

**EREP: Prospects for Renewable Power in the
Economic Community of West African States
Model Data and Assumptions**

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Workshop on EREP system planning model

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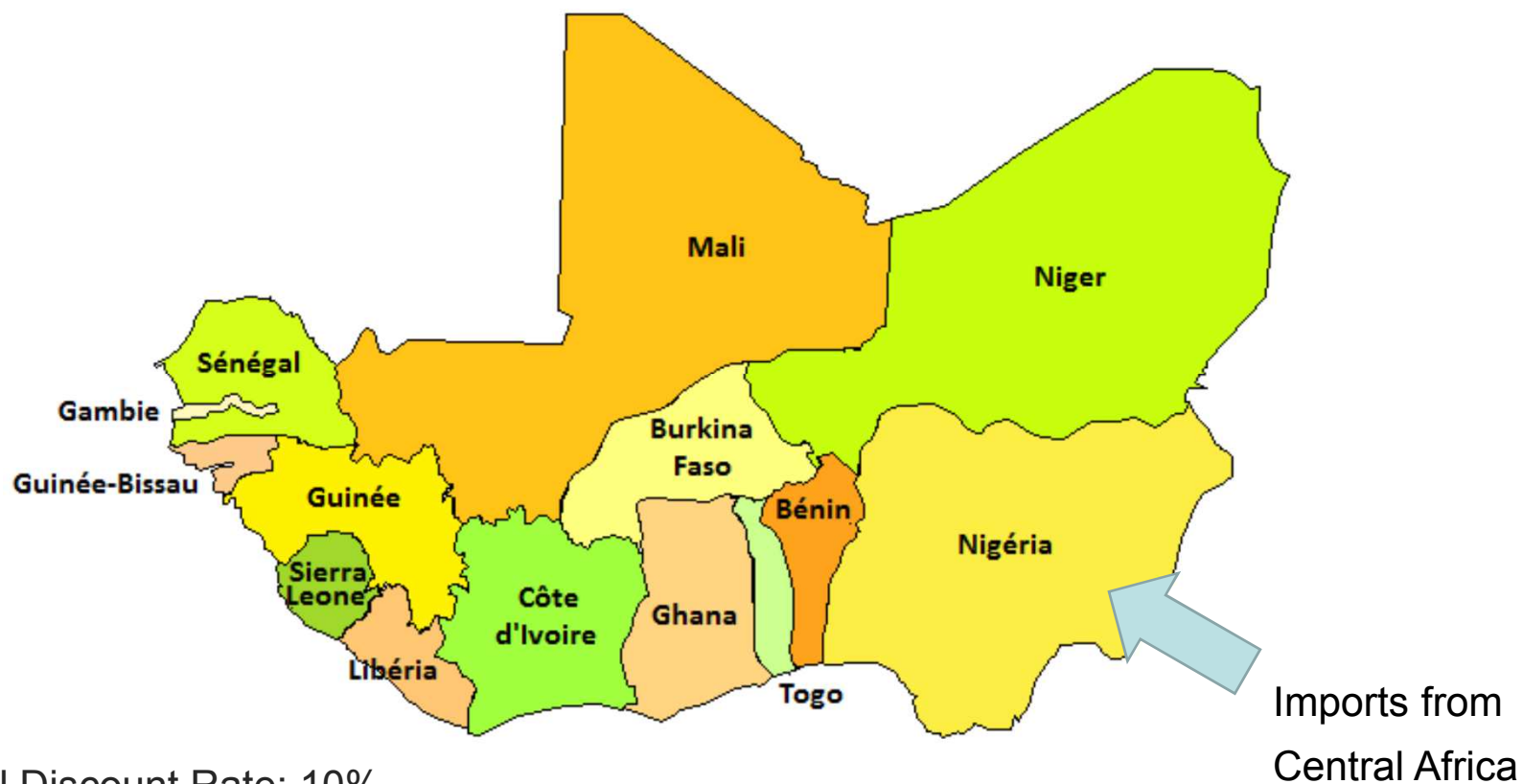
Overview of Presentation

- Introduction
- Model structure
- Scenario definitions
- Data sources
- Demand projections and profile
- Resource data
- Characterization of RE technologies (costs, capacity credit, diurnal variation)
- Characterization of Non-RE technologies (costs, fuel price etc)
- Characterization of transmission and distribution technologies (loss, cost, reserve margin etc)
- LCOE

Model in its Latest Version

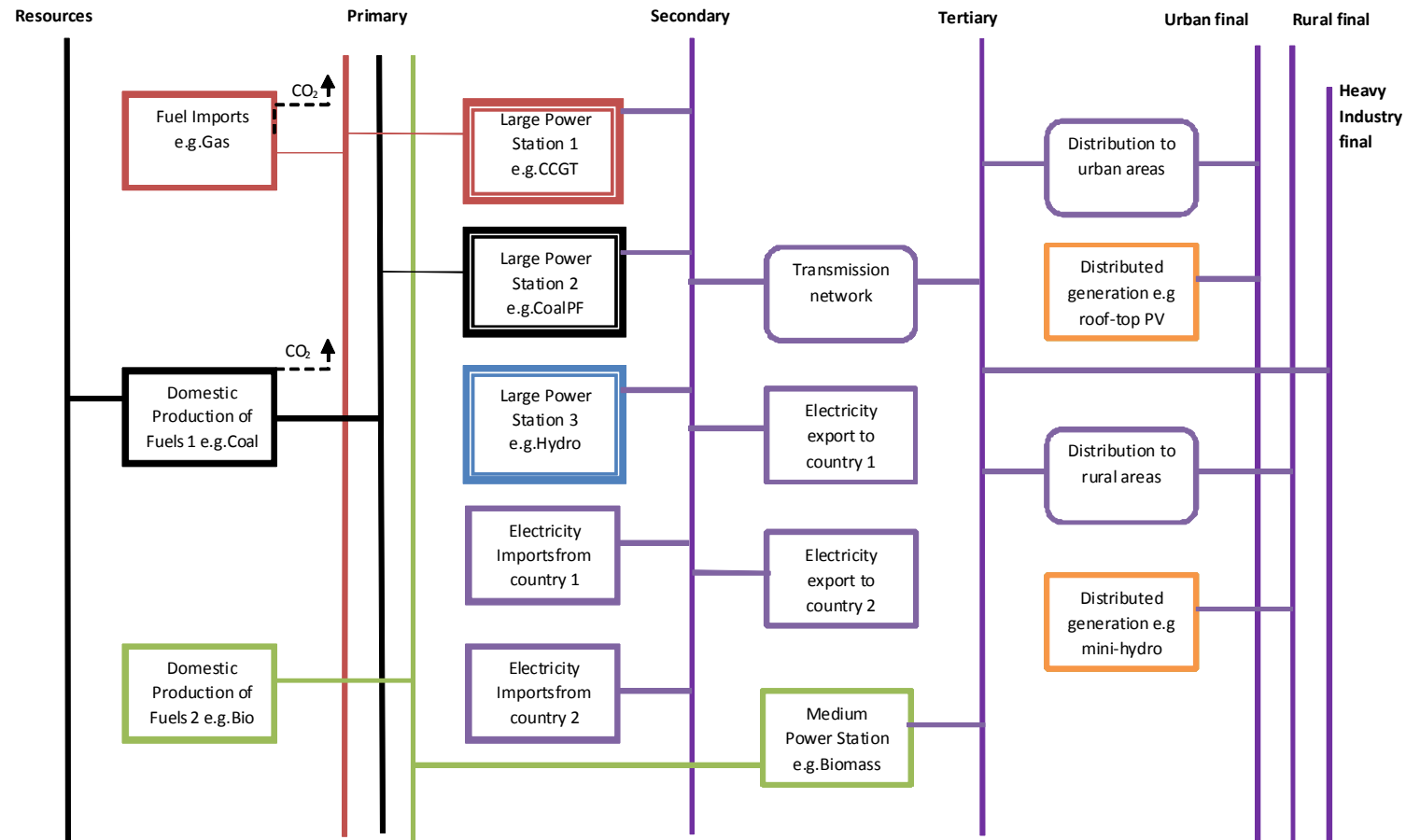
- Power pool model: initially developed by IAEA for training, further updated and enhanced by IRENA
- Enhancements include:
 - Latest publicly available data on existing power plants and projects in the region
 - Latest cost estimates and potential assessments for the RE technologies over the region
 - Daily and seasonal variation of supply for solar technologies
 - Demand split into: Heavy Industry, Urban, Rural (each with their own load shape definitions and differentiated T&D considerations)

Model Scope



- Real Discount Rate: 10%
- Monetary unit: 2010 US\$
- Modelling Horizon: 2010-2050 with focus on 2010-2030
- CO₂ Financing modelled using a CO₂ price starting at 0 in 2015 and ramping up to \$25/ton by 2030

Model Structure



Scenarios Considered (Illustrative)

-
- A Reference Scenario aligned to WAPP Master Plan (ECREE/WAPP/Tractebel)
 - An RE scenario: higher level of engagement between governments and private sector
 - Fuel prices escalated (real terms)
 - Technology learning on inv. cost of RE techs
 - Hydro imports from Central Africa
 - 2 Variations on RE Scenario:
 - Without hydro imports from CA
 - With limited trade (25% imports)

Data Sources

TRACTEBEL Engineering
GDF SUEZ

ACTUALISATION DU PLAN
DIRECTEUR RÉVISÉ DES MOYENS
DE PRODUCTION ET DE TRANSPORT
D'ÉNERGIE ÉLECTRIQUE
DE LA CEDEAO
Rapport Final Tome 1 :
Données de l'étude

Ministère Central
de l'Énergie de Côte d'Ivoire



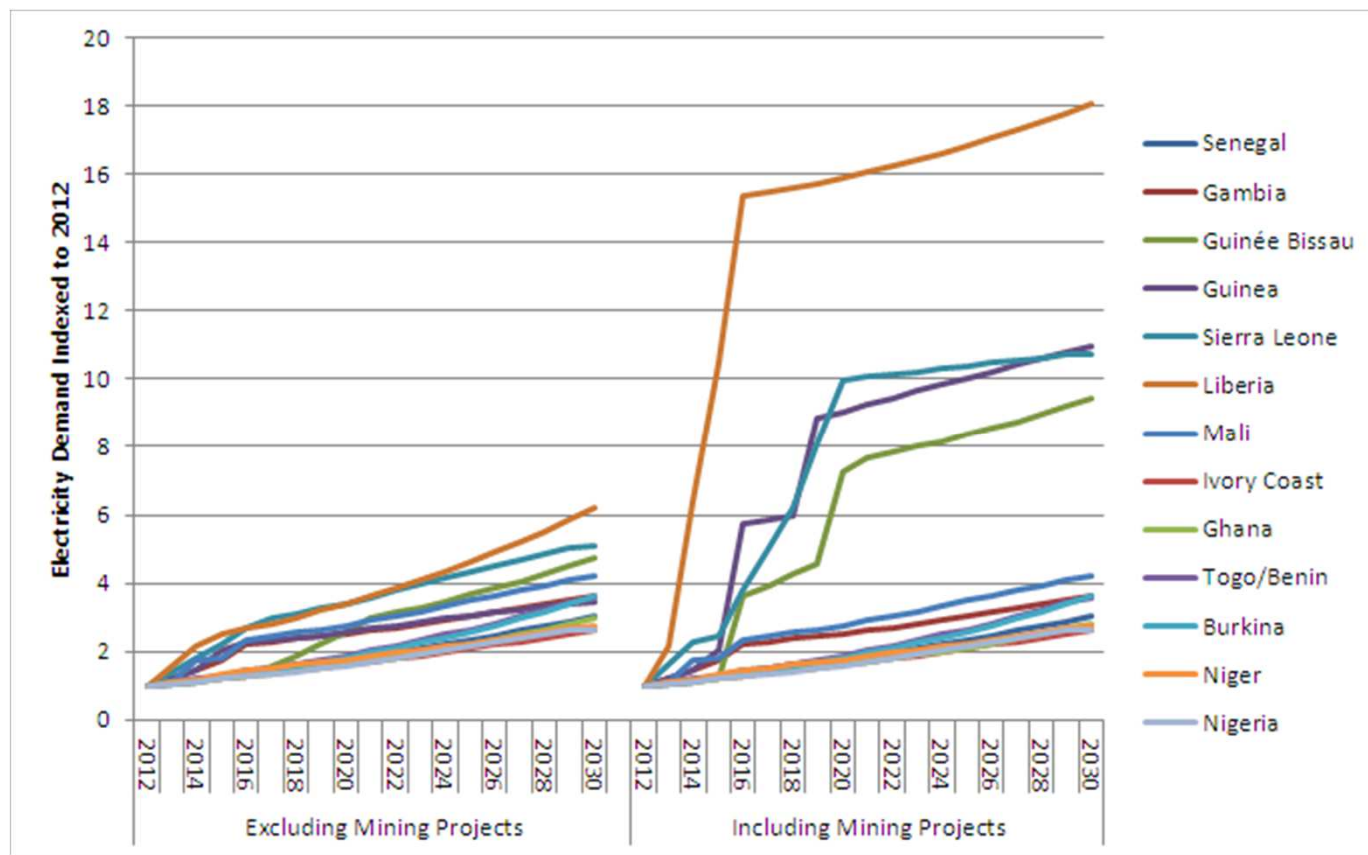
Commissariat Économique
des États de l'Afrique de l'Ouest

General Secretariat / Secrétariat Général

- Electricity demand projections
- Existing Generation and Transmission
- New Generation and Transmission Projects
- Base year fuel price and availability
- Large Hydro projects

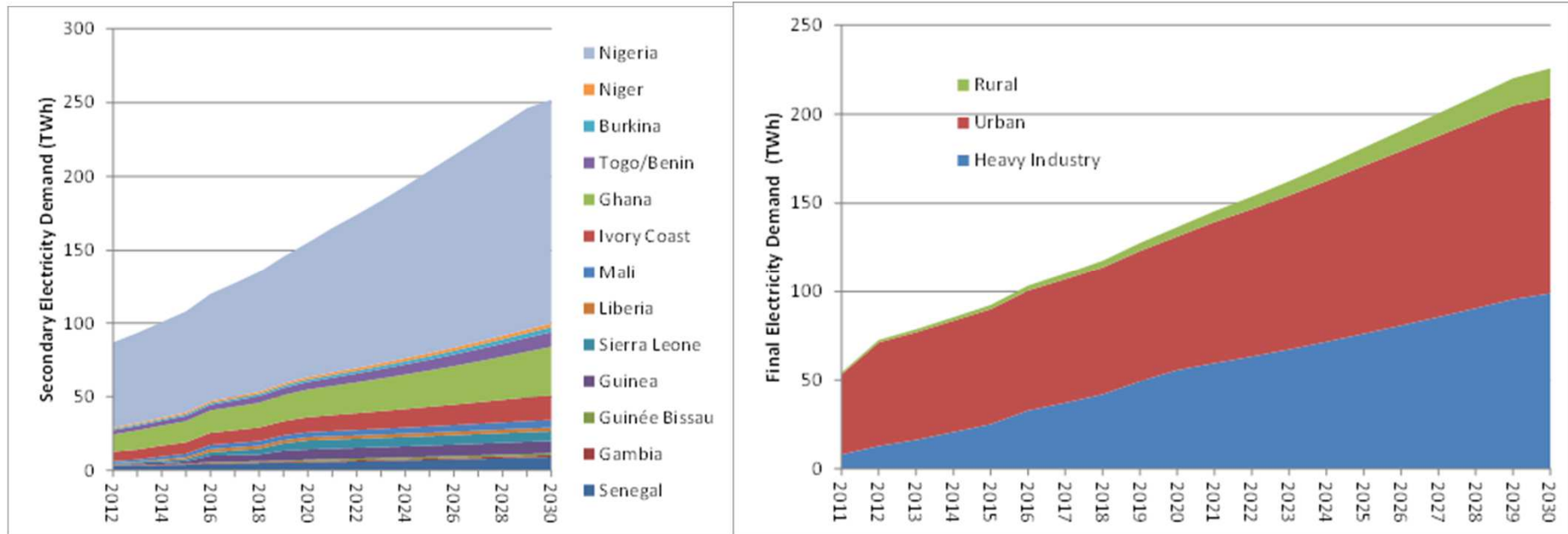
- Other Data:
 - Wind and Solar Resources: IRENA (from wind and solar maps)
 - Generic RE technology inv. cost projections: IRENA
 - Small hydro: UNIDO

Demand Projections



- Demand grows 2.5-6 times 2012 value without Mining/large industrial projects
- Mining projects included (Liberia, Sierra Leone, Guinea, Ghana)

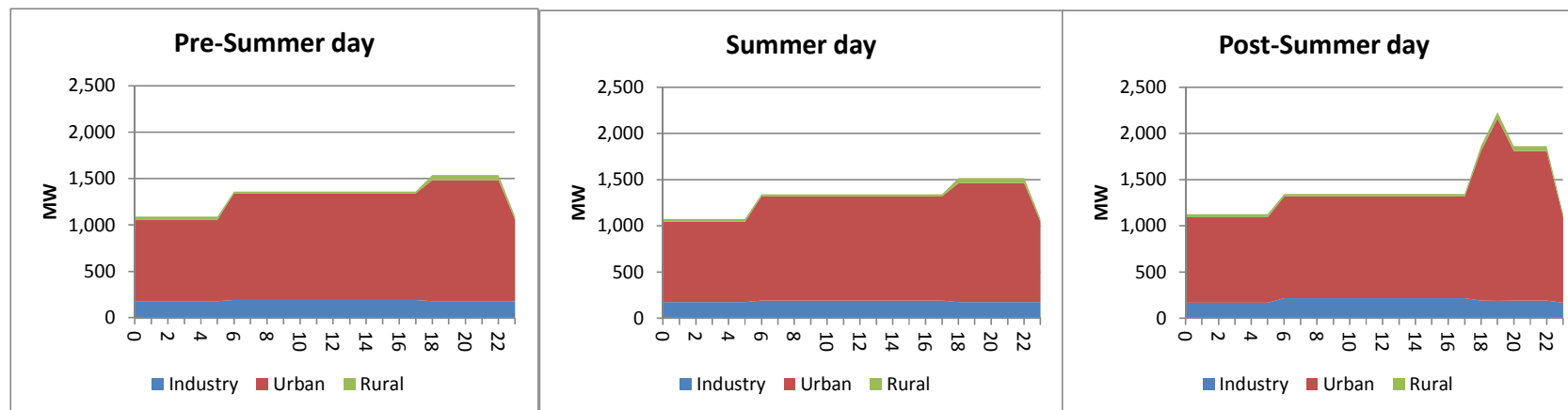
Demand Projections



- Resulting Demand: 90TWh to 250 TWh in 2030
- By 2030: 50% large industries, 45% Urban, and 5% rural

Load Profile

- E.g. Ghana in 2012



- 3 Seasons:

- Pre-Summer: 3 Time-Slices (night, day, evening)
- Summer: 3 Time-Slices (night, day, evening)
- Post-Summer: 4 Time-Slices (night, day, peak, evening)¹⁰

Existing Thermal Capacity Summary (2009)

	Existing Capacity	Fuel Mix (in terms of capacity)
	MW	
Burkina	146	80% HFO, remainder diesel
Cote d'Ivoire	765	Gas open cycle
Gambia	49	Mainly HFO with some diesel
Ghana	865	Light crude and gas closed-cycle and some diesel and light crude open cycle
Guinea	19	HFO
Guinea-Bissau	4	Diesel generators
Liberia	13	Diesel generators
Mali	134	Diesel generators and open cycle, and some HFO generators
Niger	67	50% coal fired steam turbine and a third gas open cycle, remainder diesel generators
Nigeria	3,858	11% Diesel, remainder Gas
Senegal	444	Mainly HFO with some combined and open cycle turbines
Sierra Leone	44	Mainly HFO with some diesel generators
Togo/Benin	196	Some gas turbines, diesel and HFO generators

- Summary of Table 16 in Appendix B – taken from WAPP master plan data report

Planned and Committed Projects



MW	Oil	Coal	Gas	Hydro	Biomass	Wind	Solar
Burkina	120	-	-	60	-	-	40
Cote d'Ivoire	-	-	1,313	1,072	-	-	-
Gambia	16	-	-	68	-	1	-
Ghana	100	-	2,265	661	-	150	10
Guinea	227	-	-	3,346	-	-	-
Guinea-Bissau	15	-	-	14	-	-	-
Liberia	50	-	-	967	35	-	-
Mali	332	-	-	434	33	-	40
Niger	32	200	18	279	-	30	50
Nigeria	-	-	13,581	3,300	-	-	-
Senegal	540	1,000	-	530	30	225	8
Sierra Leone	-	-	-	755	115	-	5
Togo/Benin	-	-	630	357	-	20	35
Total	1,432	1,200	17,807	11,840	213	426	188

- Summary of table 19 of Appendix B of report, taken from the WAPP Master Plan Report.

Resource Data: Large Hydro

Country	Existing Hydro			Identified Hydro Projects			
	Capacity	Average Generation	Dry Year Generation	Capacity	Average Generation	Dry year generation	
	MW	GWh	GWh	MW	GWh	GWh	
Burkina	23	91	41	60	192	146	
Cote d'Ivoire	585	2,424	1,842	1,072	4,953	3,764	
Gambia	0	0	0	68	241	92	
Ghana	1,044	5,051	3,722	661	2,330	1,770	
Guinea	95	482	379	3,202	13,728	10,838	
Guinea-Bissau	0	0	0	14	48	18	
Liberia	0	0	0	967	4,763	3,633	
Mali	153	683	495	384	1,589	1,127	
Niger	0	0	0	279	1,269	486	
Nigeria	1,358	7,476	4,632	10,142	43,710	33,220	
Senegal	68	264	165	530	1,988	1,100	
Sierra Leone	56	321	158	755	4,168	3,468	
Togo/Benin	65	173	91	357	1,004	722	
Total	3,447	16,965	11,525	11,646	50,495	37,975	

- Existing 3.4 GW, Identified projects: 11.6 GW
- Existing: 17 TWh, Identified projects: 38 TWh (dry-year)
- Data from WAPP master plan. Nigeria has some extra hydro resource specified based on 2005 REMP

Resource Data: Other RE

	Mini Hydro	Solar CSP	Solar PV	Biomass	Wind 20%	Wind 30%
	MW	TWh	TWh	MW	MW	MW
Burkina	140	18.1	77.4	2,250	4,742	28.7
Cote d'Ivoire	242	2.21	103	1,530	491	0.0
Gambia	12	3.16	4.74	23.75	197	5.1
Ghana	1	2.29	76.4	1,133	691	9.1
Guinea	332	4.67	52.0	656	2.4	0.0
Guinea-Bissau	2	9.06	14.9	71	142	0.0
Liberia	1,000	0.00	6.67	459	0.0	0.0
Mali	67	36.2	79.1	1,031	2,195	0.0
Niger	50	88.3	157	1,115	16,698	5,015
Nigeria	3,500	100	325	10,000	14,689	363
Senegal	104	15.4	75.2	475	6,226	1,243
Sierra Leone	85	1.97	15.0	166	0.0	0.0
Togo/Benin	336	0.00	51.6	957	551	0.0

- Mini hydro – based on a UNIDO paper (2010)
- Solar: Mines Paris Tech dataset summarized by KTH/IRENA
- Wind: Vortex dataset (9km resolution) summarized by KTH/IRENA
- Biomass: preliminary work by IRENA – needs update

Generic Technologies

Non-RE techs:

- Diesel Centralized
- HFO
- OCGT
- CCGT
- Supercritical coal

Distributed

- Diesel 100 kW system (industry)
- Diesel/Gasoline 1kW system (residential/commercial)

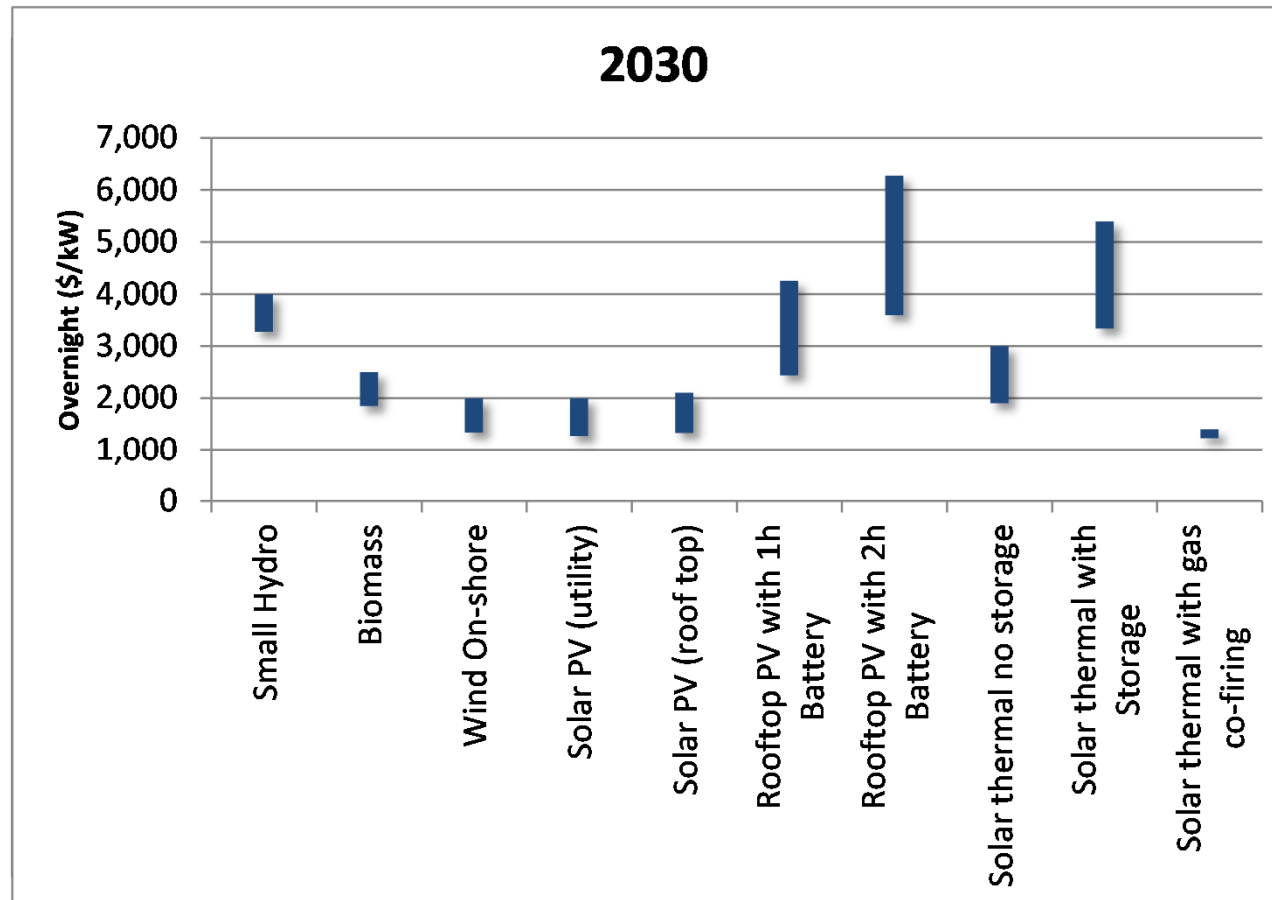
RE techs:

- Biomass
- Bulk Wind (20% CF)
- Bulk Wind (30% CF)
- Solar PV (utility)
- Solar thermal no storage
- Solar thermal with Storage
- Solar thermal with gas co-firing

Distributed

- Small Hydro
- Solar PV (roof top)
- Rooftop PV with 1h Battery
- Rooftop PV with 2h Battery

RE Tech Costs

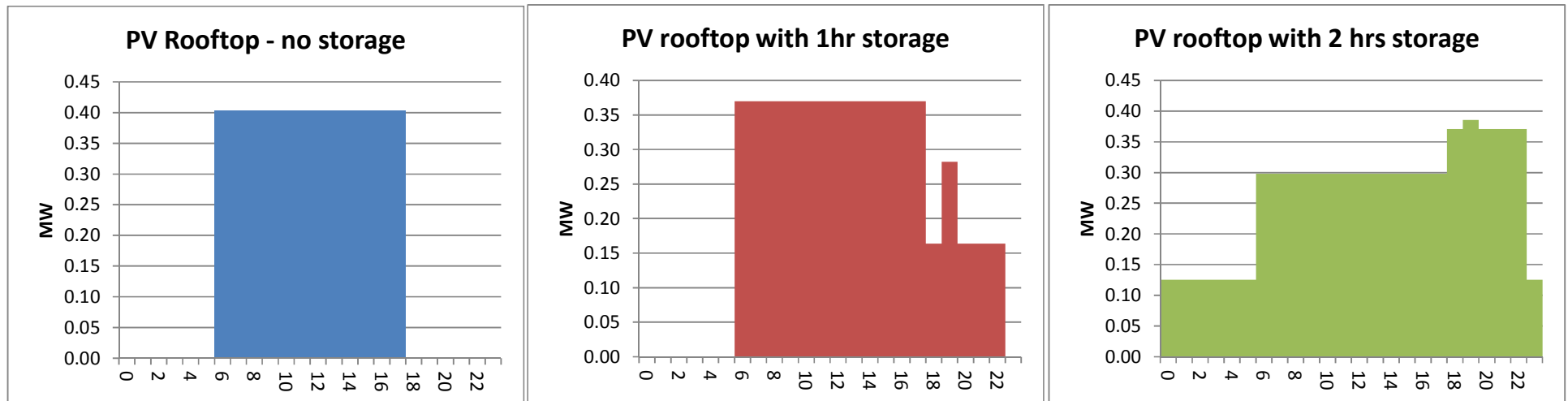


- Reference scenario assumes no learning - keeps 2010 value (top of bar)
- RE scenario with learning based on trends observed by IRENA

	Load Factor	O&M	Efficiency	Const. Duration	Life
	%	\$/MWh	%	Years	Years
Small Hydro	50%	5.4		2	30
Biomass	50%	20.0	38%	4	30
Bulk Wind (20% CF)	20%	17.4		2	25
Bulk Wind (30% CF)	30%	14.3		2	25
Solar PV (utility)	25%	20.1		1	25
Solar PV (roof top)	20%	23.8		1	20
PV with Battery 1hr storage	22.5%	19.0		1	20
PV with Battery 2hr storage	25%	17.1		1	20
Solar CSP no storage	35%	22.3		4	25
Solar CSP with Storage	63%	18.9		4	25
Solar CSP with gas co-firing	85%	18.9	53%	4	25

- Mainly from IRENA

RE hourly variation



- Same load regions as demand: 3 seasons, pre-summer and summer with 3 blocks (day-night-evening), and post-summer (day-night-evening-peak)

			Overnight Costs 2010	Constr. Duration	Availability	O&M	Efficiency
			\$/kW	Years	%	\$/MWh	%
Diesel/Gasoline	1kW	system	692	0	30%	33.2	16%
(urban/rural)							
Diesel 100kW system (industry)			659	0	80%	55.4	35%
Diesel Centralized			1,070	2	80%	17.0	35%
HFO			1,350	2	80%	15.0	35%
OCGT			603	2	85%	19.9	30%
CCGT			1,069	3	85%	2.9	48%
Supercritical coal w CCS			3,605	5	85%	36.0	28%
Supercritical coal			2,403	4	85%	14.3	37%

- Based on WAPP master plan 2011, IEA projected costs of generating electricity and the Integrated Resource Plan 2010 for South Africa (DOE-ESKOM)

Fuel Prices

\$/GJ	2010	2020	2030
HFO (delivered to the coast)	12.9	15.5	17.4
HFO (delivered to the inland)	16.3	19.6	22.0
Diesel (delivered to the coast)	21.9	26.3	29.6
Diesel (delivered to the inland)	25.2	30.2	34.0
Light Crude Oil (delivered to the coast)	17.8	21.4	24.0
Light Crude Oil (delivered to the inland)	18.9	22.7	25.5
Gas Domestic	8.5	9.5	11
Gas Imported	11.0	12.3	14.2
Coal Domestic	3.0	3.3	3.5
Coal Imported	4.6	5.0	5.3
Biomass Free (Sugar Cane)	0.0	0.0	0.0
Biomass Not Free	1.5	1.5	1.5
Biomass Scarce	3.6	3.6	3.6

- Fuel Prices based on the 100\$/bbl scenario of the WAPP master plan.
- Projections:
 - 20% and 35% increase in real price of oil products
 - 10% and 30% increase in real price of gas

Assumptions on Domestic T&D

	Trans.&Dist Cost	Losses
	US cents/kwh	%
Heavy Industry	1.5	7%
Urban Residential/commercial/small industries	5	15%
Rural Residential/commercial	10	20%

- Modelled as investment cost:
 - Transmission: \$365/kW
 - Heavy Industry: \$840/kW
 - Urban: \$2440/kW
 - Rural: \$4235/kW

Other Constraints

- Contribution to Reserve (10%) Capacity: Firm capacity
 - Thermal and Large hydro units capacity as “Firm”
 - PV utility: 5% of installed capacity is “Firm”
 - Wind 30% CF: 15% of installed capacity is “Firm”
 - Wind 20% CF: 10% of installed capacity is “Firm”
- RE Intermittency and grid stability
 - PV utility can only contribute up to 10% of grid electricity
 - Wind can only contribute up to 20% of grid electricity
- All scenarios using “dry-year” for large hydro
- Ramp Rates of Base-Load coal fired plants:
 - At the moment done by de-rating the capacity by the availability

Cross-Border Transmission: Existing Capacity

Country 1	Country 2	Line Capacity
		MW
Ghana	Cote d'Ivoire	327
Ghana	Togo/Benin	310
Senegal	Mali	100
Cote d'Ivoire	Burkina	327
Nigeria	Togo/Benin	686
Nigeria	Niger	169
Ghana	Cote d'Ivoire	327

- Summary of table 20 in Appendix C

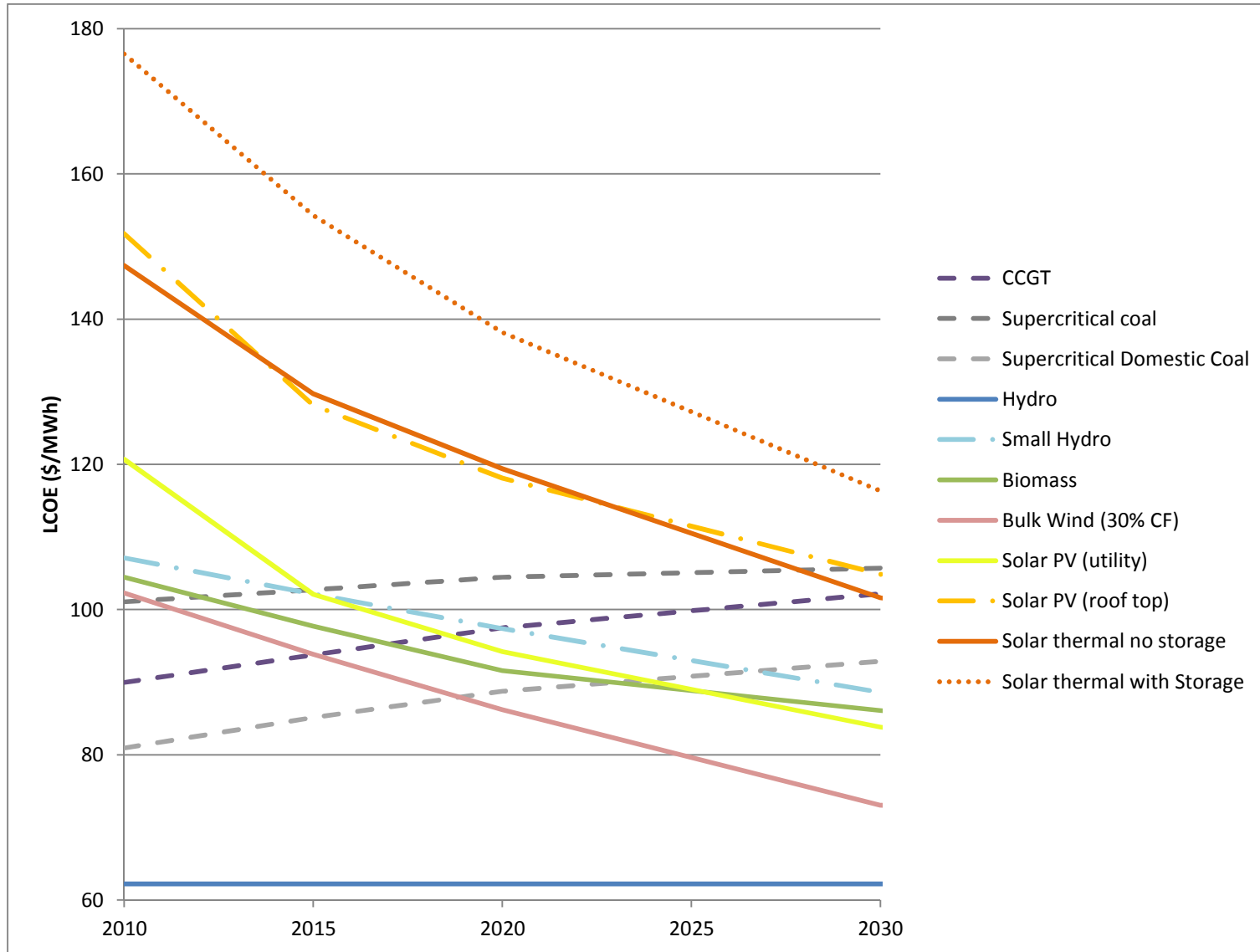
Cross-Border Transmission: Committed and Planned Projects



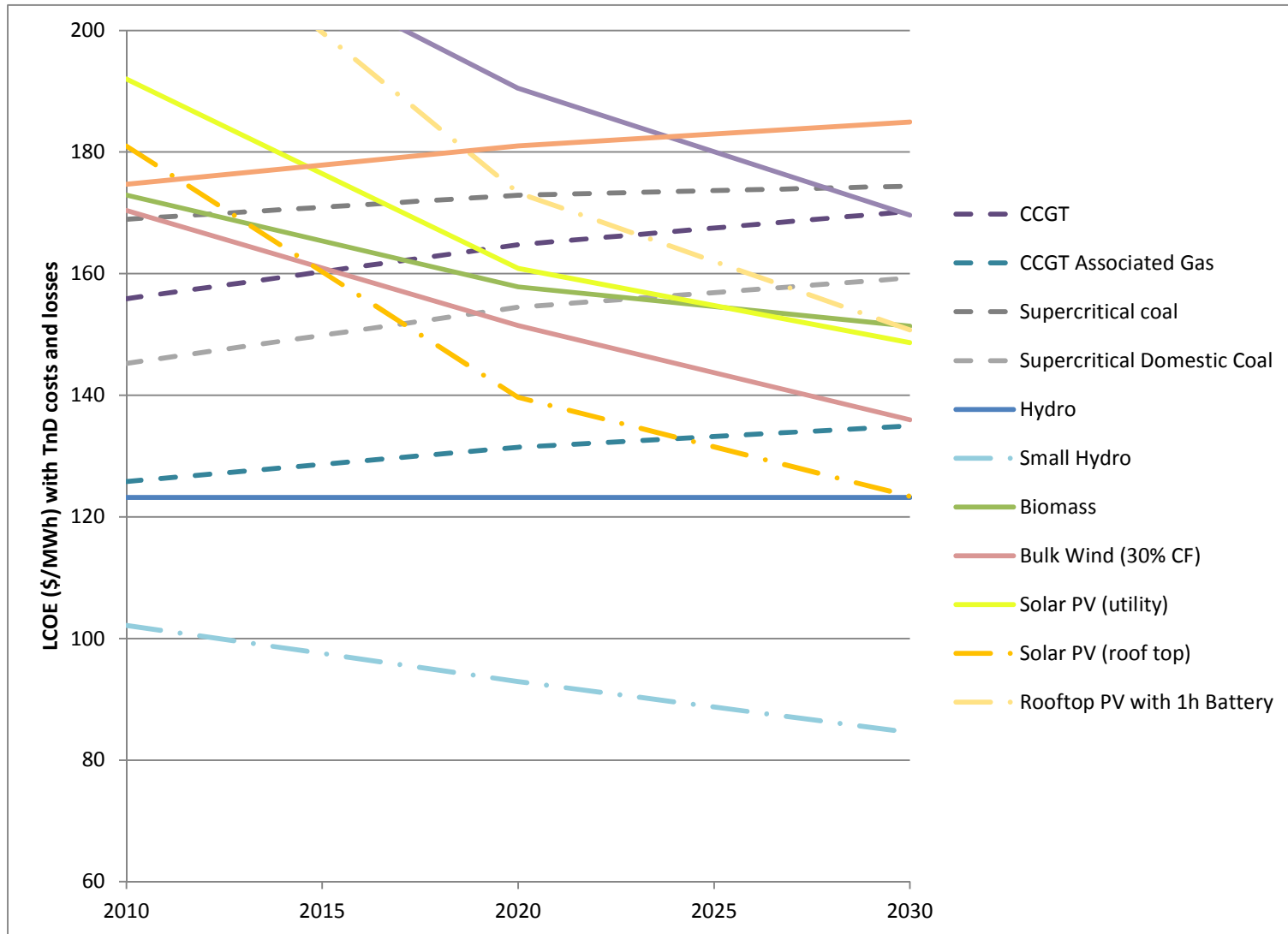
	Capacity of Line	Earliest year
	[MW]	
Committed Projects		
Dorsale 330kV (Ghana, Togo/Benin, Cote d'Ivoire)	~650	2013
CLSG (Cote d'Ivoire, Liberia, Guinea, Sierra Leone)	~330	2014
OMVG (Senegal, Guinea, Gambia, Guinea Bissau)	~315	2017
Hub Intrazonal (Ghana, Burkina, Mali, Cote d'Ivoire, Guinea)	~320	2014-2020
Planned Projects		
Corridor Nord (Nigeria, Niger, Togo/Benin, Burkina)	~650	2014
Other Projects		
Dorsale Mediane (Nigeria, Togo/Benin, Ghana)	~650	2020
OMVS (Mali, Senegal)	~330	2020

- Summary of table 21 in Appendix C of report

LCOE Analysis



LCOE Analysis with T&D considerations



Questions