $	$2,000,000 [5]	$1,500,000 [6]	$500,000 [7]	**Pessimistic assumption:** $2,000,000 over three years ($667,000/year), equivalent to the mean salary of 4 additional staff. **Realistic assumption:** $1,500,000 over three years ($500,000/year), equivalent to the mean salary of 3 additional staff. **Optimistic case:** $500,000 over three years ($167,000/year), equivalent to the mean salary of 1 additional staff.	See "Room for more funding analysis [ADD ANCHORED LINK IN THE END"	https://itif.org/publications/2018/12/10/mission-innovation-missing-element-most-countries-response-climate-change
Benefits: Counterfactual increase in clean energy R&D funding / year	$710,000	$55,250,000	$750,000,000		See "Room for more funding analysis [ADD ANCHORED LINK IN THE END"	
Benefit/cost ratio: $ in clean energy R&D spending increases per dollar spent on policy	0.4	37	1500	Leverage: $ in clean energy R&D spending increases per dollar spent on policy		
Benefits minus cost	-$1,290,000	$53,750,000	$749,500,000	Absolute counterfactual increase in clean energy R&D funding minus the costs of the policy research		
Energy publications per $1 million dollar	1	1.5	2	$1 million clean energy R&D funding increase leads to 1-2 additional publications in energy	2016 paper Economic analysis of scientific publications and implications for energy research and development .	
Cost of a energy publication by donating to this project	$2,816,901	$27,149	$667	$1 million / Benefit-Cost ratio	2016 paper Economic analysis of scientific publications and implications for energy research and development .	
Global income-weighted social cost of carbon per tonne of CO2	$177	$417 [8]	$805	Global Social cost of carbon (median, US$417 per tonne of CO2 (tCO2); 66% confidence intervals, US$177–805 per tCO2)	2018 study calculated the social cost of carbon on a country-level taking into account differences in future economic damages, GDP and population.	
Cost per tonne of CO2e averted in US energy sector alone	$37.88	$0.37	$0.01		2017 US Department of Energy Quadrennial Energy Review	
Benefit cost ratio: $ in social welfare created / $	$5	$1,142	$89,804			
Energy source weighted change in cost due to increase	enter the most pessimistic expert here (0.00%)	use the measure of central tendency from	Enter most optimistic expert average here (-17.78%)	Pessimistic: the most pessimistic expert across all studies	2018 meta-analysis summarized the results of several studies that all asked several experts by how much clean energy prices would decrease if clean energy R&D were to increase	
Elasticity (i.e. proportionate change in demand given a change in cost)	1 [9]	2	2.9	"The elasticity of substitution between clean and dirty energy inputs within the energy aggregate of the nonenergy sector and the elasticity of substitution between clean and dirty capacity in the electricity sector [are] 2 in the electricity-generating sector and values close to 3 in nonenergy industries. "	2017 Substitution between Clean and Dirty Energy Inputs: A Macroeconomic Perspective	
Increase in demand (cost decrease * elasticity)	#VALUE!	#VALUE!	#VALUE!			
Emission reduction	#REF!	#REF!	#REF!			
$ per tonne of CO2 averted	#REF!	#REF!	#REF!			
Benefit cost ratio (Social cost / $ per tonne of CO2 averted)	#REF!	#REF!	#REF!			
Overall benefit minus cost (Potential Gigatonnes averted per overall R&D increase in $billion)						

Cost-effectiveness of Clean Energy R&D policy research

	Pessimistic	Realistic	Optimistic	Notes	Source	Further notes

Cost-effectiveness of Clean Energy R&D policy research

	Pessimistic	Realistic	Optimistic	Notes	Source	Further notes

Technology	Bioelectricity	Bioelectricity	Bioelectricity	Bioelectricity	Bioelectricity	Bioelectricity	Bioelectricity	Bioelectricity	Bioelectricity	Biofuel
Study	FEEM	FEEM	FEEM	Harvard	Harvard	Harvard	UMass	UMass	UMass	FEEM
# experts	16	16	16	5	5	5	4	4	4	15
Investment scenario	Low	Mid	High	Low	Mid	High	Low	Mid	High	Low
RD&D Level (million 2010$)	$169	$254	$338	$214	$585	$5,850	$15	$50	$150	$168
Pessimistic_interval	1.30%	0.56%	0.31%	-3.61%	-3.33%	-3.33%	-0.77%	-2.82%	-5.47%	-1.71%
median	-1.34%	-1.55%	-1.83%	-7.23%	-7.26%	-7.18%	-2.99%	-6.07%	-6.92%	-2.82%
Optimistic_interval	-3.85%	-4.72%	-5.75%	-9.75%	-9.74%	-9.74%	-5.98%	-8.55%	-10.68%	-4.79%
% decrease energy costs per $million R&D spent										
Pessimistic	0.009%	0.003%		-0.001%	0.000%		0.059%	0.026%		0.011%
Median [10]	0.002%	0.003%		0.000%	0.000%		0.088%	0.009%		0.018%
Optimistic	0.010%	0.012%		0.000%	0.000%		0.073%	0.021%		0.015%
Average expert-weighted % decrease energy costs per $million										
Pessimistic	0.01%									0.01%
Median [11]	0.01%									0.00%
Optimistic	0.01%									0.01%

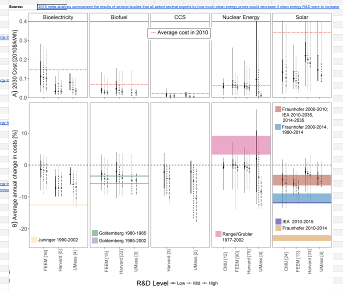
Technology	Biofuel	Biofuel	Biofuel	Biofuel	Biofuel	Biofuel	Biofuel	CCS	CCS	CCS
Study	FEEM	FEEM	Harvard	Harvard	Harvard	UMass	UMass	Harvard	Harvard	Harvard
# experts	15	15	22	22	22	3	3	3	3	3
Investment scenario	Mid	High	Low	Mid	High	Mid	High	Low	Mid	High
RD&D Level (million 2010$)	$252	$336	$214	$585	$5,850	$201	$838	$701	$2,250	$22,500
Pessimistic_interval	-2.62%	-3.24%	0.89%	-0.56%	-2.08%	-2.41%	-2.82%	0.26%	0.00%	-0.51%
median	-4.31%	-4.43%	-2.04%	-2.91%	-3.98%	-4.84%	-4.80%	-2.22%	-4.10%	-4.27%
Optimistic_interval	-6.08%	-6.94%	-5.42%	-5.42%	-6.86%	-9.09%	-9.09%	-7.18%	-10.34%	-10.43%
% decrease energy costs per $million R&D spent										
Pessimistic	0.007%		0.004%	0.000%		0.001%		0.000%	0.000%	
Median [10]	0.001%		0.002%	0.000%		0.000%		0.001%	0.000%	
Optimistic	0.010%		0.000%	0.000%		0.000%		0.002%	0.000%	
Average expert-weighted % decrease energy costs per $million										
Pessimistic								0.01%		
Median [11]								0.04%		
Optimistic								0.05%		

Technology	CCS	CCS	CCS	Nuclear	Nuclear	Nuclear	Nuclear	Nuclear	Nuclear	Nuclear
Study	UMass	UMass	UMass	FEEM	FEEM	FEEM	Harvard	Harvard	Harvard	UMass
# experts	2	2	2	90	90	90	75	75	75	4
Investment scenario	Low	Mid	High	Low	Mid	High	Low	Mid	High	Low
RD&D Level (million 2010$)	$13	$48	$108	$800	$1,514	$15,140	$466	$1,883	$18,833	$40
Pessimistic_interval	1.28%	0.00%	-1.54%	1.71%	1.11%	0.17%	0.85%	0.68%	-0.09%	10.77%
median	-2.05%	-5.04%	-10.51%	0.00%	0.00%	-0.68%	-0.60%	-0.68%	-1.11%	1.88%
Optimistic_interval	-8.97%	-16.67%	-17.78%	-1.11%	-1.11%	-1.88%	-1.28%	-1.79%	-2.56%	-8.38%
% decrease energy costs per $million R&D spent										
Pessimistic	0.037%	0.026%		0.001%	0.000%		0.000%	0.000%		0.015%
Median [10]	0.085%	0.091%		0.000%	0.000%		0.000%	0.000%		0.013%
Optimistic	0.220%	0.019%		0.000%	0.000%		0.000%	0.000%		0.010%
Average expert-weighted % decrease energy costs per $million										
Pessimistic				0.001%						
Median [11]				0.000%						
Optimistic				0.000%						

Technology	Nuclear	Nuclear	Solar	Solar	Solar	Solar	Solar	Solar	Solar	Solar
Study	UMass	UMass	FEEM	FEEM	FEEM	Harvard	Harvard	Harvard	UMass	UMass
# experts	4	4	13	13	13	33	33	33	3	3
Investment scenario	Mid	High	Low	Mid	High	Low	Mid	High	Low	Mid
RD&D Level (million 2010$)	$480	$1,980	$171	$257	$342	$143	$409	$4,090	$25	$140
Pessimistic_interval	4.10%	-5.30%	-4.36%	-4.44%	-4.96%	-0.85%	-1.97%	-2.39%	-2.14%	-3.25%
median	-3.76%	-8.29%	-5.90%	-6.50%	-7.01%	-2.22%	-2.56%	-3.16%	-4.19%	-5.21%
Optimistic_interval	-12.65%	-12.56%	-6.75%	-8.21%	-9.15%	-2.91%	-3.68%	-3.68%	-6.32%	-6.75%
% decrease energy costs per $million R&D spent										
Pessimistic	0.006%		0.001%	0.006%		0.004%	0.000%		0.010%	
Median [10]	0.003%		0.007%	0.006%		0.001%	0.000%		0.009%	
Optimistic	0.000%		0.017%	0.011%		0.003%	0.000%		0.004%	
Average expert-weighted % decrease energy costs per $million										
Pessimistic			0.0028%							
Median [11]			0.0026%							
Optimistic			0.0049%							

Average expert-weighted % decrease energy costs per $million R&D spent				Note	Source
	Pessimistic	**Median**	**Optimistic**		
Bioelectricity	0.008%	0.009%	0.012%		
Biofuel	0.005%	0.005%	0.006%		
Average Bio	0.006%	0.007%	0.009%		
Elasticity (i.e. proportionate change in demand given a change in	1.00 [12]	2.00	2.90	"The elasticity of substitution betw	2017 Substitution between Clean and Dirty Energy In
Coefficient					
BioEnergy Demand	7.27	7.27	7.27		World Energy Outlook 2018
CSS					
Annual CCS cost reduction per million dollar	0.01%	0.04%	0.05%		
Annual CCS Demand	0.58	0.58	0.58	"In the SDS, 11.6 Gt CO2 are capt	International Energy Agency
Elasticity (i.e. proportionate change in demand given a change in	1 [13]	2	2.9	"The elasticity of substitution betw	2017 Substitution between Clean and Dirty Energy In
Gigatonnes of CO2 averted per 1bn / $ per tonne of CO2 averted	0.07948938064	0.4725539347	0.7664619708		
$ per tonne of CO2 averted	$12.58	$2.12	$1.30		
Nuclear					
Nuclear Cost decrease per $1 million R&D spent	0.0002%	0.0002%	0.0005%		
Elasticity (i.e. proportionate change in demand given a change in	1 [14]	2	2.9	"The elasticity of substitution betw	2017 Substitution between Clean and Dirty Energy In
Increase in Nuclear Demand (Proportion)	0.0002%	0.0004%	0.0015%		
Current Nuclear Demand (Mtoe)	688	688	688		
Increase in Nuclear Demand (Mtoe)	0.002	0.003	0.011		
Decrease in CO2 (Gt) per Mt of Nuclear added	0.98%	0.98%	0.98%		
Decrease in CO2 (Gt) per $1 Billion spent	0.014843	0.029703	0.104208		
$ per tonne of CO2 averted	$67	$34	$10		
Solar cost reduction	0.0026%	0.0028%	0.0049%		
Solar demand per year	75	100	125	~100 GW a year in annual solar de	International Energy Agency
Elasticity (i.e. proportionate change in demand given a change in	1 [15]	2	2.9	"The elasticity of substitution betw	2017 Substitution between Clean and Dirty Energy In
CO2 averted by one GW of solar					https://www.irena.org/climatechange/Avoided-Emissi
Cost per tonne of CO2e averted					

Source: 2018 meta-analysis summarized the results of several studies that all asked several experts by how much clean energy prices would decrease if clean energy R&D were to increase



Scenarios
1.1 Overview
Table 1.1 ▷ **World primary energy demand by fuel and scenario** (Mtoe)

Source: World Energy Outlook 2018 | Global Energy Trends

Notes: Mtoe = million tonnes of oil equivalent; Gt = gigatonnes. Solid biomass includes its traditional use in three-

	historical	current	New Policies		Current Policies		Sustainable Development	
	2000	2017	2025	2040	2025	2040	2025	2040
Coal	2,308	3,750	3,768	3,809	3,998	4,769	3,045	1,597
Oil	3,665	4,435	4,754	4,894	4,902	5,570	4,334	3,156
Gas	2,071	3,107	3,539	4,436	3,616	4,804	3,454	3,433
Nuclear	675	688	805	971	803	951	861	1,293
Renewables	662	1,334	1,855	3,014	1,798	2,642	2,056	4,159
Hydro	225	353	415	531	413.00	514	431	601
Modern bioenergy	377	727	924	1,260	906	1,181	976	1,427
Other	60	254	516	1,223	479	948	648	2,132
Solid biomass	646	658	666	591	666	591	396	77
Total	**10,027**	**13,972**	**15,387**	**17,715**	**15,783**	**19,327**	**14,146**	**13,715**
Fossil fuel share	80%	81%	*78%*	*74%*	*79%*	*78%*	*77%*	*60%*
CO2 emissions (Gt)	**23.1**	**32.6**	**33.9**	**35.9**	**35.5**	**42.5**	**29.5**	**17.6**

Increase in nuclear, decrease in CO2

Increase in Modern bioenergy, decrease in CO2

		Coal	Oil	Gas	Nuclear	Renewables	Hydro	Modern bioenergy	Other	Solid biomass	**Total**	Fossil fuel share	**CO2 emissions (Gt)**
historical	2000	2,308	3,665	2,071	675	662	225	377	60	646	**10,027**	80%	**23.1**
current	2017	3,750	4,435	3,107	688	1,334	353	727	254	658	**13,972**	81%	**32.6**
New Policies	2025	3,768	4,754	3,539	805	1,855	415	924	516	666	**15,387**	*78%*	**33.9**
	2040	3,809	4,894	4,436	971	3,014	531	1,260	1,223	591	**17,715**	*74%*	**35.9**
Current Policies	2025	3,998	4,902	3,616	803	1,798	413.00	906	479	666	**15,783**	*79%*	**35.5**
	2040	4,769	5,570	4,804	951	2,642	514	1,181	948	591	**19,327**	*78%*	**42.5**
	2025	3,045	4,334	3,454	861	2,056	431	976	648	396	**14,146**	*77%*	**29.5**
Sustainable Development	2040	1,597	3,156	3,433	1,293	4,159	601	1,427	648	77	**13,715**	*60%*	**17.6**

http://structural-analyser.com/domains/regression/

Nuclear (co-efficient)

https://www.mitpressjournals.org/doi/abs/10.1162/REST_a_00592

Non-energy: In doing so, we are adding up biogasoline, biodiesel, biogas, other renewables, electricity, heat production, hydro, geothermal, solar, wind, other sources, nuclear, and waste into the clean aggregate. All other types of energy-generating technologies sum up to the dirty aggregate.

	Elasticity of Substitution	Substitution Parameter	Elasticity of Substitution (Using estimated capital stock rather than Gwh)	allows substitution between dirty capacity and dirty fuels assuming a unitary elasticity
Electrity	1.84	0.46	1.734	2.031

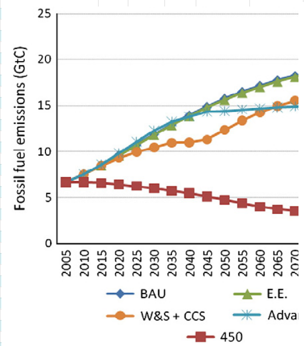
	Non-linear CES	Linear CES
Non-energy	2.868	1.651

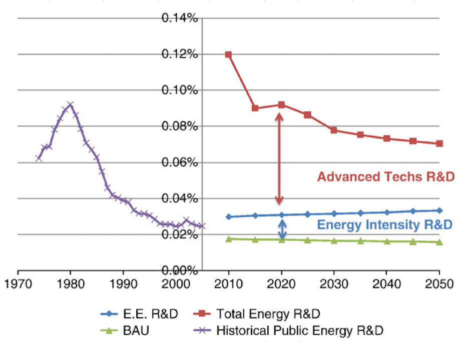
	RD&D Level (million 2010$)														
	Bioelectricity			**Biofuel**			**CCS**			**Nuclear**			**Solar**		
	Low	**Medium**	**High**	**Low**	**Medium**	**High**	**Low**	**Medium**	**High**	**Low**	**Medium**	**High**	**Low**	**Medium**	**High**
UMass	15	50	150	13	201	838	13	48	108	40	480	1980	25	140	
Harvard	214	585	5,850	*Combined w/ bioelectricity*			701	2,250	22,500	466	1,883	18,833	143	409	4,090
FEEM	169	254	338	168	252	336				800	1,514	15,140	171	257	342
CMU							0	10 BAU		BAU			BAU	10 BAU	

			UMass	Harvard	FEEM	CMU
		Low	15	214	169	
		Medium	50	585	254	
	Bioelectricity	**High**	150	5,850	338	
	Biofuel	**Low**	13		168	
		Medium	201		252	
		High	838	*Combined w/ bio*	336	
	CCS	**Low**	13	701		BAU
		Medium	48	2,250		10 BAU
		High	108	22,500		
	Nuclear	**Low**	40	466	800	BAU
		Medium	480	1,883	1,514	
		High	1980	18,833	15,140	
	Solar	**Low**	25	143	171	BAU
		Medium	140	409	257	10 BAU
RD&D Level (mi		**High**		4,090	342	

R&D scenario	Year	Fossil fuel Emissions in GtC	averted	Sum of years * 5 to fill in missing years	Scenario	Year	% of GWP	GWP	Difference in % of GWP		GWP in $trillion (approximation)	Cost in trillion	Benefits: Cumulative emissions averted in Gigatonnes	R&D costs in billions	Cost per tonne of CO2e averted
Advanced Tech R&D	2045	14.2	0.5	176.0208834	Advanced R&D	2010	0.12	0.12%	0.10%	3.05%	100	3.047058824	176	$3,047bn	$17
BAU	2045	14.7			BAU	2010	0.02	0.02%							
Advanced Tech R&D	2050	14.4	0.9		Advanced R&D	2015	0.09	0.09%	0.07%						
BAU	2050	15.3			BAU	2015	0.02	0.02%							
Advanced Tech R&D	2055	14.5	1.8		Advanced R&D	2020	0.09	0.09%	0.08%						
BAU	2055	16.2			BAU	2020	0.02	0.02%							
Advanced Tech R&D	2060	14.6	2.2		Advanced R&D	2025	0.09	0.09%	0.07%						
BAU	2060	16.8			BAU	2025	0.02	0.02%							
Advanced Tech R&D	2065	14.7	2.7		Advanced R&D	2030	0.08	0.08%	0.06%						
BAU	2065	17.4			BAU	2030	0.02	0.02%							
Advanced Tech R&D	2070	14.8	3.0		Advanced R&D	2035	0.08	0.08%	0.06%						
BAU	2070	17.8			BAU	2035	0.02	0.02%							
Advanced Tech R&D	2075	14.9	3.4		Advanced R&D	2040	0.07	0.07%	0.06%						
BAU	2075	18.2			BAU	2040	0.02	0.02%							
Advanced Tech R&D	2080	15.0	3.7		Advanced R&D	2045	0.07	0.07%	0.06%						
BAU	2080	18.7			BAU	2045	0.02	0.02%							
Advanced Tech R&D	2085	15.1	3.9		Advanced R&D	2050	0.07	0.07%	0.05%						
BAU	2085	19.0			BAU	2050	0.02	0.02%							
Advanced Tech R&D	2090	15.2	4.1												
BAU	2090	19.3													
Advanced Tech R&D	2095	15.3	4.4												
BAU	2095	19.6													
Advanced Tech R&D	2100	15.3	4.6												
BAU	2100	19.9													

Source paper: Bosetti et al 2011





R&D scenario	Year	Fossil fuel Emissions in GtC	averted	Sum of years * 5 to fill in missing years	Scenario	Year	% of GWP	GWP	Difference in % of GWP		GWP in $trillion (approximation)	Cost in trillion	Benefits: Cumulative emissions averted in Gigatonnes	R&D costs in billions	Cost per tonne of CO_2e averted

R&D scenario	Year	Fossil fuel Emissions in GtC	averted	Sum of years * 5 to fill in missing years	Scenario	Year	% of GWP	GWP	Difference in % of GWP		GWP in $trillion (approximation)	Cost in trillion	Benefits: Cumulative emissions averted in Gigatonnes	R&D costs in billions	Cost per tonne of CO2e averted										

R&D scenario	Year	Fossil fuel Emissions in GtC	averted	Sum of years * 5 to fill in missing years	Scenario	Year	% of GWP	GWP	Difference in % of GWP		GWP in $trillion (approximation)	Cost in trillion	Benefits: Cumulative emissions averted in Gigatonnes	R&D costs in billions	Cost per tonne of CO2e averted

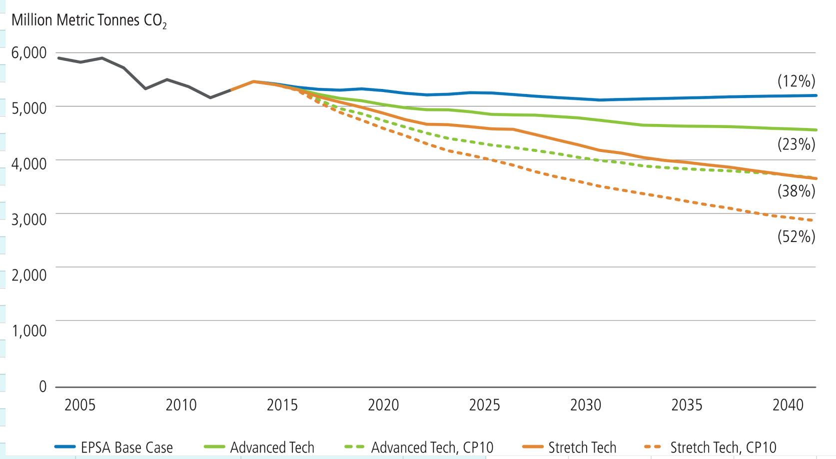
R&D scenario	Year	Fossil fuel Emissions in GtC	averted	Sum of years * 5 to fill in missing years	Scenario	Year	% of GWP	GWP	Difference in % of GWP		GWP in $trillion (approximation)	Cost in trillion	Benefits: Cumulative emissions averted in Gigatonnes	R&D costs in billions	Cost per tonne of CO2e averted										

R&D scenario	Year	Fossil fuel Emissions in GtC	averted	Sum of years * 5 to fill in missing years	Scenario	Year	% of GWP	GWP	Difference in % of GWP		GWP in $trillion (approximation)	Cost in trillion	Benefits: Cumulative emissions averted in Gigatonnes	R&D costs in billions	Cost per tonne of CO2e averted

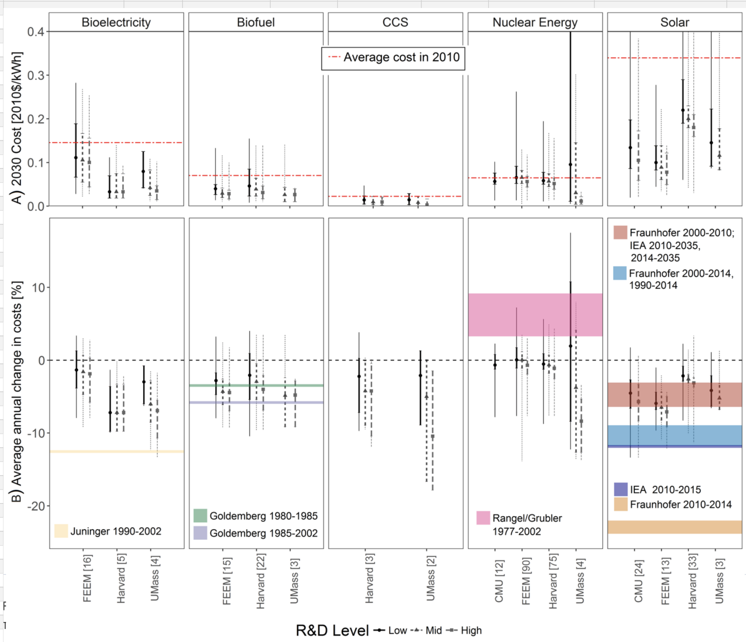
R&D scenario	Year	Fossil fuel Emissions in GtC	averted	Sum of years * 5 to fill in missing years	Scenario	Year	% of GWP	GWP	Difference in % of GWP		GWP in $trillion (approximation)	Cost in trillion	Benefits: Cumulative emissions averted in Gigatonnes	R&D costs in billions	Cost per tonne of CO2e averted

R&D spending scenario	Year	Emissions in MT	Emissions averted through R&D in million tonnes	Benefits: Cumulative emissions averted in Gigatonnes	R&D costs in billions	Cost per tonne of CO2e averted	Source:
Doubling R&D spending	2020	4923	155	**11**	**$142bn**	**$13**	**US Department of Energy**
Current R&D spending	2020	5078					
Doubling R&D spending	2021	4817	204				
Current R&D spending	2021	5021					
Doubling R&D spending	2022	4724	277				
Current R&D spending	2022	5001					
Doubling R&D spending	2023	4700	271		https://www.energy.gov/sites/prod/files/2017/01/f34/Energy%20CO2%20Emissions%20Impacts%20of%20Clean%20Energy%20Technology%20Innovation%20and%20Policy.pdf		
Current R&D spending	2023	4971			https://www.energy.gov/sites/prod/files/2017/02/f34/Quadrennial%20Energy%20Review--Second%20Installment%20%28Full%20Report%29.pdf#page=220		
Doubling R&D spending	2024	4669	282		https://itif.org/publications/2018/12/10/omission-innovation-missing-element-most-countries-response-climate-change		
Current R&D spending	2024	4952					
Doubling R&D spending	2025	4632	266				
Current R&D spending	2025	4897					
Doubling R&D spending	2026	4635	247				
Current R&D spending	2026	4882					
Doubling R&D spending	2027	4556	331				
Current R&D spending	2027	4887					
Doubling R&D spending	2028	4440	408				
Current R&D spending	2028	4848					
Doubling R&D spending	2029	4354	484				
Current R&D spending	2029	4838					
Doubling R&D spending	2030	4268	530				
Current R&D spending	2030	4799					
Doubling R&D spending	2031	4196	558				
Current R&D spending	2031	4754					
Doubling R&D spending	2032	4135	565				
Current R&D spending	2032	4700					
Doubling R&D spending	2033	4076	619				
Current R&D spending	2033	4695					
Doubling R&D spending	2034	4042	643				
Current R&D spending	2034	4685					
Doubling R&D spending	2035	3997	702				
Current R&D spending	2035	4700					
Doubling R&D spending	2036	3956	719				
Current R&D spending	2036	4675					
Doubling R&D spending	2037	3894	766				
Current R&D spending	2037	4660					
Doubling R&D spending	2038	3860	805				
Current R&D spending	2038	4665					
Doubling R&D spending	2039	3781	854				
Current R&D spending	2039	4636					
Doubling R&D spending	2040	3726	875				
Current R&D spending	2040	4601					

Figure 3-18a. U.S. Energy CO_2 Emissions, 2005–2040[245]



Technology	Study	Invest	# experts	RD&D Level (million 2010$)	Pessimistic	Pessimistic_interval	median	Optimistic_interval	Optimistic	Regression Coefficient [1	#expert weighted	Global average annual net capacity additions by technology from 2017-2040 in GW [17]			
Bioelectricity	FEEM	Low	16	$169	3.33%	1.30%	-1.34%	-3.85%	-7.89%	-0.003%	-0.01%		230.05		
Bioelectricity	FEEM	Mid	16	$254	2.87%	0.56%	-1.55%	-4.72%	-9.05%						https://www.iea.org/renewables2018/
Bioelectricity	FEEM	High	16	$338	2.78%	0.31%	-1.83%	-5.75%	-7.89%						
Bioelectricity	Harvard	Low	5	$214	-1.34%	-3.61%	-7.23%	-9.75%	-9.83%	0.00001%					
Bioelectricity	Harvard	Mid	5	$585	-0.26%	-3.33%	-7.26%	-9.74%	-9.74%						
Bioelectricity	Harvard	High	5	$5,850	-2.31%	-3.33%	-7.18%	-9.74%	-9.74%						
Bioelectricity	UMass	Low	4	$15	-0.77%	-0.77%	-2.99%	-5.98%	-6.24%	-0.02458%					
Bioelectricity	UMass	Mid	4	$50	-1.62%	-2.82%	-6.07%	-8.55%	-12.31%						
Bioelectricity	UMass	High	4	$150	-1.79%	-5.47%	-6.92%	-10.68%	-13.25%						
Biofuel	FEEM	Low	15	$168	3.25%	-1.71%	-2.82%	-4.79%	-7.95%	-0.00958%	-0.01%		230.05		
Biofuel	FEEM	Mid	15	$252	2.41%	-2.62%	-4.31%	-6.08%	-9.17%						
Biofuel	FEEM	High	15	$336	1.71%	-3.24%	-4.43%	-6.94%	-9.17%						
Biofuel	Harvard	Low	22	Combined w/ bioelectricity	3.90%	0.89%	-2.04%	-5.42%	-10.41%	#VALUE!					
Biofuel	Harvard	Mid	22	Combined w/ bioelectricity	3.40%	-0.56%	-2.91%	-5.42%	-9.50%						
Biofuel	Harvard	High	22	Combined w/ bioelectricity	3.44%	-2.08%	-3.98%	-6.86%	-9.50%						
Biofuel	UMass	Mid	3	$201	3.32%	-2.41%	-4.84%	-9.09%	-9.13%	0.00006%					
Biofuel	UMass	High	3	$838	-2.58%	-2.82%	-4.80%	-9.09%	-9.13%						
CCS	Harvard	Low	3	$701	3.76%	0.26%	-2.22%	-7.18%	-9.66%	-0.00006%	-0.04%				
CCS	Harvard	Mid	3	$2,250	0.09%	0.00%	-4.10%	-10.34%	-11.79%						
CCS	Harvard	High	3	$22,500	0.00%	-0.51%	-4.27%	-10.43%	-11.88%						
CCS	UMass	Low	2	$13	1.28%	1.28%	-2.05%	-8.97%	-8.97%	-0.08930%					
CCS	UMass	Mid	2	$48	0.00%	0.00%	-5.04%	-16.67%	-16.67%						
CCS	UMass	High	2	$108	-1.45%	-1.54%	-10.51%	-17.78%	-17.78%						
Nuclear	CMU	Low	12		2.22%	0.77%	-0.60%	-1.20%	-7.78%						
Nuclear	FEEM	Low	90	$800	7.18%	1.71%	0.00%	-1.11%	-7.61%	-0.00005%	-0.0001%	4			
Nuclear	FEEM	Mid	90	$1,514	3.42%	1.11%	0.00%	-1.11%	-13.85%						
Nuclear	FEEM	High	90	$15,140	2.99%	0.17%	-0.68%	-1.88%	-7.61%						
Nuclear	Harvard	Low	75	$466	5.56%	0.85%	-0.60%	-1.28%	-8.72%	-0.00003%					
Nuclear	Harvard	Mid	75	$1,883	4.79%	0.68%	-0.68%	-1.79%	-7.52%						
Nuclear	Harvard	High	75	$18,833	4.27%	-0.09%	-1.11%	-2.56%	-7.61%						
Nuclear	UMass	Low	4	$40	17.44%	10.77%	1.88%	-8.38%	-12.14%	-0.00467%					
Nuclear	UMass	Mid	4	$480	7.95%	4.10%	-3.76%	-12.65%	-13.50%						
Nuclear	UMass	High	4	$1,980	-3.42%	-5.30%	-8.29%	-12.56%	-13.59%						
Solar	CMU	Low	24		1.71%	-2.74%	-4.62%	-6.58%	-13.33%	#VALUE!		74			
Solar	CMU	High	24		0.60%	-3.33%	-5.81%	-8.38%	-13.33%						
Solar	FEEM	Low	13	$171	-1.03%	-4.36%	-5.90%	-6.75%	-9.66%	-0.00650%	-0.002%				
Solar	FEEM	Mid	13	$257	-2.14%	-4.44%	-6.50%	-8.21%	-10.94%						
Solar	FEEM	High	13	$342	-4.36%	-4.96%	-7.01%	-9.15%	-12.14%						
Solar	Harvard	Low	33	$143	2.22%	-0.85%	-2.22%	-2.91%	-8.21%	-0.00021%					
Solar	Harvard	Mid	33	$409	1.37%	-1.97%	-2.56%	-3.68%	-11.20%						
Solar	Harvard	High	33	$4,090	3.33%	-2.39%	-3.16%	-3.68%	-11.20%						
Solar	UMass	Low	3	$25	1.03%	-2.14%	-4.19%	-6.32%	-6.58%	-0.00892%					
Solar	UMass	Mid	3	$140	1.20%	-3.25%	-5.21%	-6.75%	-6.84%						



Technology	Study	Invest	# experts	RD&D Level (million 2010$)	Pessimistic	Pessimistic_interval	median	Optimistic_interval	Optimistic	Regression Coefficient [1	#expert weighted	Global average annual net capacity additions by technology from 2017-2040 in GW [17]					

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[1] U.S. clean energy R&D budget / year

[2] Global clean energy R&D spending / year in 2016

[3] Assumes just a 1% increase in the U.S. clean energy R&D budget

[4] Mission Innovation countries committed to double clean energy R&D funding from $15 billion in 2016 to $30 billion by 2021, but will only meet 50% of their targets based on current trends. The optimistic case assumes that they will meet their targets i.e. the other 50% — this is equal to $7.5bn counterfactual increase.

[5] equivalent to the mean salary of 4 additional staff for 3 years

[6] equivalent to the mean salary of 4 additional staff for 3 years

[7] equivalent to the mean salary of 4 additional staff for 3 years

[8] Median from paper

[9] Price elasticity for most products clusters around 1.0, it is a commonly used rule of thumb. https://scholar.harvard.edu/files/alada/files/price_elasticity_of_demand_handout.pdf

[10] change in cost if R&D increases by $1mil

[11] change in cost if R&D increases by $1mil

[12] Price elasticity for most products clusters around 1.0, it is a commonly used rule of thumb. https://scholar.harvard.edu/files/alada/files/price_elasticity_of_demand_handout.pdf

[13] Price elasticity for most products clusters around 1.0, it is a commonly used rule of thumb. https://scholar.harvard.edu/files/alada/files/price_elasticity_of_demand_handout.pdf

[14] Price elasticity for most products clusters around 1.0, it is a commonly used rule of thumb. https://scholar.harvard.edu/files/alada/files/price_elasticity_of_demand_handout.pdf

[15] Price elasticity for most products clusters around 1.0, it is a commonly used rule of thumb. https://scholar.harvard.edu/files/alada/files/price_elasticity_of_demand_handout.pdf

[16] change in cost if R&D increases by $1mil

[17] Source:
https://www.iea.org/renewables2018/