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Use of energy balances to assess impacts of renewable energy projects on RE share and energy intensity

Joint APEC-IRENA Workshop on Renewable Energy Statistics
(18th APEC Workshop on Energy Statistics) 15-17 December 2020

- Adrian Whiteman (IRENA)

Outline

Some worked calculations to show how renewables projects have different impacts and how these can be assessed

1. Renewable electricity generation project
2. Solar street lights
3. Solar water heaters

Baseline (simple) energy balance

ORIGINAL ENERGY BALANCE	Energy Balance						
	Oil (TJ)	Wood fuel (TJ)	Solar PV (TJ)	Wind (TJ)	Electricity (TJ)	Total (TJ)	Electricity (MWh)
Production		1,210				1,210	
Imports	1,000					1,000	
Exports							
Total Primary Energy Supply (TPES)	1,000	1,210				2,210	
Electricity plants	-550				180	-370	50,000
Own use					-5	-5	1,400
Distribution losses					-13	-13	3,600
Total Final Energy Consumption (TFEC)	450	1,210			162	1,822	45,000
Industry	50	400			54	504	15,000
Transport	300					300	
Commercial and public		200			54	254	15,000
Residential	100	600			54	754	15,000
Other		10				10	

Note: all figures are positive unless the minus sign is shown

RE share of TFEC = 1,210/1,822 = 66%
Primary energy intensity = 2,210/500 = 4.42 MJ/USD
(Assume GDP = USD 500 million)

- Share of renewables calculated from TFEC row
- Energy intensity from TPES row and GDP
- Renewable share should include electricity (if applicable)

Wind project to replace diesel generation

The country has 10MW diesel generation and a target to replace half of this with renewables. If a 5MW wind farm was commissioned, what would be the change in the share of renewable energy consumption and energy intensity?

Assume that generation from fossil fuels declines by an equivalent amount and that the wind farm has a capacity utilisation factor of 34.25%.

Energy balance with 5MW wind

ENERGY BALANCE WITH WIND POWER (5MW @ 34.25% capacity factor is 5 x 8,760 x 0.3425 = 15,000 MWh)	Energy Balance						
	Oil (TJ)	Wood fuel (TJ)	Solar PV (TJ)	Wind (TJ)	Electricity (TJ)	Total (TJ)	Electricity (MWh)
Production		1,210		54		1,264	
Imports	835					835	
Exports							
Total Primary Energy Supply (TPES)	835	1,210		54		2,099	
Electricity plants (fossil)	-385				126	-259	35,000
Electricity plants (renewable)				-54	54	0	15,000
Own use					-5	-5	1,400
Distribution losses					-13	-13	3,600
Total Final Energy Consumption (TFEC)	450	1,210			162	1,822	45,000
Industry	50	400			54	504	15,000
Transport	300					300	
Commercial and public		200			54	254	15,000
Residential	100	600			54	754	15,000
Other		10				10	

RE share of TFEC = (1,210+(54/180*162))/1,822 = 69%
Primary energy intensity = 2,099/500 = 4.20 MJ/USD
(Assume GDP = USD 500 million)

- RE share of capacity is 50%
- RE share of generation is 30%
- RE share of TFEC has increased from 66% to 69% (exc. wood fuel: 0% to 8%)
- PEI fallen from 4.42 MJ/USD to 4.20 MJ/USD

Solar streetlights project

One-third of commercial and public electricity consumption is used on street lighting, so the government is considering replacing all the 250W high-pressure sodium streetlights with 100W LED lights with their own individual solar panels. What would be the impact on the RE share of consumption and energy intensity?

Assume that this is an alternative to the 5MW wind project (i.e. recalculate a separate energy balance).

Energy balance with solar streetlights

ENERGY BALANCE WITH SOLAR LIGHTS (Replace 5,000 MWh with 2,000 MWh by changing 250W bulbs to 100W LEDs)	Energy Balance						
	Oil (TJ)	Wood fuel (TJ)	Solar PV (TJ)	Wind (TJ)	Electricity (TJ)	Total (TJ)	Electricity (MWh)
Production		1,210	7			1,217	
Imports	945					945	
Exports							
Total Primary Energy Supply (TPES)	945	1,210	7			2,162	
Electricity plants (fossil)	-495				162	-333	45,000
Electricity plants (renewable)			-7		7	0	2,000
Own use					-5	-5	1,400
Distribution losses					-13	-13	3,600
Total Final Energy Consumption (TFEC)	450	1,210			151	1,811	42,000
Industry	50	400			54	504	15,000
Transport	300					300	
Commercial and public		200			43	243	12,000
Residential	100	600			54	754	15,000
Other		10				10	

RE share of TFEC = (1,210+(7/169*151))/1,811 = 67%
Primary energy intensity = 2,162/500 = 4.32 MJ/USD
(Assume GDP = USD 500 million)

- RE share of capacity is 15% (5,000 or 1.6MW solar lights, 1.6/11.6 = 15%)
- RE share of generation is 4%
- RE share of TFEC has increased from 66% to 67% (exc. wood fuel: 0% to 1%)
- PEI fallen from 4.42 MJ/USD to 4.32 MJ/USD

Solar water heaters project

An electricity end-use survey in a small country has identified water heating as a significant use of electricity in some businesses and households. The results of the survey are shown below.

Number of properties	Annual consumption (MWh)			
	All electricity use		For water heating	
	Total	Each	Total	Each
Commercial and public				
20	8,000	400	1,600	80
70	7,000	100	1,400	20
Residential				
1,000	5,000	5.0	1,000	1.0
4,000	5,000	0.8	1,200	0.3
15,000	5,000	0.3	1,500	0.1

Solar water heaters (SWH) can be imported into the country in a range of sizes, with a minimum collector area of one square-meter. Annual gross horizontal irradiation is 1,800 kWh/m^2 so, with a typical efficiency of 44%, one square-meter of collector area will generate 800 kWh of thermal energy each year that can directly substitute for the same amount of electricity used for water heating.

The survey has indicated that it would be technically feasible for 1,000 households and all commercial and public establishments to use SWH to replace their current consumption of electricity for water heating (i.e. their consumption is above the minimum production of a one square-meter SWH). This suggests that it's possible to replace 4,000 MWh of electricity consumption by installing SWH (see table above, the boxes marked in red are those properties where their electricity consumption for water heating is greater than 800 kWh/year). Based on the figures above, this switch would require the installation of 5,000 m^2 of SWH (i.e. 4,000/0.8 = 5,000).

Energy balance with solar water heaters

ENERGY BALANCE WITH 5,000m² SWH (Generating 14.4 TJ heat per year replacing 4,000 MWh commercial+resident electricity)	Energy Balance						Electricity
	Oil (TJ)	Wood fuel (TJ)	Solar Water (TJ)	Wind (TJ)	Electricity (TJ)	Total (TJ)	(MWh)
Production		1,210	14			1,224	
Imports	956					956	
Exports							
Total Primary Energy Supply (TPES)	**956**	**1,210**	**14**			**2,180**	
Electricity plants	-506				166	-340	46,000
Own use					-5	-5	1,400
Distribution losses					-13	-13	3,600
Total Final Energy Consumption (TFEC)	**450**	**1,210**	**14**		**148**	**1,822**	**41,000**
Industry	50	400			54	504	15,000
Transport	300					300	
Commercial and public		200	11		43	254	12,000
Residential	100	600	4		50	754	14,000
Other		10				10	

RE share of TFEC = (1,210+14)/1,822 = 67%

Primary energy intensity = 2,180/500 = 4.36 MJ/USD (Assume GDP = USD 500 million)

Calculation (adjustment to energy balance):

1. Installation of SWH leads to less electricity use
2. Less electricity use leads to less generation
3. Less generation leads to less oil use
4. Less oil use leads to less oil imports (and lower GHG emissions)

RE share of TFEC up 66% to 67%; PEI down from 4.42 to 4.36 MJ/USD; diesel use down by 44 TJ

Solar water heaters project (other benefits)

In addition to the benefits of such a switch for meeting energy targets, the government has asked you to assess the impact of such a change on the following:

- Greenhouse gas emissions
- Savings in foreign exchange needed for imports
- Local economic impact (e.g. income from installing and maintaining the SWH)
- The costs and benefits of switching for property owners

For this assessment, the following information is also available:

- Emissions factor for diesel generation is 74.4 TCO_2eq per TJ of diesel use
- NCV of diesel is 43 GJ/tonne
- Import cost of diesel is USD 1,100/tonne
- Average import cost of SWH is USD 250/m^2
- Installation cost of SWH (local labour) is also USD 250/m^2
- Annual maintenance/servicing cost for SWH (mostly local labour) is USD 25/m^2 (5% of total cost)
- The electricity tariff for public, commercial and residential consumers is USD 0.15/kWh

Assume that all the SWH can be installed in one year and advise the government on the issues they have raised.

Solar water heaters project (other benefits)

Annual GHG emissions reduction (reduction in fuel use x emissions factor) 44 x 74.4 = 3,274	3,274 TCO_2eq
Reduction in annual fuel import cost (reduction in fuel use x import cost) (44 x 1,000 / 43) x 1,100 = 1,125,580	1,125,580 USD
SWH import cost (amount imported x import cost) 5,000 x 250 = 1,250,000	1,250,000 USD
SWH installation cost for a residential consumer using 1,000 kWh/year (required area x import and installation cost) 1 / 0.8 x 500 = 625	625 USD
Annual electricity cost saving for a consumer using 1,000 kWh/year (electricity consumption x price) 1,000 x 0.15 = 150	150 USD

SWH result in a modest reduction in energy-sector emissions:

- A reduction of 46 TJ from the original TPES of 1,000 TJ is a 4.6% reduction.

SWH make a big contribution to foreign exchange savings after first year:

- SWH import cost is slightly larger than fuel import cost savings, but the latter occur every year.

SWH have a significant local income impact:

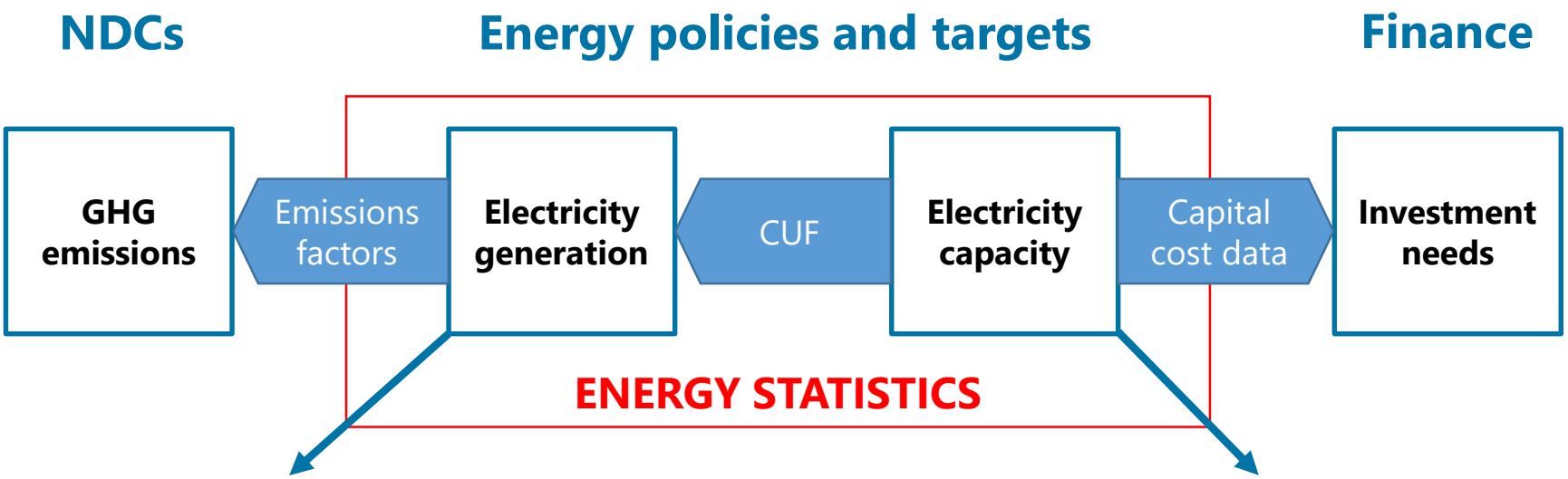
- Labour cost of installation is USD 250 x 5,000 m2 = USD 1,250,000
- Annual maintenance is an additional 10% of this every year (USD 125,000/year)

The payback period for property owners is just over 5 years:

- Accumulated electricity cost savings will be USD 750 after 5 years (USD 150/year x 5 years)
- SWH cost is USD 625, plus USD 30/year, which equals USD 775 after 5 years (625 + (30 x 5))

Final message……..

Energy statistics are at the centre of analysis of targets, NDCs, other development goals and investment plans



Other benefits:
- Energy security
- Import substitution
- Electricity access
- Electricity quality
- Economic development
- Environmental impacts

Other benefits:
- Local income
- Local employment