Comparisons of Electricity Generation Plants using New Metrics (2019)

1. PETROLEUM **Diesel Engine** **40 ft. Container ANYWHERE**	**2. NATURAL GAS** **Combined Cycle** **Brighton Beach CDN**	**3. NUCLEAR** **Thermal Turbine** **R. E. Ginna USA**
4. WAVE **NeptuneWave** **Vancouver CDN**	**5. COAL** **Thermal Turbine** **Plant Scherer USA**	**6. SOLAR** **Photovoltaic** **Avg. 2 plants INDIA**
7. HYDRO **Gravity Dam** **3 Georges CHINA**	**8. WIND** **Offshore Turbine Tower** **Anholt 1 Denmark**	**9. TIDAL** **Range** **Annapolis CDN**
	10. TIDAL **Stream** **SeaGen N. IRELAND**	

Charles Haynes

Chart, Table, Spreadsheet, Notes and Data References

Available from:

https://www.neptunewave.ca/electric-generator-plant-comparison

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press ctrl button to use links to pages

GRAPH:

Electrical Generation Plant Comparisons using new metrics 2019

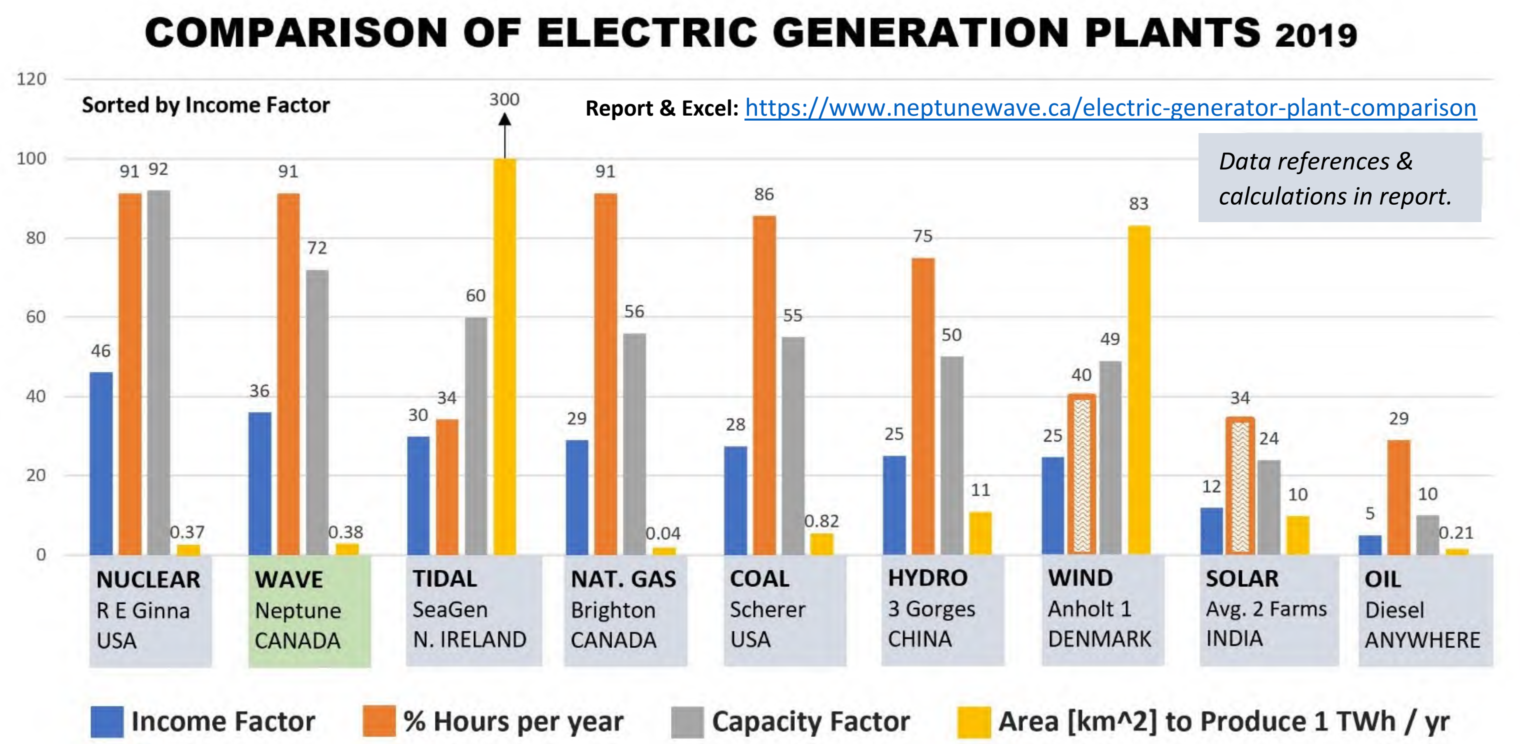

TABLE: Electrical Generation Plant Comparisons using new metrics 2019

ordered by area required to produce 1TWh using new metric, see below for details

Electricity Generation Comparison 2019 *Ranked on km2 per TWh*	LCOE various sources* per MWh [$]	Plant Income Factor using New ** Metric [Factor]	w/m^2 Calc using "Smil"*** [w]	Area to make 1TWh using w/m^2 as basis **** [km^2]	Area to make 1TWh using New***** Metric [km^2]	Capacity Factor [Factor]	Available Hours/Year as % [% & Hours]
1. NAT. GAS Combined Cycle	60	29	2,835	353	.04 km^2	.52	91% 8,000 h
2.PETROLEUM Diesel Engine	239	5	538	1,858	.21 km^2	.30	30% 2,600 h
3. NUCLEAR Thermal Turbine	147.5	46	311	3,216	.37 km^2	.91	91% 8,000 h
4. WAVE NeptuneWave	67	36	670	1,493	.38 km^2	.72	.91% 8,000 h
5. COAL Thermal Turbine	101.5	0.28	139.8	7,154	.82 km^2	.57	86% 7,500 h
6. SOLAR Photovoltaic	49.5	0.12	11.6	86,284	10 km^2	.19	34% 3,000 h
7. HYDRO Gravity Dam	63.9	25	10.4	96,112	11 km^2	.50	50% 4,400 h
8. WIND Turbine on Tower	45	25	146.5	6,825	83 km^2	.46	40% 3,500 h
9. TIDAL RANGE Gravity Pool	77	30	.39	2,586,207	300 km^2	.29	29% 2,550 h
10. TIDAL Stream	205	30	.0048	208,333,333	20,000+ km^2	.40	34% 3,000 h

Data References in Full Report at: https://www.neptunewave.ca/electric-generator-plant-comparison

Notes:

* **LCOE** In essence the LCOE is calculated as: the lifetime costs of the plant divided by the lifetime energy production (in MWh or kWh) it "Allows the comparison of different technologies (e.g., wind,

solar, natural gas) of unequal life spans, project size, different capital cost, risk, return, and capacities." (*https://www.energy.gov/sites/prod/files/2015/08/f25/LCOE.pdf*) But in fact, there are many different ways to make this calculation hence the different LCOE calculations are not equal and not comparable.

*To enhance the LCOE the **Plant Income Factor** is used. See next Note below.*

In this table the following sources are used for this list of LCOE values.

Petroleum, Nat Gas CC, Nuclear, Coal Solar & Wind values from Lizard (see below "General References) for; Wave from NREL calculator for Wave (see below "4. Wave"); Hydro from Wikipedia LCOE (see below General References -Projected LCOE in US by 2020); Tidal Range from GEMAX (see below "9. Tidal Range" ; Tidal Stream from World Energy Council (see below "General References"

** **Plant Income Factor** (to supplement **LCOE** value) results from determining the income a plant will receive at a nominal US$ per kWh ($ 0.05) from the production of 1 TWh of electricity and then obtains the Plant Income Factor by dividing the $ value by the max possible annual output (Name Plate Capacity * 8766 hours)

The values used in the calculation are from published sources, it allows universal comparison of a plants income from electricity production of a specific amount of energy – the higher the factor value the more income the plant receives. To verify the actual $ amount simply multiply the (Plant Income Factor number) by (the Name Plate Rating * 8766). See below, "New Data Metrics" for details.

*** **w/m^2** Smil: http://www.vaclavsmil.com/wp-content/uploads/docs/smil-article-power-density-primer.pdf declares the following simple w / m^2 formula for generation plants:

W/m^2 = (Name Plate Rating [w] * Capacity Factor) / Area of Plant [m^2]

which is used here throughout because of the large number of published inconsistent values for this metric. Other sets of w/ m^2 data can be found at: https://www.strata.org/pdf/2017/footprints-full.pdf for Coal, N. Gas, Nuclear, Solar. Wind & Hydro, and, the Brook and Bradshaw set in "Key role for nuclear energy in global biodiversity conservation" at: https://onlinelibrary.wiley.com/doi/full/10.1111/cobi.12433 .
the main problem with the w/m^2 metric is that there is no consistence with the are used for the plant some include mining, others transportation, some just use the plant area, other include the area used for maintenance and others for the mining and building components of the plant, e.g. for wind turbines.

**** **Area per TWh** (to supplement **w/m^2** value) Enables the comparison of the area required by a generating plant in km^2 to produce the same amount of energy in a year (1 TWh / year). it only uses the published data for the plants annual output & area, and, a declared energy amount (1 TWh) common to all compared plants, this results in a verifiable km^2 values for easy comparisons of the different plants. see details in "New Data Metrics", page 8 below.

SPREADSHEET: Electrical Generation Plant Comparisons using new metrics

Comparisons of Electrical Generation Plants using new metrics 2019

Data References in Full Report at: https://www.neptunewave.ca/electric-generator-plant-comparison

	TIDAL STREAM	TIDAL RANGE (Pool)	WIND	HYDRO DAM	SOLAR	COAL	WAVE	NUCLEAR	PETROLEUM (Diesel)	NAT. GAS
	SeaGen N. Ireland	Annapolis Tidal CDN	Anholt 1 W. Farm Denmark	3 Gorges China	Avg. 2 Plants in India	Plant Scherer Ga US	NeptuneWave CDN	R.E. Ginna Plant NY US	Unit in 40 Ft. Container	Brighton Beach CDN
Plant Rating MW	**1**	**20**	**400**	**22,500**	**824**	**3,600**	**2.30**	**582**	**1**	**564**
Plant Rating watts	1,200,000	20,000,000	399,600,000	22,500,000,000	824,000,000	3,600,000,000	2,300,000	582,000,000	1,000,000	564,000,000
Capacity Factor	**0.60**	**0.29**	**0.49**	**0.50**	**0.24**	**0.55**	**0.72**	**0.92**	**0.10**	**0.56**
for w / m^2 P. Rating * Capacity F. in watts	720,000	5,800,000	196,603,200	11,278,538,813	197,760,000	1,980,000,000	1,656,000	536,022,000	100,000	317,532,000
Annual Output MWh	**6,290**	**50,000**	**1,732,162**	**98,800,000**	**1,727,000**	**17,344,800**	**14,596**	**4,697,675**	**876**	**2,781,580**
Annual Output GWh	6.29	50	-	-	-	-	14.60	-	-	-
Annual Output TWh	0.0063	0.05	1.73	98.80	1.73	17.34	0.01460	4.70	0.000876	2.7816
Plant Area km^2	**150.00**	**15.00**	**144.00**	**1,084**	**17.06**	**14.16**	**0.0056**	**1.72**	**0.00019**	**0.1120**
for w / m^2 Plant area [m^2]	150,000,000	15,000,000	144,000,000	1,084,000,000	17,060,000	14,164,019	5,600	1,723,963	186	112,000
Plant Area to make 1 MWh [km^2]	23,847.38	300.00	83.13	10.97	9.88	0.82	0.000000	0.000000	0.000000	0.000000
Plant Area to make 1 GWh [km^2]					0.01	0.00	0.000384	0.000367	0.000212	0.000040
Plant Area to make 1TWh / yr [km^2]	**23,847**	**300**	**83**	**11**	**9.88**	**0.82**	**0.38**	**0.37**	**0.21**	**0.04**
Brook 2015 Plant Area for 1 TWh [km^2]	**-**	**-**	**46**	**50**	**5.70**	**2.10**	**-**	**0.10**	**-**	**1.10**
W/ m^2 using Smil Formula	**0.0048**	**0.39**	**1.4**	**10.4**	**11.6**	**139.8**	**295.7**	**310.9**	**538.2**	**2,835.1**
Area for 1 TW using w/m^2 values [km^2]	**208,333,333**	**2,586,207**	**732,440**	**96,112**	**86,266**	**7,154**	**3,382**	**3,216**	**1,858**	**353**
No of Times more Area Req'd than Nuclear	64,982.37	817.48	226.53	29.90	26.92	2.23	1.05	1.00	0.58	0.11
No of Times more Area Req'd than Wave	62,156.48	781.93	216.68	28.60	25.75	2.13	1.00	0.96	0.55	0.10
Hours of Production per Year	**3,000**	**1,650**	**3,500**	**6,570**	**3,000**	**7,500**	**8,000**	**8,000**	**2,500**	**8,000**
Hours of Production per year as %	**0.34**	**0.19**	**0.40**	**0.75**	**0.34**	**0.86**	**0.91**	**0.91**	**0.29**	**0.91**
LCOE US $ per MWh	77.00	410.00	45.00	63.90	49.50	101.50	67.00	147.50	239.00	60.00
Income if paid US$ 0.05 / kWh per year	$314,500	$2,500,000	$86,608,100	$4,940,000,000	$86,350,000	$867,240,000	$729,800	$234,883,750	$43,800	$139,079,016
T. Income after 30 years in [$ Million]	**$9.4**	**$75**	**$2,598.2**	**$148,200**	**$2,590.5**	**$26,017.2**	**$22**	**$7,046.5**	**$1.3**	**$4,172.4**
Income/y @ .05/kWh per Name Plate MW	$262,083	$125,000	$216,737	$219,556	$104,794	$240,900	$317,304	$403,580	$43,800	$246,594
Income Factor [$]	**29.9**	**14.3**	**24.7**	**25.1**	**12.0**	**27.5**	**36.2**	**46.1**	**5.0**	**28.2**
	TIDAL STREAM	**TIDAL RANGE (Pool)**	**WIND**	**HYDRO DAM**	**SOLAR**	**COAL**	**WAVE**	**NUCLEAR**	**PETROLEUM (Diesel)**	**NAT. GAS**

Available from**:** https://www.neptunewave.ca/electric-generator-plant-comparison

Spreadsheet screen copy DETAIL

Comparisons of Electrical Generation Plants using new metrics 2019

	TIDAL STREAM	TIDAL RANGE (Pool)	WIND	HYDRO DAM	SOLAR
	SeaGen N. Ireland	Annapolis Tidal CDN	Anholt 1 W. Farm Denmark	3 Gorges China	Avg. 2 Plants in India
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for w / m^2 Plant area [m^2]	150,000,000	15,000,000	144,000,000	1,084,000,000	17,060,000
Plant Area to make 1 MWh [km^2]	23,847.38	300.00	83.13	10.97	9.88
Plant Area to make 1 GWh [km^2]					0.01
Plant Area to make 1TWh / yr [km^2]	**23,847**	**300**	**83**	**11**	**9.88**
Brook 2015 Plant Area for 1 TWh [km^2]	**-**	**-**	**46**	**50**	**5.70**
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Income Factor [$]	**29.9**	**14.3**	**24.7**	**25.1**	**12.0**
	TIDAL STREAM	**TIDAL RANGE (Pool)**	**WIND**	**HYDRO DAM**	**SOLAR**

DATA REFERENCES

This section has 4 parts:

- New Data Metrics: Plant Income Factor & Plant Area per TWh
- General References for Comparisons of the 10 Generation Plants
- Worldwide Energy & CO2 Production Charts from British Petroleum (BP) data 2017
- References Specifically used for the 10 Generation Plants

Statement of bias & expectations by the authors

(1) Globally, we expect the production of electricity will continue to be a mix of non-renewable & renewables.

(2) BP reports (2018), that non-renewables (Coal, Nat. Gas & Oil) provide 86% of worldwide energy.

We expect electricity production in 2050 will be:
30% non-renewables,
30% nuclear &,
40% renewables.
We expect wave energy will provide 15-20% of renewable electricity production by 2050.

(3) We assume, like MIT, that electricity provided by intermittent sources (primarily wind and solar) will be fully utilized by the respective grids whenever and wherever it is produced, and non-renewables will reliably provide "dispatchable and peaker generation" when needed.

4) We look forward to the day when an over abundance of electrical energy is available for all people such that fossil fuel dispatchable and peaker power is not needed and the excess power not required during off peak periods will be utilized for non-time critical activities such as desalination and as yet undefined energy intensive activities. No shortages equals no scarcity ergo lower prices.

5)We understand that Power is power, we must have it, that we need more of it increasingly, and that our future demands for power will continue to put pressure on power production.

New Data Metrics: Plant Income Factor & Plant Area per TWh

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Two new data metrics to strengthen energy production comparisons between each of non-renewable (coal, gas, oil & nuclear) and renewable (hydro, wind, solar, wave & tidal) sources of electrical generation plants have been included in this analysis.

These new data metrics are **Plant Income Factor** & **Plant Area per TWh**.

Plant Income Factor is a $ value of income, based on the same amount (US$ 0.05 / kWh) paid to each generation plant to produce 1 TWh relative to 100% of name plate capacity. It uses only publicly available data (the plants annual output and name plate capacity), and, a declared $ amount common to all compared plants, which results in verifiable $ values to supplement **LCOE** $ values for comparisons of generation plants.

Plant Area per TWh is the area (in km^2) required by each generation plant to produce the same amount of energy in a year (1 TWh / year). It only refers to a specific generation plant at a specific time which can then be compared to other specific plants; it only uses the published data for the plants annual output & area, and, a declared energy amount (1 TWh) common to all compared plants, this results in verifiable km^2 values to supplement **w/m^2** values for comparisons of generation plants.

1. **Formula for the new Plant Income Factor metric**
   which is the US $ Plant Income Factor for each generation plant

$$\text{Plant Income Factor} = \frac{(\text{US \$ Paid for Energy} * \text{Plant Annual Output MWh})}{\text{Maximum Possible Annual Plant Output MWh}}$$

First part: Plant Income Factor Formula:

Part 1 = ($50.00 * Plant Annual Energy Output in MWh)

yields a $-MWh value based on the amount of output energy produced per year.

For Example:

the 22,500 MW 3 Gorges Dam gets a large $-MWh 4,940,000,000; and,
the 20 MW Annapolis Tidal Range gets a small $-MWh 2,500,000

These large & small cumbersome values are evened out by the
Second part: Plant Income Factor Formula:

Part 2 = *dividing (the first part) by (the name plate rating in MW * 8,766)*

For Example: **(Plant Income Factor)**

the 3 Gorges Dam value ($-MWh 4,940,000,000) / (22,500*8,766 MWh) = **$ 25.** and,
the Annapolis Tidal Range value ($-MWh 2,500,000) / (20*8766 MWh) = **$ 14.**

This division by 100% of the maximum possible plant energy (in MWh), that can be produced in a year, brings the Capacity Factor relationship into the calculation and yields a value, less than $ 100, for easy and accurate comparisons between the different generation Plants regardless of the system: fossil or renewable.

NOTE:

To verify, convert back to the actual $ earned per year, simply:
*multiply the (Plant Income Factor number) by (the Name Plate Rating * 8766)*
For Example:
the 3 Gorges Dam Plant Income Factor (25.0634 *(22,500*8766)) = $ 4,940,000,000.
the Annapolis Tidal Range Plant Income Factor (14.2694 *(20*8766)) =$ 2,500,000.

This new **Plant Income Factor** metric overcomes concerns raised about the use of the **LCOE** metric for determining a uniform value for comparisons of non-renewable and renewable generation plants, due to the fact that different LCOE formulas are used for different generation plants, by:
(a) using a declared value of the price paid to the plant for energy it produces; (b) using the value of the plants actual energy output per year; and, (c) using the value of the plants name plate capacity so the result is a consistent **US $ Plant Income Factor** for each plant for verifiable and easy comparisons.

2. Formula for the new Plant Area per TWh metric
(which is the Area Required to Produce 1 TWh per Year by each generation plant)

Plant Area per TWh = (Plant Area in km^2) / (Number of TWh produced in a year)

HENCE using the formula for Plant Area per TWh we get:

For Example:

the 3 Gorges Dam Plant requires: (1,084 / 98.8) = **11 km^2 per 1 TWh**
the R.E. Ginna Nuclear Steam Plant requires: (1.7 / 4.7) = **.37 km^2 per 1 TWh**

NOTE:

To verify that this new data metric is true simply:
multiply the result by the number of TWh produced by the plant / year
For Example:
the 3 Gorges Dam Plant (Area / TWh) 10.9717 * 98.8 = **1,084 km^2 plant area**
the R.E. Ginna Nuclear Plant (Area / TWh) .3617 * 4.7 = **1.7 km^2 plant area**

This new **Plant Area per TWh** metric overcomes concerns raised about the calculation of the **w/m^2** value, with respect to (a) non-consistent determination of the watt value and (b)non-consistent determination of the area of the plant to be included in the calculation, by: (a) using a declared value of energy (1 TWh) to measure each plant to; (b) using the value of the plants actual energy output per year (in TWh); and, (c) using the value of the plants area from published data so the result is a consistent **km^2 per 1 TWh produced** for each plant for verifiable and easy comparisons.

General References for the Comparisons of Generation Plants

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Lazard (2017)

On November 2, 2017 the investment bank Lazard released version 11[75] of their LCOE report and version 3[76] of their LCOS report.[77]

Generation Type	Low ($/MWh)	High ($/MWh)	Average Per MWh
Solar PV - Rooftop Residential	187	319	
Solar PV - Rooftop C&I	85	194	
Solar PV - Community	76	150	
Solar PV - Crystalline Utility Scale	46	53	
Solar PV - Thin Film Utility Scale	43	48	49.5
Solar Thermal Tower with Storage	98	181	
Fuel Cell	106	167	
Microturbine	59	89	.
Geothermal	77	117	
Biomass Direct	55	114	
Wind	30	60	45
Diesel Reciprocating Engine	197	281	239
Natural Gas Reciprocating Engine	68	106	
Gas Peaking	156	210	
IGCC	96	231	
Nuclear	112	183	147.5
Coal	60	143	101.5
Gas Combined Cycle	42	78	60

https://en.wikipedia.org/wiki/Cost_of_electricity_by_source

Started Intellicast - Weather A...

Projected LCOE in the U.S. by 2022 (as of 2016) $/MWh

Plant Type	Min	Capacity Weighted Average	Max
Coal with 30% carbon sequestration	128.9	NB	196.3
Coal with 90% carbon sequestration	102.7	NB	142.5
Natural Gas-fired Conventional Combined Cycle	52.4	58.6	83.2
Natural Gas-fired Advanced Combined Cycle	51.6	53.8	81.7
Natural Gas-fired Advanced CC with CCS	63.1	NB	90.4
Natural Gas-fired Conventional Combustion Turbine	98.8	100.7	148.3
Natural Gas-fired Advanced Combustion Turbine	85.9	87.1	129.8
Advanced Nuclear	95.9	96.2	104.3
Geothermal	42.8	44.0	53.4
Biomass	84.8	97.7	125.3
Wind Onshore	43.4	55.8	75.6
Wind Offshore	136.6	NB	212.9
Solar PV	58.3	73.7	143.0
Solar Thermal	176.7	NB	372.8
Hydro	57.4	63.9	69.8

Convert	To km^2
Acre	/ 247.105
Hectar	/ 100
sq miles	* 2.59
sq feet	/ 10763910.4
sq meter	/1000000

Energy-facts1.pdf

also http://neinuclearnotes.blogspot.com/2015/07/how-much-land-does-nuclear-wind-and.html

Units and conversion factors for power

1 watt = 1 joule per second
1 kilowatt = 1 kilojoule per second

Units and conversion factors for energy

1 watt-second = 1 joule
1 kilowatt-hour = 3600 kilojoules

Production factor (the availability)

production factor = actual annual yield / theoretical annual yield

For example: wind energy

- suppose, a windmill has a power of 3 megawatts
- then the **theoretical annual yield** is
  3 megawatts x 24 hours x 365 days = 26 280 megawatt-hours
- suppose, the **actual annual yield** is 7 884 megawatt-hours
- then the **production factor** is (7 884 / 26 280) x 100% = 30%

https://www.eia.gov/electricity/monthly/epm_table_grapher.php?t=epmt_c_4

ng Started Intellicast - Weather A...

eia + Sources & Uses

Table C.4. Unit of Measure Equivalents for Electricity

Unit	Equivalent
Kilowatt (kW)	1,000 (One Thousand) Watts
Megawatt (MW)	1,000,000 (One Million) Watts
Gigawatt (GW)	1,000,000,000 (One Billion) Watts
Terawatt (TW)	1,000,000,000,000 (One Trillion) Watts
Gigawatt	1,000,000 (One Million) Kilowatts
Thousand Gigawatts	1,000,000,000 (One Billion) Kilowatts
Kilowatthours (kWh)	1,000 (One Thousand) Watthours
Megawatthours (MWh)	1,000,000 (One Million) Watthours
Gigawatthours (GWh)	1,000,000,000 (One Billion) Watthours
Terawatthours (TWh)	1,000,000,000,000 (One Trillion) Watthours
Gigawatthours	1,000,000 (One Million) Kilowatthours
Thousand Gigawatthours	1,000,000,000(One Billion Kilowatthours

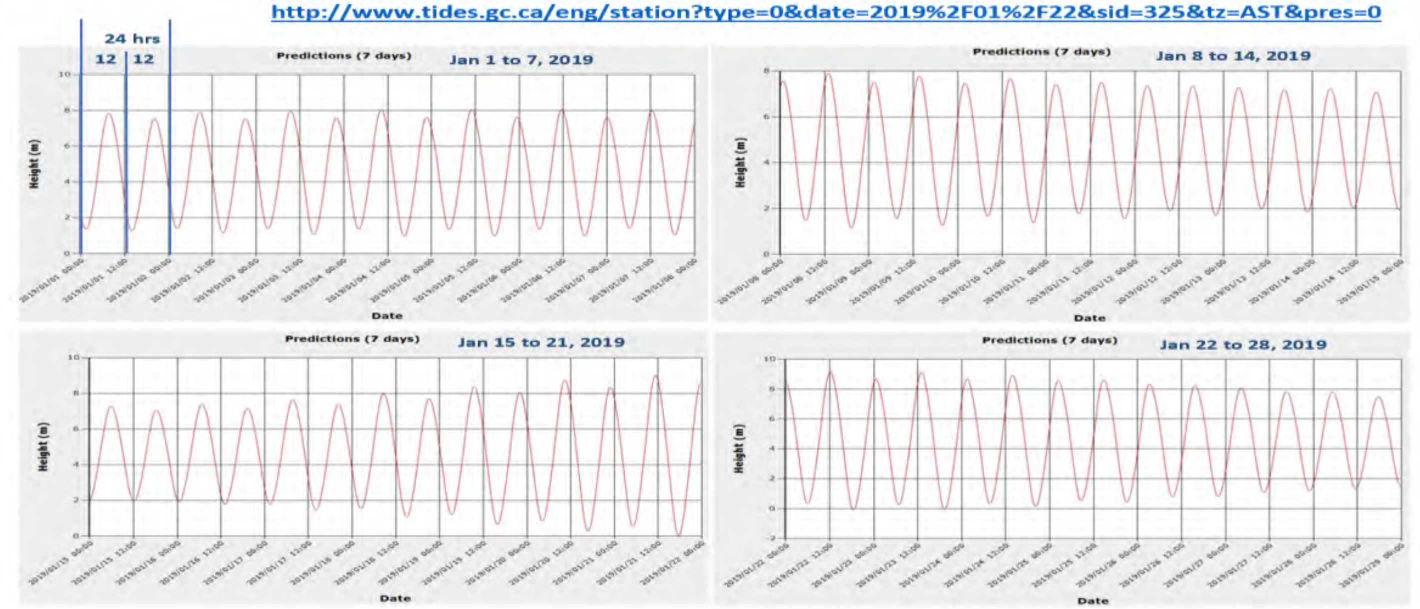
Source: U.S. Energy Information Administration

IRENA
International Renewable Energy Agency
is an intergovernmental organization to **promote adoption and sustainable use of renewable energy.**
It was founded in 2009 and its statute entered into force on 8 July 2010.
The agency is headquartered in Abu Dhabi.

NREL
National Renewable Energy Laboratory,
located in Golden, Colorado, USA, specializes in **renewable energy** and **energy** efficiency research and development. ...
NREL has a number of PV research capabilities including research and development, testing, and deployment.
Operating agency:
MRIGlobal and Battelle Memorial Institute

TIDE CHART -- Month of January 2019 for **Digby, Nova Scotia**, Canada (Near Annapolis Tidal Range Generator)

http://www.tides.gc.ca/eng/station?type=0&date=2019%2F01%2F22&sid=325&tz=AST&pres=0



Brook & Bradshaw: “Key role for nuclear energy in global biodiversity conservation”

The Brook & Bradshaw values for “**Land Use km^2**” for 1 TWh are for “for fuel mining and plant footprint” and are included in the excel spreadsheet, see page 6 above.

https://onlinelibrary.wiley.com/doi/abs/10.1111/cobi.12433

Brook & Bradshaw *Biodiversity and Sustainable Energy* 707

Table 1. Per terawatt hour (TWh) data for key sustainability and economic–environmental impact indicators associated with 7 electricity generation options and relative ranks[a] of the energy source.

	Coal		*Natural gas*		*Nuclear*		*Biomass*		*Hydro*		*Wind (onshore)*		*Solar (PV)*	
Indicator (per TWh)	*value*	*rank*	*value*	*rank*	*value*	*rank*	*value*	*rank*	*value*	*rank*	*value*	*rank*	*value*	*rank*
GHG emissions (t CO_2)[b]	1,001,000	7	469,000	6	16,000	3	18,000	4	4,000	1	12,000	2	46,000	5
Electricity cost ($US)[c]	100.1	4	65.6	1	108.4	5	111	6	90.3	3	86.6	2	144.3	7
Dispatchability[d]	A	1	A	1	A	1	B	4	B	4	C	6	C	6
Safety (fatalities)[f]	161	7	4	5	0.04	1	12	6	1.4	4	0.15	2	0.44	3
Solid waste (t)	58,600	7	NA	1	NA	1	9,170	6	NA	1	NA	1	NA	1
Radiotoxic waste[g]	mid	6	low	3	high	7	low	3	trace	1	trace	1	trace	1
Weighted Rank[h]		6.0		2.0		1.3		6.7		3.3		2.3		5.3

[a] *Energy source with the lowest environmental or economic impact for a given indicator (e.g., greenhouse-gas emissions, cost of electricity, etc.) is assigned a rank of 1, whereas the worst performing of the 7 energy sources is assigned a rank of 7. Ties are given the same rank. All calculations and supporting data behind this table are detailed in the Supporting Information.*
[b] *Includes production-related and life-cycle-embodied emissions.*
[c] *Levelized cost of electricity, includes cost amortization for long-term waste management and plant decommissioning for nuclear energy.*
[d] *Categorical rating of capacity and availability to deliver electricity on demand.*
[e] *For fuel mining and generating footprint.*
[f] *Deaths from accidents, excluding chronic health problems.*
[g] *Categorical classification of the volume of the radiotoxic waste stream.*
[h] *Average of 3 multicriteria decision-making analysis scenarios with multiplicative weightings applied to the indicator ranks: (1) no weighting = 1 × multiplier for all ranks; (2) economic rationalist = 1 × land use, solid waste, and radioactive waste, 2 × cost and dispatchability, and 0.5 × greenhouse gas emissions and safety; and (3) environmentalist = 1 × safety, solid waste and radioactive waste, 2 × greenhouse gas emissions and land use, and 0.5 × cost and dispatchability. Weightings are arbitrary but illustrative of typical viewpoints.*

Conservation Biology
Volume 29, No. 3, 2015

NOTE: In the Comments to:
https://www.energycentral.com/c/ec/how-much-land-does-solar-wind-and-nuclear-energy-require
How Much Land Does Solar, Wind and Nuclear Energy Require? By Jesse Jenkins the author cautions us:

Jesse Jenkins on June 26, 2015
Mark,

The land use figures for solar are not mind, but are from the MIT *Future of Solar Energy* report, which I clearly referenced. A vareity of assumptions go into any of these calculations, and I wouldn't be surprised if two different papers/studies differed by a factor of 2x. If they are in agreement on the order of magnitude, that is what I would expect. And note that a 2x increase in the land use figure still doesn't change the general conclusion at all. If solar took up 7-22,000 sq-km rather than 4-11,000, would that change much of anything about my post? I don't think so.

w / m^2 Notes from **Vaclav Smil**:
http://www.vaclavsmil.com/wp-content/uploads/docs/smil-article-power-density-primer.pdf

700 MW/279,615 m2 = 2,503.4 W/m2

Robert W. Scherer Coal Plant in Georgia with installed capacity of about 3.5 GW, indicate the actual claims: coal storage yard of 36 ha, and an ash-settling pond of 120 ha (designed to last for the plant's lifespan of some 50 years) with the plant's total operating area covering about 1,400 ha (all data from Georgia Power). With an average load factor of 75% this translates to power density of close to **190 W/m2.**

HENCE:

3.5 * .75 = 2.625 GW = 2,625,000,000 w
1,400 ha * 10,000 = 14,000,000 m

So: 2,625,000,000 / 14,000,000 = 187.5 w / m^2 rounded = **190 w / m^2** https://www.strata.org/pdf/2017/footprints-full.pdf

footprints-full.pdf - Adobe Acrobat Reader DC

File Edit View Window Help

Home Tools Leigh_Fi... MCTSea... R.E. GIN... Invoice_... IRENA_...

1 (4 of 25) 96.5%

Chart 1: Land Use by Electricity Source in Acres/MW Produced

Electricity Source	Acres per Megawatt Produced
Coal	12.21
Natural Gas	12.41
Nuclear	12.71
Solar	43.50
Wind	70.64
Hydro	315.22

Generation Type	w / m^2
Coal	20
Natural Gas	20
Nuclear	20
Solar	6
wind	4
Hydro	1

https://www.worldenergy.org/wp-content/uploads/.../WEResources_Marine_2016.pdf

WORLD ENERGY COUNCIL | WORLD ENERGY RESOURCES 2016

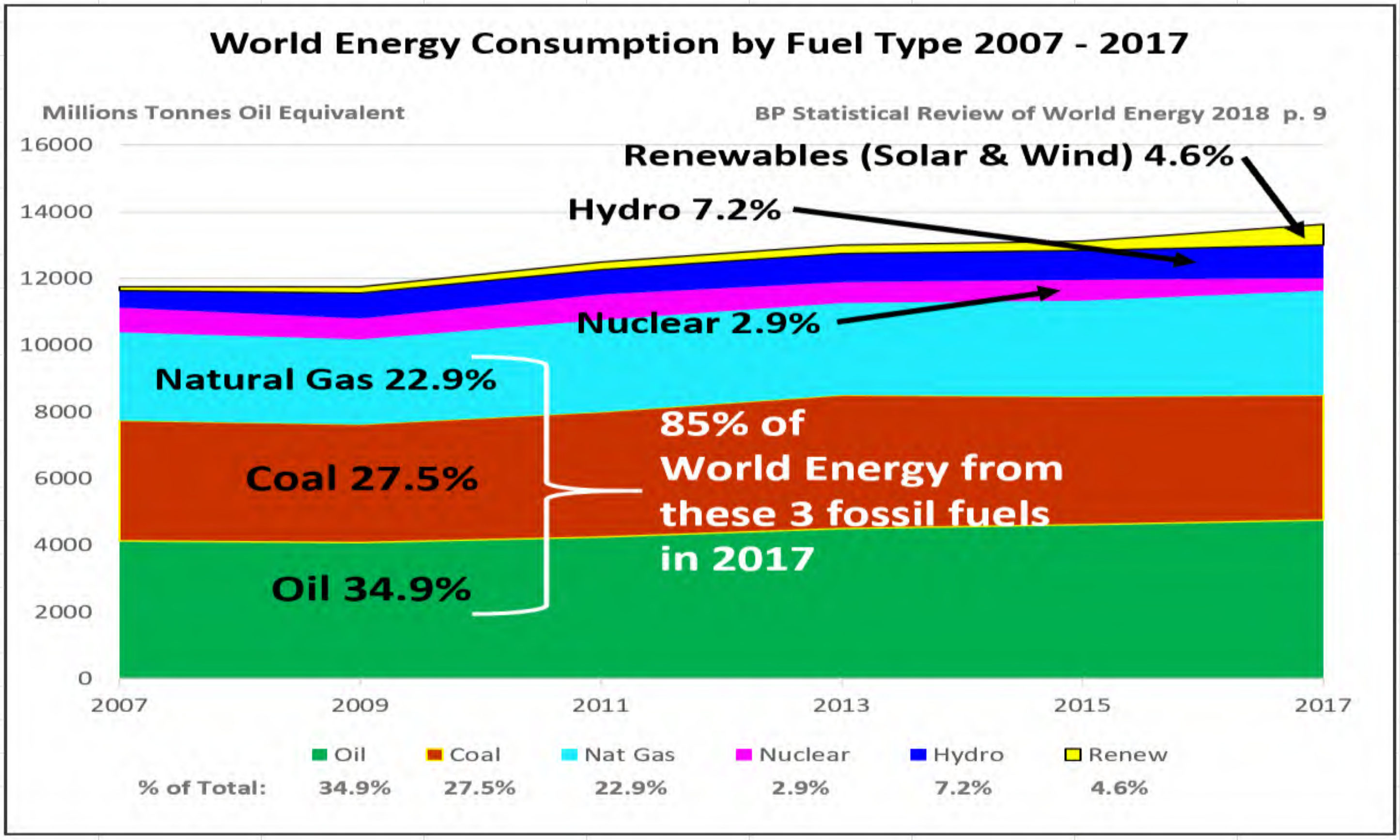
Variable	Wave		Tidal Stream		OTEC	
	Min	Max[56]	Min	Max	Min	Max
Availability (%)	95%	98%	92%	98%	95%	95%
Capacity Factor (%)	35%	40%	35%	40%	97%	97%
LCOE ($/MWh)	120	470	130	280	150	280

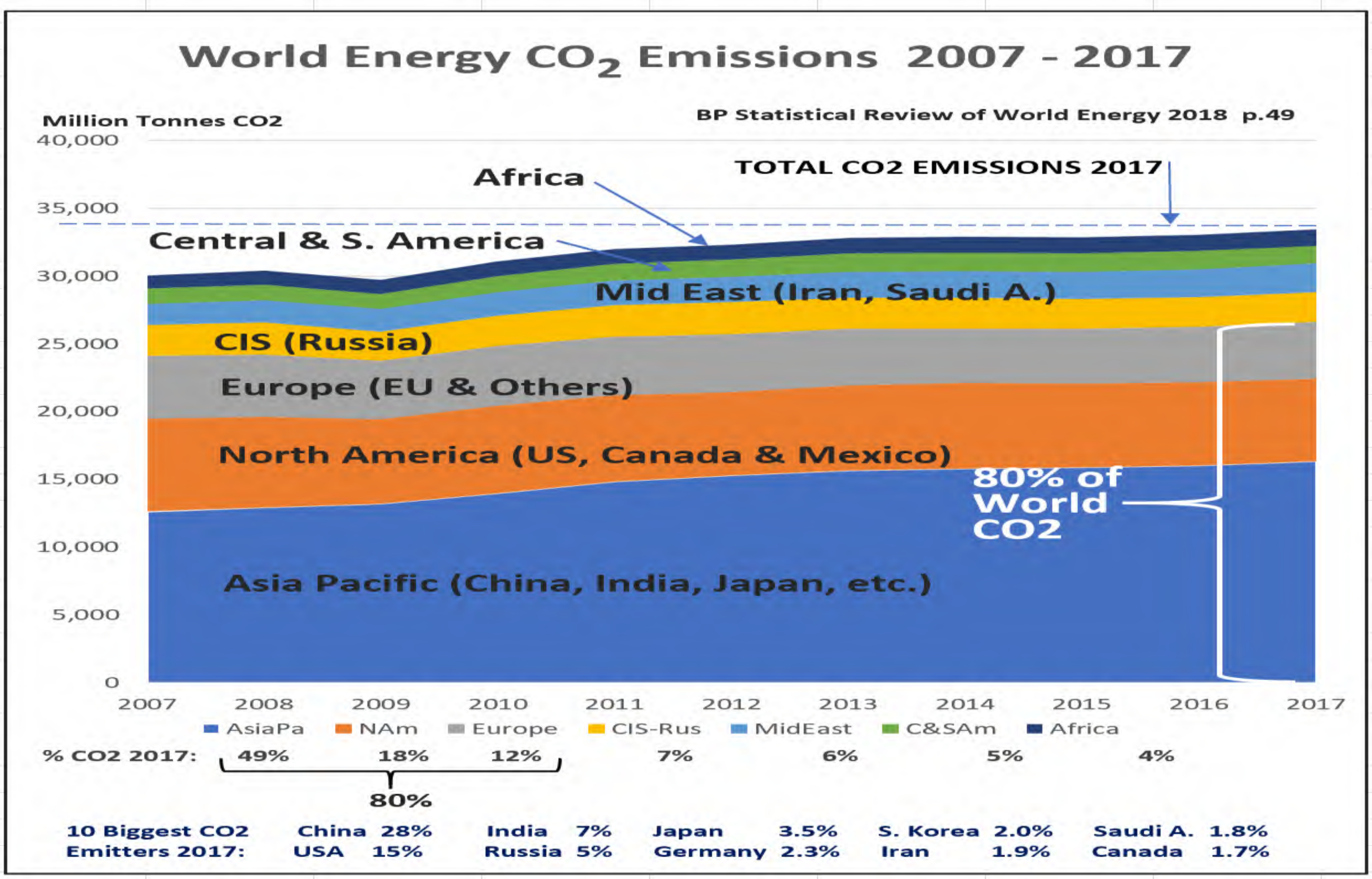
Source: OES - IEA (2015)

130 + 280 / 2 =

LCOE US$ 205 / MWh

CHARTS: Worldwide Energy Consumption & CO_2 Emissions to 2017





References used for the 10 Electrical Generation Plants

1. PETROLEUM DIESEL ENGINE

TOC

Rated MW	1 MW
Capacity Factor .099	.10 see chart below
Output per Year	1MW * 8760 = 8,760 MWh * .1 = 876 MWh
Area for Plant	2,000 sq. ft Based on 6 units the size of 1 (8 ft. by 40 ft.) generator container 1 for generator, 2 for fuel storage, 2 for office and storage, 1 for parking = 6 units = 6*(8*40) = 2,000 Sq. Ft.
Hours Available per Year	Hours / year = (8760*.10) = 876 h/y (because it is running at full rated MW)
LCOE Cost per MWh	US$ 239.00 (see Lizard, p. 5, Third Party General References)

Consumes 269 Liters / hour at 1000 kW (1MW) output
Diesel Fuel US 2018= $ 3.123 / Gal (us) = 3.123/3.79 = US$ 0.824 per liter 1 US Gal = 3.79 liter
Hence 269 liters costs (2018) 269 * .824 = US $ 221.656 per 1 MWh (221.66/1000 = **$0.22 per kWh TO RUN**

https://www.eia.gov/electricity/monthly/epm_table_grapher.php?t=epmt_6_07_a

ng Started Intellicast - Weather A...

eia *Independent Statistics & Analysis* U.S. Energy Information Administration

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+ Tools + Learn About Energy + News

Electric Power Monthly

Previous Issues Issue: November 20 Format: pdf

Data for October 2018 | Release Date: December 26, 2018 | Next Release: January 25, 2019 | full report

Table 6.7.A. Capacity Factors for Utility Scale Generators Primarily Using Fossil Fuels, January 2013-October 2018

	Coal	Natural Gas				Petroleum		
Period		Natural Gas Fired Combined Cycle	Natural Gas Fired Combustion Turbine	Steam Turbine	Internal Combustion Engine	Steam Turbine	Petroleum Liquids Fired Combustion Turbine	Internal Combustion Engine
Annual Factors								
2013	59.8%	48.2%	4.9%	10.6%	6.1%	12.1%	0.8%	2.2%
2014	61.1%	48.3%	5.2%	10.4%	8.5%	12.5%	1.1%	1.4%
2015	54.7%	55.9%	6.9%	11.5%	8.9%	13.3%	1.1%	2.2%
2016	53.3%	55.5%	8.3%	12.4%	9.6%	11.5%	1.1%	2.6%
2017	53.7%	51.3%	6.7%	10.5%	9.9%	13.5%	0.9%	2.3%

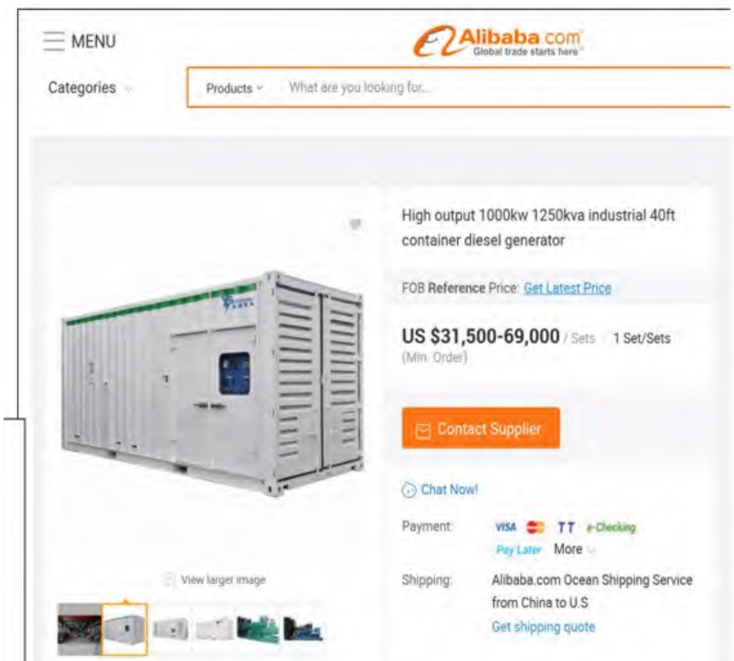
Diesel generator

From Wikipedia, the free encyclopedia

A **diesel generator** (also known as diesel genset) is the combination of a diesel engine with an electric generator (often an alternator) to generate electrical energy. This is a specific case of engine-generator. A diesel compression-ignition engine is usually designed to run on diesel fuel, but some types are adapted for other liquid fuels or natural gas.

Diesel generating sets are used in places without connection to a power grid, or as emergency power-supply if the grid fails, as well as for more complex applications such as peak-lopping, grid support and export to the power grid.

Proper sizing of diesel generators is critical to avoid low-load or a shortage of power. Sizing is complicated by the characteristics of modern electronics, specifically non-linear loads. In size ranges around 50 MW and above, an open cycle gas turbine is more efficient at full load than an array of diesel engines, and far more compact, with comparable capital costs; but for regular part-loading, even at these power levels, diesel arrays are sometimes preferred to open cycle gas turbines, due to their superior efficiencies.



Overview

Quick Details

Place of Origin:	Chongqing, China (Mainland)
Brand Name:	YuanShuo
Model Number:	YS-1000GF
Rated Power:	1000KW
Output Type:	AC Three Phase
Rated Voltage:	400/230V
Rated Current:	1800A
Speed:	1500/1800 RPM
Frequency:	50/60HZ
Product Name:	High output 1000kw 1250kva industrial 40ft container diesel generator
Color:	Request
Type:	Container,Silent
Engine:	Cummins, DEUTZ, GOOGOL, Yuchai, Shangchai, Weichai, Tongchai, etc
Alternator:	STAMFORD, SIMENS, Engga, Wattek, Lingyu, etc.
Controller:	SmartGen / Deepsea / Harson, etc.
Certificate:	ISO9001
Warranty:	12 Months/1000 Hours
Logo Options:	Customized

Cost Comparison for 1 MW Diesel Generator Purchase (2019)

1 MW Diesel Generator (China) = US$ 70,000

1 MW Diesel Generator (USA with UL approval) = US$ 230,000

https://csdieselgenerators.com/new-blue-

CENTRAL STATES DIESEL GENERATORS

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BROWSE GENERATORS FOR SALE

Product Details

- ITEM ID: 1008
- PRICE: $229,500
- KW: 1000 KW
- CONDITION: New
- MANUFACTURER: Blue Star Power Systems
- ENGINE MANUFACTURER: MTU
- ENGINE MODEL: 16V2000G85
- HP: 1495 HP
- VOLTAGE: 277/480
- ENCLOSURE: Open Power Unit
- CATEGORY: Generator Set
- SUB-CATEGORY: Diesel Generator
- YEAR: 2018
- FREQUENCY: 60 Hz

$ 230,000

MTU / Blue Star Power Systems 1000kW standby (900 kW prime) diesel generator set.

MTU 16V2000G85 engine rated 1495 HP at 1800 RPM, emissions EPA tier 2 certified, electronic isochronous governor.

Marathon model 575RSL4044 generator wired 3/60/277/480V, other voltages available, 130 Deg C rise. DVR2000E automatic voltage regulator with PMG excitation (permanent magnet generator).

UL 2200 and CSA approved.

Basler 2020 digital gen-set controller with the following features, low oil pressure, high coolant temp, overspeed, overcrank. Shutdowns include emergency stop pushbutton and audible alarm buzzer with silencing switch, optional features include generator protection for undervoltage, overvoltage, underfrequency, overfrequency and overcurrent.

1500 Amp 100% rated main-line circuit breaker mounted and wired in a NEMA 1 enclosure.

Coolant heater 240V rated for -20 deg F, installed with isolation valves and wired to terminal. Dry single stage air cleaner. Critical grade silencer ... V battery system and cables. 24V 5 Amp ... and wired to terminal. Shipped with oil and ... mercial test performed includes verification of ... settings, block loading to rated kW and PF. ... our limited standby warranty.

... ble upon request, weather protective or sound ... 142 sub-base fuel tank, 5 year / 3000 hour ... tic transfer switch, installation, start up,

... o order upon receipt of PO + deposit

Consumes 269 Liters / hour at 1000 kW (1MW) output

Area = 40 ft containers
1 for system 1 for fuel storage

= 8*40*2 = 640 sq. ft.= **60 m^2**

blue_star_power_systems_MTU_1000_kW_16V2000G85_EPA_Tier_2_emissions_spec_sheet.pdf

Diesel Product Line
1000 kWe / 900 kWe

BLUE STAR Power Systems Inc.

Application Data

Fuel Consumption	
At 100% of Power Rating: gal/hr (lit/hr)	71.0 (269
At 75% of Power Rating: gal/hr (lit/hr)	53.7 (203
At 50% of Power Rating: gal/hr (lit/hr)	36.7 (139

Consumes 269 Liters / hour at 1000 kW (1MW) output

Area = 40 ft containers
1 for system 1 for fuel storage

= 8*40*2 = 640 sq. ft.= **60 m^2**

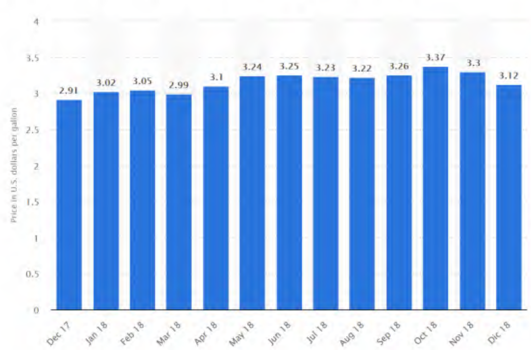
https://www.statista.com/statistics/204169/retail-prices-of-diesel-f...

statista The Statistics Portal
Statistics and Studies from more than 22,500 Sources

Prices & Access Statistics Reports Expert Tools Infographics Services Global Survey NEW Login

Chemicals & Resources › Petroleum & Refinery › U.S. retail prices of diesel fuel monthly 2017-2018

Monthly retail prices of diesel fuel in the United States from December 2017 to December 2018 (in U.S. dollars per gallon)



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DESCRIPTION SOURCE MORE INFORMATION

This statistic shows the monthly retail prices of diesel fuel in the United States from December 2017 to December 2018. In December 2017, one gallon of diesel cost 2.909 U.S. dollars. One year later, in December 2018, one gallon cost 3.123 U.S. dollars. That was a price increase of 0.214 U.S. dollars, or some 7.4 percent within a year.

U.S. retail prices of diesel fuel

The usage of diesel began in the 1930s, but until further European development in the 1960s, diesel

AREA of 1 MW Diesel Unit
Complete Plant

Need space of
8 - 40 ft. by 8 ft. Containers

1 for diesel unit
2 for fuel storage
2 for Office and Storage
1 for parking
2 for space around

8*(40*8) = 640 sq. ft.
= 60 m^2

Diesel Fuel US 2018= $ 3.123 / Gal (us) = 3.123/3.79 = **US$ 0.824 per liter**

1 US Gal = 3.79 Liter

Unit consumes 269 liters / hour at 1000 kW (1 MW) output = 269 * .0824 = **$ 22.16 per hour of capacity operation**

2. NATURAL GAS Brighton Beach Ontario CDN

TOC

Rated MW	541.3 MW (570 or 580 MW ?) Avg = 564 MW
Capacity Factor	from average USA C.F. (see below) for Combined Cycle Gas Plants = .563
Output per Year	564 * 8760 = 4,940,640 * .563 = 2,781,580
Area for Plant	from Google Earth (see below) .112 sq. km
Hours Available per Year	8,000 h/y (only does not run for planned & unplanned maintenance)
LCOE Cost per MWh	US$ 60.00 (see Lizard, p. 5, Third Party General References)

Brighton Beach Generating Station - Wikipedia
https://en.wikipedia.org/wiki/Brighton_Beach_Generating_Station
Brighton Beach Generating Station is a natural **gas** fired combined cycle fossil fuel power ... Description[edit]. The **plant** consists of: Two General Electric 7FA **gas** ...

Nameplate capacity: 541.3 MW
Units operational: 3
Location: Windsor, Ontario
Owner(s): Atco Power 50%; Ontario Power Ge...

Brighton Beach Gas Power Plant - IndustryAbout.com
https://www.industryabout.com/country.../32243-brighton-beach-gas-power-plant
Aug 30, 2018 - Type: **Gas** Power **Plant** Area: Ontario Kind of Fuel: Natural **Gas** Power Capacity: 570 MW (2 x 170 MW, 1 x 230 MW) Owner: **Brighton Beach** ...

Brighton Beach Power - SourceWatch
https://www.sourcewatch.org/index.php/Brighton_Beach_Power
Oct 19, 2004 - July 21, 2004 - Windsor, Ontario: **Brighton Beach** Power L.P., ... the 580 megawatt combined cycle **gas** fired power **plant** located in Windsor, ...

Area of Brighton Beach Gas Power Plant Windsor Ontario

414 * 270 = 111,780 sq. m

= /1,000,000 = **0.112 km^2**

Brighton Beach Combined-Cycle Generation Plant

Capacity
580 megawatts

Equipment
Two natural gas-fired turbines
One steam turbine
Two vertical heat recovery steam generators
State-of-the-art control systems

Highlights
Low emissions
High efficiency
Plant is connected to the Ontario grid at J. Clark Keith substation
Industry leading reliability

Commissioned
2004

Ownership
ATCO Power - 50%
Ontario Power Generation - 50%

Download tearsheet

ATCO Power and Ontario Power Generation Inc. have partnered on a natural gas-fired power plant located on the bank of the Detroit River in the City of Windsor. The plant is a state-of-the-art combined-cycle facility capable of generating 580 megawatts of electricity, which is approximately 3% of Ontario's total requirement for electric power.

This environmentally progressive project consists of two large industrial gas turbines and a single steam turbine, which combine to achieve high efficiency and low emissions in the production of electricity. The combined-cycle process uses the waste heat from the gas turbines to generate steam for the steam turbine, which significantly increases the efficiency of power production.

The electricity produced at the plant is controlled and marketed by Coral Energy Canada Inc., an independent power marketer and a member of the global Shell Trading network. Coral provides natural gas fuel required to operate the plant.

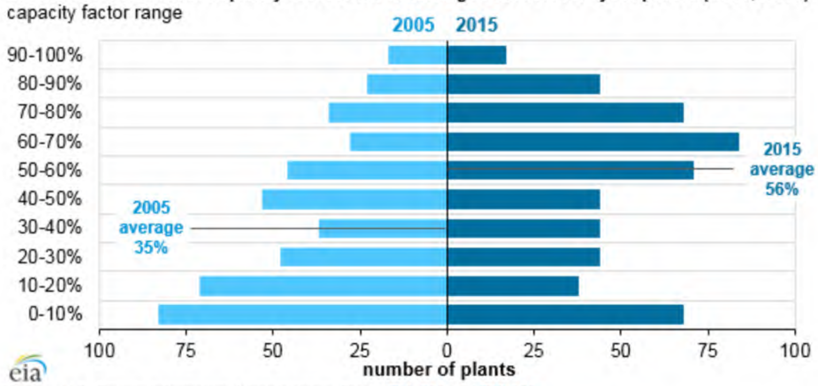
Construction of the facility started in early 2002 and the plant entered commercial service in July 2004.

Capacity factors describe how intensively a particular generating unit or a fleet of generators is run. For instance, a capacity factor near 100% means that the unit is operating almost all the time at a rate close to its maximum possible output.

When natural gas prices exceeded coal prices by a large margin, as was typically the case over the 2005-08 period, electricity systems where both natural gas-fired combined-cycle and coal-fired power plants were available to serve load would typically run combined-cycle units only after making maximum use of available coal-fired generation. As natural gas prices have declined, power plant operators have found it more economical to run combined-cycle units at higher levels.

The capacity factor of the U.S. natural gas combined-cycle fleet has risen steadily from an average of 35% in 2005 to more than 56% in 2015. Although there is a wide variation of capacity factors for natural gas combined-cycle power plants, many of these units operated in the 50%-80% range in 2015. In 2005, combined-cycle units commonly operated at capacity factors lower than 30%.

Distribution of annual capacity factors for natural gas combined-cycle plants (2005, 2015)



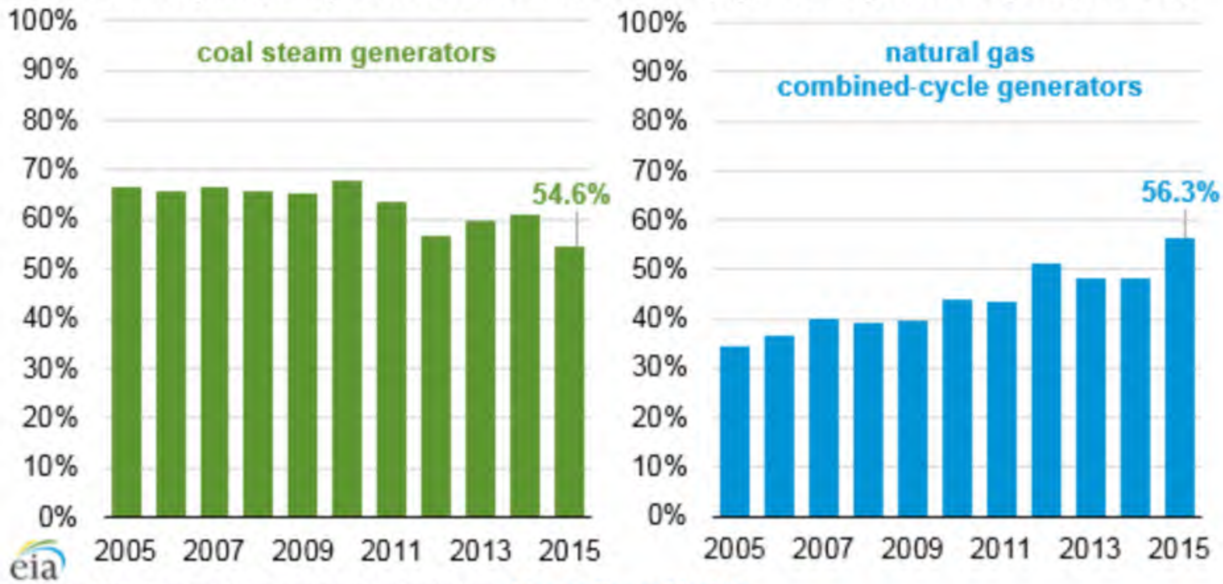
Source: U.S. Energy Information Administration, Forms EIA-860 and EIA-923

Coal steam power plants require more energy input per megawatthour of generation than natural gas-fired

APRIL 4, 2016

Average utilization for natural gas combined-cycle plants exceeded coal plants in 2015

Annual average capacity factor of selected electricity generating technologies (2005-15)



Source: U.S. Energy Information Administration, *Electric Power Monthly*

Last year marked the first time on record that the average capacity factor of natural gas combined-cycle plants exceeded that of coal steam plants. The power industry has been running natural gas combined-cycle generating units at much higher rates than just 10 years ago, while the utilization of the capacity at coal steam power plants has declined. The capacity factor of the U.S. natural gas combined-cycle fleet averaged 56% in 2015, compared with 55% for coal steam power plants.

The mix of energy sources used in U.S. electricity generation has changed dramatically over the past few years. This change is particularly evident in the shift from the use of coal to natural gas for power generation. The industry has been building new natural gas capacity and retiring coal plants, but another important factor behind the changing generation mix is the day-to-day pattern of how existing power plants are used.

Coal power plants primarily rely on steam-driven generating units. In contrast, power plants fueled by natural gas rely on a variety of technologies. Natural gas-fired generating units driven by combustion turbines or steam turbines accounted for about 28% and 17%, respectively, of total natural gas-fired capacity in 2015. Combined-cycle plants, which are designed as an efficient hybrid of the other two technologies, accounted for 53% of gas-fired generation capacity and tend to be used more often than the other types of natural gas generators, as measured by capacity factors.

Siemens-Technical-Paper-Life-Cycle-Value-for-combined-cycle-power-plants.PDF excerpt

Siemens built its first-ever combined cycle plant in Bang Pakong, Thailand, in the early 1980s. The plant had an efficiency rating of around 48 percent. In just three decades Siemens has increased the efficiency of its combined cycle plants by over 12 percentage points. That corresponds to a more than a 25 percent increase in fuel conversion.

3.1.1. Challenging Market

The Asian market is one of the strongest and fastest growing markets worldwide. According the Asia Development Bank Asia's GDP contribution to the global GDP will double to 52% in 2050. This tremendous increase has major impact for the entire power generation business.

The strive for efficient use of primary energy in combination with a worldwide increasing demand for eco-friendly power generation are some of the requirements to accomplish with environmental regulations and increase the business case of the power plants.
It is important to understand the impact of the eco-friendly power generation with long-term CO_2 reduction targets today and in the future. The integration of more renewable resources in the

<u>Optimized start-up times</u>

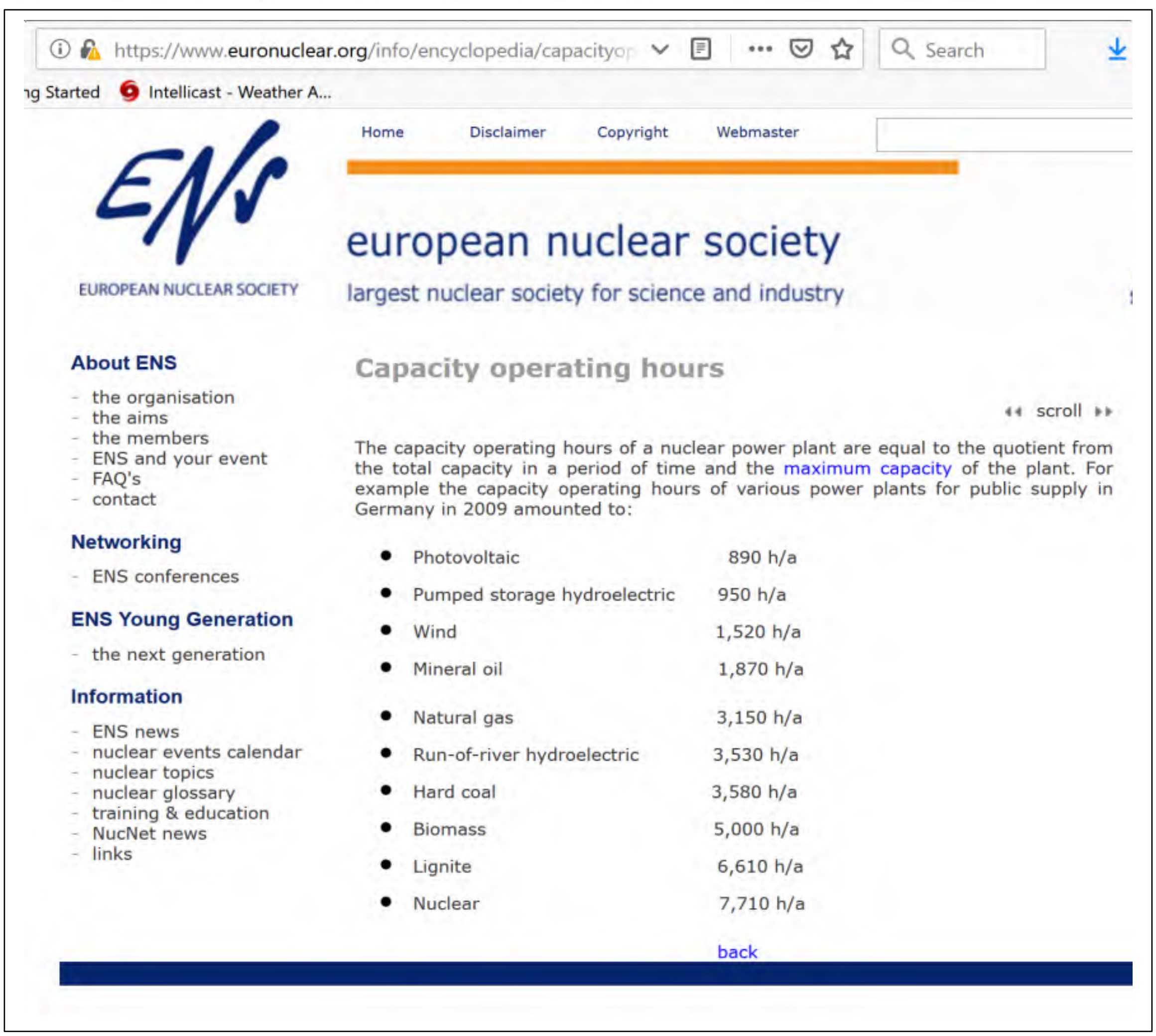
The cycling capability of a power plant is getting more and more important in the energy business as increasing share of renewables amongst other requires full flexibility of the power producers.
Siemens Fast Cycling (FACY^{TM}) Technology optimizes the start-up efficiency which leads to a drastic reduction of fuel consumption. The optimization of the start-up procedure from ignition of the gas turbine to Base load power production leads to a reduction of around 40 minutes in comparison to the competition. Based on these two effects, Siemens Fast Cycling Technology guarantees optimized fuel consumption driven by highest start-up efficiencies in combination with increased power production as a Siemens Power plant delivers far earlier base load energy while the competition is still in the ramp-up procedure.
Based on a typical annual start-up regime of 145 hot starts, 45 warm starts and 5 cold starts a benefit of >1.5Mio € during the start-up procedure can be generated within one year for a typical power plant in the Asian region.

3. NUCLEAR R.E. GINNA Reactor New York USA

TOC

Rated MW	582 MW
Capacity Factor	4,697,675 MWh / (582 * 8760 = 5,098,320 MWh / year) = .921
Output per Year	4,697,675 MWh
Area for Plant	426 acres / 247.105 = 1.7239 sq. km
Hours Available per Year	Hours / year = (8760*.921) = 8068 h/y; German Avg (2009) = 7,710 hours / year We are using 8,000 hours / year
LCOE Cost per MWh	US$ 147.50 (see Lizard, p. 5, Third Party General References)

The amount of electricity that a power plant generates during a period of time depends on the amount of time it operates at a specific capacity. For example, if the R. E. Ginna reactor operates at 582 MW capacity for 24 hours, it will generate 13,968 megawatthours (MWh). If the reactor generated that amount of electricity every day of the year, it would generate 5,098,320 MWh. However, most power plants do not operate a full capacity every hour of every day of the year. In 2017, the R. E. Ginna nuclear power plant actually generated 4,697,675 MWh..



Capacity operating hours

The capacity operating hours of a nuclear power plant are equal to the quotient from the total capacity in a period of time and the maximum capacity of the plant. For example the capacity operating hours of various power plants for public supply in Germany in 2009 amounted to:

- Photovoltaic 890 h/a
- Pumped storage hydroelectric 950 h/a
- Wind 1,520 h/a
- Mineral oil 1,870 h/a
- Natural gas 3,150 h/a
- Run-of-river hydroelectric 3,530 h/a
- Hard coal 3,580 h/a
- Biomass 5,000 h/a
- Lignite 6,610 h/a
- Nuclear 7,710 h/a

Robert Emmett Ginna Nuclear Power Plant - Stanford University
large.stanford.edu/courses/2017/ph241/sebastian1/

May 18, 2017 - The Robert Emmet Ginna nuclear power plant, shown in Fig. 1 and commonly known as simply "Ginna", is a single unit nuclear power plant located on **426** acres along the south shore of **Lake Ontario** in **Ontario**, New York.

https://www.power-eng.com/articles/2016/01/us-nuclear-power-plants-set-average-capacity-factor-record-in-2015.html

NEI said 99 operating power plants in 30 states posted an estimated average capacity factor of 91.9 percent, based on preliminary 2015 data. That number surpasses the industry's prior record set in 2007 by one-tenth of a percentage point. Capacity factor measures the total electricity generated as a percentage of potential generation for the entire year.

https://www.nei.org/news/2015/land-needs-for-wind-solar-dwarf-nuclear-plants

Land Needs for Wind, Solar Dwarf Nuclear Plant's Footprint

News

Sustainable Development

July 9, 2015

- A 1,000-megawatt nuclear facility needs just over one square mile
- Intermittent wind and solar need much more area to generate the same power
- No U.S. wind or solar facility generates as much as the average nuclear plant

Wind farms require up to 360 times as much land area to produce the same amount of electricity as a nuclear energy facility, a Nuclear Energy Institute analysis has found. Solar photovoltaic (PV) facilities require up to 75 times the land area.

A 2015 report, "Land Requirements for Carbon-Free Technologies," compared the land area that various types of electricity generation facilities would require to produce the same amount of electricity as a 1,000-megawatt nuclear power plant in a year. The results highlight the exemplary performance reliability of nuclear energy facilities as well as the very high energy density of nuclear fuel.

A nuclear energy facility has a small area footprint, requiring about 1.3 square miles per 1,000 megawatts of installed capacity. This figure is based on the median land area of the 59 nuclear plant sites in the United States. In addition, nuclear energy facilities have an average capacity factor of 90 percent, much higher than intermittent sources like wind and solar.

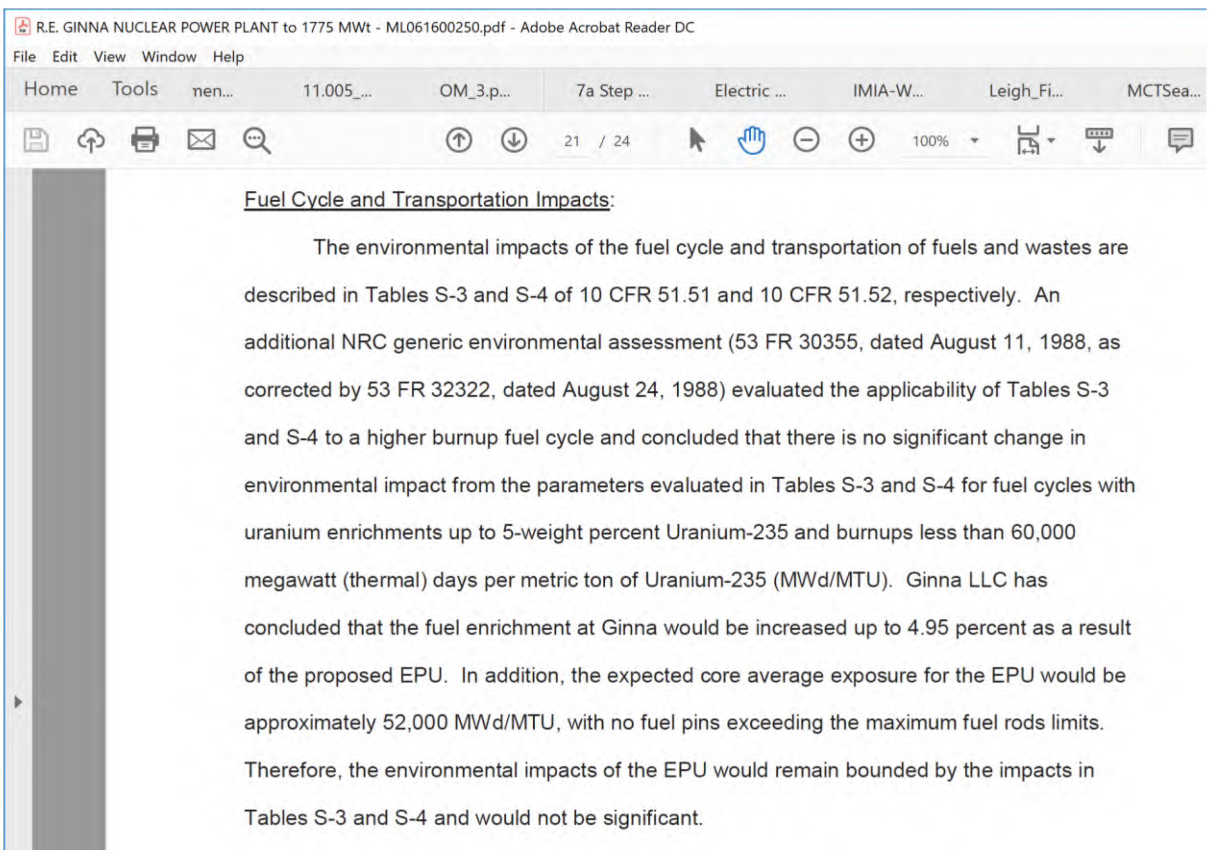
By contrast, wind farm capacity factors range from 32 to 47 percent, depending on differences in wind resources in a given area and improvements in turbine technology. Solar PV capacity factors also vary based on location and technology, from 17 to 28 percent.

Taking these factors into account, a wind farm would need an installed capacity between 1,900 megawatts and 2,800 MW to generate the same amount of electricity in a year as a 1,000-MW nuclear energy facility. Such a facility would require between 260 square miles and 360 square miles of land.

A solar PV facility must have an installed capacity of 3,300 MW and 5,400 MW to match a 1,000-MW nuclear facility's output, requiring between 45 and 75 square miles.

For comparison, the District of Columbia's total land area is 68 square miles. The island of Manhattan is 34 square miles, and New York City's five boroughs (Manhattan, Brooklyn, Queens, Staten Island and the Bronx) take up 305 square miles.

No wind or solar facility currently operating in the United States is large enough to match the output of a 1,000-MW nuclear reactor. The country's largest wind farm, Alta Wind Energy Center in California, has an installed capacity of 1,548 MW. The largest solar PV plants are the 550-MW Topaz Solar Farm and Desert Sunlight Solar Farm, both in California. Between six and 10 of these facilities would be needed to equal the annual output of the average nuclear reactor.



Fuel Cycle and Transportation Impacts:

The environmental impacts of the fuel cycle and transportation of fuels and wastes are described in Tables S-3 and S-4 of 10 CFR 51.51 and 10 CFR 51.52, respectively. An additional NRC generic environmental assessment (53 FR 30355, dated August 11, 1988, as corrected by 53 FR 32322, dated August 24, 1988) evaluated the applicability of Tables S-3 and S-4 to a higher burnup fuel cycle and concluded that there is no significant change in environmental impact from the parameters evaluated in Tables S-3 and S-4 for fuel cycles with uranium enrichments up to 5-weight percent Uranium-235 and burnups less than 60,000 megawatt (thermal) days per metric ton of Uranium-235 (MWd/MTU). Ginna LLC has concluded that the fuel enrichment at Ginna would be increased up to 4.95 percent as a result of the proposed EPU. In addition, the expected core average exposure for the EPU would be approximately 52,000 MWd/MTU, with no fuel pins exceeding the maximum fuel rods limits. Therefore, the environmental impacts of the EPU would remain bounded by the impacts in Tables S-3 and S-4 and would not be significant.

R.E. GINNA NUCLEAR POWER PLANT to 1775 MWt - ML061600250.pdf - Adobe Acrobat Reader DC

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10 / 24 72.1%

The current SPDES permit limit for the Ginna thermal discharge plume mixing area is 320 acres. In 2004, Ginna LLC commissioned studies to determine the effect of the proposed EPU on water temperatures, temperature distribution in near-field and far-field areas associated

- 10 -

with the discharge, and to assess the impacts on aquatic species. According to the information calculated by the near-field plume model (CORMIX) and far-field hydrodynamic and thermal model (ECOM), under existing plant operating conditions, the thermal plume mixing area is less than 300 acres in summer and winter months. An increased mixing zone of 360 acres from the point of discharge on a daily basis (24 hours) would be needed to support operation under the proposed EPU operating conditions. The discharge environmental impacts of the proposed EPU conditions are described in the "Impacts to Aquatic Biota" section of the ER.

By letters dated March 8, April 2, July 29, October 18, November 18, 2005, January 12, and March 15, 2006, Ginna LLC submitted a permit modification request to NYSDEC regarding an increase in the Ginna Station Outfall 001 discharge temperature limit, intake-discharge ΔT, and the size of the mixing zone to accommodate the proposed EPU conditions described above. The NYSDEC sets limits on and regulates the amount of heat discharged to Lake Ontario. Approval from the NYSDEC for these SPDES Permit modifications is currently pending.

Based on information provided in the ER and NUREG-1437 Supplement 14, the NRC staff has determined the thermal discharge environmental impacts to Lake Ontario under the proposed EPU conditions would not be significant.

R.E. GINNA NUCLEAR POWER PLANT to 1775 MWt - ML061600250.pdf - Adobe Acrobat Reader DC

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18 / 24 72.1%

Solid Radioactive Wastes:

The solid radioactive waste system collects, processes, packages, and temporarily stores radioactive dry and wet solid wastes prior to shipment offsite and permanent disposal. Ginna produces dry active waste (paper, plastic, wood, rubber, glass, floor sweepings, cloth, metal), sludge, oily waste, bead resin and filters. The increase in volume of solid waste would not be linear, because the proposed EPU would neither alter installed equipment performance nor require drastic changes in system operation or maintenance. In recent years (2003-2004), the solid waste volume generated by Ginna has been significantly above the 9-year non-outage average of 2,500 cubic feet, and outage year average of 5,000 cubic feet. This increase in volume is a result of the roof and reactor head replacement projects and mandated security upgrades.

Under the proposed EPU conditions, any increase in volume of solid waste would be due to increases in disposal of bead resins and filters. This increase would not be significant, although the amount of radioactivity in the waste would linearly increase. Even with such increases, Ginna LLC expects the results would remain below the generation volumes and

- 19 -

doses in the FES. Therefore, the NRC concludes that there would be no significant impact to offsite dose due to solid waste disposal following the EPU.

4. WAVE NeptuneWave.ca Vancouver CDN

TOC

Based on Calculated projections from test measurements on smaller neptunewave units

Rated MW	2.3 MW
Capacity Factor	.72
Output per Year	14,892 MWh over 8,000 hours / year Firm Power (% of 8,000 h / y) = 1.1 MWh for 1% [FIRM BASE OUTPUT]; 1.4 MWh for 34%; 1.9 MWh for 41% and, 2.3 MWh for 24% [PEAK OUTPUT].
Area for Plant	75.0 m * 75.0 = 2,500 m^2 /1,000,000 = .0056 km^2 (includes area between adjacent units in an array)
Hours Available per Year	8,000 h/y (min. hrs depends on wave location & planned & unplanned maintenance)
LCOE Cost per MWh	US$ 67.00 (using NREL LCOE Calculator see below)

LCOE for NeptuneWave using: https://www.nrel.gov/analysis/tech-lcoe.html

NREL LCOE DOCUMENTATION SAYS:

Levelized Cost of Energy (LCOE, also called Levelized Energy Cost or LEC) is a cost of generating energy (usually electricity) for a particular system. It is an economic assessment of the cost of the energy-generating system including all the costs over its lifetime: initial investment, operations and maintenance, cost of fuel, cost of capital. A net present value calculation is performed and solved in such a way that for the value of the LCOE chosen, the project's net present value becomes zero (Source: 2, 3).

This means that the LCOE is the minimum price at which energy must be sold for an energy project to break even.

NeptuneWave.ca
2.3 MW units Costs
(US$)

Basically the 2.3 MW NeptuneWave unit will cost $7.5 million to build & deploy and $460,000 per year for O & M.

Over 30 years (Capital Build and O&M) alone totals: $ 21,300,000.

With other costs added in, 6.7 cents per kWh ($ 67.00 / MWh) for power produced is required for the project to break even over 30 years (LCOE).

See next page for LCOE Data and Calculation

Wave Energy Advantages:

Power
Wave provides continuous power with a firm (guaranteed) base level of energy (MWh) for over 8,000 hours per year (91% of year).
Solar & wind provide intermittent power

Hours of Operation
8,000 h/y for wave
3,000 h/y solar
3,500 h/y wind)

Capacity Factor
72% for Wave
24% for solar
50% for wind)

Footprint to make 1 TWh per year
wave = < .5 km^2;
solar = 10 km^2;
off shore wind [Anholt] = 83 km^2

ONLINE SOURCE: https://www.nrel.gov/analysis/tech-lcoe.html

Simple Levelized Cost of Energy Calculator

Financial

Periods (Years): 30 ?

Discount Rate (%): 2.5 ?

Renewable Energy System Cost and Performance

Capital Cost ($/kW): 3260 ?

Capacity Factor (%): 72 ?

Fixed O&M Cost ($/kW-yr): 200 ?

Variable O&M Cost ($/kWh): .01 ?

Heat Rate (Btu/kWh): 0 ?

Fuel Cost ($/MMBtu): 0 ?

Today's Utility Electricity Cost

Electricity Price (cents/kWh): 8 ?

Cost Escalation Rate (%): 1.5 ?

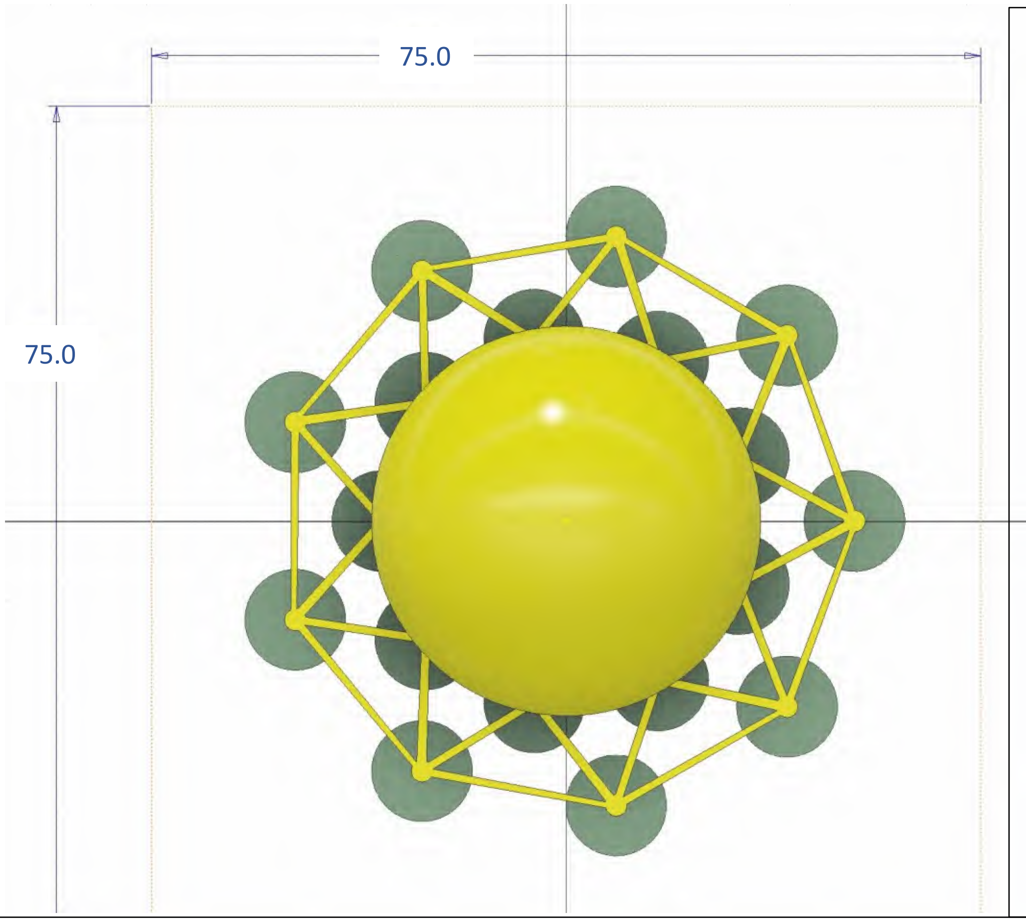
Results

This is the levelized or annualized cost of electricity from the utility assuming today's cost of electricity escalates at the rate you entered above

Levelized Cost of Utility Electricity (cents/kWh): 9.9 ?

Simple Levelized Cost of Renewable Energy (cents/kWh): 6.7 ?

AREA of 2.3 MW NeptuneWave Plant -- including space for adjacent Plants in an array



NeptuneWave 2.3 Area Calculation

75.0 m * 75.0 = 5,625 m^2 =

.0056 km^2

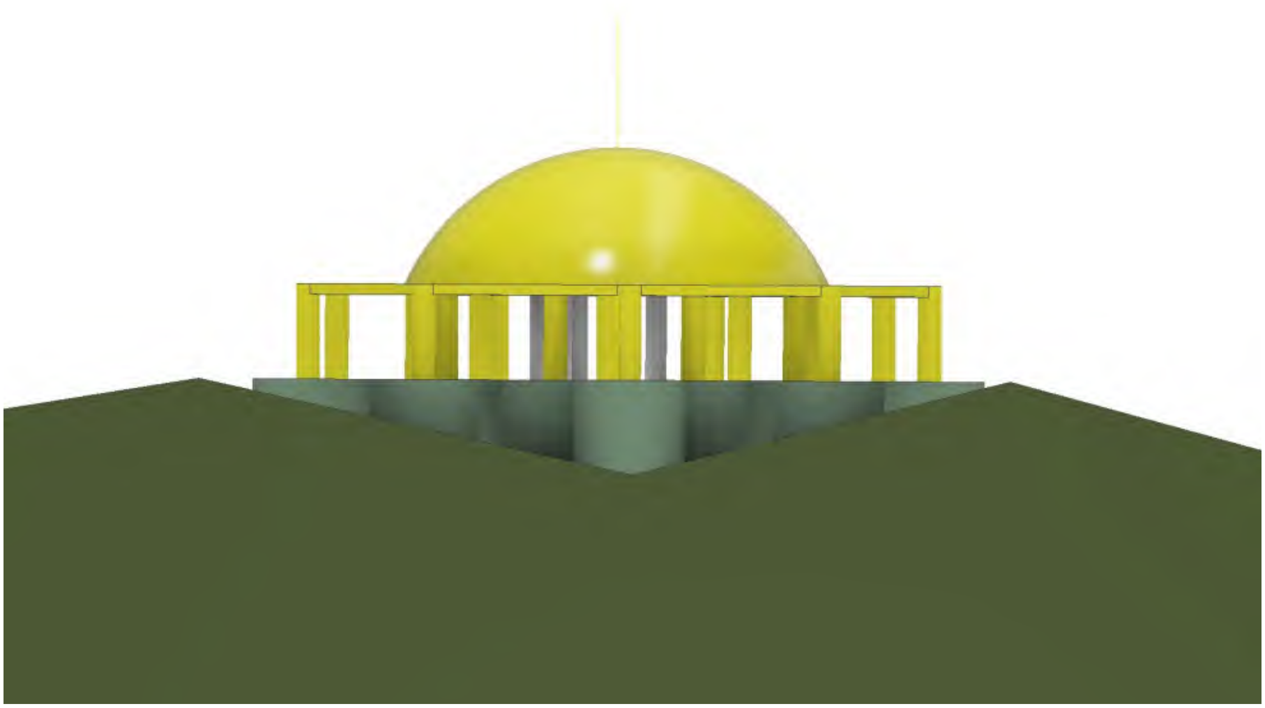
Note:

Density of Air = **1.25 kg/m3**

Density of Seawater = **1025 kg/m3**

Seawater has **837 times more** Density than Air at sea-level.

VIEW of 2.3 MW NeptuneWave Plant from sea level (2019)



https://www.power-technology.com/features/tides-change-can-tidal-power-compete-cost/

"Tides are predictable centuries in advance, and we also know how strong they will be. However, the capacity factor – meaning the amount of power the turbine harvests compared to its potential – is not as high as offshore wind, for example, say 30% compared to 45% and above."

http://www.oceanenergycouncil.com/ocean-energy/tidal-energy/

Tidal range may vary over a wide range (4.5-12.4 m) from site to site. A tidal range of at least 7 m is required for economical operation and for sufficient head of water for the turbines. A 240 MWe facility has operated in France since 1966, 20 MWe in Canada since 1984, and a number of stations in China since 1977, totaling 5 MWe. Tidal energy schemes are characterised by low capacity factors, usually in the range of 20-35%.

Why ocean wave energy?

With acknowledgement to Capital Technology, Inc. "While lagging behind wind and solar in commercial development, ocean wave power is a more promising resource than either:

- Because waves originate from storms far out to sea and can travel long distances without significant energy loss, power produced from them is much steadier and more predictable, both day to day and season to season. This reduces project risk;
- Wave energy contains roughly 1000 times the kinetic energy of wind, allowing much smaller and less conspicuous devices to produce the same amount of power in a fraction of the space;
- Unlike wind and solar power, power from ocean waves continues to be produced around the clock, whereas wind velocity tends to die in the morning and at night, and solar is only available during the day in areas with relatively little cloud cover;
- Wave power production is much smoother and more consistent than wind or solar, resulting in higher overall capacity factors;
- Wave energy varies as the square of wave height, whereas wind power varies with the cube of air speed. Water being 850 times as dense as air, this results in much higher power production from waves averaged over time;
- Estimating the potential resource is much easier than with wind, an important factor in attracting project lenders;
- Because wave energy needs only 1/200 the land area of wind and requires no access roads, infrastructure costs are less;
- Wave energy devices are quieter and much less visually obtrusive than wind devices, which typically run 40-60 meters in height and usually requiring remote siting with attendant high transmission costs. In contrast, 10 meter high wave energy devices can be integrated into breakwaters in busy port areas, producing power exactly where it is needed;
- When constructed with materials developed for use on off-shore oil platforms, ocean wave power devices (which contain few moving parts) should cost less to maintain than those powered by wind;

Even though wave energy is at the very beginning of the manufacturing learning curve, capital costs per net kw are already down in the range of wind energy devices, and below solar. In areas of higher power costs, such as diesel-based communities not connected to the grid, investment returns from wave energy projects are potentially very attractive. In 1909, ocean wave power was used to light lamps on the Huntington Beach Wharf until a storm carried the apparatus out to sea. Long-term reliability of the OWC technology has now been demonstrated, with one device in India still going strong after 10 years of continuous operation."

Rick Wave Energy 03.25.2014

5. COAL Plant Scherer Georgia USA

TOC

Rated MW	3,600MW
Capacity Factor	.55 (source US EIA – see below)
Output per Year	3,600 * 8760 = 31,526,000 *.55 = 17,344,800 MWh
Area for Plant	3,500 acres / 247.105 = 14.16 sq. km
Hours Available per Year	7,500 h/y (based on typical O&M and unscheduled shutdowns)
LCOE Cost per MWh	US$ 101.5 (see Lizard, p. 5, Third Party General References)

Georgia Power's Plant Scherer named 2017 Plant of the Year

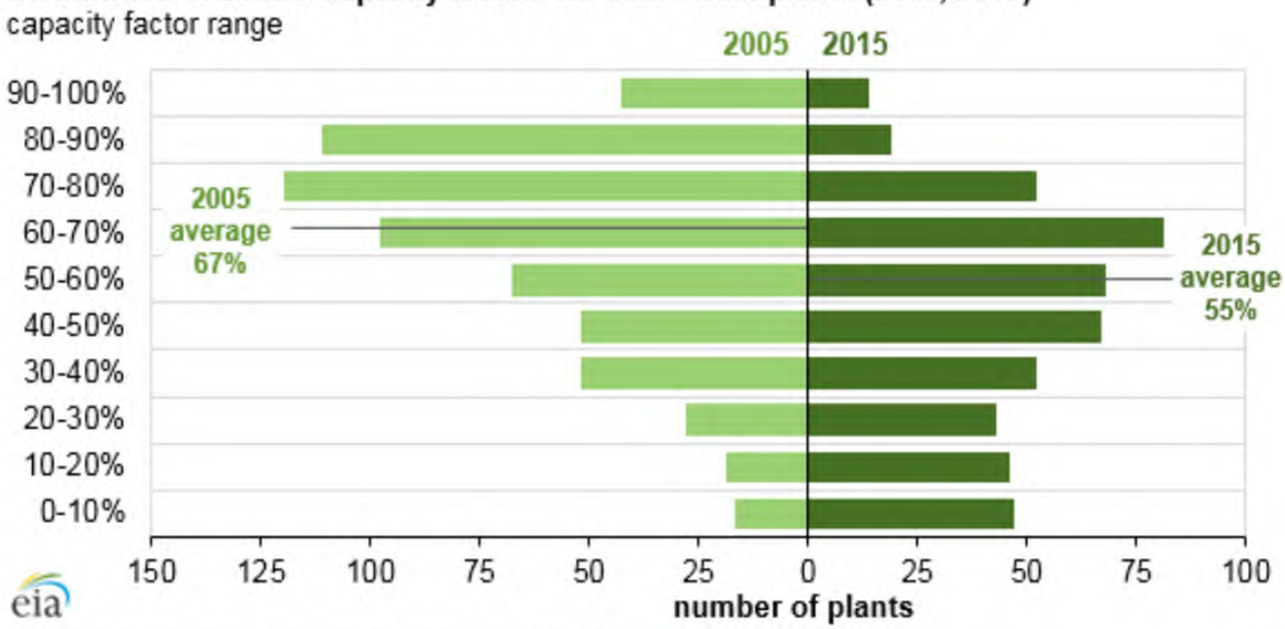
https://www.prnewswire.com/.../georgia-powers-plant-scherer-named-2017-plant-of-t...

Aug 9, 2017 - Plant Scherer is located on more than 3,500 acres next to Lake Juliette in Monroe County, Georgia, between Atlanta and Macon. The **four** units of the coal-fired power plant are capable of producing **3,600** megawatts of electricity and, on average, can supply enough energy to power approximately **1.5 million** homes.

Coal steam power plants require more energy input per megawatthour of generation than natural gas-fired combined-cycle plants. Yet, the low cost of coal relative to natural gas until recent years favored the use of coal-fired generating units to fulfill baseload electricity demand, leading plant operators to run these units at rates close to their output capacity during peak demand hours. During off-peak hours, such as overnight, coal plants generally continued to operate. But, in areas with large amounts of available coal or nuclear generation capacity, many coal plants would run at rates closer to their minimum operable capacity.

Nearly half of all coal plants ran at capacity factors above 70% in 2005. Since 2012, coal plants have faced much more competition from natural gas combined-cycle units for supplying baseload demand. In 2015, less than one-fifth of all coal plants operated at capacity factors higher than 70%.

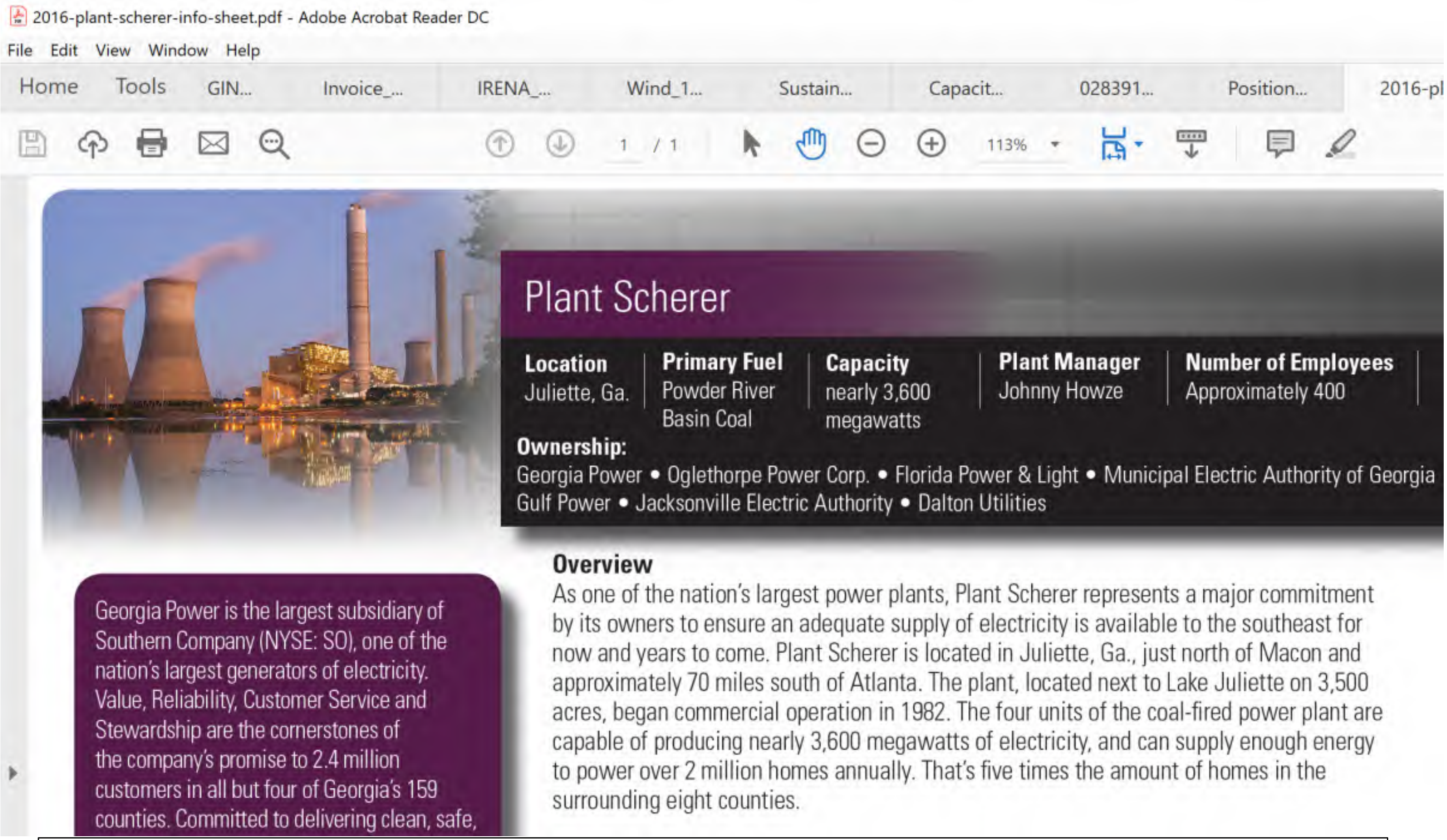
Distribution of annual capacity factors for coal steam plants (2005, 2015)



Source: U.S. Energy Information Administration, Forms EIA-860 and EIA-923

Principal contributor: Tyler Hodge

coal plant stats: http://www.nrel.gov/docs/fy17osti/66506.pdf



Plant Scherer

Location	Primary Fuel	Capacity	Plant Manager	Number of Employees
Juliette, Ga.	Powder River Basin Coal	nearly 3,600 megawatts	Johnny Howze	Approximately 400

Ownership:
Georgia Power • Oglethorpe Power Corp. • Florida Power & Light • Municipal Electric Authority of Georgia
Gulf Power • Jacksonville Electric Authority • Dalton Utilities

Georgia Power is the largest subsidiary of Southern Company (NYSE: SO), one of the nation's largest generators of electricity. Value, Reliability, Customer Service and Stewardship are the cornerstones of the company's promise to 2.4 million customers in all but four of Georgia's 159 counties. Committed to delivering clean, safe,

Overview

As one of the nation's largest power plants, Plant Scherer represents a major commitment by its owners to ensure an adequate supply of electricity is available to the southeast for now and years to come. Plant Scherer is located in Juliette, Ga., just north of Macon and approximately 70 miles south of Atlanta. The plant, located next to Lake Juliette on 3,500 acres, began commercial operation in 1982. The four units of the coal-fired power plant are capable of producing nearly 3,600 megawatts of electricity, and can supply enough energy to power over 2 million homes annually. That's five times the amount of homes in the surrounding eight counties.

https://www.sourcewatch.org/index.php/Scherer_Steam_Generating_Station

Scherer Steam Electric Oil Fired Generating Station

6. SOLAR Average of 2 Solar Farms in INDIA

TOC

Rated MW	824 MW
Capacity Factor	.24
Output per Year	1,727,000 MWh (1.727 TWh)
Area for Plant	17.06 sq. km
Hours Available per Year	3,000 h/y (typical from many references, see below)
LCOE Cost per MWh	US$ 49.50 (see Lizard, p. 5, Third Party General References)

2 SOLAR Farms INDIA	Kamuthi Solar Plant	Kumool Solar Plant	Avg 2 Plants India
Plant Rating MW	648.00	1,000.00	**824.00**
Capacity Factor	0.24	0.24	**0.24**
Annual Output TWh	1.35	2.10	**1.73**
Plant area KM^2	10.12	24.01	**17.06**
Area (km^2) req'd for 1 TWh/ yr	**7.49**	**11.41**	**9.88**

http://wgbis.ces.iisc.ernet.in/energy/paper/hotspots_solar_potential/results.htm

Prospects of solar power in India (2011)

India receives annual sunshine of 2600 to 3200 hours [2]. Table 4 shows the power input (Global insolation), maximum rated and actual on-site output (67.5 % of the rated as observed earlier) values at two different efficiencies (16% and 20%) for a system without battery backup considering the minimum ~7 hours of daily sunshine (or 2600 hours of annual). Regions receiving Global insolation of 5 kWh/m^2/day and above can generate at least 77 W/m^2 (actual on-site output) at 16% efficiency.

[2] Citation: T. V. Ramachandra, Rishabh Jain and Gautham Krishnadas, 2011. Hotspots of solar potential in India. *Renewable and Sustainable Energy Reviews* 15 (2011) 3178–3186.

http://www.sunwattindia.com/whysolar.html

Solar Energy In India (2013)

With about 300 clear, sunny days in a year, India's theoretical solar power reception, on only its land area, is about 5000 Petawatt-hours per year (PWh/yr) (i.e. 5000 trillion kWh/yr or about 600 TW).**The daily average solar energy incident over India varies from 4 to 7 kWh/m2 with about 1500–2000 sunshine hours per year** (depending upon location),

Kamuthi Solar Power Project

Kamuthi Solar Power Project is a photovoltaic power station spread over an area of 2,500 acres in Kamuthi, Ramanathapuram district, 90 km from Madurai, in the state of Tamil Nadu, India. The project was commissioned by Adani Power. Wikipedia

Construction cost: Rs 4 550 crore = 699 MUSD (2017)

Capacity factor: 24 %

Owner: Adani Power

Annual net output: Appr. 1.35 TWh/yr

Construction began: February 2016

Did you know: Kamuthi Solar Power Project is the second-largest photovoltaic power station in the world by capacity (648 MW). wikipedia.org

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2500 acres = 10.12 km^2

1.35 TWh / year so 1.35 / 10.12 = .1334 TWh / km^2

Hence 1/ .1334 = 7.496 km^2 per 1 TWh

Kurnool Ultra Mega Solar Park

Website · Directions · Save

4.6 ★★★★★ 28 Google reviews

Solar photovoltaic power plant in India

Kurnool Ultra Mega Solar Park is a solar park spread over a total area of 5,932.32 acres in Panyam mandal of Kurnool district, Andhra Pradesh, with a capacity of 1,000 MW. Wikipedia

Address: Kurnool, Andhra Pradesh 518010, India

Site area: 24.01 km²

Units operational: 1,000 MW

Phone: +91 80089 94874

Nameplate capacity: 1000 MW

Suggest an edit · Own this business?

Assume Capacity Factor of .24

Then 1,000 MW * 8760 hours = 8,760,000 MWh / year

Hence .24 * 8,760,000 = 2,102,400 MWh / year

2,102,400 MWh / 1000 = 2,104 GWh / year

Area 24 km^2

2,104/24 = 87.66 GWh per km^2

hence 1 GWh requires 1/87.66 = .01140 km^2

hence 1 TWh = .01140 * 1000 = 11.41 km^2

Sunrise Farms SOLAR PV CDN	Data (dark green) from Owner Jan 2019
0.25	250 kW Name Plate Rating
0.16	Capacity Factor
360	Annual Output MWh/yr (avg 3 yrs)
0.000360	Annual Output TWh
0.0020	km^2 (21,000 ft^2 Panel Area)
5.42	km^2 Area Req'd for 1 TWh (panels only)
15	Times more area req'd than for Nuclear / TWh
14	Times more area req'd than for Wave / TWh
2,500	Hours of Production per Year
8	Income Factor (for comparison other Gen. Plants)

Note: Solar Panels Float on Hydro Dam Reservoir

https://qz.com/426718/japan-is-building-huge-solar-power-plants-that-float-on-water/

Japan is building huge solar power plants that float on water

By Steve MollmanJune 12, 2015

Unlike coal-fired plants, solar power stations don't produce smog but they do take up land. Or, at least they did.

In Japan's Hyogo prefecture, a solar station was recently launched that floats on a reservoir and will produce about 2,680 megawatt hours per year—enough for 820 typical households. Kyocera plans to build dozens of such stations on reservoirs around Japan, especially in areas lacking available land for utility-scale generation.

With construction completed in late May and operations begun this week, the new installation measures 333 by 77 meters (1,093 by 253 ft) and will sell the energy it produces to Kansai Electric Power in Osaka for about ¥96 million ($780,000) annually, according to the Japan Times. Helpful, as Japan's energy strategy in the aftermath of Fukushima calls for roughly doubling the amount of renewable power sources in the country by 2030.

It employs nearly 9,100 waterproof solar panels and a float made of high-density polyethylene. It's Kyocera's third such installation, the first two being smaller versions launched on ponds earlier this year.

One advantage of floating solar stations is efficiency. The water cools the system and thereby helps it generate power more efficiently (pdf) than if it were on the ground. Such installations also work particularly well on reservoirs. By shading the water, they also reduce evaporation and algae growth, two common concerns with reservoirs.

Kyocera will next launch a particularly large floating solar installation in the Chiba prefecture's Yamakura Dam reservoir next March, which will generate an estimated 15,635 megawatt hours per year—more than five times as much as the plant that just went online.

7. HYDRO 3 Gorges Dam CHINA

TOC

Rated MW	22,500 MW
Capacity Factor	98,800,000 MWh / (22,500 * 8760 = 197,100,000 MWh / year) = .501
Output per Year	98.8 TWh = 98,800,000 MWh
Area for Plant	= 1084 sq. km
Hours Available per Year	6,750 h/y (75% of the year) see calculation and references below
LCOE Cost per MWh	US$ 63.90 (see projected LCOE COSTS in US 2022, p. 5, Third Party General References)

Three Gorges Dam

Three Gorges Dam 三峡大坝	
Total capacity	39.3 km^3 (31,900,000 acre·ft)
Catchment area	**1,000,000 km^2** (390,000 sq mi)
Surface area	1,084 km^2 (419 sq mi)
Maximum length	600 km (370 mi)

30 more rows

Three Gorges Dam - Wikipedia
https://en.wikipedia.org/wiki/Three_Gorges_Dam

https://en.wikipedia.org/wiki/Three_Gorges_Dam Search

Started Intellicast - Weather A...

Three Gorges Dam

From Wikipedia, the free encyclopedia

The **Three Gorges Dam** is a hydroelectric gravity dam that spans the Yangtze River by the town of Sandouping, in Yiling District, Yichang, Hubei province, China. The Three Gorges Dam is the world's largest power station in terms of installed capacity (22,500 MW). In 2014, the dam generated 98.8 terawatt-hours (TWh) and had the world record, but was surpassed by the Itaipú Dam, which set the new world record in 2016, producing 103.1 TWh.[5]

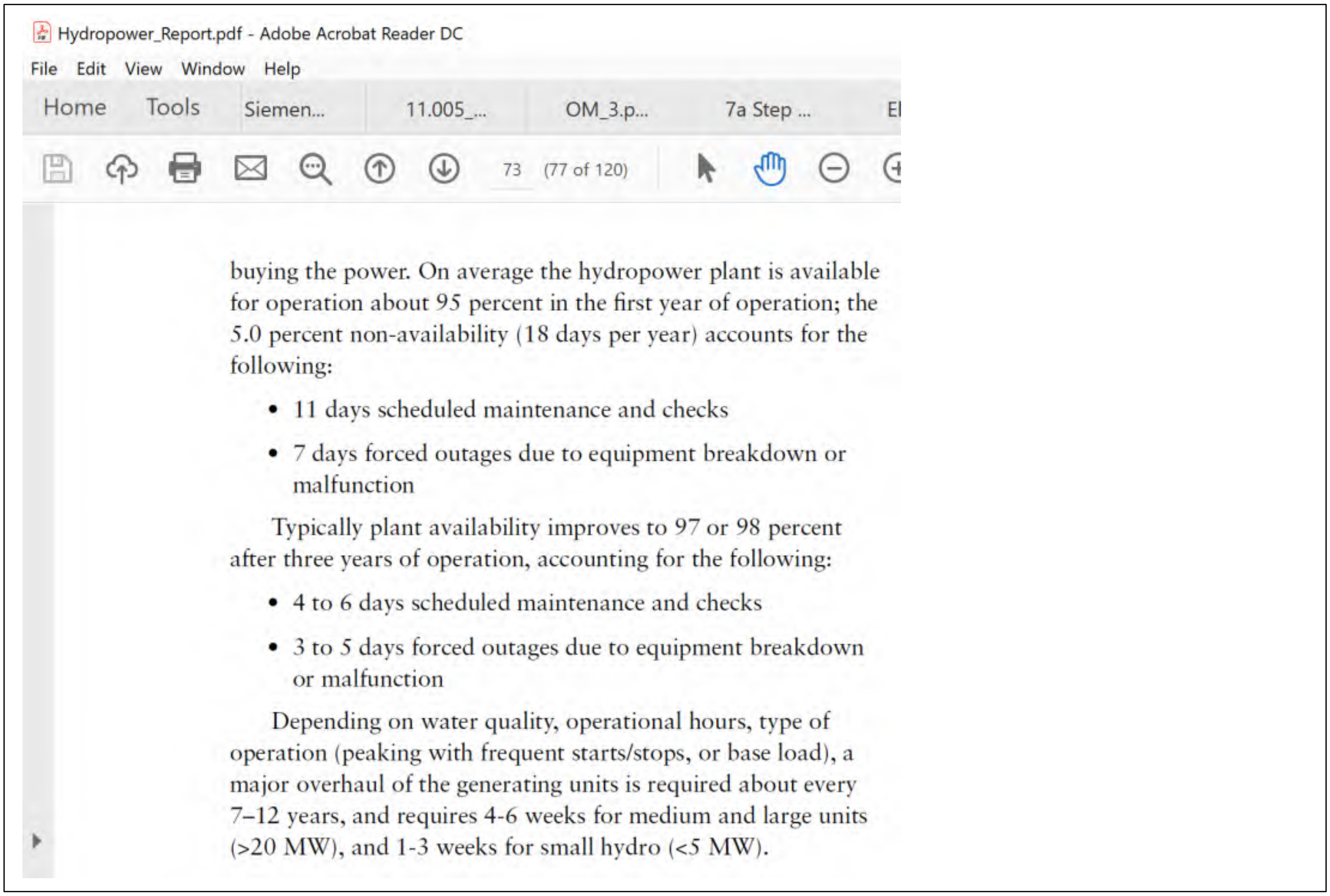
From: https://water.usgs.gov/edu/hybiggest.html

https://water.usgs.gov/edu/hybiggest.html Search 100%

Intellicast - Weather A... Dashboard | Wix.com

In 2012, the Three Gorges Dam in China took over the #1 spot of the largest hydroelectric dam (in electricity production), replacing the Itaipú hydroelectric power plant in Brazil and Paraguay. The Three Gorges Dam has a generating capacity of 22,500 megawatts (MW) compared to 14,000 MW for the Itaipu Dam. But, over a year-long period, both dams can generate about the same amount of electricity because seasonal variations in water availability on the Yangtze River in China limit power generation at Three Gorges for a number of months during the year.

The height of Three Gorges is about 594 feet (181 meters (m)) and the length is about 7,770 feet (2, 335 m). The dam creates the Three Gorges Reservoir, which has a surface area of about 400 square miles (1,045 square kilometers) and extends upstream from the dam about 370 miles (600 kilometers).



buying the power. On average the hydropower plant is available for operation about 95 percent in the first year of operation; the 5.0 percent non-availability (18 days per year) accounts for the following:

- 11 days scheduled maintenance and checks
- 7 days forced outages due to equipment breakdown or malfunction

Typically plant availability improves to 97 or 98 percent after three years of operation, accounting for the following:

- 4 to 6 days scheduled maintenance and checks
- 3 to 5 days forced outages due to equipment breakdown or malfunction

Depending on water quality, operational hours, type of operation (peaking with frequent starts/stops, or base load), a major overhaul of the generating units is required about every 7–12 years, and requires 4-6 weeks for medium and large units (>20 MW), and 1-3 weeks for small hydro (<5 MW).

HENCE 3 Gorges is can be available to produce electricity for up to 8,500 hours per year (97%) but in fact the highest annual output of 98,800,000 MWh shows that the dam is only operating at

98,800,000 / (22,500 * 8760 = 197,100,000 MWh / year) = .50 capacity,

or at full capacity for half the year or 4,383 hours per year.

The report by https://water.usgs.gov/edu/hybiggest.html above says “because seasonal variations in water availability on the Yangtze River in China limit power generation at Three Gorges for a number of months during the year.”

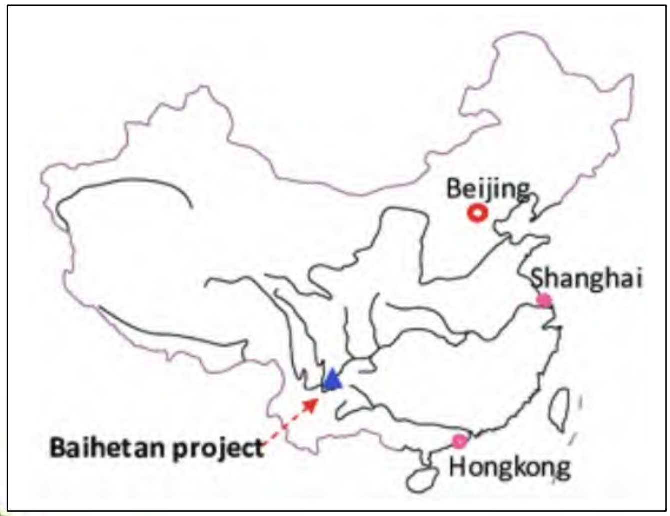
Hence we calculate the 3 Georges Hydro facility to be operational for 8766 hours per year – (24 hrs * 30.5 days per month * 3 months) = 6,570 hours per year or 6570/8766 = 75% of the year https://www.hydroworld.com/articles/2017/08/ctgc-begins-construction-on-the-16-gw-baihetan-hydropower-station-in-southwest-china.html

CTGC begins construction on the 16-GW Baihetan hydropower station in Southwest China

WUHAN, Hubei, China

08/03/2017

By Gregory B. Poindexter
Associate Editor



China Three Gorges Corp. (CTGC) has begun construction of the 16-GW Baihetan hydropower station located on the lower reaches of the Jinsha River, between the borders of Sichuan and Yunnan provinces in Southwest China.

China's state-run news agency, *Xinhua*, reports construction on the station began today. According to 2016 estimates from China's National Development and Reform Commission, the project will cost about US$6.3 billion.

According to CTGC, the project's main structures consist of the dam, flood discharge structures, water diversion and power generation facilities. The dam is a double-curvature arch dam with a maximum height of 277 m, a crest elevation of 827 m, a crest width of 13 m and a maximum bottom width of 72 m.

The underground powerhouse will contain 16 generating units at 1,000 MW each and have an average annual power output of 60.24 TWh, which is equal to two-thirds of Beijing's electricity consumption in 2015, CTGC said.

The first group of units are expected to begin operating in 2021. The project should be fully-commissioned by the end of 2022.

About 100,000 residents in Sichuan and Yunnan will be relocated to make way for the project that will manage a basin area of 430,000 km^2, which is 91% of Jinsha River's basin area.

Baihetan will be the world's second highest capacity hydropower facility, second to the 22.5-GW Three Gorges hydroelectric project spanning the Yangtze River in Hubei province. Currently, the 14-GW Itaipu hydroelectric power plant is the world's second-largest hydro facility, located on the Parana River at the border between Brazil and Paraguay.

During the first week of July in an attempt to ease flood pressure on the Yangtze River, Three Gorges and the 2.9 GW Gezhouba hydro plants shut down a combined 26 generators, according to *Xinhua*. Three Gorges cut its output from 18.12 GW to 6 GW and Gezhouba from 2.9 GW to 1.5 GW.

In July, Voith Group and CTGC signed an agreement in Berlin, Germany, in which Voith will supply two 350 MW units for the US$1.5 billion 2.1-GW Zhejiang Changlongshan pumped storage hydropower station.

The project is located in Anji County, Zhejiang province, between the cities of Tianhuangping and Shanchuan.

HYDRO PROJECTS DECLARED RENEWABLE ENERGY By Indian Government 2019

https://www.hydroworld.com/articles/2019/03/indian-government-to-declare-large-hydropower-projects-a-renewable-energy-source.html?cmpid=&utm_source=enl&utm_medium=hydro&utm_campaign=hydro_updates&utm_content=2019-03-12&eid=302187755&bid=2390692

Home » More Regulation & Policy News » Government & Policy » Indian government to declare large hydropower projects a renewable energy source

Print Article

Indian government to declare large hydropower projects a renewable energy source

03/08/2019

The Indian government's Union Cabinet, chaired by the Prime Minister Narendra Modi, has approved measures to promote the hydropower sector that include declaring large hydropower projects to be part of the non-solar renewable purchase obligation (RPO).

According to the PMIndia website, large hydropower projects are to be declared a renewable energy source. Previously, only hydropower projects less than 25 MW were categorized as renewable energy, and these small projects were covered under the non-solar RPO.

Per this announcement, large hydropower projects commissioned after notification of these measures will be included in the non-solar RPO.

The government says that India is endowed with large hydropower potential of 145,320 MW, of which only about 45,400 MW has been utilized so far. Only about 10,000 MW of hydropower has been added in the past 10 years. The hydropower sector is going through a challenging phase and the share of hydropower in total electricity generating capacity has declined from 50.36% in the 1960s to around 13% in 2018 to 2019.

Besides being environment friendly, hydropower has several other unique features, like ability for quick ramping, black start, reactive absorption, etc., that make it ideal for peaking power, spinning reserve and grid balancing/ stability. Hydropower also provides water security, irrigation and flood moderation benefits, apart from socioeconomic development of the entire region by providing employment opportunities and boosting tourism etc.

HYDROPOWER PROJECTS


GRAND INGA HYDROPOWER PROJECT


RUSUMO FALLS HYDROPOWER PROJECT


TARBELA HYDROPOWER PROJECT


SITE C HYDROPOWER PROJECT


RED ROCK HYDROPOWER PROJECT

https://www.eia.gov/electricity/monthly/epm_table_grapher.php?t=epmt_6_07_b

ng Started Intellicast - Weather A...

eia *Independent Statistics & Analysis* U.S. Energy Information Administration

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+ Tools + Learn About Energy + News

Electric Power Monthly

Data for October 2018 | **Release Date:** December 26, 2018 | **Next Release:** January 25, 2019 | full report

Previous Issues

Issue: November 20 **Format:** pdf

Table 6.7.B. Capacity Factors for Utility Scale Generators Not Primarily Using Fossil Fuels, January 2013-October 2018

Period	Nuclear	Conventional Hydropower	Wind	Solar Photovoltaic	Solar Thermal	Landfill Gas and Muncipal Solid Waste	Other Biomass Including Wood	Geothermal
Annual Factors								
2013	89.9%	38.9%	32.4%	NA	NA	68.9%	56.7%	73.6%
2014	91.7%	37.3%	34.0%	25.9%	19.8%	68.9%	58.9%	74.0%
2015	92.3%	35.8%	32.2%	25.8%	22.1%	68.7%	55.3%	74.3%
2016	92.3%	38.2%	34.5%	25.1%	22.2%	69.7%	55.6%	73.9%
2017	92.2%	43.1%	34.6%	25.7%	21.8%	68.0%	57.8%	74.0%

https://www.greentechmedia.com/articles/read/wind-power-could-blow-past-hydros-capacity-factor-by-2020#gs.kQU6qXwe

Jan Dell, Matthew Klippenstein February 08, 2017 **A NOTE on Capacity Factors**

Legacy hydroelectricity -- clean, dispatchable and cheap -- has long dominated the renewable energy sector as a dependable workhorse. But by the decade's end, wind may end up wearing the capacity factor crown.

Capacity factor is the ratio of a generator's annual power production to the power it could have produced if it ran at 100 percent rated capacity 24/7. It's a valuable measure of the generator's ability to operate at its full potential and maximize the value of sunk-cost capital investments. Last year the United States nuclear fleet managed a capacity factor of 92 percent, while coal plants and combined-cycle natural gas generators managed 55 percent and 56 percent, respectively. As recently as 2008, coal's capacity factor was 73 percent.

The capacity factor for conventional dam-based hydroelectricity is lower -- in the 40 percent range -- owing to its use as flexible, load-following supply. Despite the continuing shuttering of coal capacity, hydro's capacity factor has been slowly declining since 2008 as natural gas, wind and solar have seamlessly stepped in, while electricity demand has remained flat. The EIA estimates that gross U.S. electricity consumption fell 2 percent from 2007 to 2015, despite concurrent population growth of 8 percent.

Droughts have also been a factor; until the welcome wet weather this winter, operators struggled to maintain water levels in reservoirs. Lower water levels mean less hydrostatic head is available -- and incrementally more water needs to be released -- to generate each megawatt-hour, exacerbating reservoir management challenges. At the end of 2016, Lake Mead, which feeds the Hoover Dam, had dropped more than 130 feet (one third of an NFL football field, with end zones) since the turn of the millennium, falling to its lowest levels since it was filled in the 1930s. Robust water conservation efforts now underway will reduce water demand, thereby decreasing the Hoover Dam's capacity factor.

8. WIND ANHOLT 1 WIND FARM DENMARK

TOC

Rated MW	400 MW
Capacity Factor	.494
Output per Year	(400*8766) *.494 = 1,732,162 MWh
Area for Plant	144 sq. km
Hours Available per Year	3,500 h/y
LCOE Cost per MWh	US$ 45.00 (see Lizard, p. 5, Third Party General References)

https://www.renewable-technology.com/projects/anholt-offshore-wind-project/

Most Visited Getting Started Intellicast - Weather A...

TYPE	CONSTRUCTION STARTED	INSTALLED CAPACITY
Offshore wind farm	January 2012	400MW
NUMBER OF TURBINES	**TURBINE MAKE**	**INAUGURATED**
111	Siemens SWP 3.6-120	September 2013

https://www.renewable-technology.com/projects/anholt-offshore-wind-project/ Search

Most Visited Getting Started Intellicast - Weather A...

Anholt offshore wind farm make-up

The Anholt wind project site is spread over an area of 144km² covering a length of 20km and width varying between 4km and 12km.

It comprises 111 Siemens SWP 3.6-120 wind turbines with a generation capacity of 3.6MW each. Each turbine measures 120m in rotor diameter, 141.6m in height and 450t in weight. The turbines are deployed in water depths ranging from 15m to 19m. The distance between the turbines varies from 500m to 800m based on the layout design. Each wind turbine is linked to an offshore substation through cables.

The cut-in and cut-out wind speeds of the turbine are 4m/s and 25m/s respectively.

Anholt Offshore Wind Farm - Wikipedia

https://en.wikipedia.org/wiki/Anholt_Offshore_Wind_Farm

Capacity factor, 48.7 %. **Anholt** Offshore **Wind** Farm is a Danish offshore **wind** power **wind** farm in the Kattegat, between Djursland and **Anholt** island. With a nameplate capacity of 400 megawatts (MW), it is one of the largest offshore **wind** farm in ...

Capacity factor: 48.7 % **Commission date**: 4 September 2013
Construction cost: 10 billion Danish kroner **Max. water depth**: 14–17 m (46–56 ft)

You visited this page on 1/20/19.

UK offshore wind capacity factors – a semi-statistical analysis | Energy ...

euanmearns.com/uk-offshore-wind-capacity-factors-a-semi-statistical-analysis/

Oct 6, 2017 - There is a dependence of capacity factor on **age**, with older farms showing capacity factors of around 30% and younger ones factors of around 40%. This is interpreted to be a result of increased turbine sizes, with taller modern turbines accessing higher wind speeds at higher elevations.

energynumbers.info/capacity-factors-at-danish-offshore-wind-farms

ng Started Intellicast - Weather A...

Data is to the end of Feb 2018. Analysis by EnergyNumbers.info. Raw data from ens.dk	Latest rolling 12-month capacity factor	Life capacity factor	Age (y)	Installed capacity (MW_p)	Total elec. gen. (GWh)	Power per unit area spanned (W/m^2)
Anholt 1	**52.8%**	49.4%	4.9	399.6	8 487	2.2

https://ens.dk/en/our-services/statistics-data-key-figures-and-energy-maps/overview-energy-sector

https://www.wind-watch.org/faq-output.php

Intellicast - Weather A...

How much of the time do wind turbines generate energy?

Wind turbines generate electrical energy when they are not shut down for maintenance, repair, or tours and the wind is between about 8 and 55 mph. Below a wind speed of around 30 mph, however, the amount of energy generated is very small. Wind turbines produce at or above their average rate around 40% of the time. Conversely, they produce little or no power around 60% of the time.

National Wind Watch | Output From Industrial Wind Power

https://www.wind-watch.org/faq-output.php

Every **wind** turbine has **a** range of **wind** speeds, typically around 30 to 55 mph, in which it will produce at its rated, or maximum, capacity.

You've visited this page many times. Last visit: 1/13/19

How Much Power Does a Wind Turbine Generate? | Sciencing

https://sciencing.com › Science › Physics › Energy

Apr 24, 2018 - Most turbines automatically shut down when **wind** speeds reach about 88.5 kilometers **per hour** (55 miles **per hour**) to prevent mechanical ...

https://en.wikipedia.org/wiki/Wind_power

WIND Capacity Factor

Since wind speed is not constant, a wind farm's annual energy production is never as much as the sum of the generator nameplate ratings multiplied by the total hours in a year. The ratio of actual productivity in a year to this theoretical maximum is called the capacity factor. Typical capacity factors are 15–50%; values at the upper end of the range are achieved in favourable sites and are due to wind turbine design improvements.[83][84][nb 1]

Online data is available for some locations, and the capacity factor can be calculated from the yearly output.[85][86] For example, the German nationwide average wind power capacity factor over all of 2012 was just under 17.5% (45,867 GW·h/yr / (29.9 GW × 24 × 366) = 0.1746),[87] and the capacity factor for Scottish wind farms averaged 24% between 2008 and 2010.[88]

Unlike fueled generating plants, the capacity factor is affected by several parameters, including the variability of the wind at the site and the size of the generator relative to the turbine's swept area. A small generator would be cheaper and achieve a higher capacity factor but would produce less electric power (and thus less profit) in high winds. Conversely, a large generator would cost more but generate little extra power and, depending on the type, may stall out at low wind speed. Thus an optimum capacity factor of around 40–50% would be aimed for.[84][89]

A 2008 study released by the U.S. Department of Energy noted that the capacity factor of new wind installations was increasing as the technology improves, and projected further improvements for future capacity factors.[90] In 2010, the department estimated the capacity factor of new wind turbines in 2010 to be 45%.[91] The annual average capacity factor for wind generation in the US has varied between 29.8% and 34% during the period 2010–2015.[92]

A comment on the article starting on the next page

from: https://www.dailymail.co.uk/news/article-5657885/JAMES-DELINGPOLE-wind-turbine-trick.html

Colin Megson, Leeds, United Kingdom, 9 months ago viewed Jan 29, 2019

It would take a 2,328 of the very latest 9.5 MW offshore wind turbines with a capital cost £42 billion to sputter out 7% of the UK's electricity demand for 60 years, in the form of grid-degrading, intermittent electricity. By contrast, a 3,200 MW nuclear power plant will generate 7% of the UK's electricity demand for 60 years, in the form of grid-friendly, 24/7 electricity - for a capital cost of £18 billion. It would take 1,843 of these 12 MW, resource-guzzling monstrosities to do the same at a probably greater cost. Search for: "nuclear power = 22,116 mw"

Click to rate 18 6

RE: https://www.dailymail.co.uk/news/article-5657885/JAMES-DELINGPOLE-wind-turbine-trick.html Excerpts below:

12 MW Wind Turbine to be tested by GE Renewable Energy at Blyth, Northumberland.

Daily Mail London
April 28, 2018
Excerpts:

Today, huge turbines can be built more efficiently using tubular steel and concrete (for the towers) and carbon fibre (for the blades). At last, the era of Big Wind is upon us, with a new generation of turbines that are bigger — and create more electricity — than ever before.

Standing 853ft (260 metres) tall with 351ft-long blades (107 metres), it will produce electricity equal to the annual consumption of 16,000 homes. The size of such a turbine will make it too obtrusive to site on land.

Continued next page

Continued from page 45: Imagine: no more 'dirty' fossil fuel power; just thousands of offshore turbines swishing in the distance, generating free, 'low carbon' electricity until the end of time.

So runs the theory. But then, as with so many utopian schemes, there are huge catches — starting with the eye-watering cost.

Electricity produced by onshore wind costs twice as much as conventional gas-fired electricity generation; offshore wind three times as much. The only reason the wind industry is viable is because of the massive subsidies it receives. Subsidies raised silently from your energy bill.

British Gas has said that by the end of this year, green taxes will add a fifth to the average fuel bill. Iain Conn, boss of parent company Centrica, said: 'It is going to be, in our estimates, about £200 on everyone's bill which is getting on for 20 per cent.'

By 2020/21, according to the Office for Budget Responsibility (OBR), the total cost of all the subsidies for renewable electricity will be nearly £11 billion a year, and wind power will be taking more than half of that. And don't be taken in by that ad campaign by Greenpeace and a coalition of environmental groups and electricity suppliers last year, claiming that the cost of wind energy is plummeting to the point where it's now cheaper than fossil fuel power.

No it's not. The ads were withdrawn as the result of a successful complaint to the Advertising Standards Authority, because they were deliberately misleading propaganda, based on projected costs, not real, current figures.

In fact, Professor Gordon Hughes, of the University of Edinburgh, and his colleagues showed in a recent study published by the Global Warming Policy Foundation think-tank, that the capital costs of new offshore wind farms do not appear to be falling and indeed appear to be still rising as wind projects move into deeper waters.

Also, being far out at sea, they won't alienate all those rural voters who can't stand having wind turbines industrialising the countryside, disturbing their sleep and killing bats and birds.

Despite its huge cost, offshore wind remains a vital part of the Government's energy strategy — its best hope of meeting its EU-driven CO_2 reduction obligations, under the 2008 Climate Change Act. But according to John Constable, of the Renewable Energy Foundation, this is a chimera.

Wind energy, he says, will never be a solution because of 'fundamental physics: wind, by its nature, is a low density and intermittent flow of energy. Correcting those deficiencies to supply reliable electricity to consumers means huge capital expense in the turbines and in the electricity system as a whole'.

Making turbines bigger and putting them out at sea only makes things worse. They are much more expensive to erect and maintain in a remote, hostile environment, and have a much shorter working life.

Analysts have known for years that rising repair costs would mean the economic lifetimes of turbines were way under the 25 years promised by the industry.

In February this year, Danish offshore wind operator Ørsted admitted it might have to repair the blades of more than 600 turbines, after just a few years on the water, at a cost of about £1million per turbine.

And the bigger they are, the worse this is going to get, for all sorts of reasons.

These machines are already dealing with large forces, putting huge loads on their components. Making them bigger just increases the problem, and not just because of increased weight. Wind shear — the difference in wind speed at different heights — leads to uneven loading at the top and bottom of the blade radius and causes huge strain on the working parts. This is really difficult and very expensive engineering.

Then there's the erosion of the blades, due to high-speed impacts with small particles, dust, ice and salt. Ørsted is replacing those blades because their edges had become rough, and as any engineer will tell you, when a wing gets rough it becomes unstable.

But if wind is really so expensive, inefficient and environmentally damaging, why does our Government remain so committed to it?

Largely because of the lobbying of a hugely powerful industry. An industry desperate not to lose its extraordinarily generous subsidies.

For example the (mostly foreign) owners of the London Array — the largest wind farm in the world, off the coast of Kent, which was opened by David Cameron in 2013 — receives about £190 million a year in subsidies, on top of selling electricity they make. That sort of windfall, forgive the pun, ensures the industry presses its case with ruthless efficiency.

It is now under real pressure. The Treasury has put a moratorium on new subsidies until the middle of the next decade at the earliest, and the wind industry is trying to survive by pretending that falling generation costs have made them economically viable. Secretly, they are hoping for a change of policy (Jeremy Corbyn?) and a stonking carbon tax.

This latest propaganda about 'bigger', 'better', 'faster' new mega-turbines is designed to keep us and the politicians in the industry's thrall.

Even now, they are building the new biggest wind farm in the world, called Hornsea Project One, off the Yorkshire coast. It will have 174 turbines over a 240-square mile area, each 620ft high (189 metres). And that's before we get on to Hornsea Projects Two and Three, which are already in the pipeline and which, you can bet, will be still larger and with even more monstrous turbines.

As the Renewable Energy Foundation's John Constable explains: 'All this is designed to give the illusion that there has been massive technological progress in the industry when in fact the major problems remain unsolved: the energy in the wind is of low quality. Turning it into high quality, reliable energy for the consumer is still very expensive indeed.'

Yet the propaganda often finds a ready audience because so many want to believe, against all the evidence, that wind must be a preferable alternative to our gas-fired turbines, vanishing set of coal-fired plants or ageing nuclear reactors.

We don't want to hear about the intermittency of the wind, which makes it so problematic as a reliable source of power for an advanced economy and means we need alternative generating capacity as well.

Read full article:
https://www.dailymail.co.uk/news/article-5657885/JAMES-DELINGPOLE-wind-turbine-trick.html

9. TIDAL RANGE (Pool or Barrage) Annapolis Generator CDN

TOC

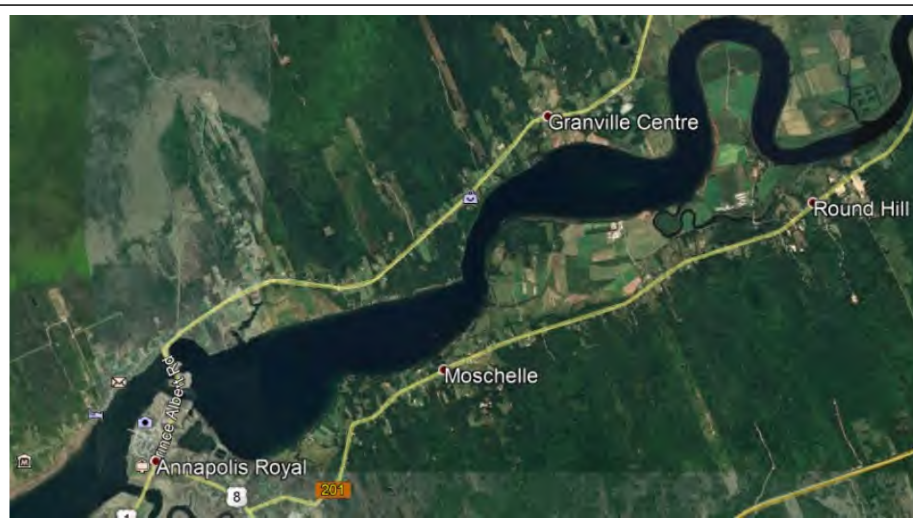
Annapolis Royal Generating Station

The Annapolis Royal Generating Station viewed at high tide.

Annapolis Royal Generating Station, Nova Scotia

Country	Canada
Location	Annapolis Royal, Nova Scotia
Coordinates	44°45′7″N 65°30′40″W
Status	Operational
Commission date	1984
Owner(s)	Nova Scotia Power
Thermal power station	
Primary fuel	Tidal
Power generation	
Nameplate capacity	20 MW
Annual net output	50 GWh

Rated Capacity MW	20 MW
Capacity Factor	50GWh/ yr = 50,000 MWh / (20MW * 8760hr) = .285
Output per Year	50 GWh
Area for Plant	ESTIMATED AREA OF ANNOPOLIS TIDAL POOL ESTUARY 50,000 m by 300 m = 15,000,000 sq. m / 1,000,000 = 15 km^2
Hours Available per Year	4.5 hours / day * 365 = 1,650 h/y (Single Direction)
Cost per MWh	US$ 410.00 assumed (see Reference below this section: Tidal Energy – IRENA www.irena.org/DocumentDownloads/Publications/Tidal_Energy_V4_WEB.pdf



Estimation of annual energy output from a tidal barrage using two ...
www.academia.edu/.../Estimation_of_annual_energy_output_from_a_tidal_barrage_u...

The accuracy of Eq. (2) can be validated from the data of a few operating tidal power plants [12]. For example, the La Rance tidal power station is located in the estuary of the Rance River in Brittany, in France, and is currently the largest tidal power station under operation in the world in terms of installed capacity, with a capacity of 240 MW. The area of the enclosed basin is 22.5 km with a mean tidal range of 8.5 m. The actual average annual energy output over the past 30 years has been approximately 533 GWh. According to Eq. (2), the theoretically estimated electricity output for the La Rance power station is about 517 GWh per year, which is very close to the actual energy generated.
The second example is the Annapolis tidal power plant of Nova Scotia Power, which is located in the Bay of Fundy, Canada. This bay has the highest ocean tidal range worldwide, with a maximum tidal range of 16 m [26]. The enclosed basin area within the Annapolis River cathment is about 6 km, with a mean tidal range of 6.4 m [9]. The station has a generating capacity of 20 MW, which is connected to the national grid. This tidal facility uses one turbine, the largest Straflo (rim) turbine under operation in the world, producing about 50 GWh of electricity per year [27]. According to Eq. (2), the theoretical estimation value is about 50 GWh per year if a value of = 0.2 is used.
Another operating experimental plant is the Jiangxia tidal power station, located in the East China Sea. The total installed capacity of this power station is 3.9 MW, which makes it the third largest tidal power station in the world [28]. The area of the enclosed basin is 1.37 km , with a mean tidal range of 5.1 m. According to Eq. (2), the theoretical estimated power output is about 7 GWh per year if a value of = 0.2 is used. This low power conversion efficiency is caused by the low operation level and the presence of local land reclamation in the basin. The actual mean annual energy output ranges from 6 to 7 GWh.
The Sihwa Lake Tidal Power Station near the southern Incheon Port in Korea is a large tidal power station currently under construction, and it will operate with a total installed capacity of 254 MW, surpassing the 240 MW of the Rance Station, to become

Annapolis Tidal Station | Nova Scotia Power
https://www.nspower.ca › ... › How We Make Electricity › Renewable Electricity ▾
Annapolis Tidal Station. We operate the first and only **tidal power plant** in North America, one of few in the world. Our **Annapolis Tidal Power Plant** came online in 1984. It can make as much as 20 megawatts of **electricity** and has a daily output of roughly 80-100 megawatt hours, depending on the **tides**.

Annapolis Generating Station Nova Scotia CDN

Annapolis River

From Wikipedia, the free encyclopedia

Location	
Country	Canada
Physical characteristics	
Source	
- location	Caribou Bog
Mouth	
- location	Annapolis Basin
- elevation	sea level

The **Annapolis River** is a Canadian river located in Nova Scotia's Annapolis Valley.

Geography

Measuring 120 kilometres in length,[2] the river flows southwest through the western part of the valley from its source in Caribou Bog (50 m [160 ft] above sea level) near the villages of Aylesford and Berwick in western Kings County, to its mouth at Port Royal where it empties into the Annapolis Basin. The estuary portion of the Annapolis River runs from Bridgetown to Port Royal and experiences a tidal range of approximately 7.5 m (25 ft) between tides.

ESTIMATED AREA OF ANNOPOLIS TIDAL POOL ESTUARY

50,000 m by 300 m = 15,000,000 sq. m / 1,000,000 = 15 km^2

Tidal Energy – IRENA
www.irena.org/DocumentDownloads/Publications/Tidal_Energy_V4_WEB.pdf

Tidal Production Hours per Day

Tidal range technology has a number of options for power generation:

I.) One way power generation at ebb tide: The reservoir is filled at flood tide through sluice gates or valves that are closed once the tide has reached its highest level. At the ebb tide, the water in the reservoir is released through the turbines and power is generated. With this single cycle, **power is generated for only four hours per day**. Annapolis in Canada is an ebb generation plant.

II.) One way power generation at flood tide: At flood tide the sluice gates are kept closed to isolate the reservoir while at its lowest level. When the tide is high, the water from the sea-side flows into the reservoir via the turbines, thus generating power. The disadvantage of this cycle is that it has less capacity and generates less electricity, and it may be ecologically disadvantageous as the water level in the impoundment is kept at a low level for a long time. Sihwa is a flood generation plant.

III.) Two way power generation: Both incoming and outgoing tides generate power through the turbines. **This cycle generates power for four hours twice daily.** However, reversible turbines are required. La Rance is an ebb and flood generation plant; bulb turbines can also pump water for optimisation.

The International Renewable Energy Agency is an intergovernmental organization to promote adoption and sustainable use of renewable energy. It was founded in 2009 and its statute entered into force on 8 July 2010. The agency is headquartered in Abu Dhabi.

Tidal Energy – IRENA
www.irena.org/DocumentDownloads/Publications/Tidal_Energy_V4_WEB.pdf

Tidal Cost indications

Tidal range power generation is dominated by two large plants in operation, the 'La Rance' barrage in France and the 'Sihwa dam' in South Korea. The construction costs for 'La Rance' were around USD 340 per kilowatt (/kW) (2012 value; commissioned in 1966), whilst the Sihwa barrage was constructed for USD 117/kW in 2011. The latter used an existing dam for the construction of the power generation technology. The construction cost estimates for proposed tidal barrages range between USD 150/kW in Asia to around USD 800/kW in the UK, but are very site specific. Electricity production costs for 'La Rance' and 'Sihwa Dam' are **EUR 0.04 per kilowatt-hour (/kWh) and EUR 0.02/kWh**, however these costs are very site specific. Tidal range technologies can be used for coastal projection or water management, which would reduce the upfront costs. On the other hand, additional operational costs may occur due to the control, monitoring and management of the ecological status within the impoundment.

EUR (.25 + .47) /2 = .36 Convert to US$ = .41 / kWh =

.41 * 1000 = **US$ 410.00 per MWh** **= LCOE ?**

TIDE CHART -- Month of January 2019 for **Digby, Nova Scotia**, Canada (Near Annapolis Tidal Range Generator)

http://www.tides.gc.ca/eng/station?type=0&date=2019%2F01%2F22&sid=325&tz=AST&pres=0

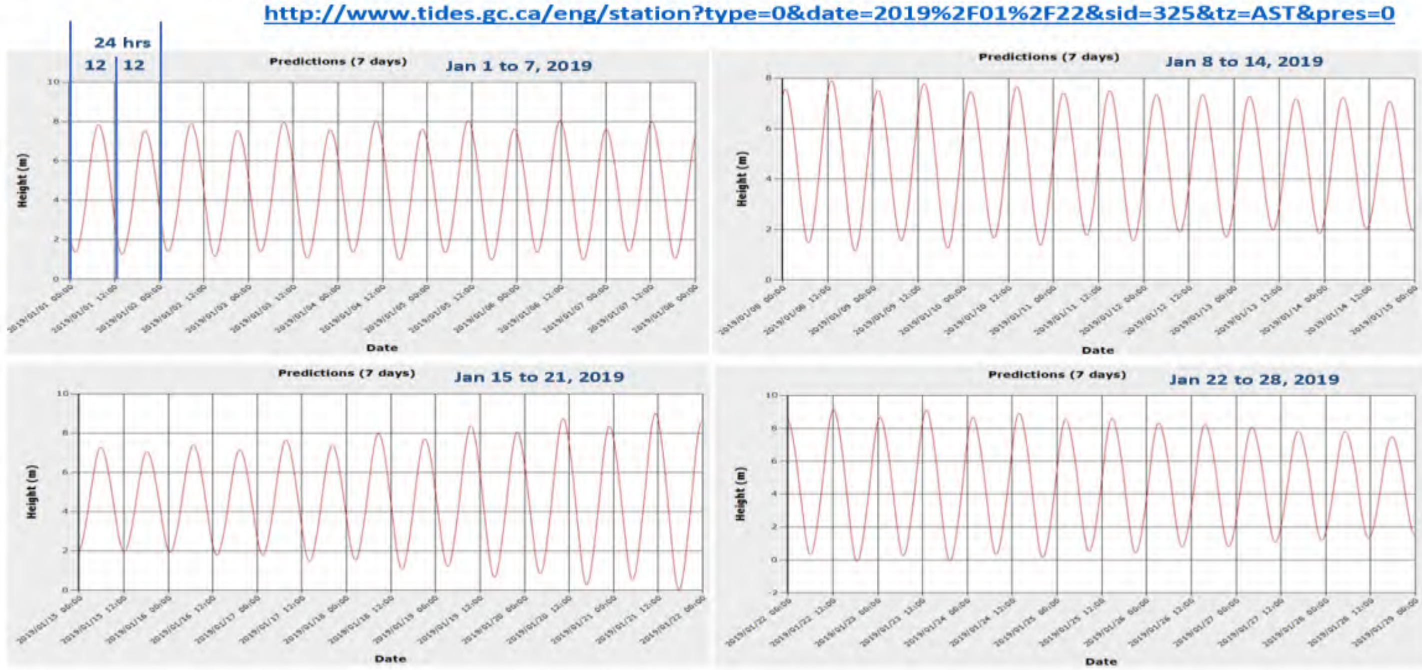


Fig. 2. Areas appropriate for traditional tidal power [1]

[PDF] Electricity Generation by the Tidal Barrages - CORE

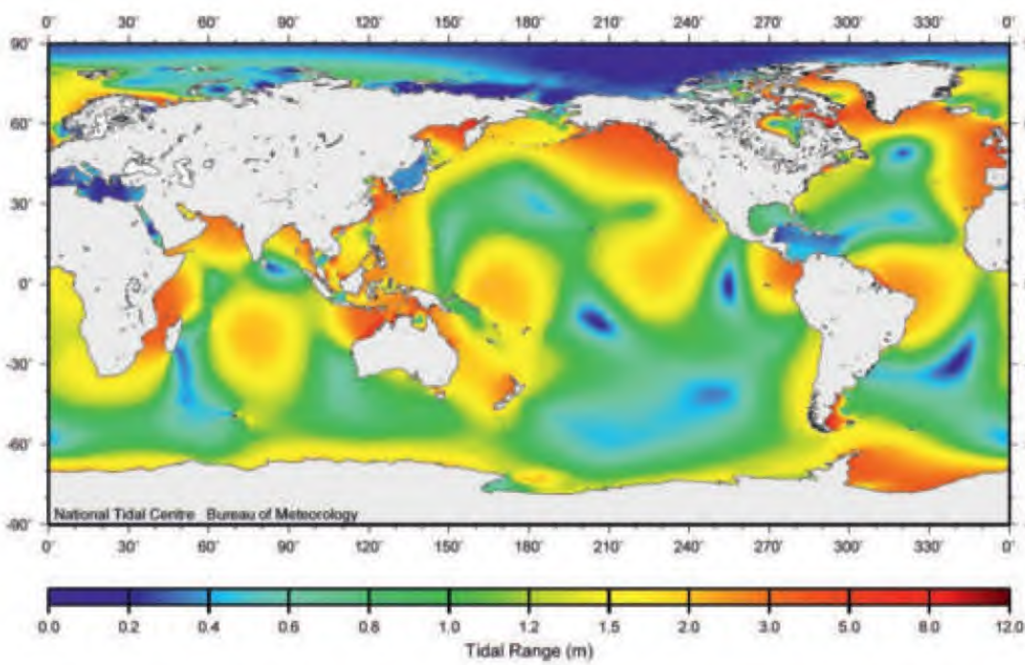
https://core.ac.uk/download/pdf/82126464.pdf

by A Etemadi - 2011 - Cited by 22 - Related articles

ICSGCE 2011: *27–30 September 2011*, Chengdu, China. *Electricity Generation by the Tidal Barrages*. Ahmad Etemadi*

Tidal Energy – IRENA www.irena.org/DocumentDownloads/Publications/Tidal_Energy_V4_WEB.pdf

Tidal Range Resources World Wide - Figure 9



Source: Bureau of Meteorology, Australian Government http://www.energybc.ca/tidal.html

One major drawback of tidal barrages is that the tide only goes out for so much time per day, and power is generated for as little as four hours a day, giving barrages low levels of efficiency in the 20-25% range.[4]

As of early 2016 the first tidal lagoon project is under construction off the coast of the Welsh city of Swansea, enclosing around 11 km^2 of water. It will produce 320 MW of power for 14 hours a day, enough to power 155,000 homes and making it the largest tidal energy facility in the world. Scheduled for completion in 2019, if successful it will be the first of six proposed tidal lagoon projects to be built on Britain's west coast.[5]

4 Hammons, 1993.

Hammons, T.J. *Tidal Power*. Proceeding of the IEEE. 1993. Vol 81. Issue 3. PP 419-433.

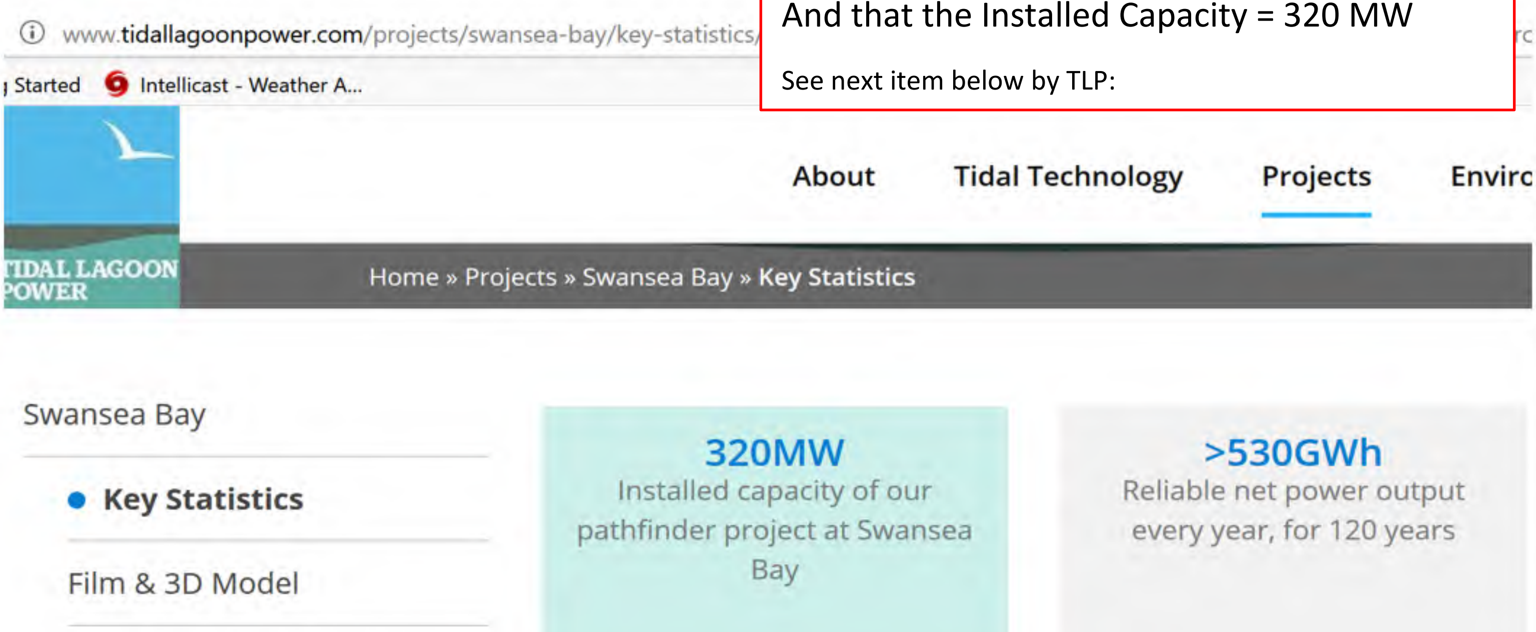
5 TLP - Tidal Lagoon Power, "Swansea Bay."

TLP -Tidal Lagoon Power. "Swansea Bay." Cached April 2, 2016.

SO: 320 MW * 14 *365 = 1,635,200 MWh per year
There is a PROBLEM with this
"320 MW of power for 14 hours per day" number:
TLP states Swansea will produce 530,000 MWh per year

And that the Installed Capacity = 320 MW

See next item below by TLP:



Following these numbers: Capacity Factor = 530,000 MWh / 320 MW * 8769 hours = **.189**

Note: 320 MW * 14 *365 = 1,635,200 MWh /yr hence 530,000/1,635,200 = .324 Capacity F.

But, of course, no one else supports that the Tidal Range will operate at a steady maximum flow for 14 hours per day, so perhaps the .189 Capacity Factor is correct http://www.darvill.clara.net/altenerg/tidal.htm

Although the energy supply is reliable and plentiful, converting it into useful electrical power is not easy.

There are eight main sites around Britain where tidal power stations could usefully be built, including the Severn, Dee, Solway and Humber estuaries. Only around 20 sites in the world have been identified as possible tidal power stations.

A major drawback of tidal power stations is that they can only generate when the tide is flowing in or out - in other words, only for 10 hours each day. However, tides are totally predictable, so we can plan to have other power stations generating at those times when the tidal station is out of action.

http://www.newworldencyclopedia.org/entry/Tidal_power

Tidal power schemes do not produce energy all day. A conventional design, in any mode of operation, would produce power for 6 to 12 hours in every 24 and will not produce power at other times. As the tidal cycle is based on the rotation of the Earth with respect to the moon (24.8 hours), and the demand for electricity is based on the period of rotation of the earth (24 hours), the energy production cycle will not always be in phase with the demand cycle. However, the tides are relatively reliable and more predictable than other alternative energy sources, such as wind.

Tidal energy *[Here referring to Tidal Range, Pool or Barrage not Tidal Stream]* has an efficiency of 80 percent in converting the potential energy of the water into electricity. *[Note: this is similar to the efficiency of a gravity dam as the tidal range operation is similar to a gravity dam]*
It is thus very efficient, compared to other energy resources such as solar power or fossil fuel power plants.

Tidal Power - Energy British Columbia - Energy BC
www.energybc.ca/tidal.html
by BCE Maps - Related articles
One major drawback of **tidal barrages** is that the **tide only goes out** for **so much time per day**, and **power** is **generated** for as **little** as **four hours** a **day**, **giving barrages low levels** of **efficiency** in the **20-25%** **range**. **Tidal barrage** technology is not ...

https://www.bbc.com/news/uk-wales-politics-44360852 25 June 2018

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£1.3bn Swansea Bay tidal lagoon (TLP) project thrown out

Image copyright TLP Image caption The Hendry review said the lagoon would make a "strong contribution" to energy supplies

Plans to build the world's first tidal power lagoon have been thrown out by the UK government.

HIGHLIGHTS of this Article:

BACKGROUND and PRICE NEGOTIATIONS

Business and Energy Secretary Greg Clark said the £1.3bn project was not value for money, despite claims by developers Tidal Lagoon Power (TLP) a revised offer made it cheaper.

TLP have asked for an unusual 90-year contract with the government, starting at a price of £123 per megawatt hour of electricity produced in the first year and reducing over time.

Highlights of Revised Offer Made February 22, 2018:

> *TLC argued: By comparison, the latest price offered to new offshore wind developments was £57.50 per megawatt hour.*
>
> *In his blog Mr. Graham, who represents the city of Gloucester where TLP are based, revealed that the company had now revised their offer and were proposing the same terms as those accepted by the government for the Hinkley Point C nuclear power station in Somerset.*
>
> *Hinkley Point C's developers, EDF Energy, were granted a 35 year contract with a fixed price of £92.50 per megawatt hour of electricity produced.*

THIS Article June 25, 2018:

Government analysis estimated that the lagoon would cost the average British household consumer an additional £700 between 2031 and 2050.

But TLP chief executive Mark Shorrock said the figures were wrong, adding that offshore wind projects had received £8bn in subsidies and the "path finder" tidal lagoon project needed £25m a year "in order to kick start an industry".

TLC FURTHER reduced price but upped the guaranteed time:

The developers had previously asked for a 90-year contract with the UK government with an average strike price - a guaranteed price for the electricity generated - of £89.90 per megawatt hour.

The new nuclear power station at Hinkley Point C in Somerset was given a strike price of £92.50/MWh for 35 years.

10. TIDAL STREAM SEAGEN N. IRELAND (2008 to 2017)

Rated Capacity MW	1.2 MW
Capacity Factor	6.29 GWh/ yr = 6,290 MWh / (1.2 MW * 8760 hr) = **.598** as reported SeaGen wiki
Output per Year	6.29 GWh
Area for Plant	150 km^2
Hours Available per Year	with 2 way stream generation = 8 hrs/ day = 3,000 h/y
LCOE Cost per MWh	US$ 77.00 (as of 2017 -- see MarineEnergy.biz below reference doc)

SeaGen

From Wikipedia, the free encyclopedia

Coordinates: 54°22′7.2″N 5°32′45.8″W

SeaGen was the world's first large scale commercial tidal stream generator.[1][2][3] It was four times more powerful than any other tidal stream generator in the world at the time of installation.[4]

The first SeaGen generator was installed in Strangford Narrows between Strangford and Portaferry in Northern Ireland, in April 2008 and was connected to the grid in July 2008.[5] It generates 1.2 MW for between 18 and 20 hours a day while the tides are forced in and out of Strangford Lough through the Narrows.[6] Strangford Lough was also the site of the very first known tide mill in the world, the Nendrum Monastery mill where remains dating from 787 have been excavated.

SeaGen

Commercial tidal stream generator — SeaGen — in Strangford Lough. The strong wake shows the power in the tidal current.

Strangford Lough covers an area of **57.9 square miles** (150 square kilometres) and has a number of towns and villages found along its shores.

Strangford Lough | National Trust

https://www.nationaltrust.org.uk/strangford-lough www.esru.strath.ac.uk/EandE/Web_sites/16-17/WindAndTidal/tidalConcept.html

http://www.esru.strath.ac.uk/EandE/Web_sites/16-17/WindAndTidal/tidalConcept.html

These calculated current speeds can then be applied to power curve of the SeaGen-S 2MW system, shown in Figure 2, to estimate the power produced throughout the lunar cycle. This value could then be used to estimate the yearly energy generation of the system and calculate the systems' capacity factor for the given location. These values are shown in Table 2, and the calculation spreadsheet can be found in the attached file "Tidal Current Calculations" below.

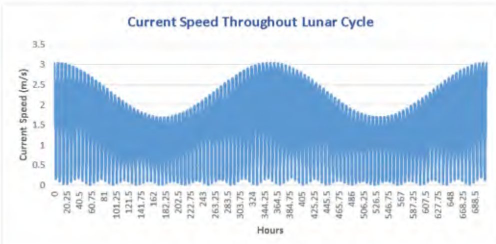


Figure 5: Lunar Cycle Current Speeds

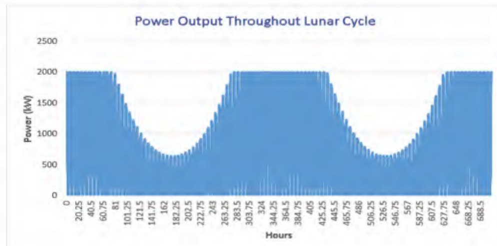


Figure 6: Lunar Cycle Power Output

Table 2: Tidal Stream Turbine Results

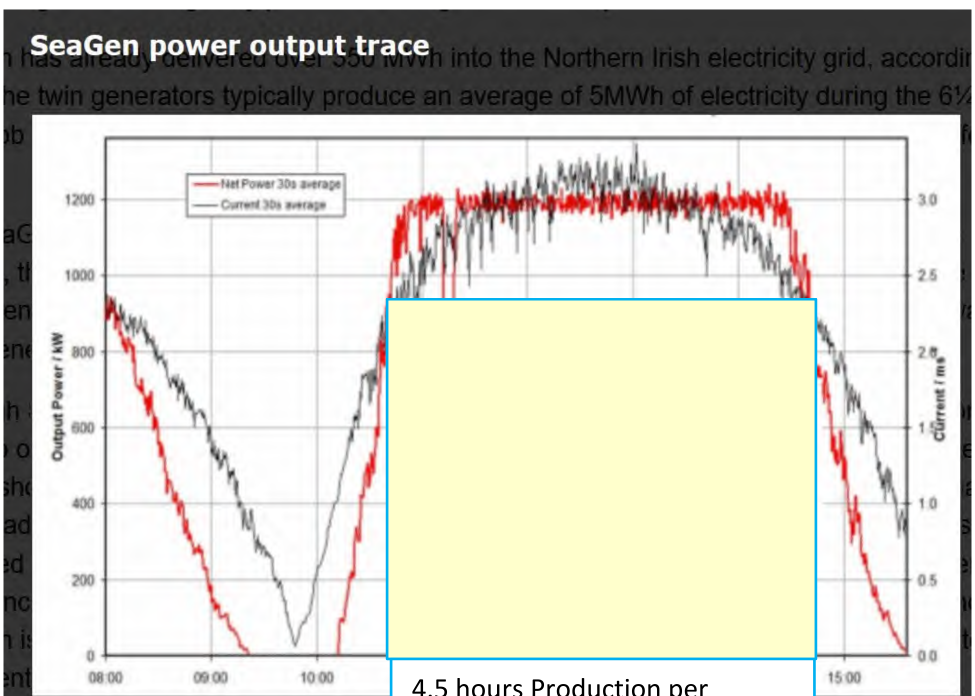
Lunar Cycle Energy Output	508.9 MWh
Annual Energy Output	6.29 GWh
Mean Energy Output	718.8 kW
Capacity Factor	0.36

Tidal Current Calculations

References

Dated 2017

Strathclyde University
16 Richmond Street
Glasgow G1 1XQ
Scotland, United Kingdom



4.5 hours Production per approx. 12 hours (1 flow in and out cycle)
Max 9 hrs per 24 = **3,285 h/y**

Tidal Energy – IRENA JUNE 2014

www.irena.org/DocumentDownloads/Publications/Tidal_Energy_V4_WEB.pdf

Tidal Cost indications

Tidal current technologies are still in the demonstration stage, so cost estimates are projected to decrease with deployment. Estimates from across a number of European studies for 2020 for current tidal technologies are between EUR 0.17/kWh and EUR 0.23/kWh, although current demonstration projects suggest the levelized cost of energy (LCOE) to be in the range of **EUR 0.25-0.47/kWh**. It is important to note that costs should not be considered as a single performance indicator for tidal energy. For example, the costs for both tidal range and tidal stream technologies can fall by up to 40% in cases where they are combined and integrated in the design and construction of existing or new infrastructure.

EUR (.17 + .23) /2 = .20 Convert to US$ = .2281 / kWh =

.2281 * 1000 = **US$ 228.10 per MWh** **by 2020** **LCOE ?**

Tidal Energy – IRENA JUNE 2014

https://marineenergy.biz/2017/01/31/gmax-targets-lcoe-reductions/

LCOE US$ 77.00 per MWH January 31, 2017

GMax targets LCOE reductions

GMax Tidal Energy has calculated the levelized cost of energy (LCOE) for its tidal platform, currently under development, to be at $77 per MWh.

The US-based tidal energy developer said the calculation was done using National Renewable Energy Laboratory's LCOE calculator.

GMax said the tidal platform could produce energy at 7.7 cents per kWh, or at $77 per MWh.

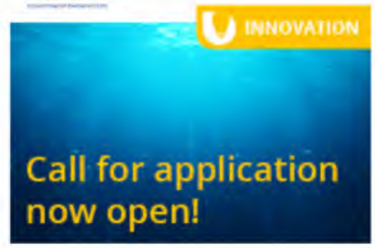
The company noted that for the LCOE calculations, the data from the in-house study by the GMax team on the water flow dynamics which showed potential output increases up to 20%, was incorporated in the calculations, along with the use of new state-of-the-art materials.

Also, GMax team estimates the cost per megawatt when mass-produced will not exceed $3.9 million when purchased in a 3MW platform including the cost of installation.

"Within this offering the GMax team has developed a dynamic lend lease approach for potential power purchase agreements with local and regional utility companies. There is the possibility of no initial capital investment depending on the rating by Moody's Investors Service. A lend lease program will provide cost effective accessibility, and apprising deal structure for our future customers," GMax said.

GMax's modular unit device uses linear flow technology to produce power. It's design incorporates 2 GMax permanent magnet generators with the nameplate capacity between 2-4MW, according to the company.

These generators are supported by a connecting structure upon a deck, on a floating structure, which excludes the need for ocean floor contact.



https://core.ac.uk/download/pdf/82816024.pdf

Once defined the background, it is possible to write a raw breakdown list of the components, common to different technologies, in order to define a standard for evaluating the costs of each solution and compare the related LCOE. A first comparison is in the Table 5.

Table 5 LCOE comparison for certain plants

	ref.	year	LCOE
MCT SeaGen	[22]	2006	0.146
Kobold	[24]	2005	0.080
Wind land-based	[23]	2011	0.097
Wind offshore	[23]	2011	0.304
SintEnergy	[20]	2014	0.118

SeaGen
In .146 EUR / kWh = US$ .167 /kWh
= US$ 167 / MWh

The LCOE may vary depending on different markets, government incentives and taxations, for a commercial plant. As in [22] LCOE strongly depends on number of turbines, speed, site availability: more turbines (array) reduce the LCOE, higher speed and availability reduce also the costs and LCOE. Not so many LCOE evaluations for specific plants can be found due to the early step of development (TRL 7-8), in addition only sometimes the evaluation is referred to a single turbine or to a same pick velocity so the costs look like higher. SintEnergy turbine is evaluated at 3m/s of pick speed: 7 m/s velocity increases the

Different Claims for SeaGen Output and Capacity Factor

Strathclyde University

Capacity Factor .36

Annual Output 6.29 GWh

Hence Rating Capacity = 2MW supposed to be 1.2 MW

IF Rated Capacity = 1.2 MW*8760 = 10,512 MWh

Then 6.29 GWh*1000 = 6,280 MWh

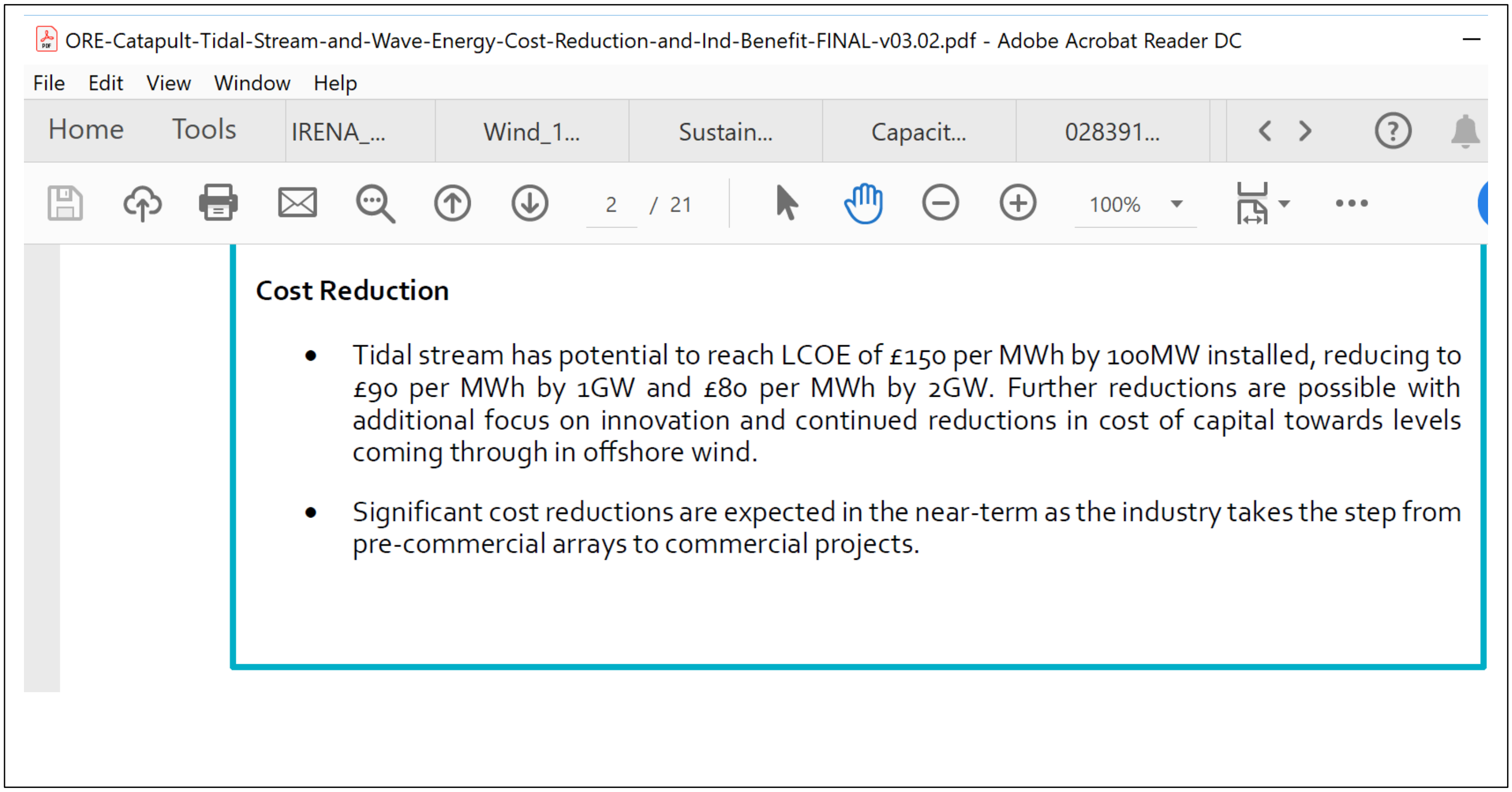
Hence Capacity Factor = 6,280/10,512 = .598

SeaGen Data

Annual Output = 7 GWh

Name Plate Capacity = 1.2 MW

Hence Capacity Factor = .67


ORE-Catapult-Tidal-Stream-and-Wave-Energy-Cost-Reduction-and-Ind-Benefit-FINAL-v03.02.pdf - Adobe Acrobat Reader DC

Cost Reduction

- Tidal stream has potential to reach LCOE of £150 per MWh by 100MW installed, reducing to £90 per MWh by 1GW and £80 per MWh by 2GW. Further reductions are possible with additional focus on innovation and continued reductions in cost of capital towards levels coming through in offshore wind.
- Significant cost reductions are expected in the near-term as the industry takes the step from pre-commercial arrays to commercial projects.

Comparison RE TIDAL STREAM ENERG COSTS:

From: https://www.irishtimes.com/business/energy-and-resources/ocean-energy-europe-disappointed-at-openhydro-liquidation-1.3577586

"Costs are coming down fast with every new project, and the EU has set targets for tidal to reach 10€c/kWh by 2030, well below offshore wind costs only five years ago," he said.

10 Euro Cents / kWh = 11 Cents US$ / kWh (2019)

End

Comparisons of Electricity Generation Plants using New Metrics (2019) Chart, Table, Spreadsheet & Data References

Available from: www.neptunewave.ca