Cost-benefit analysis of clean energy systems

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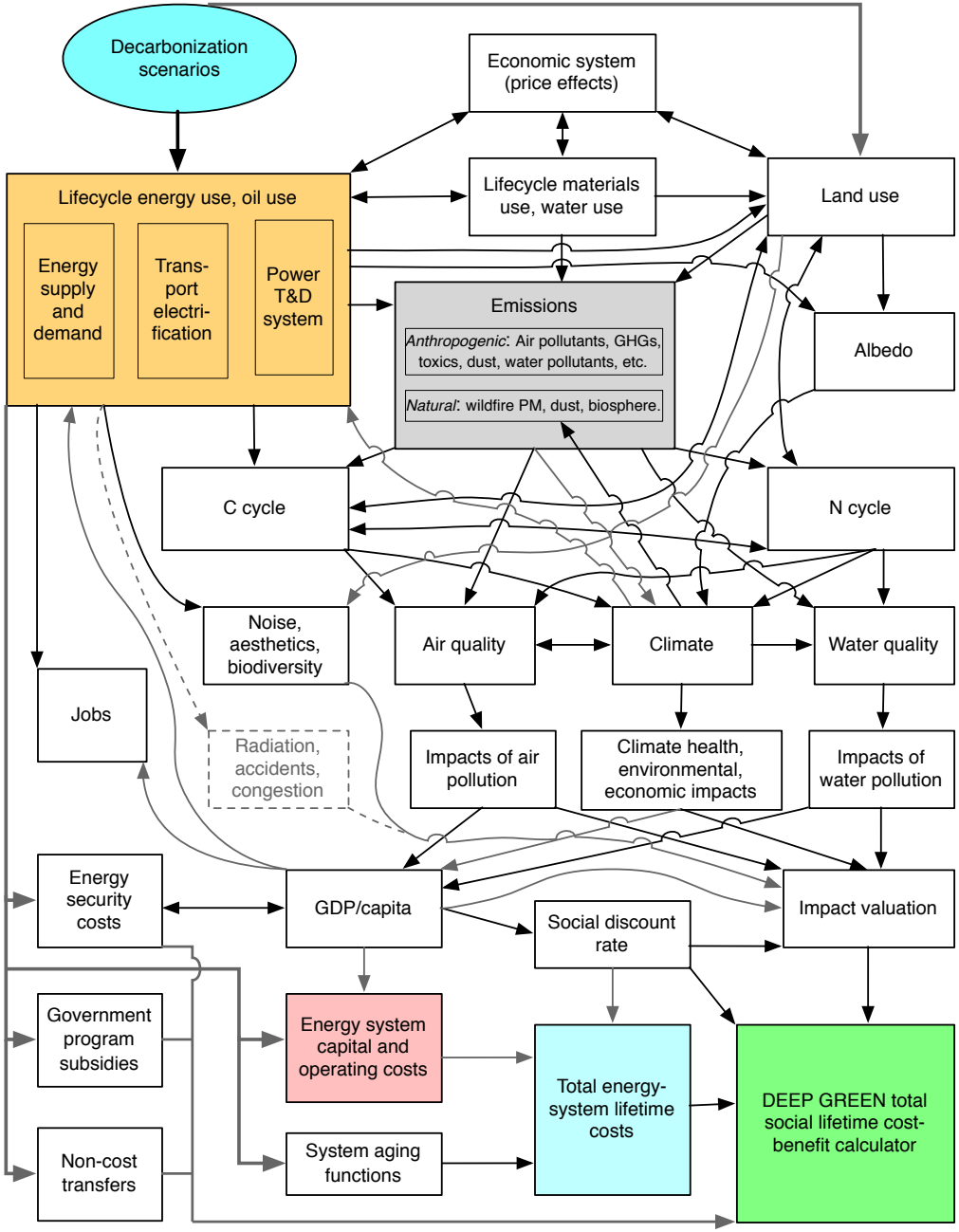
FULL SOCIAL CBA OF ENERGY SYSTEMS: DEEP GREEN MODELING SYSTEM



LCOE of WWS vs. BAU (cents/kWh in 2050)

TECHNOLOGY	Generation		Operating costs		Fuel cost		T&D, storage		Total LCEO	
	LCHB	*HCLB*	*LCHB*	*HCLB*	*LCHB*	*HCLB*	*LCHB*	*HCLB*	*LCHB*	*HCLB*
Advanced pulverized coal	0.8	2.5	0.8	1.0	2.5	3.5	3.7	3.7	7.9	10.7
Advanced pulverized coal w/CC	2.1	5.5	1.3	1.8	2.9	4.1	3.7	3.7	10.1	15.1
IGCC coal	0.9	2.9	1.6	1.7	2.3	3.2	3.7	3.7	8.4	11.5
IGCC coal w/CC	1.8	5.2	1.6	1.9	2.6	3.7	3.7	3.7	9.8	14.6
Diesel generator (for steam turbine)	4.2	12.7	5.3	4.5	11.8	18.0	3.7	3.7	25.0	38.9
Gas combustion turbine	6.1	17.3	2.5	10.0	7.0	9.4	3.7	3.7	19.3	40.4
Combined cycle conventional	0.7	1.9	0.5	0.9	5.5	7.2	3.7	3.7	10.5	13.7
Combined cycle advanced	0.3	0.9	0.4	0.6	5.1	6.7	3.7	3.7	9.6	11.9
Combined cycle advanced w/CC	0.6	1.4	0.8	1.2	6.0	7.9	3.7	3.7	11.2	14.3
Fuel cell (using natural gas)	1.2	4.9	3.4	5.2	4.9	6.8	3.7	3.7	13.3	20.6
Microturbine (using natural gas)	0.8	2.7	2.3	2.4	8.4	10.6	3.7	3.7	15.2	19.4
Nuclear, APWR	1.1	5.5	1.6	1.8	0.8	1.1	3.7	3.7	7.3	12.1
Nuclear, SMR	1.8	4.7	1.6	1.9	0.8	1.1	3.7	3.7	8.0	11.4
Distributed generation (using natural gas)	9.0	23.2	4.7	5.4	8.0	10.0	3.7	3.7	25.4	42.4
Municipal solid waste	3.5	8.9	9.7	8.8	1.1	1.3	3.7	3.7	18.0	22.8
Biomass direct	1.1	3.6	3.9	3.6	1.8	2.4	3.7	3.7	10.5	13.3
Geothermal	0.8	3.8	3.4	4.0	0.0	0.0	3.9	5.3	8.1	13.1
Hydropower	0.8	3.1	0.8	0.9	0.0	0.0	3.9	5.3	5.5	9.3
On-shore wind	1.2	3.3	1.3	1.5	0.0	0.0	3.9	5.3	6.4	10.1
Off-shore wind	2.0	7.7	3.3	5.2	0.0	0.0	3.9	5.6	9.3	18.5
CSP no storage	3.3	9.3	1.9	2.8	0.0	0.0	3.9	5.3	9.1	17.4
CSP with storage	1.5	4.8	0.7	1.0	0.0	0.0	3.9	5.3	6.1	11.1
PV utility crystalline tracking	1.6	3.3	0.5	0.6	0.0	0.0	3.9	5.3	6.1	9.1
PV utility crystalline fixed	2.0	3.8	0.4	0.6	0.0	0.0	3.9	5.3	6.3	9.8
PV commercial rooftop	3.5	6.9	0.1	0.2	0.0	0.0	3.6	5.2	7.2	12.2
PV residential rooftop	3.6	9.0	0.8	0.4	0.0	0.0	3.6	5.2	8.0	14.6
Wave power	3.7	10.5	8.0	25.0	0.0	0.0	3.9	5.3	15.6	40.7
Tidal power	2.0	6.0	2.5	8.8	0.0	0.0	3.9	5.3	8.4	20.0
Solar thermal (water or glycol solution)	0.5	1.1	0.7	1.0	0.0	0.0	3.9	5.3	5.1	7.4

LCOE = levelized cost of electricity; WWS = wind, water, and solar power; BAU = business as usual; LCHB = low cost, high benefits; HCLB = high cost, low benefits; T&D = transmission and distribution. Year 2013 dollars. Discount rate is 1.5% (LCHB) or 4.5% (HCLB).

Source: M. Z. Jacobson, M. A. Delucchi, et al. (2015).

Studies of the social cost of carbon

Authors	Moore and Diaz (2015)			Ackerman and Stanton (2012)			van den Bergh and Botzen (2014)			Johnson and Hope (2012)			Howarth et al. (2014)			Antoff et al. (2011)			Tol (2010)		
Model	gro-DICE			DICE			meta-analysis			DICE			IAM using DICE			FUND			FUND		
Emission year	2015-2100			2010, 2050			near term?			2010			2010			2010-2019			2010?		
Dollar year	2005			2007			2010?			2007			2005			1995			1995		
	Low	*Mid*	*High*	*Low*	*Mid*	*High*	*Low*	*Mid*	*High*	*Low*	*Mid*	*High*	*Low*	*Mid*	*High*	*Low*	*Mid*	*High*	*Low*	*Mid*	*High*
World SCC ($/tonne-CO2)	~200		1000+	~45, ~100	~230, ~430	~890, ~1520	125	--	--	-1	145	--	10	--	>500	0.5	10	~180	~0	1.3	11
Discount rate (DR)	n.r.	n.r.	n.r.	3%	1.5% or 3%	1.5%	avg.	--	--	5%	2.5%	--	n.r.	--	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.
Pure rate of time preference	3%	1.5%	0.1%	n.r.	n.r.	n.r.	n.r.	--	--	3.2%	1.1%	--	1.5%	--	1.5%	3%	1%	0.1%	3%	1%	0%
Equity weighting?	no	no	no	n.r.	n.r.	n.r.	no?	--	--	no	yes	--	no?	--	no?	no	no	ave.*	no	no	yes
Risk aversion rate	no?	no?	no?	n.r.	n.r.	n.r.	n.r.	--	--	no	no	--	2.0	--	5.6	no	no	no	1.5	1.5	15
Extreme climate impacts?	part.			no	part.	yes	part.	--	--	no	no	--	no (thin tail)	--	yes (fat tail)	no	no	no	no	no	no
U.S. % of world SCC	n.r.			n.r.			n.r.			n.r.			n.r.			33%	13%	< 10%	n.r.	8.5%	n.r.
Remarks	Authors did not estimate explicit low, mid, and high values, but rather estimated the importance of including feedbacks between climate change and the rate of economic growth.			SCC estimated as a function of the DR, climate sensitivity (CS), and form of damage function (DF). Our mid case includes all combos of DR, CS, and DF except low-low (our low) and high-high (our high).			SCC is equal to $41/tonne – the average reported in a meta-analysis – plus the average of separate "surcharges" for uncertainty, extreme damages, and risk aversion.			Authors did not analyze what would be a "high" cost case (a low rate of time preference with equity weights).			With high risk aversion rate, SCC decreases with increasing emission control rate (ECR): when ECR > 40%, SCC <10.			SCC is higher with U.S.-based equity weights than with global equity weights. (*= global equity weights)			High estimates are based on "illustrative" parameter values.		

IAM = Integrated Assessment Model; SCC = social cost of carbon; n.r. = not reported; part. = partially. "Extreme climate impacts?" includes extreme climate sensitivity to emissions, irreversible impacts, high-cost/low-probability impacts, and potentially large but difficult to quantify damage categories. Note that here "low" and "high refer to values of the SCC itself, and *not* to the LCHB and HCLB scenarios established here.

Quantitative comparison: social lifetime cost, 2020

Compact car, Li-ion battery, FUDS cycle (present value of costs)

Gasoline	Ethanol	BPEV-120	HEV-35	H2-300	COST ITEM
0	0	0	0	0	Blank -- not used
0	0	2,094	2	0	Purchased electricity (accounts for regenerative braking from fuel cell, power to heat battery, mai
0	0	951	0	0	Space heating fuel for EVs
0	0	18,369	19,373	613	Battery and tray and auxiliaries (Li-ion)
0	0	192	0	0	Off board battery-charging wiring and equipment
0	0	0	0	4,159	Fuel-cell stack and auxiliaries
0	0	0	0	0	On-board fuel reformer
20,854	20,704	17,576	19,023	16,890	Vehicle, excluding battery, fuel cell, and hydrogen storage
13,103	13,314	0	10,658	14,318	Motor fuel, excluding excise taxes and electricity*
see "vehicle"	62	0	0	2,660	Fuel-storage system
11,204	10,952	13,222	12,199	12,552	Insurance (calculated as a function of VMT and vehicle value)
14,527	14,527	10,755	15,232	11,929	Maintenance and repair, excluding oil, inspection, cleaning, towing, but including time costs
259	259	0	178	0	Engine oil
669	668	615	629	422	Replacement tires (calculated as a function of VMT and vehicle weight)
2,862	2,862	2,862	2,862	2,862	Parking, tolls, and fines (assumed to be the same for all vehicles)
1,248	1,241	0	1,470	1,149	Registration fee (calculated as a function of vehicle weight)
1,717	1,717	605	1,816	605	Vehicle safety and emissions inspection fee
2,867	2,867	2,867	2,867	2,867	Federal, state, and local fuel (energy) excise taxes
971	971	971	971	971	Accessories (assumed to be the same for all vehicles)
70,282	70,144	71,079	87,281	71,996	Total private (consumer) lifetime cost
1,806	1,498	0	603	0	Dollar value of air pollution external costs (lifecycle of fuels and vehicles) (best estimates)
0	0	0	0	0	Blank
619	619	464	489	441	Dollar value of noise external costs (best estimates)
19	1	0	15	0	Dollar value of oil use external costs (best estimates)
19,389	11,827	0	3,411	0	Dollar value of climate change external costs (lifecycle of fuels and vehicles) (best estimates)
-2,867	-2,867	-2,867	-2,867	-2,867	Taxes and fees that are transfers, not resource costs
-4,914	-679	-548	-3,997	-730	Producer surplus on fuel (wealth transfer in excess of resource cost)
-928	-919	-1,435	-1,481	-1,069	Producer surplus (qua "true corporate profit) on vehicle price
83,405	79,624	66,692	83,454	67,772	Total social lifetime cost
n.a.	2.86	3.03	5.96	3.20	Breakeven gasoline price, private-cost basis ($/gal)^
n.a.	2.20	-0.13	2.90	0.06	Breakeven gasoline price, social-cost basis ($/gal)^

Source: Current beta version of AVCEM; see Delucchi et al. (2000) for documentation of prior version.