Beyond the Brief Anomaly posts 37 & 38

Energy transition system dynamics model "standard run" parameter value set

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24 August 2015

See: http://beyondthisbriefanomaly.org/2015/08/07/energy-transition-renewables-and-batteries-a-systems-view/

http://beyondthisbriefanomaly.org/2015/08/20/an-integrated-view-of-energy-transition-what-can-we-learn/

Direct link to model: http://insightmaker.com/insight/32745/embed?topBar=1&sideBar=1&zoom=1

- Parameters shaded in green are user adjustable within fixed limits in the model. These parameters set the primary performance characteristics by which the battery-buffered wind and PV electricity generation satisfies the supply task.
- Parameters shaded in yellow are set as constants in the model. These parameters directly affect how the battery-buffered wind and PV electricity generation satisfies the supply task, but are considered to be only of secondary interest in characterising performance.
- Parameters that are unshaded are set as constants in the model. These parameters establish the "supply task context" that battery-buffered wind and PV electricity generation must satisfy.

Ref#	Parameter name	Parameter description	"Standard run" value	Units	"Standard run" value basis and discussion
1	[WE capacity factor initial]	Global annual mean wind capacity factor at start (based on published data available in 2015).	0.25	none (dimensionless ratio)	Source: Carbajales-Dale, Michael, Charles J. Barnhart, and Sally M. Benson. 2014. "Can we afford storage? A dynamic net energy analysis of renewable electricity generation supported by energy storage." Energy & Environmental Science no. 7 (5):1538-1544. doi: 10.1039/c3ee42125b.
2	[WE capacity factor dynamic reduction]	The best wind sites have the highest capacity factors; as sites are developed, capacity factor for remaining sites reduces. As the proportion of overall potential developed increases, global mean capacity factor will reduce.	1.0@0-1500 GW; 0.5@9500 GW; 0@11500 GW	none (dimensionless ratio)	This effect has little impact at relatively low wind electricity penetration, but as this increases, it can be expected to become more significant. A rough allowance is made for improvement in technology to offset the rate of decline with total generation. Adapted from: Moriarty, Patrick, and Damon Honnery. 2012. "What is the global potential for renewable energy?" Renewable and Sustainable Energy Reviews no. 16 (1):244-252. doi: http://dx.doi.org/10.1016/j.rser.2011.07.151, Fig. 1, land constrained case (max total global gross wind electricity output = 360 EJ/year or

					11,400 GW). Assumes that Er is directly proportional to capacity factor. Assumes capacity factor at Er(max) = 0.4, but max capacity factor is capped at 0.25 i.e. equivalent to current global mean, due to inclusion of sub-optimal sites at all stages of overall resource development.
3	[WE plant operating life]	Typical wind turbine operating life. This figure, while based on published data, is high. Other studies assume 20 years.	20	years	See for instance: Honnery, Damon, and Patrick Moriarty. 2009. "Estimating global hydrogen production from wind." *International Journal of Hydrogen Energy* no. 34 (2):727-736. doi: http://dx.doi.org/10.1016/j.ijhydene.2008.11.00.
4	[WE operating & maintenance plowback]	All energy supply entails its own ongoing energy demand for operating and maintenance loads. A nominal rate is set initially, based on published data for a particular situation.	0.06	none (dimensionless ratio)	Source as for parameter #3 above.
5	[WE energy investment adjustment factor-O&M]	The global annual mean O&M plowback rate may vary from the nominal rate. The adjustment factor allows tuning of this parameter so that overall EROI represents a sensible global mean value.	0.4	none (dimensionless ratio)	See discussion of basis for parameter #7 below.
6	[WE emplacement power demand]	Emplacing any energy supply capacity entails upfront energy demand, before energy is made available to enable other economic activity. A nominal rate is set initially, based on published data for a particular situation.	0.634	years (annual mean GW/GW emplaced, assuming all emplacement energy invested in a single year i.e. "GWy/GW)	Source as for parameter #3 above.
7	[WE energy investment adjustment factor-emplacement]	The global annual mean emplacement energy demand may vary from the nominal rate. The adjustment factor allows tuning of this parameter so that overall EROI represents a sensible global mean value.	0.4	none (dimensionless ratio)	The parameter value is adjusted so that EROI under steady state conditions (zero growth in capacity) is approximately equal to 13-15:1. This is an optimistically adjusted estimate of the global weighed mean EROI for wind generated electricity. This is derived from: Moriarty, Patrick, and Damon Honnery. 2012. "What is the global potential for renewable energy?" Renewable and Sustainable

					Energy Reviews no. 16 (1):244-252. doi: http://dx.doi.org/10.1016/j.rser.2011.07.151. From fig. 1, p. 247, land constrained case, the global weighted mean energy ratio (EROI) is approximately 8:1 (max ~22:1, min 0) when all wind potential is included, down to EROI=0. When a minimum floor for development is set at 5:1, this increases to ~10:1. For the purpose of the model, this is then adjusted upwards (somewhat arbitrarily) to 13-15:1, in recognition of the fact that the amount of wind capacity deployed in the model is a relatively small proportion of global technical potential (and so it is assumed that there will be sufficient discretion to select sites that bias the mean value in this direction). It is assumed here that this adjusted global weighted mean EROI of 13-15:1 applies at any time, rather than being a lower bound towards which EROI converges as development expands towards the technical potential limit. The basis for this is the observation that under real-world conditions, political considerations mean that development occurs simultaneously across sites covering a "quality spectrum", rather than strictly from highest to lowest quality. This is why global mean capacity factor is around 25%, while capacity factors for the highest quality sites are over 40%.
8	[WE embodied energy recycling rate]	When energy supply plant and equipment reaches the end of its operating life, material and components are recycled as far as possible. Recycling can offset some of the embodied energy demand for replacement plant and equipment where virgin materials are displaced.	0.15	none (dimensionless ratio)	
9	[WE self power demand to services conversion	EROI studies typically express life cycle energy demand in terms of either a primary or final energy equivalent. In this model, rates of energy demand are expressed in terms of energy *services* in the form of work and heat. The work and heat associated with	0.85@0y; 0.7@100; 0.6@150-200y	none (dimensionless ratio)	

	factor]	a unit of energy demand represent some fraction of that unit. An efficiency "learning curve" is assumed: over time, the energy required to deliver a given quantity of work and heat reduces.			
10	[WE to services conversion factor]	To allow aggregation of all energy output and demand on similar terms, energy output is converted to services in the form of work and heat. Each unit of energy output will enable a fraction of that output as work and heat. An efficiency "learning curve" is assumed: over time, the work and heat enabled by a unit of energy output increases.	0.6@0y; 0.7@100; 0.8@150-200y	none (dimensionless ratio)	
11	[PVE ref capacity factor]	Global annual mean reference PV capacity factor.	0.17	none (dimensionless ratio)	Global mean + 5% to bias towards utility-scale vs commercial and domestic rooftop installations. Source for global mean: Carbajales-Dale, Michael, Charles J. Barnhart, and Sally M. Benson. 2014. "Can we afford storage? A dynamic net energy analysis of renewable electricity generation supported by energy storage." Energy & Environmental Science no. 7 (5):1538-1544. doi: 10.1039/c3ee42125b. Note that this is the nominal capacity factor. The correction factor from Prieto & Hall's study (see parameter #1 source below) of 0.765 is omitted i.e. it is assumed here that the correction factor for Spain is not directly generalizable to the global situation. This nominal capacity factor is likely to yield electrical energy across the generation plant boundary higher than actually achieved in practice.
11.1	[PVE capacity factor winter bias]	Capacity factor adjustment to increase winter PVE output to match annual mean demand	0.71	none (dimensionless ratio)	At latitudes more than a few degrees from the equator, battery storage required to accommodate the difference between summer and winter PV output is too large to be viable. For PV to provide year-round supply on its own, at least up to mid-latitudes, a better approach is to orient panels for optimum winter performance and size to meet winter demand, curtailing surplus output for the rest of the year. This results in a reduced effective

					capacity factor.
12	[PVE plant operating life]	Typical utility-scale PV plant operating life. While there is some variation in assumptions of operating life across studies, 25 years is typical.	25	years	Source: Prieto, Pedro A., and Charles A.S. Hall. 2013. Spain's Photovoltaic Revolution: The Energy Return on Investment. Edited by Charles A. S. Hall, SpringerBrief in Energy: Energy Analysis. New York: Springer.
13	[PVE operating & maintenance plowback]	All energy supply entails its own ongoing energy demand for operating and maintenance loads.	0.1802	none (dimensionless ratio)	Adapted from: Prieto, Pedro A., and Charles A.S. Hall. 2013. Spain's Photovoltaic Revolution: The Energy Return on Investment. Edited by Charles A. S. Hall, SpringerBrief in Energy: Energy Analysis. New York: Springer, Table 6.18, pp. 111-2. [a3-6+a9-16+a18-19+a22+a24]/[a1-24 less a21 and a23]. See this spreadsheet for details: https://beyondthisbriefanomalydotorg.files.wordpress.com/2015/08/im-energy-transition-model-pv-eroi-parameter-calculations-20150823.xlsx
14	[PVE energy investment adjustment factor-O&M]	The global annual mean O&M plowback rate can be adjusted relative to the set rate.	1	none (dimensionless ratio)	
15	[PVE emplacement power demand]	Emplacing any energy supply capacity entails upfront energy demand, before energy is made available to enable other economic activity.	0.596	years (annual mean GW/GW emplaced, assuming all emplacement energy invested in a single year i.e. "GWy/GW)	Adapted from: Prieto, Pedro A., and Charles A.S. Hall. 2013. Spain's Photovoltaic Revolution: The Energy Return on Investment. Edited by Charles A. S. Hall, SpringerBrief in Energy: Energy Analysis. New York: Springer, Table 6.18, pp. 111-2. [a1+a2+a7+a8+a17+a20]/[a1-24 less a21 and a23]. See this spreadsheet for details: https://beyondthisbriefanomalydotorg.files.wordpress.com/2015/08/im-energy-transition-model-pv-eroi-parameter-calculations-20150823.xlsx The value is derived by converting the emplacement energy to emplacement power, assuming that the energy to emplace each annual capacity increment is drawn over a full year. For emplacement energy of 16.4 PJ/GW, then emplacement power is 16.4E6 GJ divided by (365.25*24*3600) seconds, per installed GW of new capacity. This gives 0.521

					GW average, for a period of 1 year, to emplace each GW of new capacity. Units of years are applied to give a value for emplacement demand in GW, due to emplacement rate being expressed in GW/year.
16	[PVE energy investment adjustment factor-emplacement]	The global annual mean emplacement energy demand can be adjusted relative to the set rate.	1	none (dimensionless ratio)	
17	[PVE embodied energy recycling rate]	When energy supply plant and equipment reaches the end of its operating life, material and components are recycled as far as possible. Recycling can offset some of the embodied energy demand for replacement plant and equipment where virgin materials are displaced.	0.15	none (dimensionless ratio)	
18	[PVE self power demand to services conversion factor]	EROI studies typically express life cycle energy demand in terms of either a primary or final energy equivalent. In this model, rates of energy demand are expressed in terms of energy *services* in the form of work and heat. The work and heat associated with a unit of energy demand represent some fraction of that unit. An efficiency "learning curve" is assumed: over time, the energy required to deliver a given quantity of work and heat reduces.	0.85@0y; 0.7@100; 0.6@150-200y	none (dimensionless ratio)	
19	[PVE to services conversion factor]	To allow aggregation of all energy output and demand on similar terms, energy output is converted to services in the form of work and heat. Each unit of energy output will enable a fraction of that output as work and heat. An efficiency "learning curve" is assumed: over time, the work and heat enabled by a unit of energy output increases.	0.6@0y; 0.7@100; 0.8@150-200y	none (dimensionless ratio)	
20	[Battery storage operating life]	Operating life, with given consideration to cycle duty (cycle frequency-depth profile).	20	years	Source: http://www.lowtechmagazine.com/2015/05/sustainability-off-grid-solar-power.html (see reference 18: "Energy Analysis of Batteries in Photovoltaic systems. Part one (Performance and energy

					requirements)" (PDF) and "Part two (Energy Return Factors and Overall Battery Efficiencies)" (PDF). Energy Conversion and Management 46, 2005.). Basis: Li-ion batteries operating at 80% depth of discharge, for 5000-7000 cycles, or 14-19 years @ 1 cycle per day.
21	[Li-ion embodied energy initial]	Provision of energy storage capacity entails its own energy demand. The value of this parameter reflects published data for Li-ion battery manufacture, current in 2014.	650	none (dimensionless ratio) (GWh/GWh storage emplaced)	Recent research provides insight into how battery embodied energy is likely to improve as production volumes increase. The researchers specify three characteristic values from actual production data: Lower bound value (LBV) = 586 MJ/kWh (163 GWh/GWh) Asymptotic value (ASV) = 960 MJ/kWh (267 GWh/GWh) Average value (AVV) = 2318 MJ/kWh (644 GWh/GWh) The researchers conclude that LBV is "is likely to better reflect large-scale production volumes." Source: Ellingsen, Linda Ager-Wick, Guillaume Majeau-Bettez, Bhawna Singh, Akhilesh Kumar Srivastava, Lars Ole Valøen, and Anders Hammer Strømman. 2014. "Life Cycle Assessment of a Lithium-Ion Battery Vehicle Pack." Journal of Industrial Ecology no. 18 (1):113-124. doi: 10.1111/jiec.12072.
22	[Li-ion embodied energy mature]	The Li-ion battery manufacturing industry is currently operating part way along its maturity curve. As global capacity increases, it is expected that embodied energy per unit of energy storage will reduce significantly. The value of this parameter reflects published estimates for a mature industry.	163	none (dimensionless ratio) (GWh/GWh storage emplaced)	See source for parameter #21 above.
23	[Battery emplacement rate at maturity]	What manufacturing capacity would reflect a fully mature global Li-ion manufacturing industry?	1000	GWh/year	The value used here is a guesstimate, taking into account current global capacity (Tesla "gigafactory" currently under construction = 50 GWh/year; emplacement rates from model even at

					modest autonomy periods = multiple thousands of GWh/y).
24	[Battery embodied energy recycling rate]	When batteries reach the end of their operating life, material and components will be recycled as far as possible. Recycling can offset some of the embodied energy demand for replacement batteries where virgin materials are displaced.	0.15	none (dimensionless ratio)	
25	[Battery storage power demand to services conversion factor]	Embodied energy demand is typically expressed in terms of either primary or final energy equivalent. In this model, rates of energy demand are expressed in terms of energy *services* in the form of work and heat. The work and heat associated with a unit of energy demand represent some fraction of that unit. Here, a fixed valued is assumed, with an efficiency "learning curve" implemented by way of reducing embodied energy as the Li-ion battery industry matures.	0.7	none (dimensionless ratio)	
26	[Max autonomy period-WE]	Period for which battery storage must be able to meet global mean wind electricity generation output when wind output is zero.	72	hours	See detailed commentary on "standard run".
27	[Max autonomy period PVE]	Period for which battery storage must be able to meet global mean PV electricity generation output when PV output is zero.	154	hours	See detailed commentary on "standard run".
28	[Depth of discharge for max autonomy period]	Battery depth of discharge: the maximum amount of a battery's nominal storage capacity that is available for use. Increasing the depth of discharge generally reduces battery life. Li-ion battery life is relatively insensitive to this compared with lead acid batteries, and so much greater depth of discharge is achievable while maintaining good battery life.	0.8	none (dimensionless ratio)	Source: http://www.lowtechmagazine.com/2015/05/sustainability-off-grid-solar-power.html
29	[Typical charge-discharge cycle period-WE]	Typical period over which some fraction of the energy stored by batteries is used and replenished.	24	hours	

30	[Typical charge-discharge cycle period-PVE]	Typical period over which some fraction of the energy stored by batteries is used and replenished.	24	hours	
31	[Round trip battery efficiency]	Final energy available from battery storage system, after charging and discharging losses are deducted, divided by the energy required to charge the batteries.	0.9	none (dimensionless ratio)	Source: http://www.lowtechmagazine.com/2015/05/sustainability-off-grid-solar-power.html
32	[New RE emplacement rate cap]	The maximum combined rate at which new wind and PV electricity generation capacity can be emplaced. In other words, the combined wind and PV generation capacity emplaced each year will be some fraction of the value set by this parameter. For full scale PID controller output (output = 1), the cap amount would be emplaced.	2000	GW/year	Current global emplacement rate for wind is approx. 50 GW/year and for PV is approx. 55 GW/year. C.f. Jacobson & Delucchi's model for providing all global energy use from renewable sources with hydrogen storage by 2030, in which the average emplacement rate for wind is ~~1000 GW/year, and average emplacement rate for solar electricity (all sources) is ~~1500 GW/year. See Jacobson, Mark Z., and Mark A. Delucchi. 2011. "Providing all global energy with wind, water, and solar power, Part I: Technologies, energy resources, quantities and areas of infrastructure, and materials." Energy Policy no. 39 (3):1154-1169. doi: http://dx.doi.org/10.1016/j.enpol.2010.11.040.
33	[Wind fraction new RE emplaced]	Proportion of new RE emplacement rate cap that is allocated to wind generation capacity (with the remainder allocated to PV capacity).	0.45	none (dimensionless ratio)	A rough proxy comparison (0.56) can be made with data from Jacobson and Delucchi (2011). See parameter #32 reference, Table 4, p. 1160. The proportion for solar PV is derived by combining the shares given in the source article for rooftop solar PV, utility scale solar PV and CSP plant. In the source article, the percentage share of global power demand in 2030 met by various sources is given as: Wind turbine 50%; Wave device 1%; Geothermal plant 4%; Hydroelectric plant 4%; Tidal turbine 1%; Roof PV system 6%; Solar PV

					plant 14%; CSP 20%.
34	[Proportional gain]	Tuning parameter for the PID controller that determines the rate at which wind and PV electricity generation capacity is emplaced. This parameter scales the contribution that current error makes to the overall PID controller output.	1	none (dimensionless ratio)	Trial and error to establish acceptable response shape.
35	[Integral gain]	Tuning parameter for the PID controller that determines the rate at which wind and PV electricity generation capacity is emplaced. This parameter scales the contribution that accumulated error makes to the overall PID controller output.	10.5	none (dimensionless ratio)	Trial and error to establish acceptable response shape.
36	[Derivative gain]	Tuning parameter for the PID controller that determines the rate at which wind and PV electricity generation capacity is emplaced. This parameter scales the contribution that rate of change of error makes to the overall PID controller output.	5	none (dimensionless ratio)	Trial and error to establish acceptable response shape.
37	[Smoothing period]	Averages error values for the specified period in order to reduce noisiness of controller output.	3	years	Trial and error to establish acceptable response shape.
38	[Max TFES target integral retention period]	Conditions the accumulated error parameter to improve controller's ability to converge on target value.	75	years	Trial and error to establish acceptable response shape.
39	[Minimum active PID controller output]	Sets a floor on the controller output, to prevent negative values. This means that if total supply overshoots the target value, convergence on the target value must occur as a result of end-of-life capacity retirement, rather than by forcing early retirement.	0	none	
40	[BEFH supply EROI]	Biomass electricity, fuel and heating energy return on investment.	5	none (dimensionless ratio)	
41	[BEFH capacity factor]	Capacity factor for biomass electricity, fuels and heating plant & equipment. Included only to provide consistent structure for each energy supply module.	1	none (dimensionless ratio)	

42	[BEFH self power demand to services conversion factor]	EROI studies typically express life cycle energy demand in terms of either a primary or final energy equivalent. In this model, rates of energy demand are expressed in terms of energy *services* in the form of work and heat. The work and heat associated with a unit of energy demand represent some fraction of that unit. An efficiency "learning curve" is assumed: over time, the energy required to deliver a given quantity of work and heat reduces.	0.65@0y; 0.5@100; 0.4@150-200y	none (dimensionless ratio)	
43	[BEFH to services conversion factor]	To allow aggregation of all energy output and demand on similar terms, energy output is converted to services in the form of work and heat. Each unit of energy output will enable a fraction of that output as work and heat. An efficiency "learning curve" is assumed: over time, the work and heat enabled by a unit of energy output increases.	0.4@0y; 0.5@100; 0.6@150-200y	none (dimensionless ratio)	
44	[BEFH plant operating life]	Assumed typical operating life for biomass energy supply plant & equipment.	40	years	
45	[HE supply EROI]	Hydro-electricity energy return on investment.	35	none (dimensionless ratio)	
46	[HE capacity factor]	Hydro-electricity capacity factor. This is matched with EROI value i.e. varying the capacity factor requires commensurate adjustment to EROI value.	0.45	none (dimensionless ratio)	
47	[HE self power demand to services conversion factor]	EROI studies typically express life cycle energy demand in terms of either a primary or final energy equivalent. In this model, rates of energy demand are expressed in terms of energy *services* in the form of work and heat. The work and heat associated with a unit of energy demand represent some fraction of that unit. An efficiency "learning curve" is assumed: over time, the energy required to deliver a given quantity of work and heat reduces.	0.85@0y; 0.7@100; 0.6@150-200y	none (dimensionless ratio)	
48	[HE to services conversion factor]	To allow aggregation of all energy output and demand on similar terms, energy output is converted to services in the form of work and heat. Each unit of	0.6@0y; 0.7@100; 0.8@150-	none (dimensionless ratio)	

		energy output will enable a fraction of that output as work and heat. An efficiency "learning curve" is assumed: over time, the work and heat enabled by a unit of energy output increases.	200y		
49	[HE plant operating life]	Typical operating life for hydro-electricity plant & equipment.	75	years	
50	[NuE supply EROI]	Nuclear electricity plant energy return on investment. This is assumed to increase as the proportion of later-generation technology in the global installed capacity base increases.	5@0-100y; 20@150-200y	none (dimensionless ratio)	
51	[NuE capacity factor]	Nuclear electricity capacity factor. This is matched with EROI value i.e. varying the capacity factor requires commensurate adjustment to EROI value.	0.85	none (dimensionless ratio)	
52	[NuE self power demand to services conversion factor]	EROI studies typically express life cycle energy demand in terms of either a primary or final energy equivalent. In this model, rates of energy demand are expressed in terms of energy *services* in the form of work and heat. The work and heat associated with a unit of energy demand represent some fraction of that unit. An efficiency "learning curve" is assumed: over time, the energy required to deliver a given quantity of work and heat reduces.	0.85@0y; 0.7@100; 0.6@150-200y	none (dimensionless ratio)	
53	[NuE to services conversion factor]	To allow aggregation of all energy output and demand on similar terms, energy output is converted to services in the form of work and heat. Each unit of energy output will enable a fraction of that output as work and heat. An efficiency "learning curve" is assumed: over time, the work and heat enabled by a unit of energy output increases.	0.6@0y; 0.7@100; 0.8@150-200y	none (dimensionless ratio)	
54	[NuE plant operating life]	Operating life for nuclear electricity generation plant & equipment.	50	years	
55	[PTF supply EROI]	Petroleum transport fuel supply energy return on investment (boundary = refinery gate). This is assumed to decrease sharply in future, though the impact of this is limited due to declining proportion	37.5@0y; 3@145y; 1@200y	none (dimensionless ratio)	

		of petroleum transport fuels in overall energy supply.			
56	[PTF capacity factor]	Petroleum transport fuel supply plant & equipment capacity factor. Included only to provide consistent structure for each energy supply module.	1	none (dimensionless ratio)	
57	[PTF plant operating life]	Operating life for petroleum transport fuel plant & equipment.	30	years	
58	[PTF to services conversion factor]	EROI studies typically express life cycle energy demand in terms of either a primary or final energy equivalent. In this model, rates of energy demand are expressed in terms of energy *services* in the form of work and heat. The work and heat associated with a unit of energy demand represent some fraction of that unit. An efficiency "learning curve" is assumed: over time, the energy required to deliver a given quantity of work and heat reduces.	0.15@0y; 0.25@100y; 0.35@150-200y	none (dimensionless ratio)	
59	[PTF self power demand to services conversion factor]	To allow aggregation of all energy output and demand on similar terms, energy output is converted to services in the form of work and heat. Each unit of energy output will enable a fraction of that output as work and heat. An efficiency "learning curve" is assumed: over time, the work and heat enabled by a unit of energy output increases.	0.65@0y; 0.5@100y; 0.4@150-200y	none (dimensionless ratio)	
60	[CFE capacity factor]	Coal-fired electricity plant & equipment capacity factor.	0.75	none (dimensionless ratio)	
61	[CFE plant operating life]	Operating life for coal-fired electricity plant and equipment.	30	years	
62	[CFE operating & maintenance plowback]	All energy supply entails its own ongoing energy demand for operating and maintenance loads. A nominal rate is set initially, based on published data for a particular situation.	0.16	none (dimensionless ratio)	Source: International Energy Agency. 2002. Environmental and Health Impacts of Electricity Generation. The International Energy Agency–Implementing Agreement for Hydropower Technologies and Programmes. As cited in: Kessides, Ioannis N., and David C. Wade. 2011. "Deriving an Improved Dynamic EROI to Provide Better Information for Energy

					Planners." Sustainability no. 3 (12):2339-57.
63	[CFE energy investment adjustment factor-O&M]	The global annual mean O&M plowback rate may vary from the nominal rate. The adjustment factor allows tuning of this parameter so that overall EROI represents a sensible global mean value.	0.32	none (dimensionless ratio)	Set to give EROI of around 18:1.
64	[CFE emplacement power demand]	Emplacing any energy supply capacity entails upfront energy demand, before energy is made available to enable other economic activity. A nominal rate is set initially, based on published data for a particular situation.	0.095	none (dimensionless ratio) (GWh/GWh storage emplaced)	Source: International Energy Agency. 2002. Environmental and Health Impacts of Electricity Generation. The International Energy Agency–Implementing Agreement for Hydropower Technologies and Programmes. As cited in: Kessides, Ioannis N., and David C. Wade. 2011. "Deriving an Improved Dynamic EROI to Provide Better Information for Energy Planners." Sustainability no. 3 (12):2339-57.
65	[CFE energy investment adjustment factor-emplacement]	The global annual mean emplacement energy demand may vary from the nominal rate. The adjustment factor allows tuning of this parameter so that overall EROI represents a sensible global mean value.	0.75	none (dimensionless ratio)	Set to give EROI of around 18:1.
66	[CFE self power demand to services conversion factor]	To allow aggregation of all energy output and demand on similar terms, energy output is converted to services in the form of work and heat. Each unit of energy output will enable a fraction of that output as work and heat. An efficiency "learning curve" is assumed: over time, the work and heat enabled by a unit of energy output increases.	0.85@0y; 0.7@100y; 0.6@150-200y	none (dimensionless ratio)	
67	[CFE to services conversion factor]	EROI studies typically express life cycle energy demand in terms of either a primary or final energy equivalent. In this model, rates of energy demand are expressed in terms of energy *services* in the form of work and heat. The work and heat associated with a unit of energy demand represent some fraction of that unit. An efficiency "learning curve" is assumed: over time, the energy required to deliver a given quantity of work and heat reduces.	0.6@0y; 0.7@100y; 0.8@150-200y	none (dimensionless ratio)	

68	[NGE plant operating life]	Nautural gas-fired electricity plant & equipment capacity factor.	30	years	
69	[NGE capacity factor]	Operating life for natural gas-fired electricity plant and equipment.	0.5	none (dimensionless ratio)	This assumes natural-gas fired electricity is used for a mix of baseload and peak supply, weighted towards peak supply.
70	[NGE operating & maintenance plowback]	All energy supply entails its own ongoing energy demand for operating and maintenance loads. A nominal rate is set initially, using same value as for coal-fired electricity.	0.16	none (dimensionless ratio)	Based on parameter #62.
71	[NGE energy investment adjustment factor-O&M]	The global annual mean O&M plowback rate may vary from the nominal rate. The adjustment factor allows tuning of this parameter so that overall EROI represents a sensible global mean value.	0.75	none (dimensionless ratio)	Set to give EROI of around 8-10:1. This assumes function weighted towards peak electricity supply. For higher proportion of baseload, EROI would increase.
72	[NGE emplacement power demand]	Emplacing any energy supply capacity entails upfront energy demand, before energy is made available to enable other economic activity. A nominal rate is set initially, using the same value as for coal-fired electricity.	0.095	none (dimensionless ratio) (GWh/GWh storage emplaced)	Based on parameter #64.
73	[NGE energy investment adjustment factor-emplacement]	The global annual mean emplacement energy demand may vary from the nominal rate. The adjustment factor allows tuning of this parameter so that overall EROI represents a sensible global mean value.	0.75	none (dimensionless ratio)	Set to give EROI of around 8-10:1. This assumes function weighted towards peak supply is peak electricity supply. For higher proportion of baseload, EROI would increase.
74	[NGE to services conversion factor]	To allow aggregation of all energy output and demand on similar terms, energy output is converted to services in the form of work and heat. Each unit of energy output will enable a fraction of that output as work and heat. An efficiency "learning curve" is assumed: over time, the work and heat enabled by a unit of energy output increases.	0.6@0y; 0.7@100y; 0.8@150-200y	none (dimensionless ratio)	
75	[NGE self power demand to services conversion	EROI studies typically express life cycle energy demand in terms of either a primary or final energy equivalent. In this model, rates of energy demand are expressed in terms of energy *services* in the form of work and heat. The work and heat associated with	0.85@0y; 0.7@100y; 0.6@150-200y	none (dimensionless ratio)	

	factor]	a unit of energy demand represent some fraction of that unit. An efficiency "learning curve" is assumed: over time, the energy required to deliver a given quantity of work and heat reduces.			
76	[CH supply EROI]	Coal heating supply plant & equipment energy return on investment.	30@0-200y	none (dimensionless ratio)	
77	[CH plant operating life]	Coal heating supply plant & equipment operating life.	30	years	
78	[CH capacity factor]	Coal heating plant & equipment capacity factor. Included only to provide consistent structure for each energy supply module.	1	none (dimensionless ratio)	
79	[CH self power demand to services conversion factor]	To allow aggregation of all energy output and demand on similar terms, energy output is converted to services in the form of work and heat. Each unit of energy output will enable a fraction of that output as work and heat. An efficiency "learning curve" is assumed: over time, the work and heat enabled by a unit of energy output increases.	0.6	none (dimensionless ratio)	
80	[CH to services conversion factor]	EROI studies typically express life cycle energy demand in terms of either a primary or final energy equivalent. In this model, rates of energy demand are expressed in terms of energy *services* in the form of work and heat. The work and heat associated with a unit of energy demand represent some fraction of that unit. An efficiency "learning curve" is assumed: over time, the energy required to deliver a given quantity of work and heat reduces.	0.6	none (dimensionless ratio)	
81	[NG supply EROI]	Natural gas heating supply plant & equipment energy return on investment.	50@0y; 45@50y; 30@100y; 1@200y	none (dimensionless ratio)	
82	[NGH plant operating life]	Natural gas heating supply plant & equipment operating life.	30	years	
83	[NGH	Natural gas heating plant & equipment capacity	1	none	

	capacity factor]	factor. Included only to provide consistent structure for each energy supply module.		(dimensionless ratio)	
84	[NGH to services conversion factor]	To allow aggregation of all energy output and demand on similar terms, energy output is converted to services in the form of work and heat. Each unit of energy output will enable a fraction of that output as work and heat. An efficiency "learning curve" is assumed: over time, the work and heat enabled by a unit of energy output increases.	0.8	none (dimensionless ratio)	
85	[NGH self power demand to services conversion factor]	EROI studies typically express life cycle energy demand in terms of either a primary or final energy equivalent. In this model, rates of energy demand are expressed in terms of energy *services* in the form of work and heat. The work and heat associated with a unit of energy demand represent some fraction of that unit. An efficiency "learning curve" is assumed: over time, the energy required to deliver a given quantity of work and heat reduces.	0.8	none (dimensionless ratio)	