Using META in Worldwatch's Sustainable Energy Roadmaps

Alexander Ochs, EWG Chair LEDS-LAC Regional Platform December 5, 2013







Model for Electricity Technology Assessment (META)

META calculates economic costs of different electricity generation technologies

- 1. Objective comparison of various investment projects
- 2. Demonstrate long-term effects of different fuel-cost developments
- 3. LCOE that includes negative externalities
- 4. Interpret data and derive policy recommendations



Sustainable Energy Roadmap



Financing Options

Gap Analysis International Support & Cooperation

Domestic Reform & Capacity Building Socio-Economic Analysis

Levelized Cost of Energy + Energy Scenarios Macroeconomic Effects



META Overview



- CAPEX
- 0&M
- Fuel Cost
- Externalities
- Commodity Cost & Forecast

- Simulation
- Transmission System Costs
- Risk Calculation
- Regression Analysis

- Cost
- Energy Costs
- Externality Costs
- Comparison Among **Technologies**



Changing Inputs for Customized META

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B B Segmentation (mail) 0.1 0.93 97.03 46.1 Nutral gas 93.6 0.5 First Source Source 20 Concept 20.0 20	17	Diesel generator (large)	18	85%	20	1,800,00	0.62%	1.5	Fuel oil	38%	0%		1)Zone F	20%	-	
B B	18	Gas generator (small)	0.1	80%	20	992.93	7.00%	4.6	Natural gas	35%	0%	[mg	Zone F	20%		
20 Mode gas unine 0.05 005	19	Gas generator (large)	5	10%	20	560.02	7.00%	3.3	Natural gas	45%	0%	Pdri	Zone F	20%		
2 Purker (framit) 0.025 000.5 0.005	20	Micro gas turbine	0.15	80%	20	937.30	4.36%		Natural gas	32%	0%		0 Zone F	20%	1	
2 2 1 983 2 3455 94 3128 Navard gas 483 0.5 0 2005 2005 2 Difface Conduction Turbine (F-type) 33 0.855 700.00 0.725 0.5 Navard gas 255 15 4 2 2005	21	Fuel cell (small)	0.025	80%	20	4,180,54	2.58%		Natural gas	46%	0%		0 Zone F	20%	30%	
2 Diffact Computing Turbure (Fupp) 3 95 2 and F 2000 F	22	Fuel cell (large)	1	80%	20	3,455,94	3.12%		Natural das	46%	0%		0 Zone F	20%	30%	
21 2003/E Construction Turburé (F-type) 33 95: 27 700.00 0.72:: 0.1 Naruar gas 25:: 15: 2. 2.000 F 2.0	23	Dil/Gas Combustion Turbine (E-tupe)	()		25	200.00			Natural gas		15		Zone E	20%	-	
25 Oldsa Continued Caple (CCAT, Furge) 40 40 Natural part 40 22 2000 2000 0 27 Oldsa Continued Caple (CCAT, Furge) 800 80% ± 5 766.28 1.77% 0.11 Natural part 55% 2% 0 2 conf 20% - 28 Conf State Continued Caple (CCAT, Grupe) 800 80% ± 5 766.28 1.77% 0.11 Natural part 55% 2% 0 2 conf 20% - 28 Conf Statement Caple (CCAT, Grupe) 800 80% ± 30 1.867.71 1.30% 0.425 Conf Statement Caple (CCAT, Grupe) 20% - 20% - 20% - 20% - 20% - 20% 0 20% 20% 1 20% 20% 1 1.80% 0.80% 20% 1 20% 20% 1 20% 1 20% 1 20% 1 20% 1 20% 1 20% 1 20% 1 <td< td=""><td>24</td><td>Oil/Gas Combustion Turbine (F-tupe)</td><td>33</td><td>85%</td><td>25</td><td>700.00</td><td>0.72%</td><td>0.5</td><td>Natural gas</td><td>25%</td><td>1%</td><td>-</td><td>2 Zone F</td><td>20%</td><td></td><td></td></td<>	24	Oil/Gas Combustion Turbine (F-tupe)	33	85%	25	700.00	0.72%	0.5	Natural gas	25%	1%	-	2 Zone F	20%		
28 Olivas Combined Opel (CCT, Frage) 80 90% 25 776. 25 1776. 401 Natural gas 54% 25 0 0.0 200% - 29 Olivas Combined Opel (CCT, Grage) 900 90% 25 776. 25 1776. 401 Natural gas 58% 25 0 20.0 20.0% - 20 Cal Subcritical 900 90% 30 1.466.77 1.30% 0.425 Coal Supervintal 45% 85 0 2.00%	25	Oil/Gas Combined Cucle (CCGT, E-tupe)	10		25	1,100.00	1005		Natural gas	4844	2%		Zone F	20%		
27 000 001 002 776 0.21 Norwalpact 985 22 0.02 0.02 0.02 0.02 28 Coal Supervitual 000 005 30 2.200.00 1.232 0.2 Coal Supervitual 495 64 64 60 2.007 2.005 1.005 0.425 Coal Supervitual With CCS 00 2005 2.2005 1.005 0.425 Coal Supervitual With CCS 500 805 30 2.237 2.2 1.005 0.042 0.041 0.042 0.041 0.042 0.042 0.042 0.041 0.042	26	Oil/Gas Combined Cycle (CCGT, F-type)	650	80%	25	766.98	1.77%	0.311	Natural gas	54%	2%	1	0 Zone F	20%		
28 Col: Superinial 100 802 30 1.232 Q.2 Col: Superinial 402 Col: Superinial 500 801 30 1.667.77 1.305 0.42 Col: Superinial 405 60 Zore F 2.005	27	Oil/Gas Combined Cycle (CCGT, G-type)	800	80%	25	706.25	1.77%	0.311	Natural gas	59%	2%		0 Zone F	20%	-	
22 Coal Supercritical 500 600; x 106; x 20, cal Under 43% 8% 0 20 are F 20% - 31 Coal Supercritical with CCS 500 80%; x 0 2,387,62 180%; 0.930 Coal Under 33%; 10%; 0 2 Coal GCC without CCS 500 80%; x 0 2,087,62 180%; 0.930 Coal Under 33%; 10%; 0 2 Coal GCC without CCS 500 80%; x 0 2,084,66 Coal Under 33%; 10%; 0 2 Cone F 20%; 10%; 30 Coal GCC without CCS 500 80%; x 0 2 Coal Under 33%; 13%; 0 2 Cone F 20%; 40%; 30 Coal FE [subertitical] 300 80%; x 0 2 Coal SPE [subertitical] 37%; 45%; 0 2 Cone F 20%; 20%; 30 Restram (supercitical) 300 80%; x 0 2 Restram (supercitical) 0 2 Restram (supercitical) 0 2 Restram (supercitical) 0 2 Restram (supercitical) 0 2 Restra	28	Coal Subcritical	100	80%	30	2,200.00	1.23%	0.7	Coal - lignite	40%	8%		2 Zone F	20%		
30 Coal Upra Supervisal with CCS 500 80% 30 1.677.44 1.674.44	29	Coal Supercritical	500	80%	30	1,466.77	1.30%	0.425	Coal - lignite	43%	8%		0 Zone F	20%	÷.	
31 Coal Supervinical with CCS 500 800 30 2,387,62 1,100 0.000 Coal-ignite 33% 000 0 2004 30% 20% Coal-ignite 33% 40% 30% 20% 40% 30 Olasteam (subcritical) 500 80% 33 80% Coal-ignite 37% 45% 0 20neF 20% - 31 Olasteam (subcritical) 500 80% 331.88 135% 0.4% valum (enriched) 33% 45% 0 20neF 20% - - - 20% - - - 20% - - -	30	Coal Ultra Supercritical	500	80%	30	1,677.41	1.30%	0.425	Coal - lignite	45%	8%		0 Zone F	20%	10.00	
32 Coal IGCC without CCS 500 800 900	31	Coal Supercritical with CCS	500	80%	30	2,387.62	1.60%	0.905	Coal - lignite	33%	10%		0 Zone F	20%	30%	
33 Coal IGCC with CCS 500 500 2,844.66 1551 0.004 Coal - Ignite 332 132 0.02 Cone F 2001 4002 41 Coal CFB (supercitical) 500 800: 30 1,364.92 2,500: 0.00 Coal - Ignite 307: 55: 0.02 Cone F 2,000: - 35 Coal CFB (supercitical) 300 800: 30 1,364.92 2,500: 0.00 Coal - Ignite 307: 55: 0.02 Cone F 2,000: - - 36 Olateam (supercitical) 300 800: 331.88 1,000:<0.804	32	Coal IGCC without CCS	500	80%	30	1,900.42	1.80%	0.687	Coal - lignite	42%	10%		0 Zone F	20%	10%	
34 Coal CFB (subcritical) 300 800: 300 1141.0 2500: 0.0 Coal-ignite 372: 572: 0 20ne F 200: - 35 Coal CFB (supercritical) 300 800: 30 1.364.32 2.500: 0.0 Coal-ignite 372: 400: 500 20ne F 200: - 37 Gas steam (supercritical) 500 800: 311.00 1.00: 0.804 Natural gas 335: 45: 0 20ne F 200: - 38 PVR (VCER) 1200 85: 40 2.311.37 1.54: 0.437 Unalum (enriched) 33: 45: 0 20ne F 200: - 40 AP100 1.20: 85: 40 2.55: 0.85: 0.87: 8aterg (off-pask grid electricity) 37: 0 20ne F 200: - - 42 1.25: 3.376.33 5.72: Baterg (off-pask grid electricity) 70%: 0 20ne F 200: - - - 42 20ne F 200: - - <	33	Coal IGCC with CCS	500	80%	30	2,844.66	1.55%	0.804	Coal - lignite	33%	13%		0 Zone F	20%	40%	
15 Coal CFB (spectricial) 500 902 902 30 1,364, 25 2,002 0.002 37% 45% 0.002 2,007 2,002 . 36 Oil steam (subcriticial) 300 902 30 9100 0.003 Natural gas 39% 45% 0.0 2,007 2,002 . 37 Gas Steam (supcriticial) 1,000 903 Natural gas 39% 45% 0.0 2,007 2,00% . 37 PMR (VVER) 1,200 85% 40 3,318.8 1,35% 0.487 Uranium (notiohed) 33% 45% 0.0 2,00F 2,00% . 38 PMR (VARD) 1 2,50 0.457 0.487 Uranium (notiohed) 33% 45% 0.0 2,00F 2,00% 2,00% . 40 APURO 1 2,50 1 3,376.83 3,72 8 8 attery (off-peak gid electricity) 70% 0.0 2,00F 2,00% 2,00% 2,00% 2,00% 2,00% 2,00% 2,00% 2,00% 2,00% 2	34	Coal CFB (subcritical)	300	80%	30	1,141.10	2.50%	0.0	Coal - lignite	37%	5%		0 Zone F	20%	2.00 g	
36 01 steam (subcritical) 300 80% 30 78 100% 0.04 Fuel oil 37% 4% 0 2 cneF 20% - 37 Gas steam (supcritical) 500 80% 30 100% 0.044 Natural gas 38% 4% 0 2 cneF 20% - 38 PVR (VER) 1200 85% 40 2,015 15% 0.477 Uranium (not enriched) 33% 4% 0 2 cneF 20% - 41 Led acid battery 1 25% 15 2,325.40 2.57% Battery (off-peak grid electricity) 70% 00 2 cneF 20% - 42 NaS 1 25% 15 3,378.83 5.72% Battery (off-peak grid electricity) 70% 00 2 cneF 20% - 00% 2 cneF 20% - 00% 2 cneF 20% - 0.00 2 cneF 20% - 0.00 2 cneF 20% <	35	Coal CFB (supercritical)	500	80%	30	1,364.92	2.50%	0.0	Coal - lignite	40%	5%		0 Zone F	20%	-	
37 Gas stam (supercitical) 500 80% 30 811.00 100% 0.80% Natural gas 39% 4% 0 Zone F 20% . 38 PMR (VER) 1,200 85% 40 2,311.37 Unanium (not enriched) 33% 4% 0 Zone F 20% . 40 AP1000 1,200 85% 40 4,635.51 0.96% 0.87 Unanium (not enriched) 33% 4% 0 Zone F 20% . 41 Lead acid battery 1 25% 15 2,325.40 2,57% Battery (off-peak grid electricity) 70% 0% 0 Zone F 20% . 42 Nas Solar PV (micor) 0.00005 1 25% 5,51.25 0.36% Solar 0% 0 Zone F 20% . 43 Solar PV (mind) 0.025 15% 2,52 0.36% Solar 0% 0 Zone F 20% . <	36	Oil steam (subcritical)	300	80%	30	798.75	1.00%	0.804	Fuel oil	37%	4%		0 Zone F	20%	•	
38 PVR (VVER) 1,200 95% 40 3.38.8 1.35% 0.487 Uranium (enriched) 33% 4% 0 2 one F 20% - 39 PHVR (CANDU) 700 85% 40 4,63.31 0.487 Uranium (enriched) 33% 4% 0 2 one F 20% - 41 Lead acid battery 1 2.5% 10 2,5% Battery (off-peak grid electricity) 70% 0.0 0 2 one F 20% - 42 NaS 1 2.5% 15 2,325.40 2,57% Battery (off-peak grid electricity) 70% 0.0 0 2 one F 20% - 43 Solar PV (inciro) 0.0005 F 25 6,554.52 0.38% Solar 0.0 0 2 one F 20% - 44 Solar PV (indig) 0.0005 F 25 6,554.52 0.38% Solar 0.0005 0.0005 - 20% - - 0.0005 - 20% - - 0.0005 - - 0.0005	37	Gas steam (supercritical)	500	80%	30	811.00	1.00%	0.804	Natural gas	39%	4%		0 Zone F	20%	100 B	
39 PHWR (CANDU) 700 95% 40 2,911.97 154% 0.487 Uranum (enriched) 33% 4% 0.2 Cone F 20% - 40 AP1000 1200 85% 40 4,653.51 0.96% 0.487 Uranum (enriched) 33% 4% 0.2 Cone F 20% - 41 Lead acid battery 1 25% 15 2,325.40 2,57% Battery (off-peak grid electricity) 70% 0.0 0.2 Cone F 20% 0.00% 42 NaS 0.00005 1 25% 3,876.93 5.72% Battery (off-peak grid electricity) 70% 0.0 2 Cone F 20% 0.00% 43 Solar PV (mior) 0.00005 15,369.28 0.03% Solar 0.00 0.2 Cone F 20% - 44 Solar PV (indigle) 0.0003 20% 2 3,914.99 0.52 Solar 0.0 2 Cone F 20% - 45 Solar PV (indigle) 0.003 20% 0 2.6 0.2 - 2 2 Cone F 20% -	38	PVR(VVER)	1,200	85%	40	3,331.88	1.35%	0.487	Uranium (enriched)	33%	4%		0 Zone F	20%	-	
40 AP1000 1,200 85% 40 4,653.51 0.96% 0.487 Uranium (enriched) 33% 4% 0 Zone F 20% - 41 Lead aid battery 1 25% 15 2,325.40 2,57% Battery (off-peak grid electricity) 70% 0% 0 0 Zone F 20% - 42 NaS 1 25% 15 3,876.33 5.72% Battery (off-peak grid electricity) 70% 0% 0 0 Zone F 20% - 43 Solar PV (mior) 0.0005 MSwitt 20 15,58.22 0.38% Solar Solar 0%	39	PHWR (CANDU)	700	85%	40	2,911.97	1.54%	0.487	Uranium (not enriched)	33%	4%		0 Zone F	20%		
41 Lead acid battery 1 25% 15 2,325,40 2,67% Battery (off-peak grid electricity) 70% 0% 0 2 Ore F 20% 42 NaS 1 25% 15 3,876,93 5,72% Battery (off-peak grid electricity) 70% 0% 0 0 0 Zone F 20% 10% 43 Solar PV (micro) 0.0005 HS writ PS writ <b< td=""><td>40</td><td>AP1000</td><td>1,200</td><td>85%</td><td>40</td><td>4,653.51</td><td>0.96%</td><td>0.487</td><td>Uranium (enriched)</td><td>33%</td><td>4%</td><td></td><td>0 Zone F</td><td>20%</td><td>•</td><td></td></b<>	40	AP1000	1,200	85%	40	4,653.51	0.96%	0.487	Uranium (enriched)	33%	4%		0 Zone F	20%	•	
42 NaS 1 25% 15 3.876.93 5.72% Battery (off-peak grid electricity) 70% 0% 0 20n F 20% 10% 43 Solar PV (micro) 0.0005 15.89.28 0.13% Solar SO 0% 0% 0% 0% 0.20n F 20% - 44 Solar PV (midle) 0.003 165.89.28 0.36% Solar SO 0% 0% 0% 0% 0.20n F 20% - 45 Solar PV (midle) 0.003 165.232.2 5.304.9 Solar Solar 0% 0% 0% 0% - - - 46 Solar PV (midle) 0.003 20% 20 0.52% Solar Solar 0% 0% 0% 0% -	41	Lead acid battery	1	25%	15	2,325.40	2.57%		Battery (off-peak grid electricity)	70%	0%		0 Zone F	20%		
43 Solar PV (mioro) 0.0005 BS-wit 20 15.369.28 0.13% Solar 0.001 0.0007 20% - 44 Solar PV (min) 0.0003 BS-wit Solar Solar 0.0005 0.0005 20% - 45 Solar PV (midle) 0.0005 BS-wit Solar Solar 0.0005 0.0005 20% - 46 Solar PV (midle) 0.05 BS-wit Solar Solar 0.0005 0.20% - - 47 Wind onshore (min) 0.0003 20% 20 0.5% Solar Vind 0.0005 20% - - 48 Wind onshore (min) 0.1 20% 0 20% Vind 0.0005 20% - 49 Wind onshore (min) 0.1 20% 1.00% Wind 0.00% 2.20m F 2.00% - 49 Wind onshore (midle) 2 2.44% 0 2.00% Vind 0.00% 2.20m F 2.00% - 50 Wind onshore (midle) 2 <	42	NaS	1	25%	15	3,876.93	5.72%		Battery (off-peak grid electricity)	70%	0%		0 Zone F	20%	10%	
44 Solar PV (mini) 0.0003 Mark' date 25 6,554.52 0.36% Solar 0% 0 Zone F 20% - 45 Solar PV (midle) 0.025 15% 25 3,314.49 0.52% Solar 0% 0 Zone F 20% - 46 Solar PV (large) 0.5 382% 25 5,000 0.96% Solar 0% 2 Zone F 20% - 47 Wind onshore (mioro) 0.003 20% 2 0,28% Wind 0% 0 Zone F 20% - 48 Wind onshore (mini) 0.1 20% 2,00% Wind 0% 0 Zone F 20% - 49 Wind onshore (midle) 2 24% 20 1,250.00 2,00% Wind 0% 2 Zone F 20% - 50 Wind onshore (large) 18 24% 20 2,27% Wind 0% 2 Zone F 20% - 5	43	Solar PV (micro)	0.00005	HSerie	20	15,369.28	0.13%		Solar		0%		0 Zone F	20%	-	
45 Solar PV (middle) 0.025 15% 25 3,314.49 0.52% Solar 0% 0 Zone F 20% - 46 Solar PV (large) 0.5 3.82% 25 5.200.00 0.96% Solar 0% 2 Zone F 2.0% - 47 Wind onshore (minio) 0.003 2.0% 7,162.26 0.28% Wind 0% 0 2.0ne F 2.0% - 48 Wind onshore (minio) 0.1 2.0% 7,162.26 0.28% Wind 0% 0 2.0ne F 2.0% - 49 Wind onshore (midle) 0.1 2.0% 1,250.00 2.00% Wind 0% 2 2.0ne F 2.0% - 50 Wind onshore (large) 18 2.45% 2.00% Vind 0% 2 2.0ne F 2.0% - 51 Wind onshore (large) 100 3.0% 2.02% Vind 0% 0 2.0ne F 2.0% - 52 PV-wind hybrid (minio) 0.1 2.0% 2.0% Vind 0%	44	Solar PV (mini)	0.0003	Mark's d	ata 25	6,554.52	0.36%		Solar		0%		0 Zone F	20%	•	
46 Solar PV (large) 0.5 3.82 2.5 5.200.00 0.95× Solar 0% 2 2.0× 2.0% 4 47 Wind onshore (micro) 0.0003 2.0½ 7,162.26 0.29% Wind 0% 0 2.0× 2.0% 4 48 Wind onshore (mide) 0.1 2.0½ 0 1,975.18 1.00% Wind 0% 0 2.0× - 49 Wind onshore (mide) 2 3.4½ 2.00% Vind 0% 2 2.0×F 2.0% - 50 Wind onshore (mide) 2 3.4½ 2.00% Vind 0% 2 2.0×F 2.0% - 50 Wind onshore (large) 18 3.4½ 2 2.00% Vind 0% 2 2.0×F 2.0% - 51 Wind onshore (large) 100 3.0½ 2 2.0½ Vind 0% 0% 2.0×F 2.0% - 52 PV-w	45	Solar PV (middle)	0.025	15%	25	3,914.49	0.52%		Solar		0%		0 Zone F	20%	÷.	
47 Wind onshore (mioro) 0.0003 20% 20 7.162.26 0.28% Wind 0% 0 20ne F 20% - 48 Wind onshore (mini) 0.1 20% 1.975.18 1.00% Wind 0% 0 20ne F 20% - 49 Wind onshore (mini) 2 34% 0 1.950.00 2.00% Wind 0% 2 20ne F 20% - 50 Wind onshore (large) 18 34% 20 1.250.00 2.00% Wind 0% 2 20ne F 20% - 51 Wind onshore (large) 18 34% 20 2.023.14 2.27% Wind 0% 0 2 one F 20% - 51 Wind offshore 100 30% 20 2.02% Wind 0% 0 2 one F 20% - 52 PV-wind hybrid (mini) 0.1 20% 5.07% Wind 0% 0 2 one F	46	Solar PV (large)	0.5	38%	25	5,200.00	0.96%		Solar		0%		2 Zone F	20%	•	
48 Wind onshore (mini) 0.1 20% 20 1,975.18 1.00% Wind 0% 0% 0% 20% - 49 Wind onshore (midde) 2 34% 20 1,250.00 2.00% Wind 0% 2 Zone F 20% - 50 Wind onshore (large) 18 344% 20 1,250.00 2.00% Wind 0% 2 Zone F 20% - 51 Wind onshore (large) 18 344% 20 2,20% Wind 0% 2 Zone F 20% - 51 Wind onshore (large) 100 30% 2,02% Wind 0% 0% 0% - - 51 Wind onshore (large) 0.0003 15% 2 2,27% Wind 0% 0% 0% 2,00% - 52 PV-wind hybrid (micro) 0.0003 15% 20% Vind 0% 0% 0% 2,00% - <	47	Wind onshore (micro)	0.0003	20%	20	7,162.26	0.28%		Wind		0%	-	0 Zone F	20%		
49 Vind onshore (middle) 2 24x 20 1,250.00 2.00x Vind 0% 2 Zone F 20% - 50 Vind onshore (large) 18 24x 20 1,250.00 2.00x Vind 0% 2 Zone F 20% - 51 Vind onshore (large) 10 30% 2 2,27% Vind 0% 0 Zone F 20% - 52 PV-wind hybrid (minor) 0.0003 15% 2 2,27% Vind 0% 0 Zone F 20% - 53 PV-wind hybrid (minor) 0.0003 15% 2 0.25% Vind 0% 0 Zone F 20% - 53 PV-wind hybrid (minin) 0.1 20% 5,719.76 0.70% Vind 0% 0 Zone F 20% - 54 Solar thermal with storage 30 40% 30 5,821.94 2,42% Solar 0% 0% 0% 0% 20% 15%	48	Wind onshore (mini)	0.1	20%	20	1,975.18	1.00%		Wind		0%		0 Zone F	20%	•	
50 Wind onshore (large) 18 24x 20 1,250.00 2.00x Vind 0x 2 2 Zone F 20x . 51 Wind offshore 100 30x 2 2,023.14 2.27x Vind 0% 0 Zone F 20x . 52 PV-wind hybrid (micro) 0.003 15x 20 5,591.88 0.25x Vind 0% 0 Zone F 20x . 53 PV-wind hybrid (mini) 0.1 20x 20 5,713.76 0.70% Vind 0% 0 Zone F 20% . 54 Solar thermal with storage 30 40% 30 5,821.94 2.42% Solar 0% 0 Zone F 20% 15%	49	Wind onshore (middle)	2	34%	20	1,250.00	2.00%		Wind		0%		2 Zone F	20%	*	
51 Wind offshore 100 30% 20 2,023,14 2,27% Wind 0% 0 Zone F 20% - 52 PV-wind hybrid (micro) 0.0003 15% 20 15,091,88 0.25% Wind 0% 0 Zone F 20% - 53 PV-wind hybrid (mini) 0.1 20% 0.70% Wind 0% 0 Zone F 20% - 54 Solar thermal with storage 30 40% 30 5,821.94 2,42% Solar 0% 0 Zone F 20% -	50	Wind onshore (large)	18	34%	20	1,250.00	2.00%		Wind	-	0%	-	2 Zone F	20%		
52 PV-wind hybrid (micro) 0.0003 15% 20 15,091.88 0.25% Vind 0% 0 Zone F 20% - 53 PV-wind hybrid (mini) 0.1 20% 20 5,719.76 0.70% Vind 0% 0 Zone F 20% - 54 Solar thermal with storage 30 40% 30 5,821.94 2,42% Solar 0% 0 Zone F 20% 15%	51	Wind offshore	100	30%	20	2,023.14	2.27%		Wind		0%		0 Zone F	20%		
53 PV-wind hybrid (mini) 0.1 20% 20 5,719.76 0.70% Vind 0% 0 Zone F 20% - 54 Solar thermal with storage 30 40% 30 5,821.94 2.42% Solar 0% 0 Zone F 20% 15%	52	PV-wind hybrid (micro)	0.0003	15%	20	15,091.88	0.25%		Wind		0%		0 Zone F	20%	•	
54 Solar thermal with storage 30 40% 30 5.821.94 2.42% Solar 0% 0 Zone F 20% 15%	53	PV-wind hybrid (mini)	0.1	20%	20	5,719.76	0.70%		Wind		0%		0 Zone F	20%		
	54	Solar thermal with storage	30	40%	30	5,821.94	2.42%		Solar		0%		0 Zone F	20%	15%	
55 Solar hermal without storage 30 1504 201 5034 201 0.9842 I Solar (1997) 1 Solar (1997) 1 Concerned and Concer	55	Solar thermal without storage		15% Porule	30	5 094 20	0.98%	Gon	INDUTE TYPY INDUTE	Others	CALCULATION	S Gan	CALCULATI	ONS TYDY	DATABACE	Gon Por



META Application: Jamaica







LCOE Without Externalities: Jamaica



LCOE With Externalities (LCOE+): Jamaica



Savings from High RE Penetration: Jamaica



Key Outcomes from Jamaica Analysis

- 1. Switching to highly renewable system can decrease average electricity costs by 67% by 2030
- 2. USD \$15 billion saved in fossil fuel imports by 2030
- 45 million tons of CO2-equivalent can be saved by building no new fossil-fired generation and expanding RE penetration up to 94%
- 4. Approximately 4,000 new jobs created by switching to high penetrations of RE*



Conclusions

- 1. Versatile tool that shows the fiscal, environmental and social benefits of a renewable energy based system
- 2. LCOE+ modelling and analysis is important for policy planning as it showcases the often neglected negative externalities that are real costs of energy choices
- META analysis allows for high-level analysis as well as detailed examination of various pathways to achieve RE targets
- 4. Can be used to strengthen arguments for low-emission development by showing cost and emissions savings over time vs. BAU



Thank You!!

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