Project 1 - Energy Sustainability Modeling

ENME 489X

Group 1

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Background and Purpose of the Report

This report deals with the study of the potential for end-use energy efficiency and renewable energy in New York City to better understand future options for New York's energy supply. The primary objective of this report is to create a baseline scenario for meeting all the energy needs(electrical, heat, cooling and transportation) detailing the associated costs, efficiencies and energy capacities using non renewable sources of energy.

The secondary objective is to increase the energy sustainability of the New York City by using the renewable sources of energy. For our group, the team needs to make use of at least 5% of renewable energy sources to replace the current non renewable energy sources being used. The team also needs to provide detailed justification for the renewable source chosen and the associated costs, efficiencies and energy capacities.

Structure of Report

- Baseline Scenario
    - Meeting energy needs of the New York City using no renewable sources of energy
    - Associated costs, efficiencies and energy capacities of the non renewable energy sources.
    - Economic costs and greenhouse gas emissions from this scenario

- Secondary Scenario
    - Increase sustainability by using renewable energy sources.
    - Replacing at 5% of the non renewable energy sources with the renewable energy sources.

- Estimating the costs, efficiencies and energy capacities of the renewable energy sources selected.

I. Baseline scenario

Energy Consumption in New York city

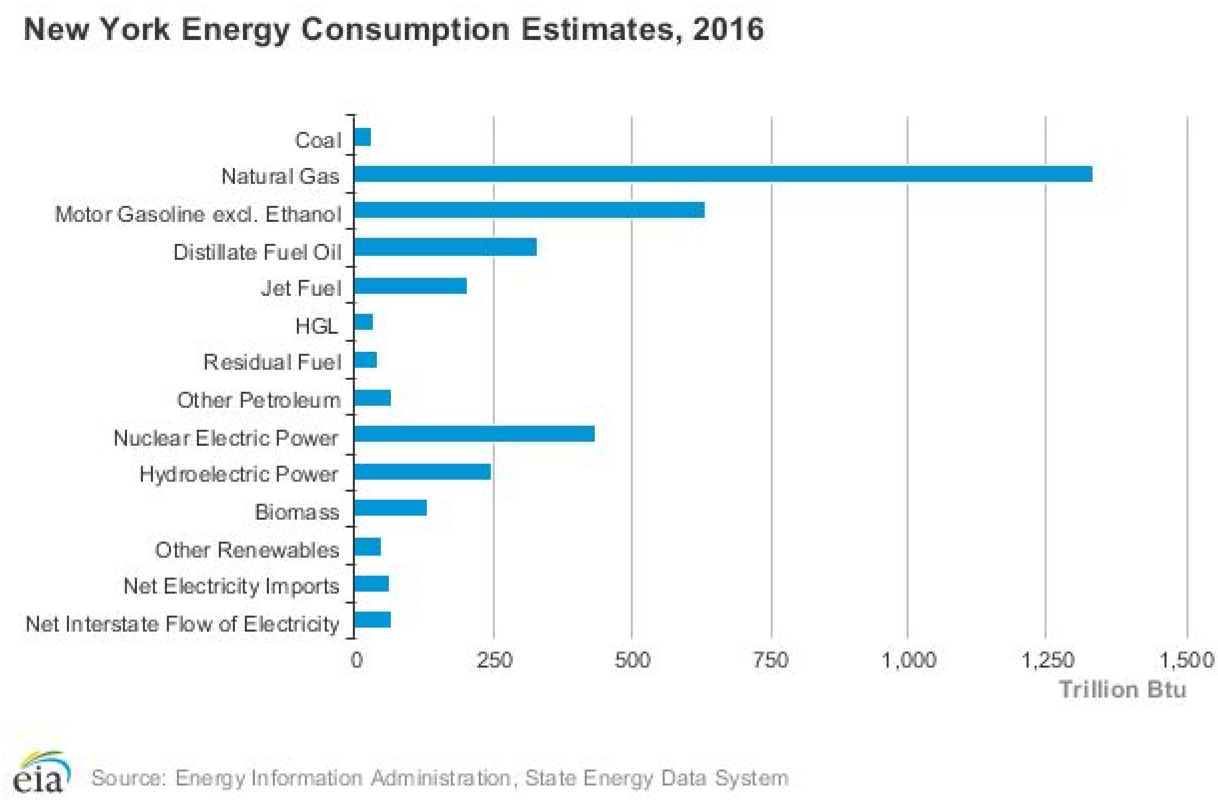


Fig 1: Energy consumption by different sectors.

The figure above shows the total energy consumption for different sectors for New York city. The energy consumption for different sectors can be added to estimate the total energy that was consumed by the New York city.

From the data provided by EIA,

Total energy consumed (in trillion BTUS) = 30 (coal) + 1335 (natural gas) + 635 (gasoline) + 330 (distillate fuel oil) + 201 (jet fuel) + 40 (residual fuel) + 66 (other petroleum) + 435 (nuclear electric power) + 248 (hydroelectric power) + 132 (biomass) + 48 (other renewables) + 61 (net electricity imports) + 67 (net interstate flow of electricity) + 33 (HGL) = **3661 Trillion BTUS**

Energy Source	Amount of energy consume (in Trillion BTUS)
Coal	30
Natural gas	1335
Gasoline	635
Distillate fuel oil	330
Jet fuel	201
Residual fuel	40
Other Petroleum	66
Nuclear electric power	435
Hydroelectric power	248
Biomass	132
Other renewables	48
Net Electricity Imports	61
Net Interstate Flow of Electricity	67
HGL (hydrocarbon gas liquids)	33
Total energy consumed:	**3661**

<u>Converting British Thermal Unit (BTUS) to Terawatt hours (TWh)</u>

1 BTU = 2.9307e-13 TWh

Similarly 3661 Trillion BTUS = 3.661e+15 BTUS = (3.661e+15) * (2.9307e-13)

<u>=1072.93 TWh</u>

Total energy consumed by the New York City was about 1072.93 TWh. This amount of energy consumed was assumed to be the total energy demand that the city required. The team then decided to use this total energy demand to create a baseline scenario for the amount of non renewable sources required to meet the total needs of the city. The value that will be used will be rounded to the nearest integer, thus taken as 1073 TWh.

<u>Renewables</u>

Given our data on the energy consumption for New York City, 428 Trillion Btus are consumed from renewable sources, including Hydroelectric power, biomass and other renewables. This accounts for approximately 11.7% of the total energy consumed. This tells us that we can increase the renewable energy demand by 5% quite easily. Our value of 1073 TWh does not account for this 11.7% renewables. The EnergyPLAN software does not account for this, so we can zero all renewable source data and increase it from 0 to 5%. This will create a 5% increase on top of the existing 11.7%, lifting renewable sources to account for 16.7% of all energy consumed. This, however, will not be represented in our baseline scenario from energyPLAN.

<u>Energy Supply</u>

To supply New York City's energy demand of 1073 TWh, a power plant capacity of 187,000 MW-e at an efficiency of 33% is required.

Baseline Scenario Analysis

Input Startdata

The EnergyPLAN model 13.0

Electricity demand (TWh/year):		Flexible demanc	0.00
Fixed demand	1073.00	Fixed imp/exp.	0.00
Electric heating + HP	0.00	Transportation	0.00
Electric cooling	0.00	Total	1073.00

District heating (TWh/year)	Gr.1	Gr.2	Gr.3	Sum
District heating demand	0.00	10.00	10.00	20.00
Solar Thermal	0.00	0.00	0.00	0.00
Industrial CHP (CSHP)	0.00	0.00	0.00	0.00
Demand after solar and CSHP	0.00	10.00	10.00	20.00

Wind	0 MW	0.00	TWh/year	0.00	Grid
Photo Voltaic	0 MW	0	TWh/year	0.00	stabili-
Offshore Wind	0 MW	0	TWh/year	0.00	sation
River Hydro	0 MW	0	TWh/year	0.00	share
Hydro Power	0 MW	0	TWh/year		
Geothermal/Nuclear	0 MW	0	TWh/year		

	Capacities		Efficiencies		
Group 2:	MW-e	MJ/s	elec.	Ther	COP
CHP	0	0	0.00	0.50	
Heat Pump	0	0			3.00
Boiler		5000		0.90	
Group 3:					
CHP	0	0	0.40	0.50	
Heat Pump	100	300			3.00
Boiler		5000		0.90	
Condensing	0		0.00		

Heatstorage:	gr.2:10	GWh	gr.10	GWh
Fixed Boiler:	gr.2 0.0	Per cent	gr0.0	Per cent

Electricity prod. from	CSHP	Waste (TWh/year)
Gr.1:	0.00	0.00
Gr.2:	0.00	0.00
Gr.3:	0.00	0.00

Regulation Strate	Technical regulation no. 1	
CEEP regulation	000000000	
Minimum Stabilisation share	0.30	
Stabilisation share of CHP	0.00	
Minimum CHP gr 3 load	300	MW
Minimum PP	0	MW
Heat Pump maximum share	0.50	
Maximum import/export	1600	MW

Distr. Name :	Hour_nordpool.txt	
Addition factor	0.00	DKK/MWh
Multiplication factor	2.00	
Dependency factor	0.00	DKK/MWh pr. MW
Average Market Price	227	DKK/MWh
Gas Storage	0	GWh
Syngas capacity	0	MW
Biogas max to grid	0	MW

Fuel Price level:

	Capacities MW-e	Storage GWh	Efficiencie elec.	Ther.
Hydro Pump:	0	0	0.80	
Hydro Turbine:	0		0.90	
Electrol. Gr.2:	0	0	0.73	0.05
Electrol. Gr.3:	0	0	0.73	0.05
Electrol. trans.:	0	0	0.73	
Ely. MicroCHP:	0	0	0.73	
CAES fuel ratio:	0.000			

(TWh/year)	Coal	Oil	Ngas	Biomass
Transport	0.00	0.00	0.00	0.00
Household	0.00	0.00	0.00	0.00
Industry	0.00	0.00	0.00	0.00
Various	0.00	0.00	0.00	0.00

Output

District Heating

	Demand: Distr. heating MW	Production: Solar MW	Waste-CSHP MW	DHP MW	CHP MW	HP MW	ELT MW	Boiler MW	EH MW	Ba-lance MW
January	3856	0	0	0	0	300	0	3556	0	0
February	3644	0	0	0	0	300	0	3344	0	0
March	3140	0	0	0	0	300	0	2840	0	0
April	2346	0	0	0	0	300	0	2046	0	0
May	1538	0	0	0	0	288	0	1250	0	0
June	1124	0	0	0	0	281	0	843	0	0
July	913	0	0	0	0	228	0	684	0	0
August	946	0	0	0	0	235	0	711	0	0
September	1333	0	0	0	0	300	0	1033	0	0
October	2072	0	0	0	0	300	0	1772	0	0
November	2923	0	0	0	0	300	0	2623	0	0
December	3533	0	0	0	0	300	0	3233	0	0
Average	2277	0	0	0	0	286	0	1991	0	0
Maximum	4049	0	0	0	0	300	0	3749	0	0
Minimum	820	0	0	0	0	205	0	615	0	0
TWh/year	20.00	0.00	0.00	0.00	0.00	2.51	0.00	17.49	0.00	0.00

Electricity

	Consumption: Elec. demand GW	Flex.& Transp MW	HP MW	Elec-trolyser MW	EH MW	Hydro Pump MW	Production: Tur-bine MW	RES MW	Hy-dro MW	Geo-thermal MW	Waste-CSHP MW	CHP MW	PP GW	Balance: Stab-Load %	Imp MW	Exp MW	CEEP MW	EEP MW
January	138	0	100	0	0	0	0	0	0	0	0	0	138	333	2	0	0	0
February	137	0	100	0	0	0	0	0	0	0	0	0	137	333	0	0	0	0
March	131	0	100	0	0	0	0	0	0	0	0	0	132	333	0	0	0	0
April	116	0	100	0	0	0	0	0	0	0	0	0	116	333	0	0	0	0
May	113	0	96	0	0	0	0	0	0	0	0	0	113	333	0	0	0	0
June	110	0	94	0	0	0	0	0	0	0	0	0	110	333	0	0	0	0
July	100	0	76	0	0	0	0	0	0	0	0	0	100	333	0	0	0	0
August	115	0	78	0	0	0	0	0	0	0	0	0	115	333	0	0	0	0
September	118	0	100	0	0	0	0	0	0	0	0	0	118	333	0	0	0	0
October	123	0	100	0	0	0	0	0	0	0	0	0	123	333	0	0	0	0
November	133	0	100	0	0	0	0	0	0	0	0	0	133	333	0	0	0	0
December	133	0	100	0	0	0	0	0	0	0	0	0	133	333	3	0	0	0
Average	122	0	95	0	0	0	0	0	0	0	0	0	122	333	0	0	0	0
Maximum	188	0	100	0	0	0	0	0	0	0	0	0	187	333	1494	0	0	0
Minimum	61	0	68	0	0	0	0	0	0	0	0	0	61	333	0	0	0	0
TWh/year	1073	0.00	0.84	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1074		0.00	0.00	0.00	0.00

Exchange

	Payment Imp (Million DKK)	Exp (Million DKK)
January	4	0
February	0	0
March	0	0
April	0	0
May	0	0
June	0	0
July	0	0
August	0	0
September	0	0
October	0	0
November	0	0
December	1	0
Average	Average price	
Maximum	(DKK/MWh)	
Minimum	1098	313
TWh/year	4	0

FUEL BALANCE (TWh/year):

	DHP	CHP2	CHP3	Boiler2	Boiler3	PP	Geo/Nu	Hydro	Waste	CAES Elc.ly.	BioCon-version	Electro-Fuel	Wind	PV	Offsh.	Hydro	Solar.Th	Transp.	househ.	Industry Various	Total	Imp/Exp Corrected Imp/Exp	Net	CO2 emission (Mt): Total	Net
Coal	-	-	-	2.78	2.08	813.51	-	-	-	-	-	-	-	-	-	-	-	-	-	-	818.37	0.00	818.37	279.88	279.88
Oil	-	-	-	2.78	2.08	813.51	-	-	-	-	-	-	-	-	-	-	-	-	-	-	818.37	0.00	818.37	218.01	218.01
N.Gas	-	-	-	2.78	2.08	813.51	-	-	-	-	-	-	-	-	-	-	-	-	-	-	818.37	0.00	818.37	167.05	167.05
Biomass	-	-	-	2.78	2.08	813.51	-	-	-	-	-	-	-	-	-	-	-	-	-	-	818.37	0.00	818.37	0.00	0.00
Renewable	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.00	0.00	0.00	0.00	0.00
H2 etc.	-	-	-	0.00	0.00	0.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.00	0.00	0.00	0.00	0.00
Biofuel	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.00	0.00	0.00	0.00	0.00
Nuclear/CCS	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.00	0.00	0.00	0.00	0.00
Total	-	-	-	11.11	8.32	3254.04	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3273.47	0.01	3273.48	664.94	664.94

10-October-2018 [10:16]

Fig 2

Output specifications Startdata The EnergyPLAN model 13.0

District Heating Production

	Gr.1 District heating MW	Gr.1 Solar MW	Gr.1 CSHP MW	Gr.1 DHP MW	Gr.2 District heating MW	Gr.2 Solar MW	Gr.2 CSHP MW	Gr.2 CHP MW	Gr.2 HP MW	Gr.2 ELT MW	Gr.2 Boiler MW	Gr.2 EH MW	Gr.2 Stor-age MW	Gr.2 Ba-lance MW
January	0	0	0	0	1928	0	0	0	0	0	1928	0	0	0
February	0	0	0	0	1822	0	0	0	0	0	1822	0	0	0
March	0	0	0	0	1570	0	0	0	0	0	1570	0	0	0
April	0	0	0	0	1173	0	0	0	0	0	1173	0	0	0
May	0	0	0	0	769	0	0	0	0	0	769	0	0	0
June	0	0	0	0	562	0	0	0	0	0	562	0	0	0
July	0	0	0	0	456	0	0	0	0	0	456	0	0	0
August	0	0	0	0	473	0	0	0	0	0	473	0	0	0
September	0	0	0	0	666	0	0	0	0	0	666	0	0	0
October	0	0	0	0	1036	0	0	0	0	0	1036	0	0	0
November	0	0	0	0	1462	0	0	0	0	0	1462	0	0	0
December	0	0	0	0	1766	0	0	0	0	0	1766	0	0	0
Average	0	0	0	0	1138	0	0	0	0	0	1138	0	0	0
Maximum	0	0	0	0	2025	0	0	0	0	0	2025	0	0	0
Minimum	0	0	0	0	410	0	0	0	0	0	410	0	0	0
Total for the whole year TWh/year	0.00	0.00	0.00	0.00	10.00	0.00	0.00	0.00	0.00	0.00	10.00	0.00		0.00

	Gr.3 District heating MW	Gr.3 Solar MW	Gr.3 CSHP MW	Gr.3 CHP MW	Gr.3 HP MW	Gr.3 ELT MW	Gr.3 Boiler MW	Gr.3 EH MW	Gr.3 Stor-age MW	Gr.3 Ba-lance MW	RES specification RES1 Wind MW	RES2 Photo MW	RES3 Offshc MW	RES 4-7 Min MW	Total MW
January	1928	0	0	0	300	0	1628	0	0	0	0	0	0	0	0
February	1822	0	0	0	300	0	1522	0	0	0	0	0	0	0	0
March	1570	0	0	0	300	0	1270	0	0	0	0	0	0	0	0
April	1173	0	0	0	300	0	873	0	0	0	0	0	0	0	0
May	769	0	0	0	288	0	481	0	0	0	0	0	0	0	0
June	562	0	0	0	281	0	281	0	0	0	0	0	0	0	0
July	456	0	0	0	228	0	228	0	0	0	0	0	0	0	0
August	473	0	0	0	235	0	238	0	0	0	0	0	0	0	0
September	666	0	0	0	300	0	366	0	0	0	0	0	0	0	0
October	1036	0	0	0	300	0	736	0	0	0	0	0	0	0	0
November	1462	0	0	0	300	0	1162	0	0	0	0	0	0	0	0
December	1766	0	0	0	300	0	1466	0	0	0	0	0	0	0	0
Average	1138	0	0	0	286	0	853	0	0	0	0	0	0	0	0
Maximum	2025	0	0	0	300	0	1725	0	0	0	0	0	0	0	0
Minimum	410	0	0	0	205	0	205	0	0	0	0	0	0	0	0
Total for the whole year TWh/year	10.00	0.00	0.00	0.00	2.51	0.00	7.49	0.00		0.00	0.00	0.00	0.00	0.00	0.00

Own use of heat from industrial CHP 0.00 TWh/year

ANNUAL COSTS (Million DKK)

Total Fuel ex Ngas exchange =	67976	
Uranium =	0	
Coal =	9133	
FuelOil =	35847	
Gasoil/Diesel=	0	
Petrol/JP =	0	
Gas handling =	1224	
Biomass =	21772	
Food income =	0	
Waste =	0	
Total Ngas Exchange costs =		26810
Marginal operation costs =		2833
Total Electricity exchange =		4
Import =	4	
Export =	0	
Bottleneck =	0	
Fixed imp/ex=	0	
Total CO2 emission costs =		19017
Total variable costs =		116641
Fixed operation costs =		11695
Annual Investment costs =		12761
TOTAL ANNUAL COSTS =		141097

NATURAL GAS EXCHANGE

	DHP & Boilers MW	CHP2 CHP3 MW	PP CAES MW	Indi-vidual MW	Trans port MW	Indu. Var. MW	Demand Sum MW	Bio-gas MW	Syn-gas MW	CO2Hy gas MW	SynHy gas MW	SynHy gas MW	Stor-age MW	Sum MW	Im-port MW	Ex-port MW
January	988	0	104666	0	0	0	105654	0	0	0	0	0	0	105654	105654	0
February	929	0	103544	0	0	0	104473	0	0	0	0	0	0	104473	104473	0
March	789	0	99673	0	0	0	100462	0	0	0	0	0	0	100462	100462	0
April	568	0	87843	0	0	0	88412	0	0	0	0	0	0	88412	88412	0
May	347	0	85706	0	0	0	86053	0	0	0	0	0	0	86053	86053	0
June	234	0	83299	0	0	0	83534	0	0	0	0	0	0	83534	83534	0
July	190	0	75942	0	0	0	76132	0	0	0	0	0	0	76132	76132	0
August	197	0	87367	0	0	0	87564	0	0	0	0	0	0	87564	87564	0
September	287	0	89673	0	0	0	89960	0	0	0	0	0	0	89960	89960	0
October	492	0	93011	0	0	0	93503	0	0	0	0	0	0	93503	93503	0
November	729	0	100503	0	0	0	101232	0	0	0	0	0	0	101232	101232	0
December	898	0	100535	0	0	0	101433	0	0	0	0	0	0	101433	101433	0
Average	553	0	92613	0	0	0	93166	0	0	0	0	0	0	93166	93166	0
Maximum	1041	0	141667	0	0	0	142623	0	0	0	0	0	0	142623	142623	0
Minimum	171	0	46417	0	0	0	46598	0	0	0	0	0	0	46598	46598	0
Total for the whole year TWh/year	4.86	0.00	813.51	0.00	0.00	0.00	818.37	0.00	0.00	0.00	0.00	0.00	0.00	818.37	818.37	0.00

RES Share: 25.0 Percent of Primary Energy 0.0 Percent of Electricity 0.0 TWh electricity from RES 10-October-2018 [10:16]

Fig 3

In our baseline scenario, energy demand is being supplied by fossil fuels including coal, oil, natural gas, and also the use of biomass.

With a power plant efficiency of 33% for all fossil fuel plants (to reduce complexity), we would need about 3250 TWh/year worth of fuel to be sourced. As the EnergyPlan report reflects, there is a total of **3273.47 TWh/year** being sourced from a power plant and two boilers.

Energy Source	Amount of CO_2 Emission (in Mt)
Coal	279.88
Oil	218.01
Natural Gas	167.05
Total CO_2 Emission:	**664.94**

Costs using energy plan are computed in DKK. To make it better understandable, we have converted these costs into USD using the conversion 1 DKK = 0.154 USD.

	Annual Cost (in Million DKK)	Annual Cost (in Million USD)
Coal	9133	1406
Oil	35847	5520
Gas Handling	1224	188
Biomass	21772	3353
Natural Gas Exchange	26810	4129
Marginal Operation	2833	436
Electricity Exchange	4	1
CO_2 Emission	19017	2929
Fixed Operation	11695	1801
Annual Investment	12761	1965
Total Cost:	**141097**	**21729**

Baseline Scenario Conclusion

As we can see from the above data, there is a large amount of CO_2 being emitted from fossil fuel plants and there is also a large cost attached to it. Excess amounts of CO_2 in the air not only harm the environment with problems such as global warming, but if it reaches a certain concentration, our air quality will actually be hindered enough to cause harm to humans.

If we could implement a plan to utilize renewable resources as a source of power, we could reduce CO_2 emissions and cost associated with it, thus creating a more sustainable future. In our case, we will be converting 5% of the total power need of New York City into that of renewable resources.

II. Renewables Scenario

Introduction

Currently, New york city receives most of its electricity from instate NY from power plants, solar/wind fields, and hydropower from many rivers.

Given that New York city is a very condensed area filled with buildings and people, it is hard to integrate renewable resources close to or inside city limits. Wind power could be used to an extent offshore. Furthermore, instate rivers could be utilized for hydropower; however, using sources farther away from the city would increase costs due to loss of efficiency in transporting the power as well as infrastructure changes and additions.

If we were to increase the amount of renewable energy used from 0% to 5%, we would need 53.65 or about **54 TWh** of the 1073 TWh of energy coming from these chosen renewable resources.

Renewable Scenario Analysis

Input Startdata — The EnergyPLAN model 13.0

Electricity demand (TWh/year):		Flexible demand	0.00
Fixed demand	1073.00	Fixed imp/exp.	0.00
Electric heating + HP	0.00	Transportation	0.00
Electric cooling	0.00	Total	1073.00

District heating (TWh/year)	Gr.1	Gr.2	Gr.3	Sum
District heating demand	0.00	10.00	10.00	20.00
Solar Thermal	0.00	0.00	0.00	0.00
Industrial CHP (CSHP)	0.00	0.00	0.00	0.00
Demand after solar and CSHP	0.00	10.00	10.00	20.00

Wind	0 MW	0.00 TWh/year	0.00	Grid
Photo Voltaic	0 MW	0 TWh/year	0.00	stabili-
Offshore Wind	2400 MW	5.55 TWh/year	0.00	sation
River Hydro	5500 MW	48.31 TWh/year	0.00	share
Hydro Power	0 MW	0 TWh/year		
Geothermal/Nuclear	0 MW	0 TWh/year		

	Capacities MW-e	Capacities MJ/s	Efficiencies elec.	Efficiencies Ther	COP
Group 2:					
CHP	0	0	0.40	0.50	
Heat Pump	0	0			3.00
Boiler		5000		0.90	
Group 3:					
CHP	0	0	0.40	0.50	
Heat Pump	100	300			3.00
Boiler		5000		0.90	
Condensing	0		0.45		

Heatstorage: gr.2:10 GWh gr.10 GWh
Fixed Boiler: gr.2:0.0 Per cent gr0.0 Per cent

Electricity prod. from	CSHP	Waste (TWh/year)
Gr.1:	0.00	0.00
Gr.2:	0.00	0.00
Gr.3:	0.00	0.00

Regulation Strategy	Technical regulation no. 1
CEEP regulation	000000000
Minimum Stabilisation share	0.00
Stabilisation share of CHP	0.00
Minimum CHP gr 3 load	0 MW
Minimum PP	0 MW
Heat Pump maximum share	0.50
Maximum import/export	1600 MW
Distr. Name :	Hour_nordpool.txt
Addition factor	0.00 DKK/MWh
Multiplication factor	2.00
Dependency factor	0.00 DKK/MWh pr. MW
Average Market Price	227 DKK/MWh
Gas Storage	0 GWh
Syngas capacity	0 MW
Biogas max to grid	0 MW

Fuel Price level:

	Capacities MW-e	Storage GWh	Efficiencies elec.	Efficiencies Ther.
Hydro Pump:	0	0	0.80	
Hydro Turbine:	0		0.90	
Electrol. Gr.2:	0	0	0.73	0.05
Electrol. Gr.3:	0	0	0.73	0.05
Electrol. trans.:	0	0	0.73	
Ely. MicroCHP:	0	0	0.73	
CAES fuel ratio:	0.000			

(TWh/year)	Coal	Oil	Ngas	Biomass
Transport	0.00	0.00	0.00	0.00
Household	0.00	0.00	0.00	0.00
Industry	0.00	0.00	0.00	0.00
Various	0.00	0.00	0.00	0.00

Output

District Heating

	Demand: Distr. heating MW	Production: Solar MW	Waste-CSHP MW	DHP MW	CHP MW	HP MW	ELT MW	Boiler MW	EH MW	Balance MW
January	3856	0	0	0	0	300	0	3556	0	0
February	3644	0	0	0	0	300	0	3344	0	0
March	3140	0	0	0	0	300	0	2840	0	0
April	2346	0	0	0	0	300	0	2046	0	0
May	1538	0	0	0	0	288	0	1250	0	0
June	1124	0	0	0	0	281	0	843	0	0
July	913	0	0	0	0	228	0	684	0	0
August	946	0	0	0	0	235	0	711	0	0
September	1333	0	0	0	0	300	0	1033	0	0
October	2072	0	0	0	0	300	0	1772	0	0
November	2923	0	0	0	0	300	0	2623	0	0
December	3533	0	0	0	0	300	0	3233	0	0
Average	2277	0	0	0	0	286	0	1991	0	0
Maximum	4049	0	0	0	0	300	0	3749	0	0
Minimum	820	0	0	0	0	205	0	615	0	0
TWh/year	20.00	0.00	0.00	0.00	0.00	2.51	0.00	17.49	0.00	0.00

Electricity — Consumption

	Elec. demand GW	Flex.& Transp MW	HP MW	Elec-trolyser MW	EH MW	Hydro Pump MW
January	138	0	100	0	0	0
February	137	0	100	0	0	0
March	131	0	100	0	0	0
April	116	0	100	0	0	0
May	113	0	96	0	0	0
June	110	0	94	0	0	0
July	100	0	76	0	0	0
August	115	0	78	0	0	0
September	118	0	100	0	0	0
October	123	0	100	0	0	0
November	133	0	100	0	0	0
December	133	0	100	0	0	0
Average	122	0	95	0	0	0
Maximum	188	0	100	0	0	0
Minimum	61	0	68	0	0	0
TWh/year	1073	0.00	0.84	0.00	0.00	0.00

Electricity — Production, Balance; Exchange

	Tur-bine MW	RES MW	Hy-dro MW	Geo-thermal MW	Waste-CSHP MW	CHP MW	PP GW	Stab-Load %	Imp MW	Exp MW	CEEP MW	EEP MW	Payment Imp Million DKK	Payment Exp Million DKK
January	0	6435	0	0	0	0	132	100	0	0	0	0	0	0
February	0	6130	0	0	0	0	131	100	0	0	0	0	0	0
March	0	6520	0	0	0	0	125	100	0	0	0	0	0	0
April	0	6056	0	0	0	0	110	100	0	0	0	0	0	0
May	0	5888	0	0	0	0	107	100	0	0	0	0	0	0
June	0	6195	0	0	0	0	104	100	0	0	0	0	0	0
July	0	5673	0	0	0	0	95	100	0	0	0	0	0	0
August	0	5880	0	0	0	0	109	100	0	0	0	0	0	0
September	0	6070	0	0	0	0	112	100	0	0	0	0	0	0
October	0	6102	0	0	0	0	117	100	0	0	0	0	0	0
November	0	6301	0	0	0	0	126	100	0	0	0	0	0	0
December	0	6333	0	0	0	0	126	100	0	0	0	0	0	0
Average	0	6132	0	0	0	0	116	100	0	0	0	0	Average price	
Maximum	0	7900	0	0	0	0	182	100	0	0	0	0	(DKK/MWh)	
Minimum	0	5500	0	0	0	0	56	100	0	0	0	0	176	246
TWh/year	0.00	53.86	0.00	0.00	0.00	0.00	1020		0.00	0.00	0.00	0.00	0	0

FUEL BALANCE (TWh/year):

	DHP	CHP2	CHP3	Boiler2	Boiler3	PP	Geo/Nu	Hydro	Waste	CAES Elc.ly.	BioCon-version	Electro-Fuel	Wind	PV	Offsh.	Hydro	Solar.Th	Transp.	househ.	Industry Various	Total	Imp/Exp Corrected Imp/Exp	Net	CO2 emission (Mt): Total	Net
Coal	-	-	-	2.78	2.08	772.71	-	-	-	-	-	-	-	-	-	-	-	-	-	-	777.57	0.00	777.57	265.93	265.93
Oil	-	-	-	2.78	2.08	772.71	-	-	-	-	-	-	-	-	-	-	-	-	-	-	777.57	0.00	777.57	207.14	207.14
N.Gas	-	-	-	2.78	2.08	772.71	-	-	-	-	-	-	-	-	-	-	-	-	-	-	777.57	0.00	777.57	158.72	158.72
Biomass	-	-	-	2.78	2.08	772.71	-	-	-	-	-	-	-	-	-	-	-	-	-	-	777.57	0.00	777.57	0.00	0.00
Renewable	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5.55	48.31	-	-	-	-	53.86	0.00	53.86	0.00	0.00
H2 etc.	-	-	-	0.00	0.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.00	0.00	0.00	0.00	0.00
Biofuel	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.00	0.00	0.00	0.00	0.00
Nuclear/CCS	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.00	0.00	0.00	0.00	0.00
Total	-	-	-	11.11	8.32	3090.84	-	-	-	-	-	-	-	-	5.55	48.31	-	-	-	-	3164.13	0.00	3164.13	631.79	631.79

12-October-2018 [12:42]

Fig 4

Output specifications Startdata

The EnergyPLAN model 13.0

District Heating Production

	Gr.1 District heating MW	Gr.1 Solar MW	Gr.1 CSHP MW	Gr.1 DHP MW	Gr.2 District heating MW	Gr.2 Solar MW	Gr.2 CSHP MW	Gr.2 CHP MW	Gr.2 HP MW	Gr.2 ELT MW	Gr.2 Boiler MW	Gr.2 EH MW	Gr.2 Storage MW	Gr.2 Balance MW
January	0	0	0	0	1928	0	0	0	0	0	1928	0	0	0
February	0	0	0	0	1822	0	0	0	0	0	1822	0	0	0
March	0	0	0	0	1570	0	0	0	0	0	1570	0	0	0
April	0	0	0	0	1173	0	0	0	0	0	1173	0	0	0
May	0	0	0	0	769	0	0	0	0	0	769	0	0	0
June	0	0	0	0	562	0	0	0	0	0	562	0	0	0
July	0	0	0	0	456	0	0	0	0	0	456	0	0	0
August	0	0	0	0	473	0	0	0	0	0	473	0	0	0
September	0	0	0	0	666	0	0	0	0	0	666	0	0	0
October	0	0	0	0	1036	0	0	0	0	0	1036	0	0	0
November	0	0	0	0	1462	0	0	0	0	0	1462	0	0	0
December	0	0	0	0	1766	0	0	0	0	0	1766	0	0	0
Average	0	0	0	0	1138	0	0	0	0	0	1138	0	0	0
Maximum	0	0	0	0	2025	0	0	0	0	0	2025	0	0	0
Minimum	0	0	0	0	410	0	0	0	0	0	410	0	0	0
Total for the whole year TWh/year	0.00	0.00	0.00	0.00	10.00	0.00	0.00	0.00	0.00	0.00	10.00	0.00		0.00

	Gr.3 District heating MW	Gr.3 Solar MW	Gr.3 CSHP MW	Gr.3 CHP MW	Gr.3 HP MW	Gr.3 ELT MW	Gr.3 Boiler MW	Gr.3 EH MW	Gr.3 Storage MW	Gr.3 Balance MW
January	1928	0	0	0	300	0	1628	0	0	0
February	1822	0	0	0	300	0	1522	0	0	0
March	1570	0	0	0	300	0	1270	0	0	0
April	1173	0	0	0	300	0	873	0	0	0
May	769	0	0	0	288	0	481	0	0	0
June	562	0	0	0	281	0	281	0	0	0
July	456	0	0	0	228	0	228	0	0	0
August	473	0	0	0	235	0	238	0	0	0
September	666	0	0	0	300	0	366	0	0	0
October	1036	0	0	0	300	0	736	0	0	0
November	1462	0	0	0	300	0	1162	0	0	0
December	1766	0	0	0	300	0	1466	0	0	0
Average	1138	0	0	0	286	0	853	0	0	0
Maximum	2025	0	0	0	300	0	1725	0	0	0
Minimum	410	0	0	0	205	0	205	0	0	0
Total for the whole year TWh/year	10.00	0.00	0.00	0.00	2.51	0.00	7.49	0.00		0.00

RES specification

	RES1 Wind MW	RES2 Photo MW	RES3 Offshc MW	RES 4-7 MW	Total /in MW
January	0	0	935	5500	6435
February	0	0	630	5500	6130
March	0	0	1020	5500	6520
April	0	0	556	5500	6056
May	0	0	388	5500	5888
June	0	0	695	5500	6195
July	0	0	173	5500	5673
August	0	0	380	5500	5880
September	0	0	570	5500	6070
October	0	0	602	5500	6102
November	0	0	801	5500	6301
December	0	0	833	5500	6333
Average	0	0	632	5500	6132
Maximum	0	0	2400	5500	7900
Minimum	0	0	0	5500	5500
Total for the whole year TWh/year	0.00	0.00	5.55	48.31	53.86

Own use of heat from industrial CH0.00 TWh/year

ANNUAL COSTS (Million DKK)

Total Fuel ex Ngas exchange =	64589
Uranium =	0
Coal =	8678
FuelOil =	34061
Gasoil/Diesel=	0
Petrol/JP =	0
Gas handling =	1164
Biomass =	20687
Food income =	0
Waste =	0
Total Ngas Exchange costs =	25473
Marginal operation costs =	2692
Total Electricity exchange =	0
Import =	0
Export =	0
Bottleneck =	0
Fixed imp/ex=	0
Total CO2 emission costs =	18069
Total variable costs =	110822
Fixed operation costs =	12178
Annual Investment costs =	13761
TOTAL ANNUAL COSTS =	136761

NATURAL GAS EXCHANGE

	DHP & Boilers MW	CHP2 CHP3 MW	PP CAES MW	Individual MW	Transport MW	Indu. Var. MW	Demand Sum MW	Biogas MW	Syngas MW	CO2Hy gas MW	SynHy gas MW	SynHy gas MW	Storage MW	Sum MW	Import MW	Export MW
January	988	0	99793	0	0	0	100780	0	0	0	0	0	0	100780	100780	0
February	929	0	98900	0	0	0	99829	0	0	0	0	0	0	99829	99829	0
March	789	0	94733	0	0	0	95522	0	0	0	0	0	0	95522	95522	0
April	568	0	83255	0	0	0	83824	0	0	0	0	0	0	83824	83824	0
May	347	0	81246	0	0	0	81593	0	0	0	0	0	0	81593	81593	0
June	234	0	78606	0	0	0	78840	0	0	0	0	0	0	78840	78840	0
July	190	0	71644	0	0	0	71834	0	0	0	0	0	0	71834	71834	0
August	197	0	82912	0	0	0	83109	0	0	0	0	0	0	83109	83109	0
September	287	0	85075	0	0	0	85362	0	0	0	0	0	0	85362	85362	0
October	492	0	88389	0	0	0	88881	0	0	0	0	0	0	88881	88881	0
November	729	0	95730	0	0	0	96458	0	0	0	0	0	0	96458	96458	0
December	898	0	95740	0	0	0	96638	0	0	0	0	0	0	96638	96638	0
Average	553	0	87968	0	0	0	88521	0	0	0	0	0	0	88521	88521	0
Maximum	1041	0	137754	0	0	0	138681	0	0	0	0	0	0	138681	138681	0
Minimum	171	0	42201	0	0	0	42383	0	0	0	0	0	0	42383	42383	0
Total for the whole year TWh/year	4.86	0.00	772.71	0.00	0.00	0.00	777.57	0.00	0.00	0.00	0.00	0.00	0.00	777.57	777.57	0.00

RES Share: 26.3 Percent of Primary Energy 5.0 Percent of Electricity 53.9 TWh electricity from RES 12-October-2018 [12:42]

Fig 5

Cost conversion:

	Annual Cost (in Million DKK)	Annual Cost (in Million USD)
Coal	8678	1336
Oil	34061	5245
Gas Handling	1164	179
Biomass	20687	3186
Natural Gas Exchange	25473	3923
Marginal Operation	2692	415
Electricity Exchange	0	0
CO2 Emission	18069	2783
Fixed Operation	12178	1875
Annual Investment	13761	2119
Total Cost:	**136761**	**21061**

<u>Cost comparison: Baseline vs. 5% Renewable</u>

	Baseline Cost (in Million USD)	5% Renewable Cost (in Million USD)	Cost Difference (in Million USD)
Coal	1406	1336	-70
Oil	5520	5245	-275
Gas Handling	188	179	-9
Biomass	3353	3186	-167
Natural Gas Exchange	4129	3923	-206
Marginal Operation	436	415	-21
Electricity Exchange	1	0	-1
CO2 Emission	2929	2783	-146
Fixed Operation	1801	1875	+74
Annual Investment	1965	2119	+154
Total Cost:	**21729**	**21061**	**-668**

As we can see through the cost comparison table above between the two different scenarios, it is clear that the total annual cost will be noticeably lower with the use of renewable resources. To be exact, it would be 3.1% lower.. While working with billions of dollars, this small change is actually quite significant. Through the minor replacement of clean, renewable resources with the previous fossil fuels and biomass, the cost reduces as expected in these areas.

Another notable difference is the reduction to 0 in electricity exchange cost. This is most likely due to the more direct and more efficient process that wind power and hydropower use to convert their mechanical energy into electrical energy. In our case, these changes were enough to make these costs negligible in the grand scheme of things.

However, not all cost areas were reduced in the switch to a more sustainable scenario. Fixed operation cost and annual investment increased after utilizing wind and hydropower. This is because of the increase in power producing units such as wind turbines and hydropower plants. For example, it would take sixty(60) 10MW wind turbines to produce the same power of a small 600 MW fossil fuel plant. The annual investment cost is higher using renewables due to clean energy's large investments to implement. As time goes on the investment costs will lower. Below is a diagram for visualization.

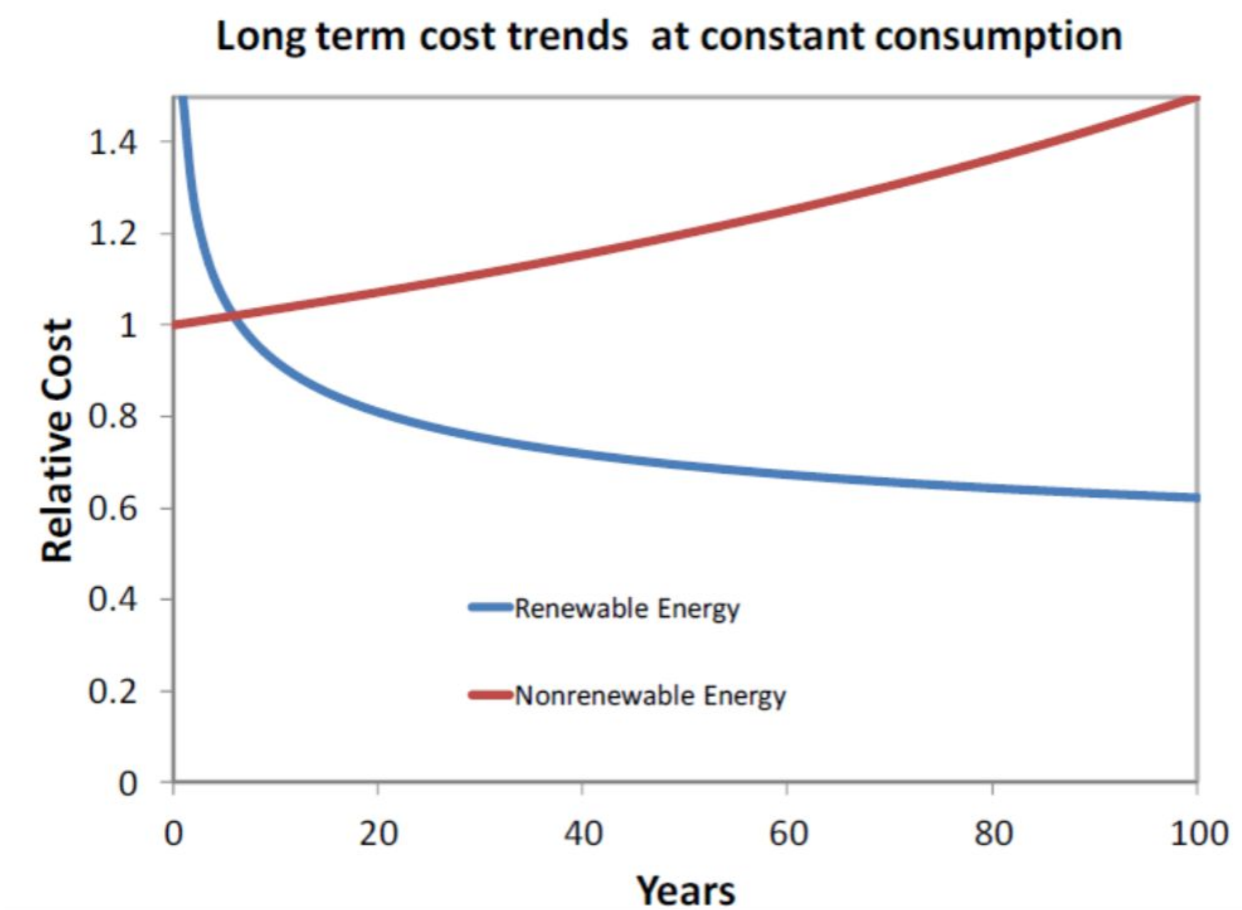


Fig 6

As we can see, initially relative cost of renewables is higher than that of fossil fuel plants but renewable energy will continue to drop over time while non renewables rise in price.

In the long term, it is cheaper to use renewable resources making this scenario very appealing and a common sense direction to take for a more sustainable future.

CO2 Emission Comparison: Baseline vs. 5% Renewable

Energy Source	Baseline CO2 Emission (in Mt)	5% Renewable CO2 Emission (in Mt)	Emission Difference (in Mt)
Coal	279.88	265.93	-13.95
Oil	218.01	207.14	-10.87
Natural Gas	167.05	158.72	-8.33
Total CO2 Emission:	**664.94**	**631.79**	**-33.15**

As expected, replacing 5% of power production with hydropower and wind power reduced the total CO2 output by 5%. Specifically by 33.15 megatons. Again, this scenario will be cleaner, thus reducing environmental damage and making it a very rational solution.

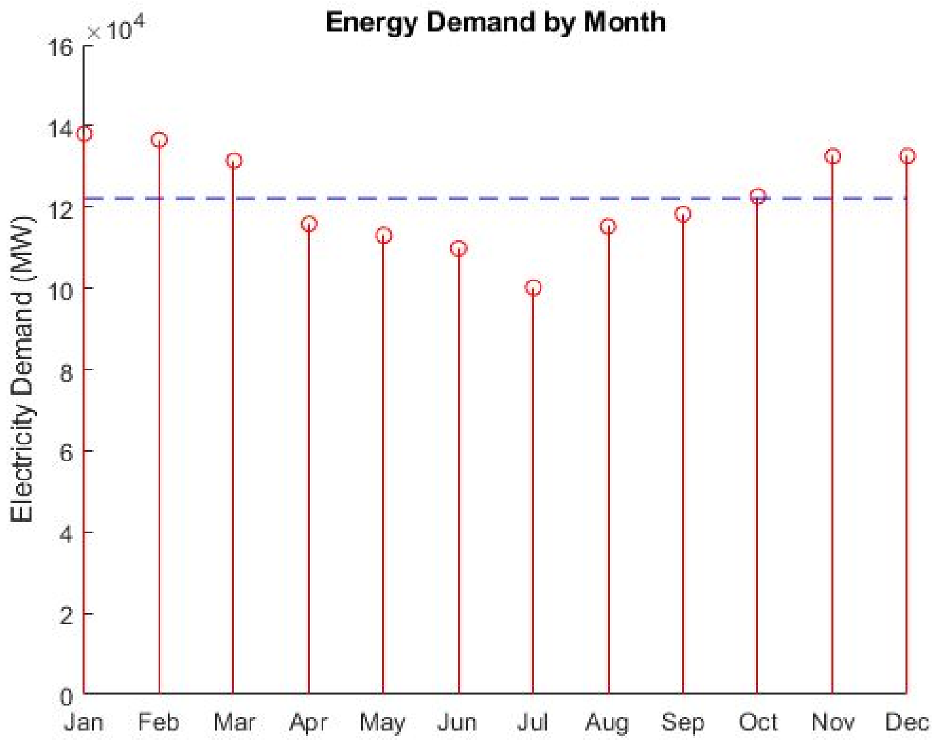


Fig 7

As can be seen in *Figure 7*, where the stems represent energy demand by month and the blue dashed line represents average energy demand, there is not a consistent electricity demand throughout the year. Since heating makes up a huge proportion of energy consumption, the winter months require more energy to be produced. This will be discussed later when the viability of the proposed energy plan is examined.

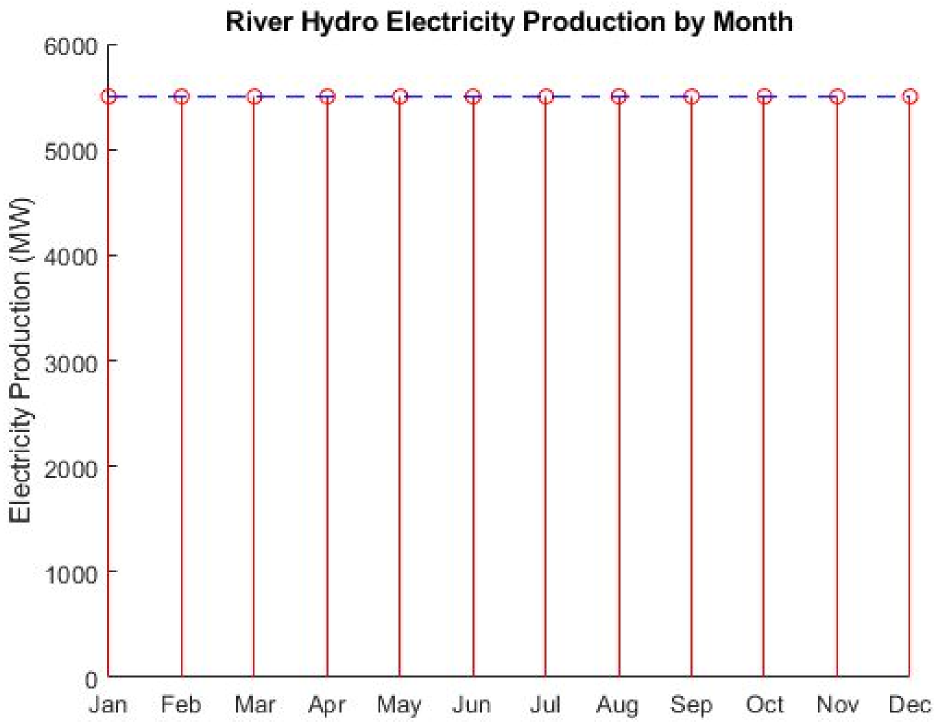
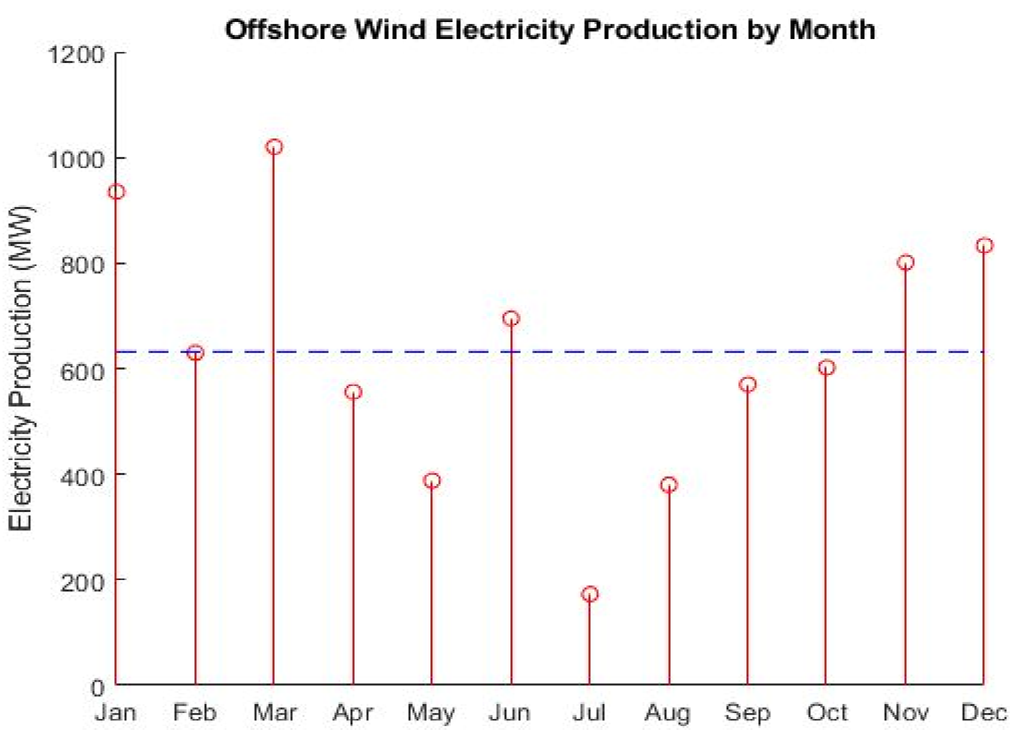

River Hydro Electricity Production by Month
Electricity Production (MW)
6000
5000
4000
3000
2000
1000
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

Fig 7


Offshore Wind Electricity Production by Month
Electricity Production (MW)
1200
1000
800
600
400
200
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

Unsurprisingly, hydroelectric energy production is consistent over the year. This is a huge benefit of hydroelectricity, and is part of the reason that New York City currently uses it to produce almost 7% of its current electricity supply. This consistency is something that most other renewables lack. This is illustrated in the graph of offshore wind production, there is far less consistency in production capabilities. This is a major weakness of wind power, but despite this, New York State plans to install over 2400 MW of offshore wind production by 2030 (1). Much of the proposed wind farm area is near NYC and could provide far more than the 5.5 TW.hr/year the current EnergyPLAN simulation includes.

Discussion of Other Energy Sources

Though there is a huge potential for other renewable electricity sources in New York City, the current state of technology limits their use. The lack of solar is especially significant. Solar, especially Photovoltaic, could be implemented on a large scale throughout the city. Rooftop solar, according to Project Sunroof (2), has the potential to provide 9.5 TW.hr/year of electricity. This amounts to just under 1% of the current total energy consumption of NYC, and while that sounds insignificant, that is only one form of implementation. However, the costs of implementing this system are currently prohibitive. At $3.47/watt (3), the total cost of implementing this solar capacity would be around $30 Billion.

Cost is not the only issue with solar. As a rapidly evolving and improving technology, large scale solar installations will inevitably be outpaced and outdated in a matter of years. This forces governments to consider the timing of implementation, as the cost of updating technology could be comparable to or greater than the initial cost.

It can be difficult to convince property owners to allow these types of installations. Solar panels are not generally considered aesthetically pleasing, and the installation process can be disruptive. For commercial buildings especially, disruptive construction can incur costs beyond the raw cost of the installation itself, as the building operation is affected by the installation.

The biggest challenge of switching to renewable energy is simply that they cannot match fossil fuel production capacity. Fossil fuels are incredibly energy dense, and as discussed above, even covering all the viable rooftops in NYC only addresses a tiny fraction of the energy consumption. There is, however, a way to cover a larger percentage of energy demand without spending huge sums of money, and that is reducing demand. The United States has an energy consumption higher than any other country in the world, and that shows a clear opportunity for improvement. Changes in lifestyle such as simple as adjusting the thermostat closer to the outdoor temperature can have profound impacts on energy consumption.

Another huge energy draw is lighting, so switching to more efficient lighting options like LEDs can lead to large reductions in total consumption. And as seen in the MacKay lecture on the first day of class, simply increasing awareness of personal energy consumption can cause individuals to reduce their use. It is important to emphasize the cost aspect of reducing use. It is not just good for the environment, it will save consumers money, in some cases significant amounts of money, to be more energy conscious.

Conclusion

Though implementing renewable energy on a large scale can be costly, the benefits more than make up for it. The annual cost of energy generation actually decreases when more renewables are used as fuel costs for many renewables, especially wind and hydroelectric, are zero. After enough time, investment in renewable energy saves money. It isn't just money that is saved when switching to renewable energy.

The IPCC reports that, unless carbon emissions are reduced by 45% of their 2010 levels by 2030 and then reach "net zero" by 2050, then the plane will exceed 1.5 degrees celsius in warming. The planet is already experiencing 1 degree increases per year and had seen some dramatic and irreversible effects, experts fear the what could happen if the world stays on its current track of 2 degrees per year.

The planet is already expected to lose 70-90% of the worlds coral reef ecosystems on the 1.5 degree track, but will be expected to lose them all if on a track of 2 degrees. Staying on the

1.5 degree track will also mean that the world's water levels will increase by 10 cm less than the worse case scenario.

But even if the IPCC's efforts had the world on net zero carbon emission, the effects of global warming will be felt harshly on the environment and the economy. With some hefty optimism, and a lot of research, perhaps the planet can be clean and efficient enough with their energy production and usage to help the planet stabilize for future generations. That is where the importance lies in this report. Simple research and use of programs like EnergyPLAN can help users plan and size the amount of energy required for different cities and even countries. This information can then be used in conjunction with feasibility studies to plan out possible sources of renewable and just how much we can cut out fossil fuels, reduce emissions, and approach sustainability just like what was done in this report.

Lastly, there is a lot of power in just simply spreading the information about the good renewables can bring to cities such as New York let alone the world. This report and ones like it can help educate average people in the importance of renewables and the feasibility behind reaching sustainability. The information in this report can help motivate and maybe even assist researchers in developing more efficient and reasonable processes of generating, transporting and storing renewable energy. Every bit will count when it comes to reaching the IPCC's goals of avoiding catastrophe and helping our planet last for many more generations.

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