United Nations Framework Convention on Climate Change

Tool to calculate the emission factor for an electricity system (Grid Tool)

Training Workshop and Public Consultation on Developing Standardized Baseline-Grid Emission Factor

SDM Programme

Agenda

1. What is the Grid Emission Factor (GEF)
2. Use of GEF
3. Concept of the 'Grid Tool'
4. Operating Margin EF
5. Build Margin EF
6. Combined Margin EF
7. Application of the Grid Tool
8. References

What is the Grid Emission Factor (GEF)

What is the Grid emission factor (GEF) ?

- Represents baseline emission intensity (tCO_2/MWh) of an electricity system (grid)

- Determines baseline emissions of a project:

  - supplies electricity to a grid - renewable energy
  - results in savings of grid electricity - energy efficiency

Use of GEF

Use of GEF

1. **Design:** energy planning
2. **Develop:** implementation of energy plans
3. **Analyze:** are national targets met?
4. **Evaluate:** are we on the right path? (NDC cycle)

Analysis (4) based on:

- **Grid emission factor**
- GHG emissions per sector
- GHG emissions per capita

Use of GEF

- <u>Mandatory</u> application - CDM project activities and PoA
- <u>Voluntary</u> used by some IFIs - Climate (Carbon) Finance
- <u>Voluntary</u> in Nationally Appropriate Mitigation Actions (NAMAs)

Concept of the Grid Tool

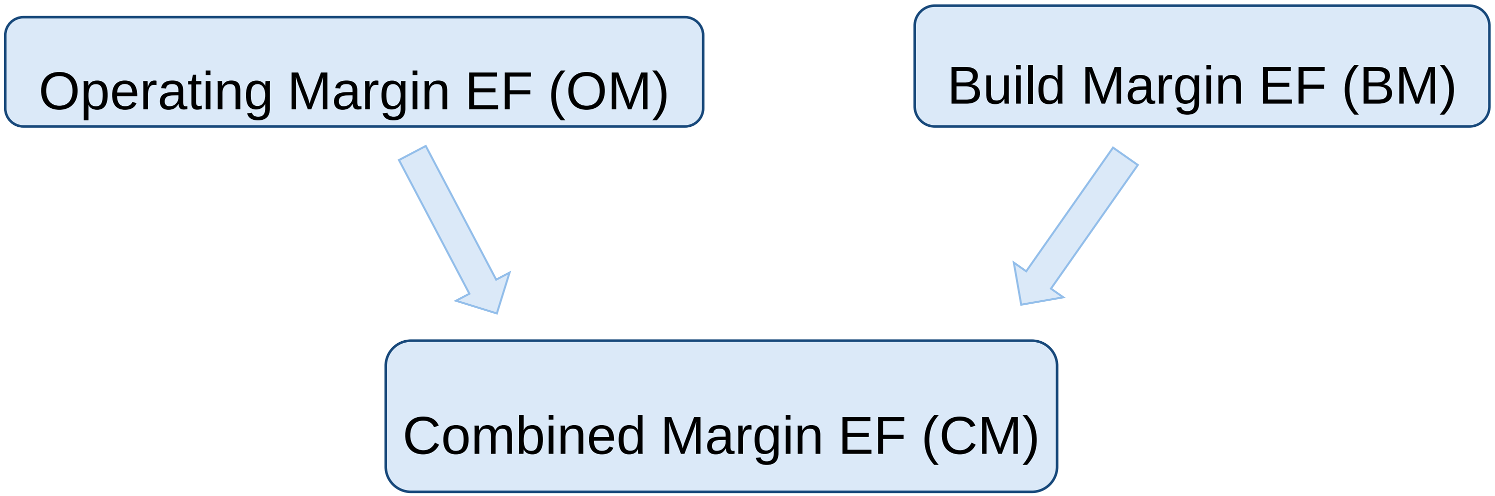
Concept of the Grid Tool

- Project mitigation effect (emission reductions) – displacement or avoidance:

  - **Operating Margin EF -** existing power plants electricity generation

  - **Build Margin EF -** Construction of prospective power plants

Concept of the Grid Tool



Operating Margin EF

Methods to determine Operating Margin

Depending upon grid composition and data availability:

1. **Dispatch Analysis OM**
2. **Simple Adjusted OM**
3. **Simple OM**
4. **Average OM**

Average OM

Operating Margin: Average OM

- ❑ Average emission rate of all power plants serving the grid

- ❑ Data required:
  1. Annual power generation by each power plant or aggregated
  2. Annual fuel consumption by each power plant or aggregated
  3. Fuel type and technology

Build Margin

Build Margin

Build Margin represents cohort of power plants that would have been built

Cohort consists of:

- ❑ Five recently built power plants or
- ❑ Recently built power plants that supplied 20 per cent of generation in the last year

Build Margin

Data required:

1. Date of commissioning
2. Annual power generation by each power plant
3. Annual fuel consumption by each power plant <u>or</u>
4. Fuel type and technology

Combined Margin

Combined Margin EF

Operating Margin EF (OM)

Build Margin EF (BM)

Combined Margin EF (CM)

CM = w x OM + y x BM (w +y =100%)

w = 75% and y= 25% (Wind & Solar)

w = 50% and y= 50% (Other projects - hydro, fossil fuel)

Application of the grid tool

Application of the grid tool

Step 1: Identify the relevant electricity systems

Step 2: Choose whether to include off-grid power plants in the project electricity system

Step 3: Select a method to determine the operating margin (OM)

Step 4: Calculate OM emission factor according to the selected method

Step 5: Calculate the build margin (BM) emission factor

Step 6: Calculate the combined margin (CM) emission factor

Application of the grid tool

Step 4: Calculate the operating margin emission factor according to the selected method

Electricity generated by power plant m

Emission factor of power plant m

$$EF_{grid} = \frac{\sum_m EG_{m,y} \times EF_{EL,m,y}}{\sum_m EG_{m,y}}$$

OM Emission factor of the grid

Total electricity generated by the grid

Application of the grid tool

Step 4: Calculate the operating margin emission factor according to the selected method

Fuel consumption of power plant m

Net calorific value of fuel i

Emission factor of fuel

$$EF_{EL,m,y} = \frac{\sum_i FC_{i,m,y} \times NCV_{i,y} \times EF_{CO2,i,y}}{EG_{m,y}}$$

Emission factor of power plant m

Application of the grid tool

Step 4: Calculate the operating margin emission factor according to the selected method

Emission factor of fuel

Conversion MWh ->GJ

$$EF_{EL,m,y} = \frac{EF_{co2,m,i,y} \times 3.6}{\eta_{m,y}}$$

Emission factor of power plant m

Efficiency of technology

References

References

Tool to calculate the emission factor for an electricity system: https://cdm.unfccc.int/methodologies/PAmethodologies/tools/am-tool-07-v5.0.pdf/history_view

NDC registry: http://unfccc.int/focus/ndc_registry/items/9433.php

Standardized baselines (GEF approved by UNFCCC): https://cdm.unfccc.int/methodologies/standard_base/index.html

CDM projects database: https://cdm.unfccc.int/Projects/projsearch.html

Institute for Global Environmental Strategies. List of GEFs: https://pub.iges.or.jp/pub/list-grid-emission-factor

NAMA registry: http://unfccc.int/cooperation_support/nama/items/7476.php

IPCC Guidelines for National Greenhouse Gas Inventories: http://www.ipcc-nggip.iges.or.jp/public/2006gl/index.html

Approaches to determine emission factor for Off-grid/Isolated system

Extra slides

Dispatch Analysis OM

Chronological representation of Load

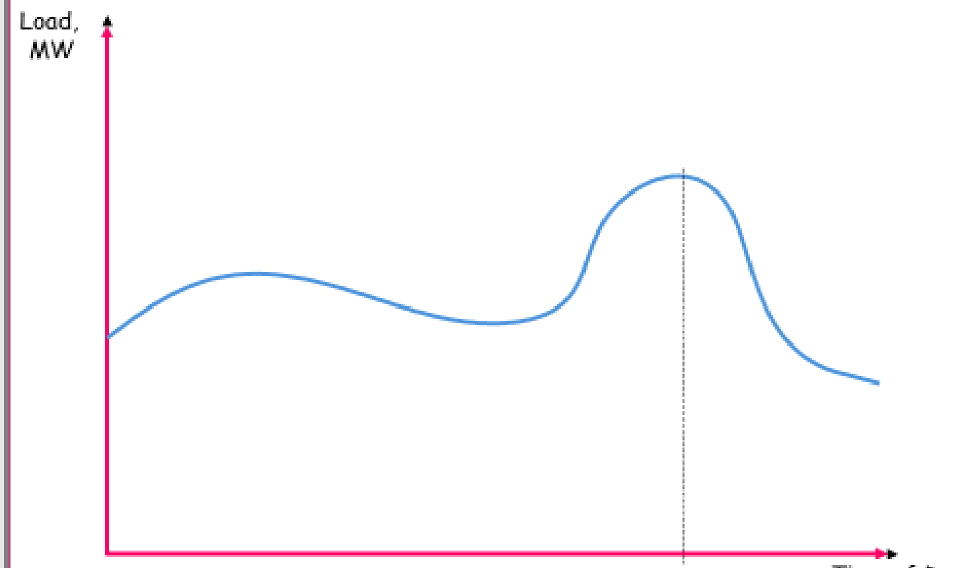
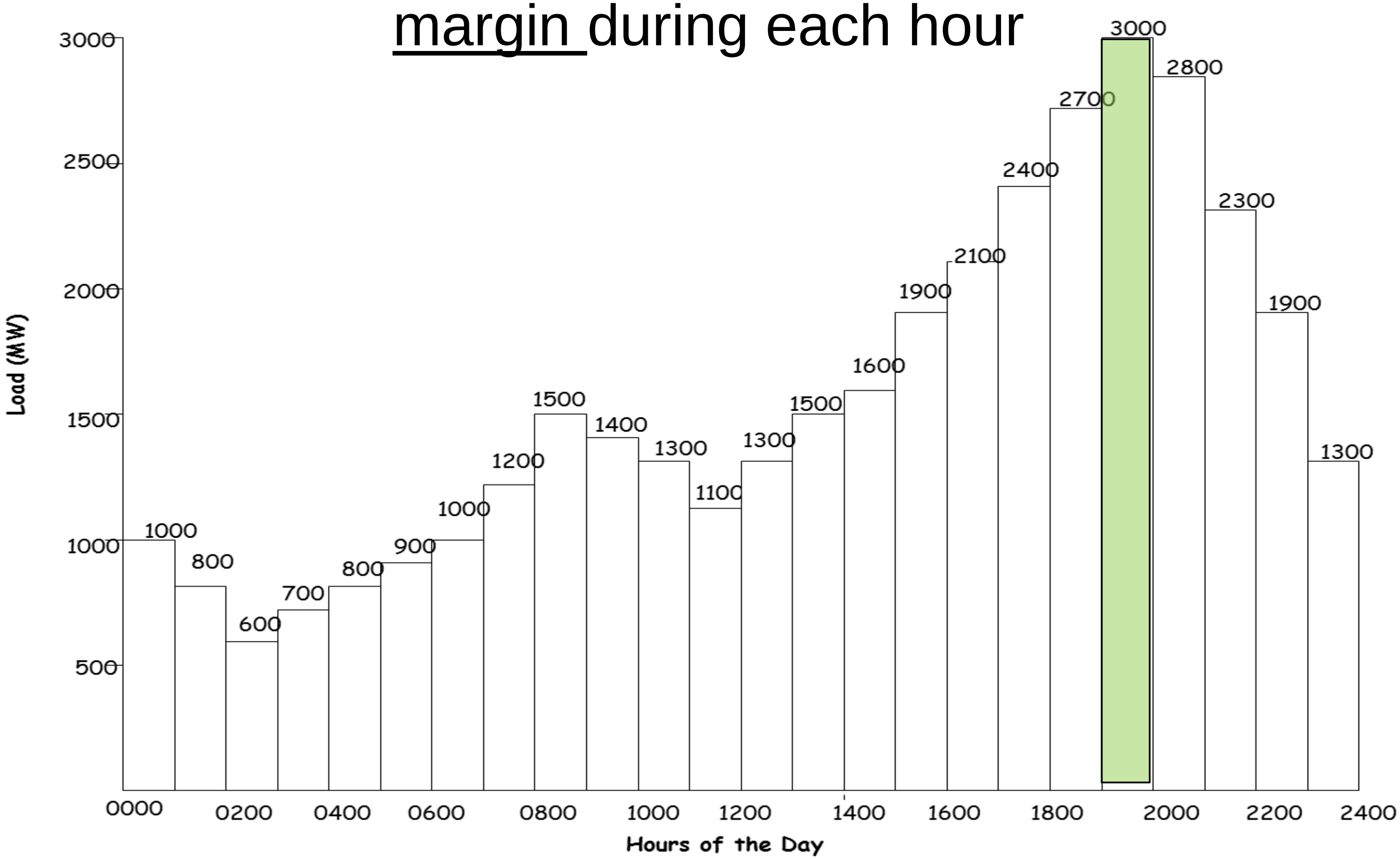


Figure 3.1

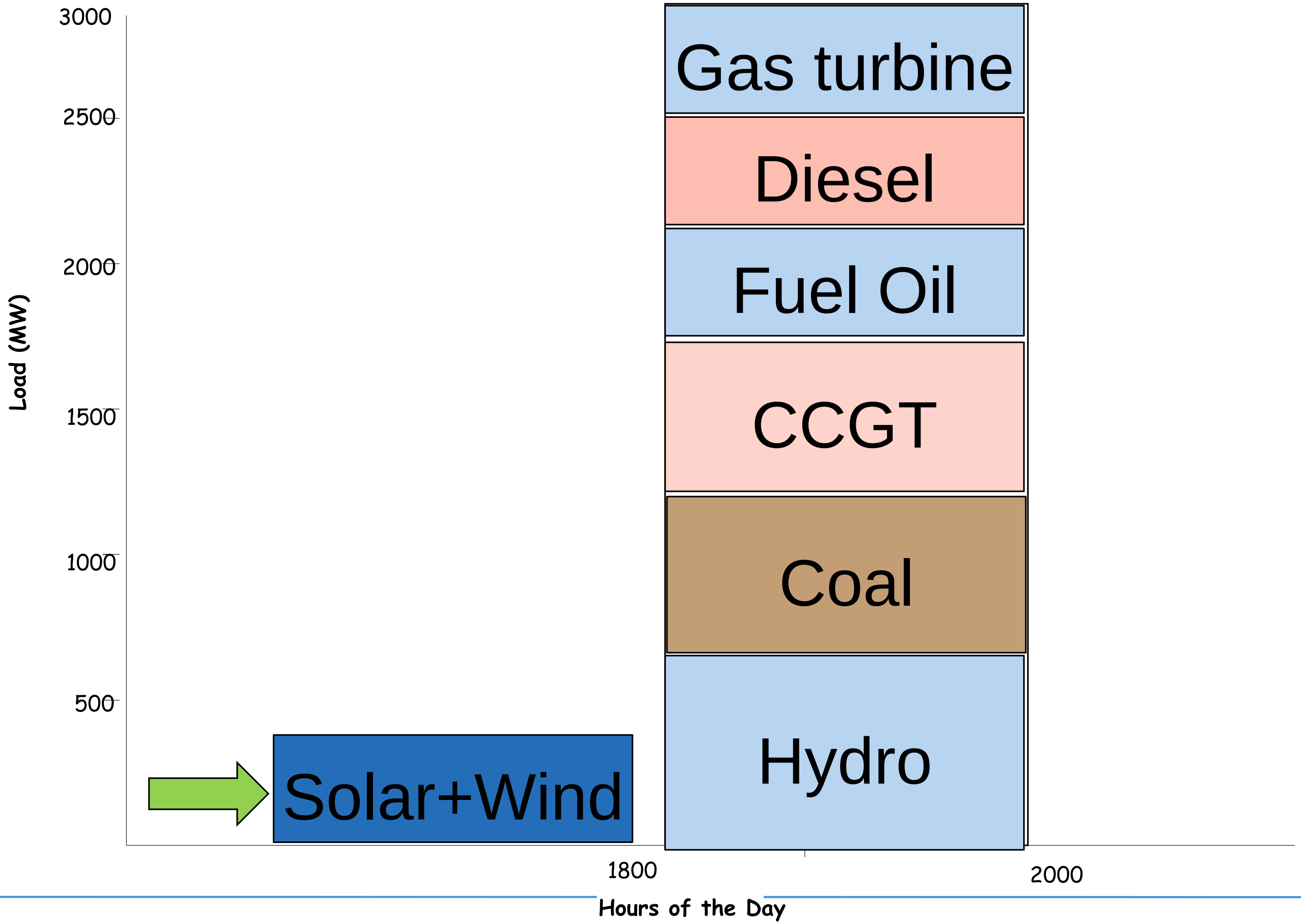
Hours of the Day	Average Load, MW
1	1000
2	800
3	600
4	700
5	800
6	900
7	1000
8	1200
9	1500
10	1400
11	1300
12	1100
13	1300
14	1500
15	1600
16	1900
17	2100
18	2400
19	2700
20	3000
21	2800
22	2300
23	1900
24	1300

Operating Margin: Dispatch data analysis OM

Emission factor of the grid power units that are at the margin during each hour



Operating Margin: Dispatch data analysis OM



Operating Margin: Dispatch data analysis OM

Wind displaces Gas turbine

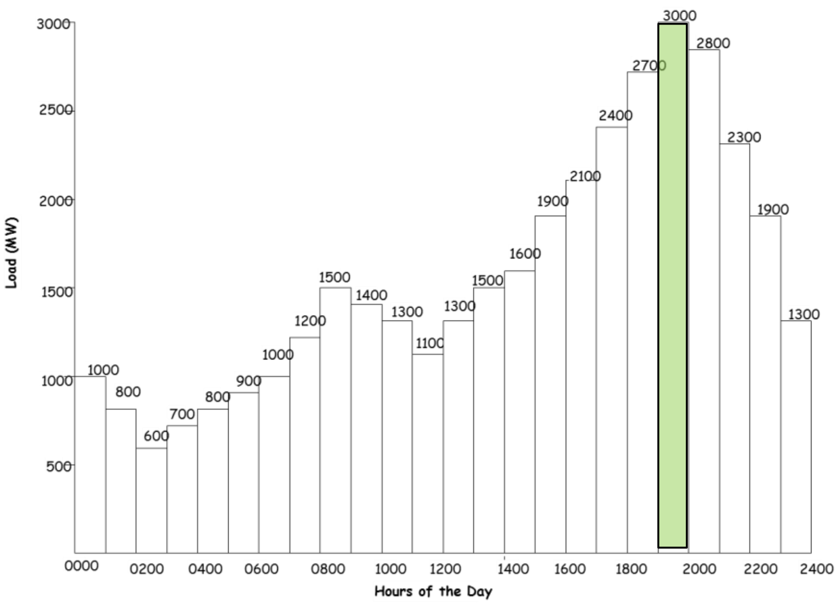
Hourly emission factor = EF of Gas Turbine

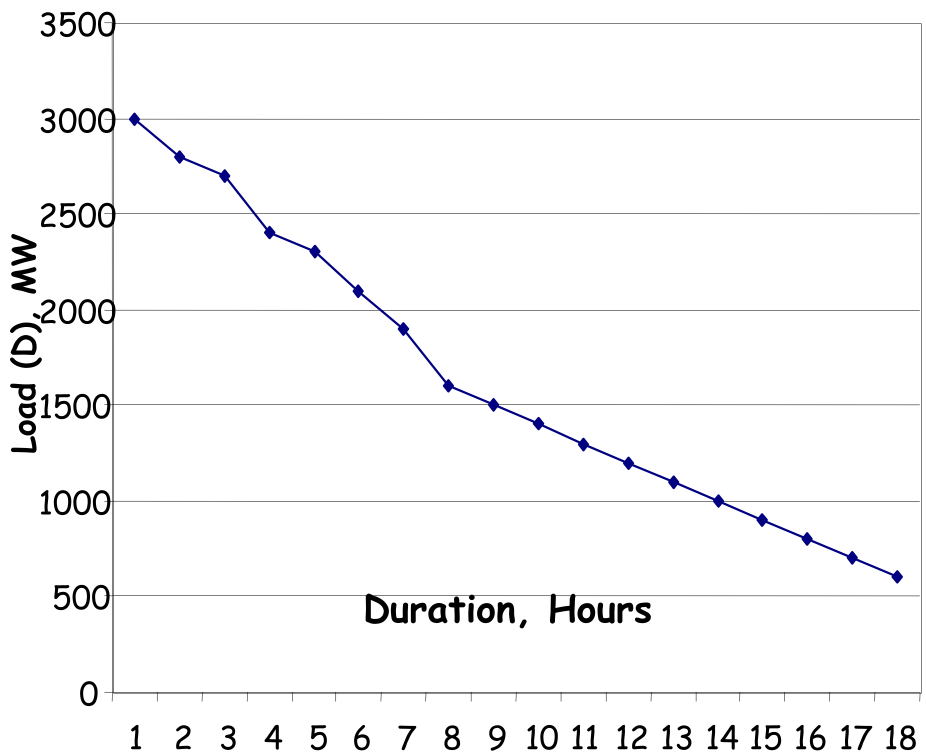
Data required:

1. hourly power generation of each power plant
2. hourly fuel consumption of each power plant

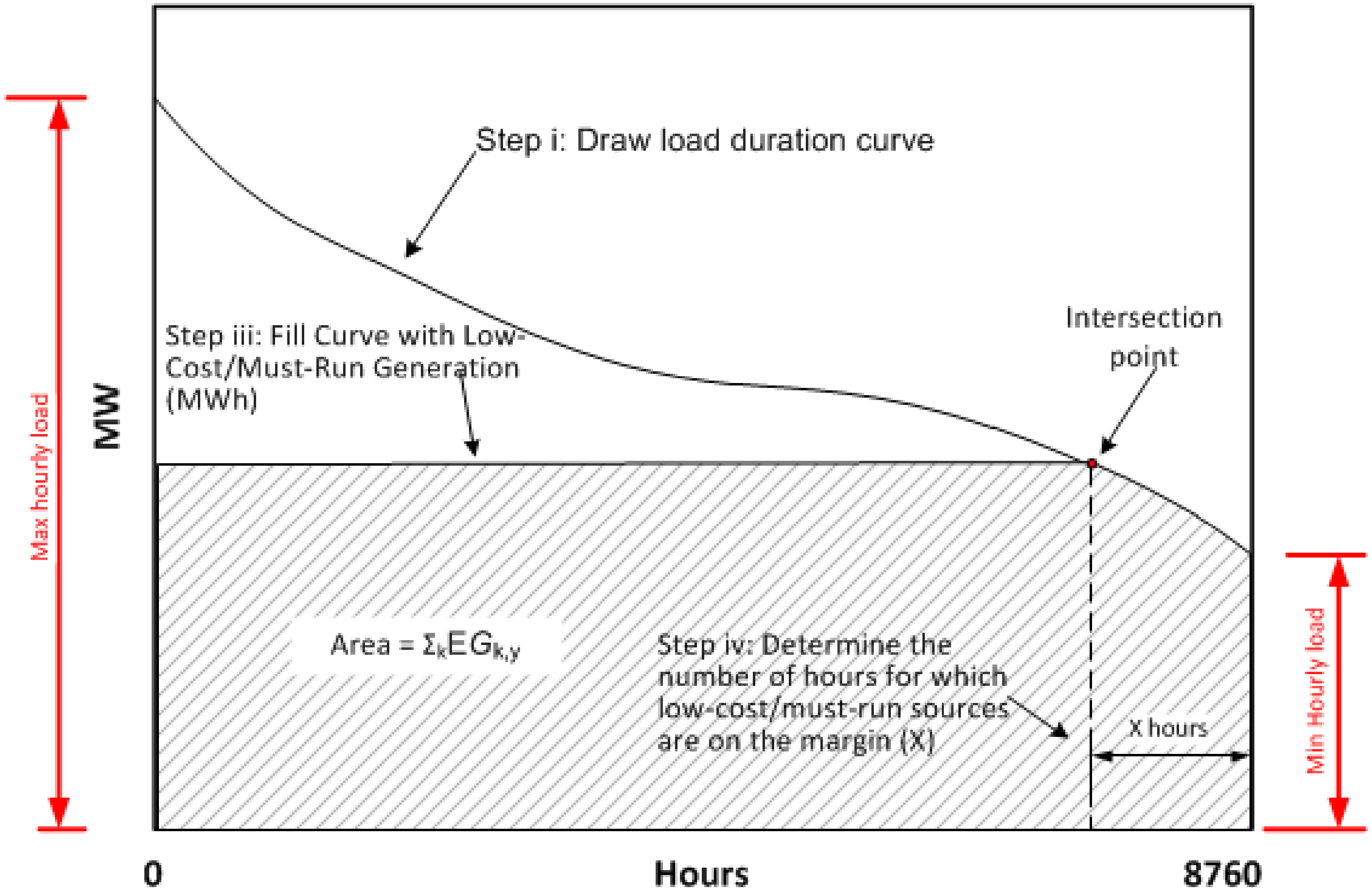
Load Duration Curve in the context of Grid Tool

Construct LDC: Arranging the load in descending order





LDC- in the context of the grid tool

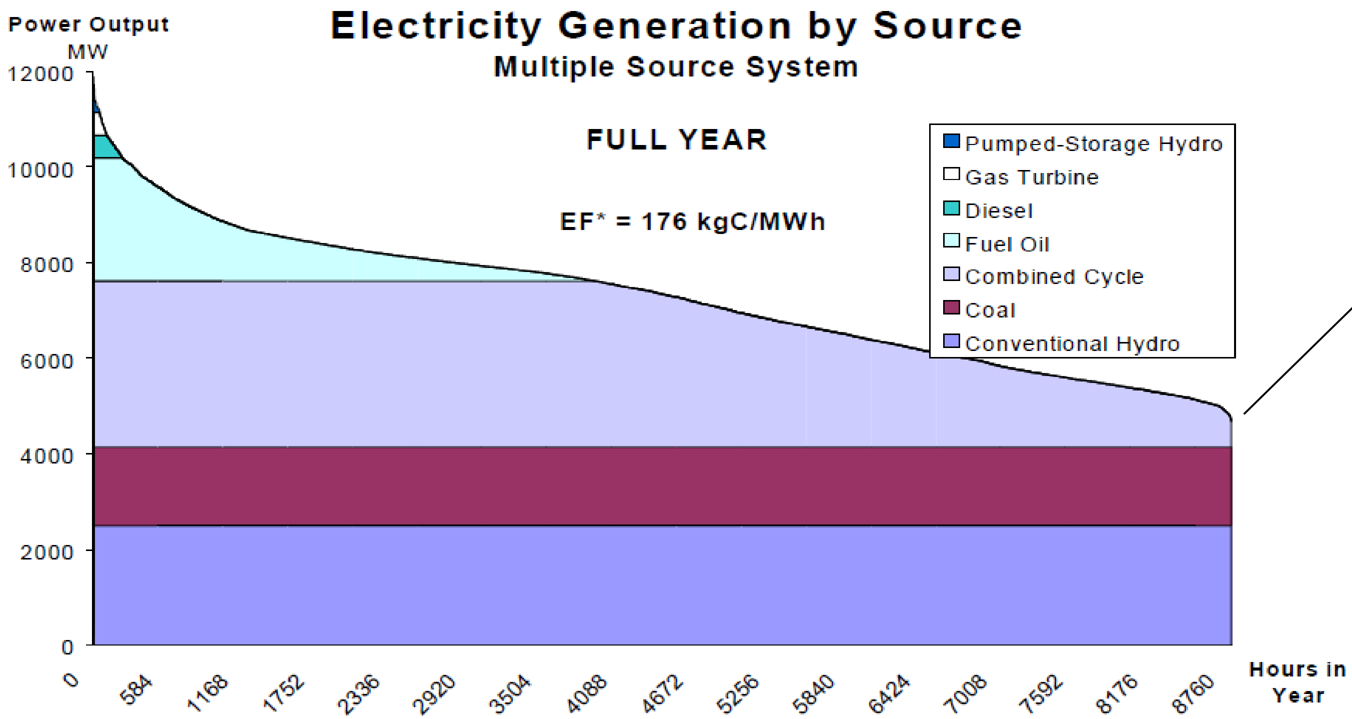


Low cost must run units: RETs, CHP with low marginal cost of electricity gen.

LDC and Dispatch data analysis

- Emission factor is determined based on the grid power units that are actually dispatched <u>at the margin</u> during each hour

Example: Typical LDC with merit order dispatch



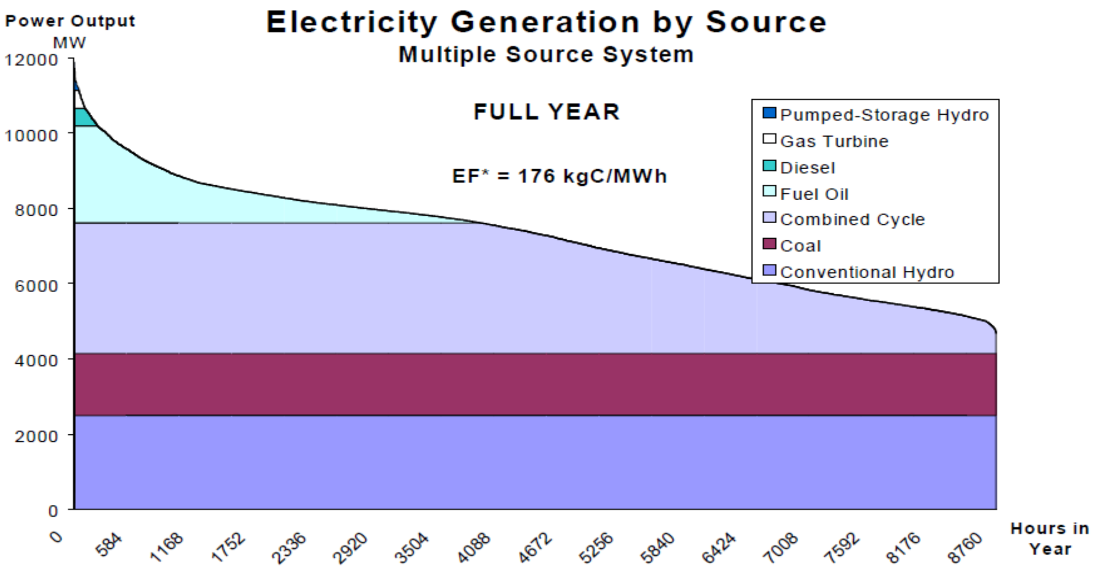
* EF is a function of the fraction of hours per year for which each source is marginal.

Here, Coal and Hydro are not on the margin

Note: Only applicable to grid system with merit order dispatch

Marginal Power Source Displacement

	Hours of Source being marginal hours	Share of Marginal Hours %	Emissions Factor kgC/MWh	Weighted Emissions Factor kgC/MWh
Conv. Hydro	0	0%	0	0
Coal Thermal	0	0%	260	0
Combined Cycle	4889	56%	137	76
Fuel Oil Thermal	3650	42%	225	94
Diesel Generation	117	1%	288	4
Gas Turbine	58	1%	257	2
Pump Stor. Hydro	46	1%	0	0
Sum	8760	100%		176



* EF is a function of the fraction of hours per year for which each source is marginal.

Simple Adjusted OM

Operating Margin: Simple Adjusted OM

Emission factor based on share and EF of:

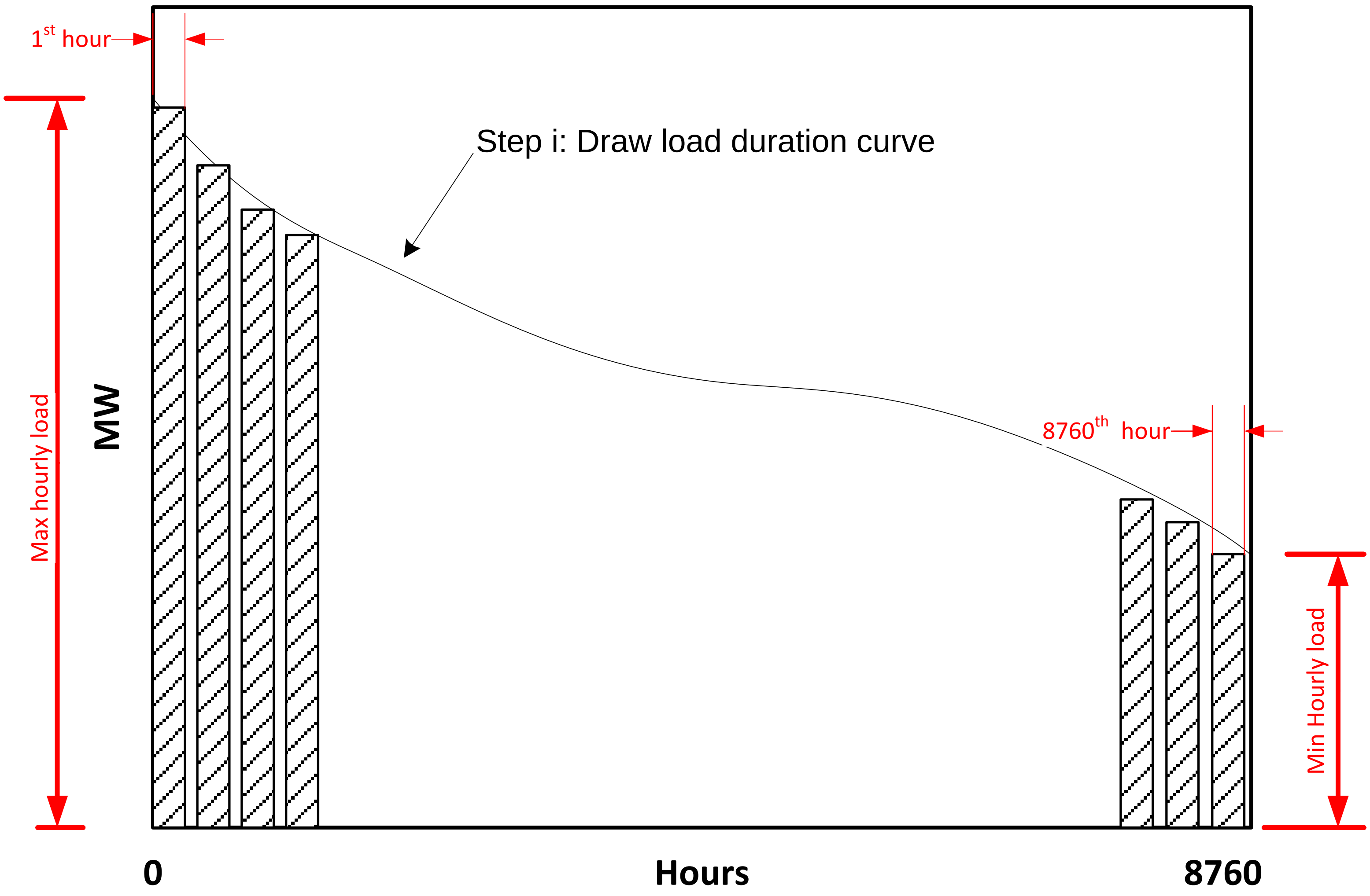
1. low cost/must run (LCMR) generation
2. Load following generation (other)

$$EF_{grid} = (1 - \lambda_y) \times EF_{other} + \lambda_y \times EF_{LCMR}$$

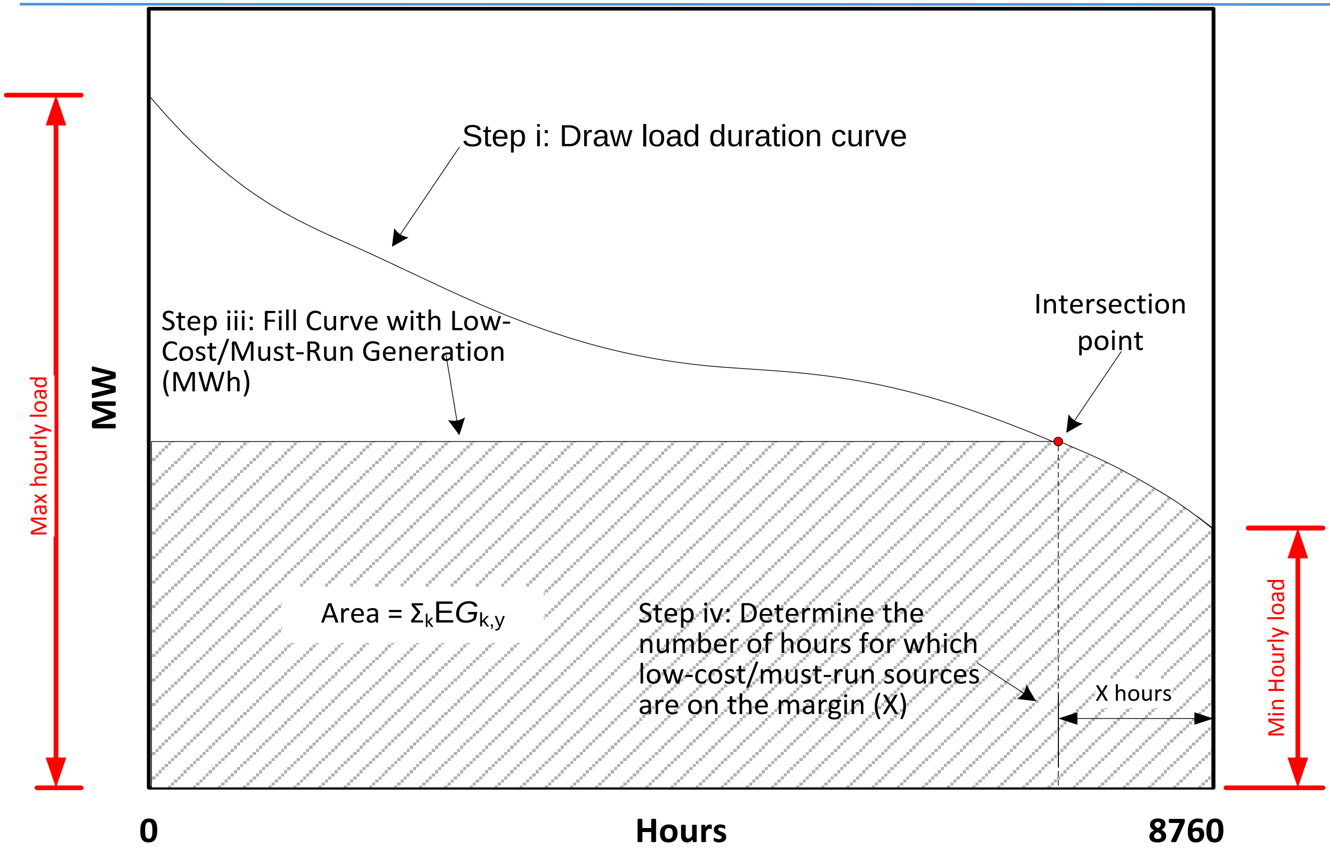
$$\lambda = \frac{x}{8760}$$

X – electricity demand met by LCMR only (hours)

Operating Margin: Simple Adjusted OM



Operating Margin: Simple Adjusted OM



$$\lambda = \frac{x}{8760}$$

$$EF_{grid} = (1 - \lambda_y) \times EF_{other} + \lambda_y \times EF_{LCMR}$$

Operating Margin: Simple Adjusted OM

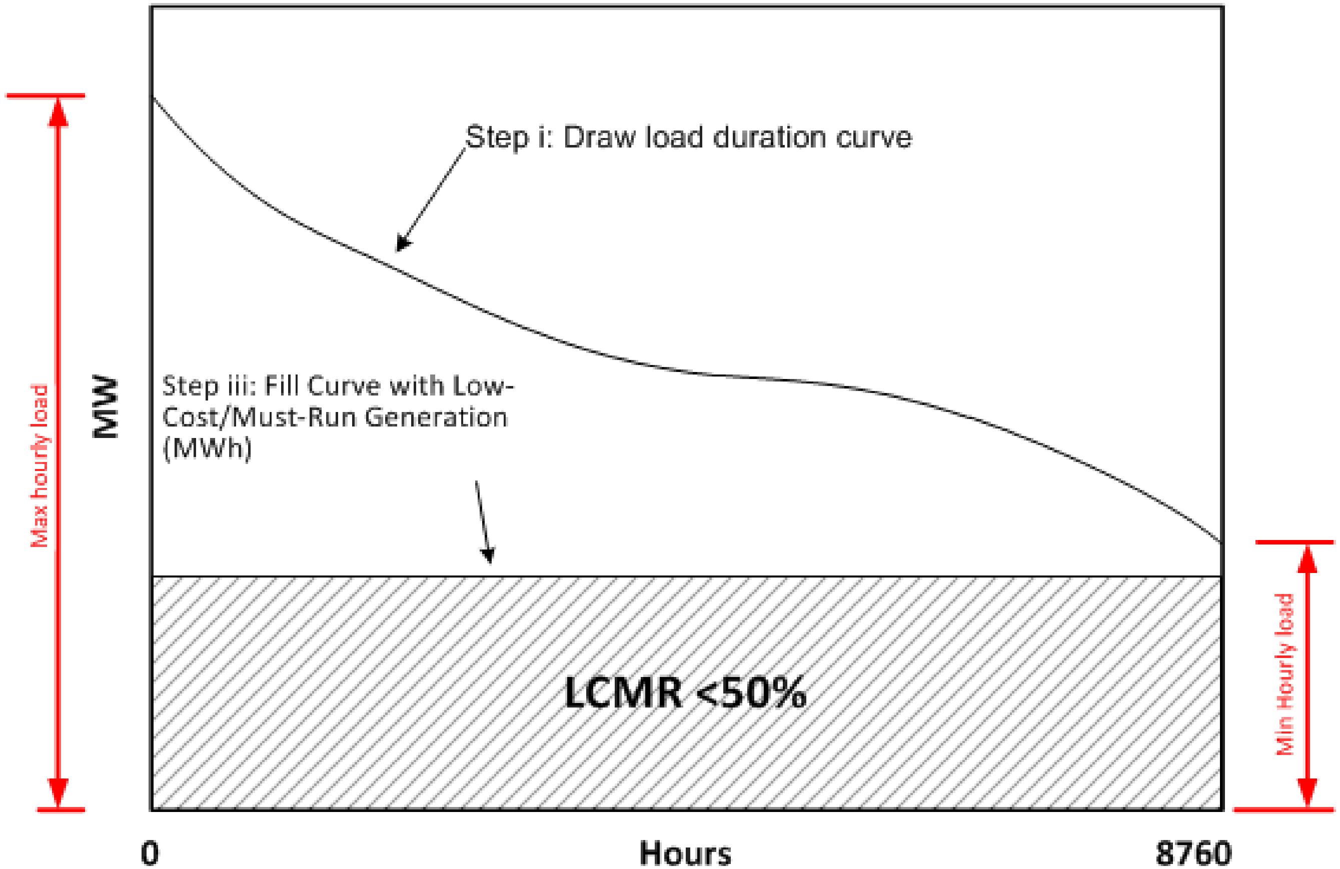
Data required:

1. Hourly load of the grid
2. Annual power generation by each power plant
3. Annual fuel consumption by each power plant or
4. Fuel type and technology

Simple OM

Operating Margin: Simple OM

Simplified case of simple adjusted OM



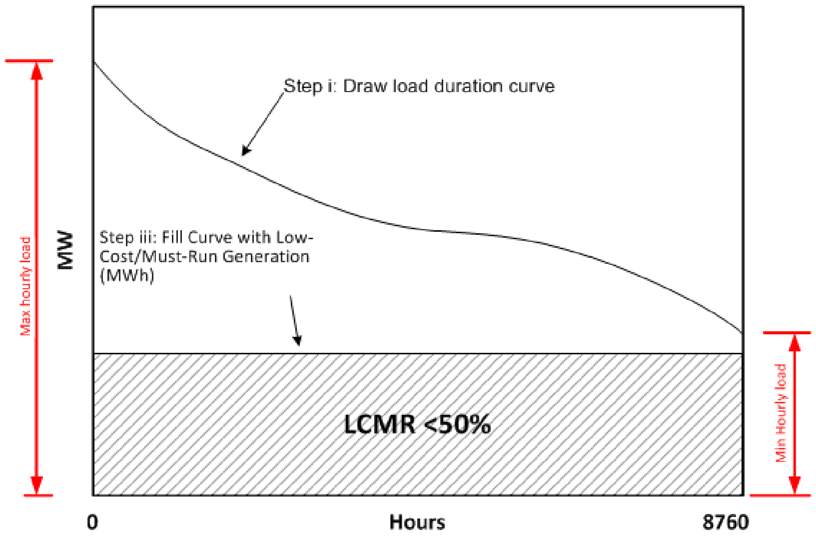
$$EF_{grid} = (1 - \lambda_y) \times EF_{other} + \lambda_y \times EF_{LCMR} \qquad \boldsymbol{\lambda_y = 0}$$

Operating Margin: Simple OM

- Share of low cost/must run (LCMR) generation **< 50%**

or

- The average LCMR load (MW) **less then** lowest annual system load



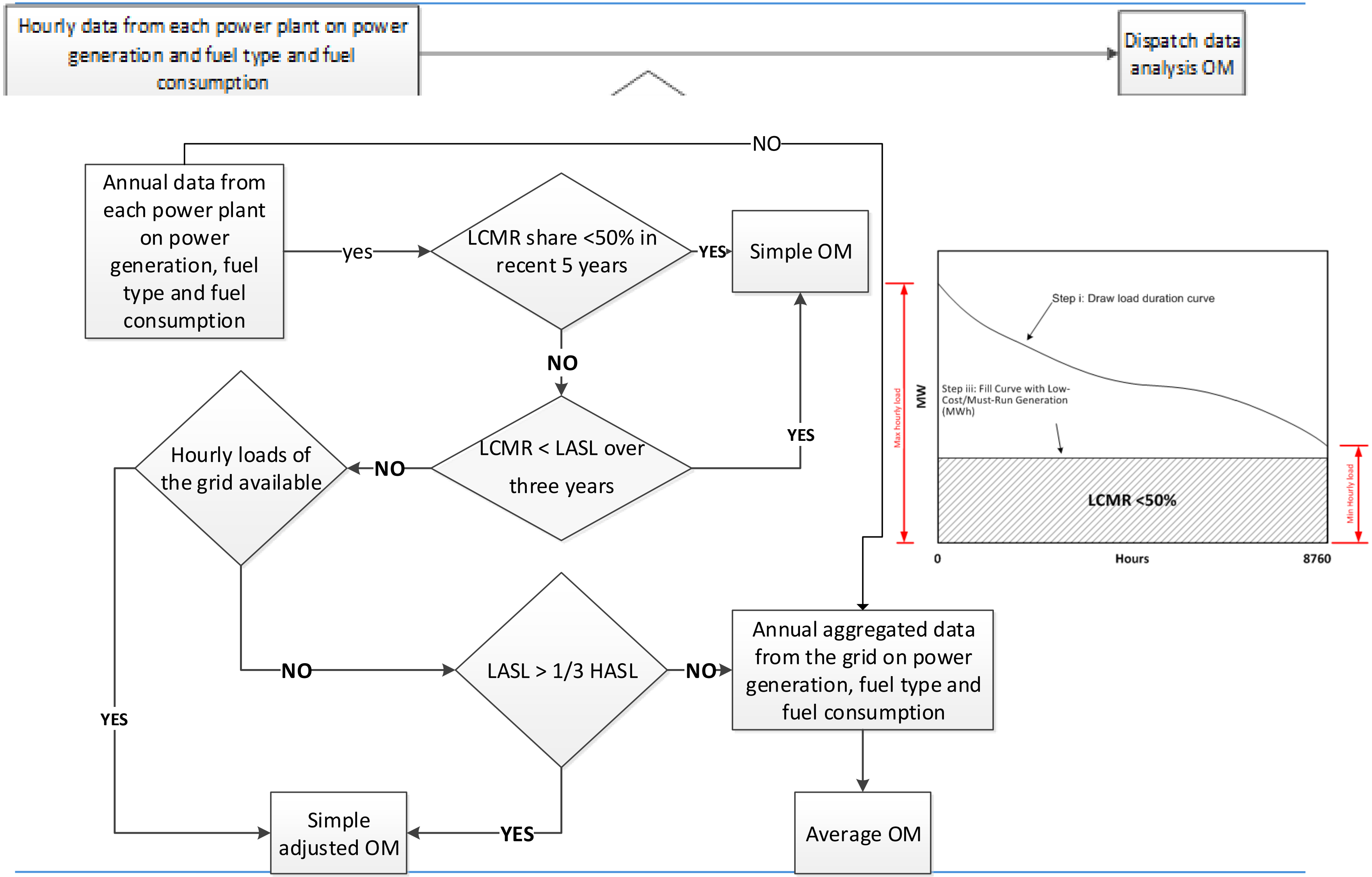
LCMR generation can be excluded from GEF determination

Operating Margin: Simple OM

Data required:

1. Annual power generation by each power plant <u>or</u> aggregated
2. Annual fuel consumption by each power plant <u>or</u> aggregated
3. Fuel type and technology
4. Annual total power generation over the last 5 years
5. Annual total power generation by LCMR over the last 5 years

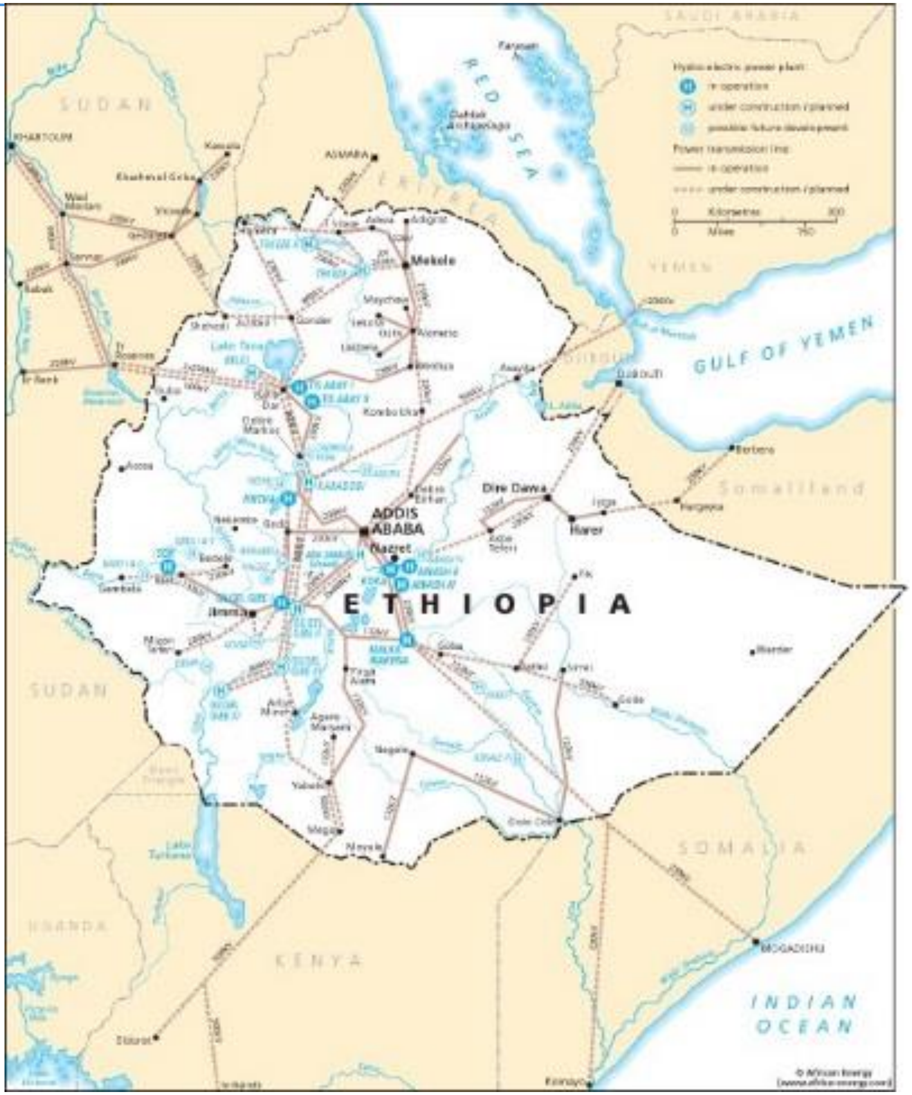
Recap: Which OM methods to use When



Application of the grid tool

Step 1: Identifying the relevant electricity systems:

1. Project electricity system
2. Connected electricity systems
3. Transmission constraints between project and connected systems



Source: Global Energy Network Institute

Application of the grid tool

Step 2: Choose whether to include off-grid power plants in the project electricity system

- **Off-grid power plant/unit** - supplies electricity to specific consumers through a power line not used by any other power plants (back-up unit for emergencies, e.g. blackouts)
- specific consumers are connected to the grid
- If 'off-grid' included :
  - Off-grid units are identified through survey

  or if in LDC/SIDSs

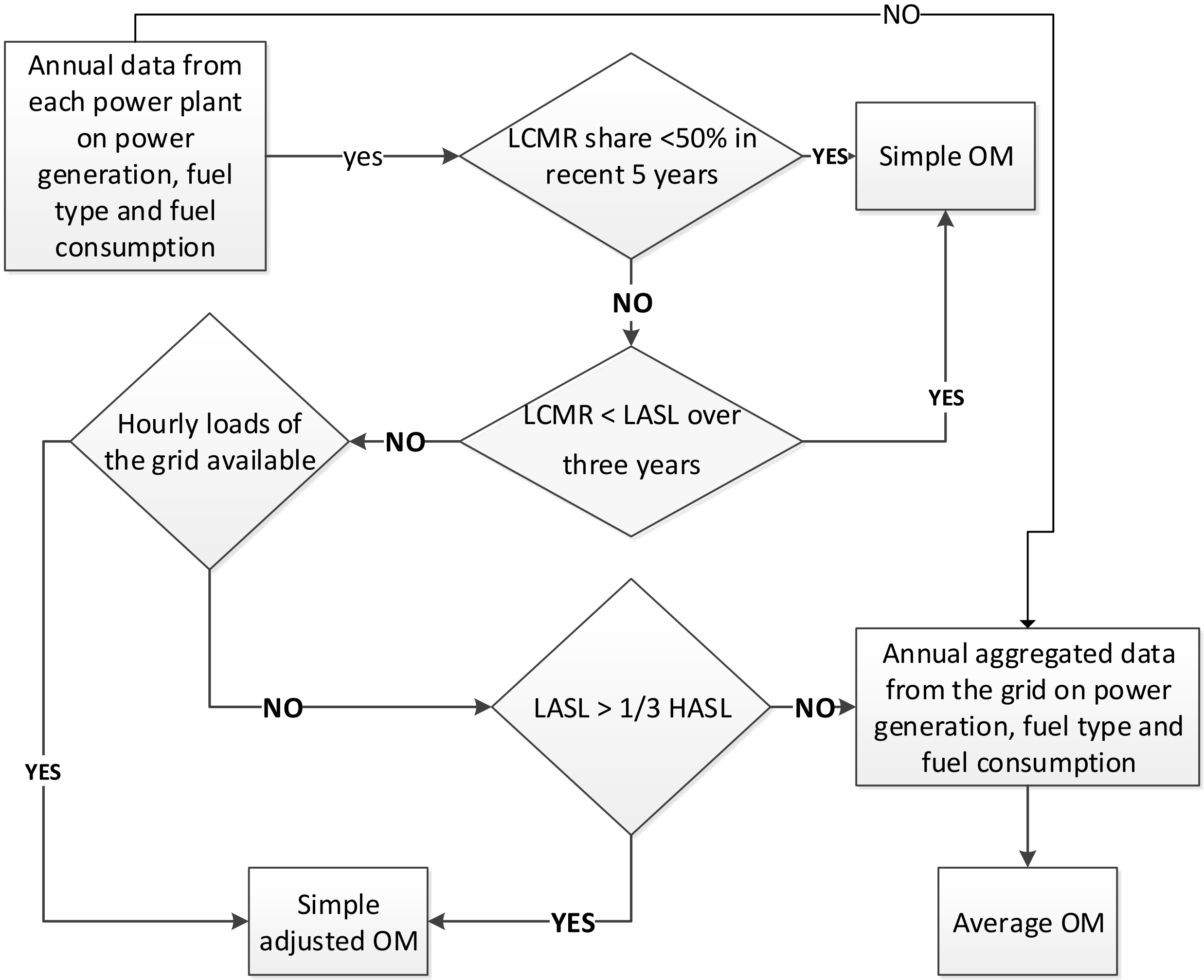
  - Simplified procedure applies

Application of the grid tool

Step 3: Select a method to determine the operating margin (OM)

Application of the grid tool

Step 3: Select a method to determine the operating margin (OM)



Application of the grid tool

Step 4: Calculate the operating margin emission factor according to the selected method

Electricity generated by power plant m

Emission factor of power plant m

$$EF_{grid} = \frac{\sum_m EG_{m,y} \times EF_{EL,m,y}}{\sum_m EG_{m,y}}$$

OM Emission factor of the grid

Total electricity generated by the grid

Application of the grid tool

Step 4: Calculate the operating margin emission factor according to the selected method

Fuel consumption of power plant m

Net calorific value of fuel i

Emission factor of fuel

$$EF_{EL,m,y} = \frac{\sum_i FC_{i,m,y} \times NCV_{i,y} \times EF_{CO2,i,y}}{EG_{m,y}}$$

Emission factor of power plant m

Application of the grid tool

Step 4: Calculate the operating margin emission factor according to the selected method

Emission factor of fuel

Conversion MWh ->GJ

$$EF_{EL,m,y} = \frac{EF_{co2,m,i,y} \times 3.6}{\eta_{m,y}}$$

Emission factor of power plant m

Efficiency of technology

Application of the grid tool

Step 4: Calculate the operating margin emission factor according to the selected method

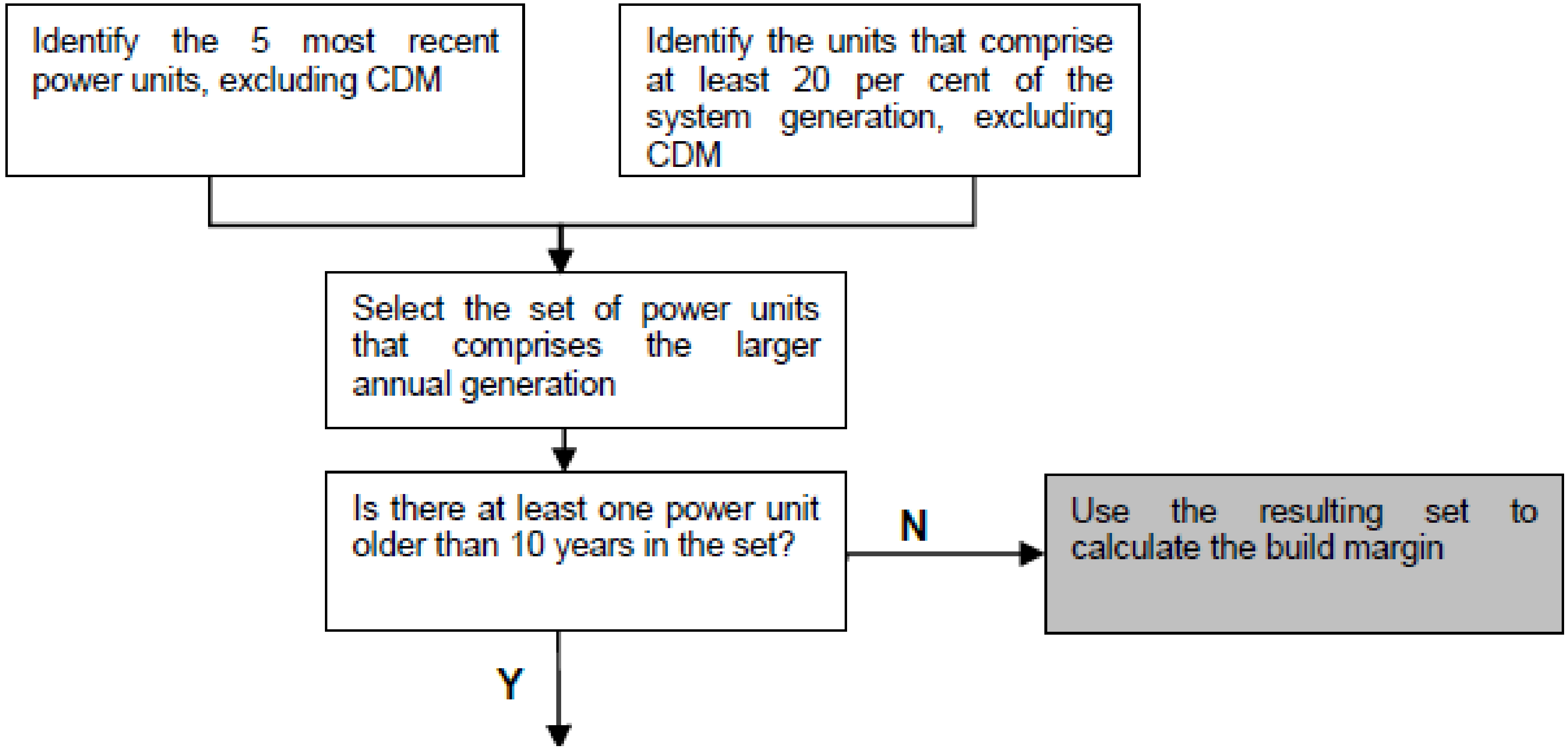
Data vintage:

1. Ex ante option - 3-year generation-weighted average
2. Ex post option – EF updated annually

- Simple OM, Simple Adjusted OM, Average OM – any data vintage
- Dispatch data analysis OM – ex post

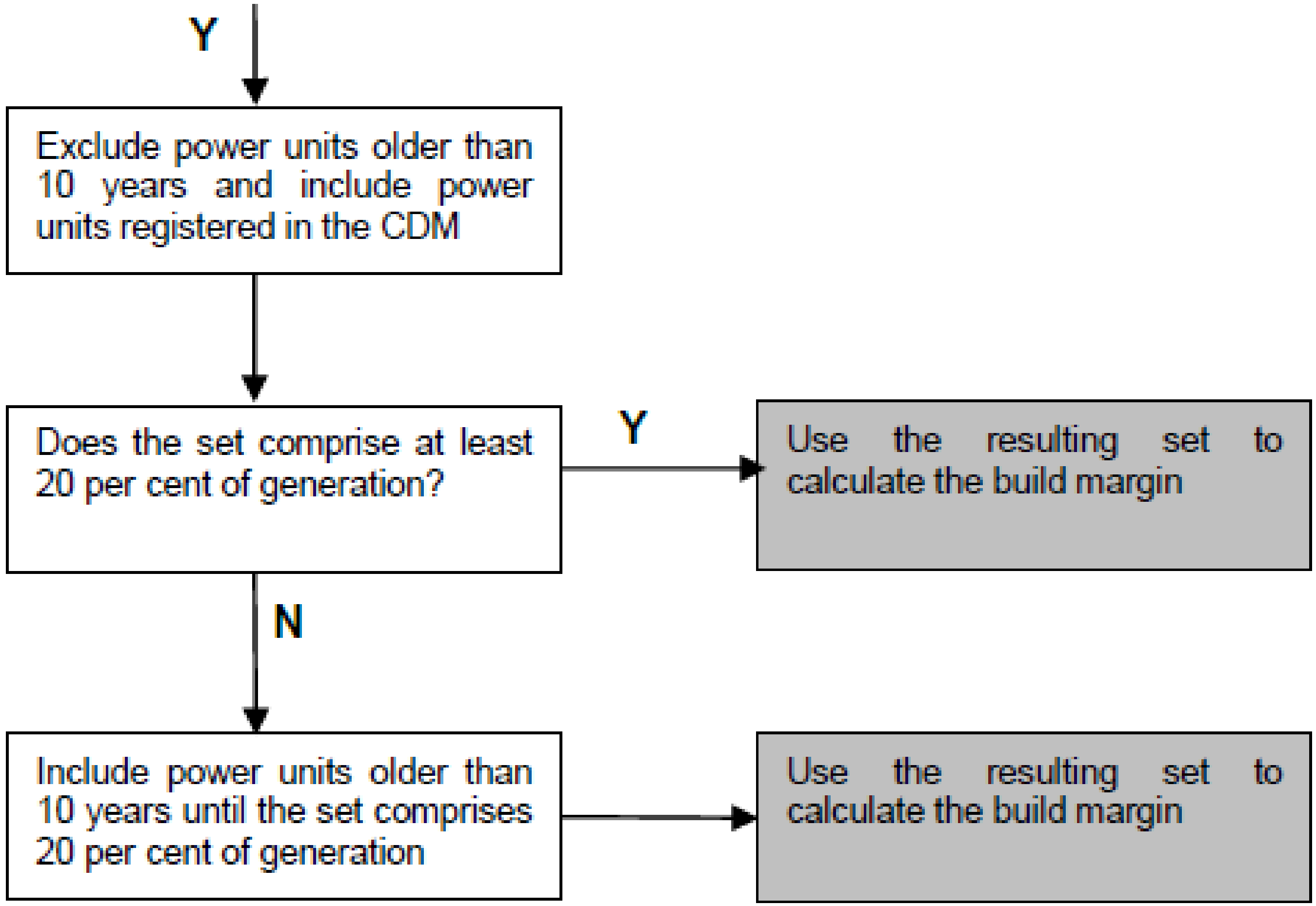
Application of the grid tool

Step 5: Calculate the build margin (BM) emission factor



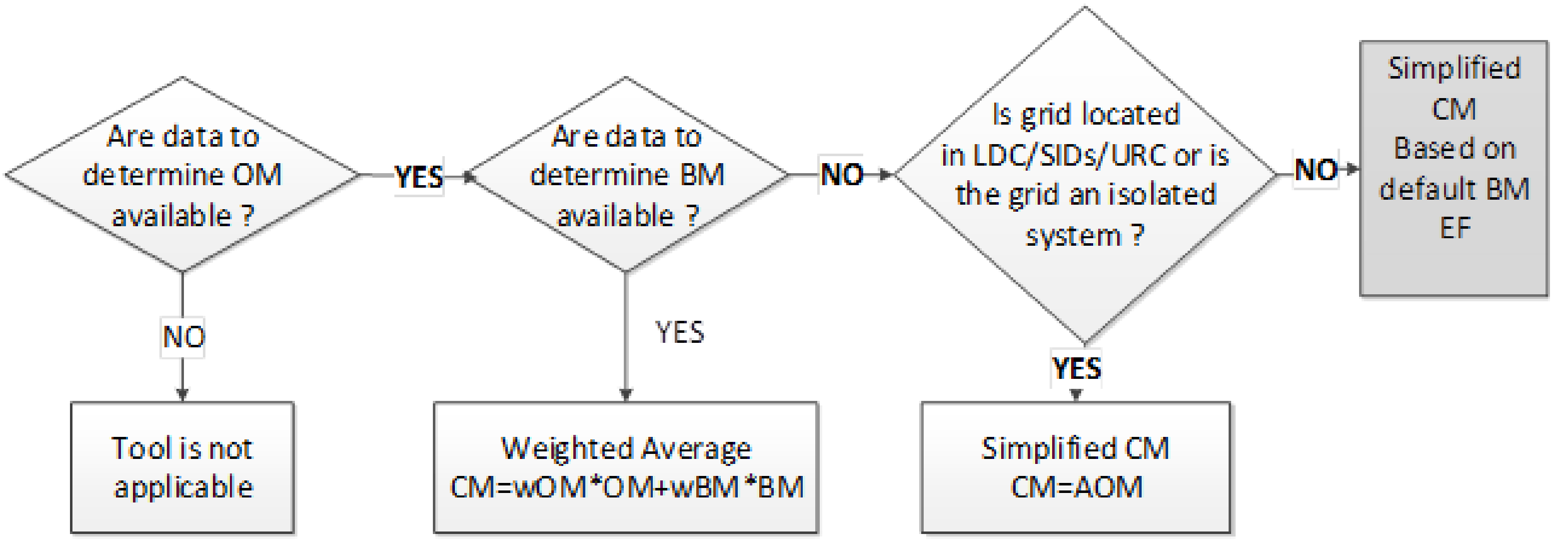
Application of the grid tool

Step 5: Calculate the build margin (BM) emission factor



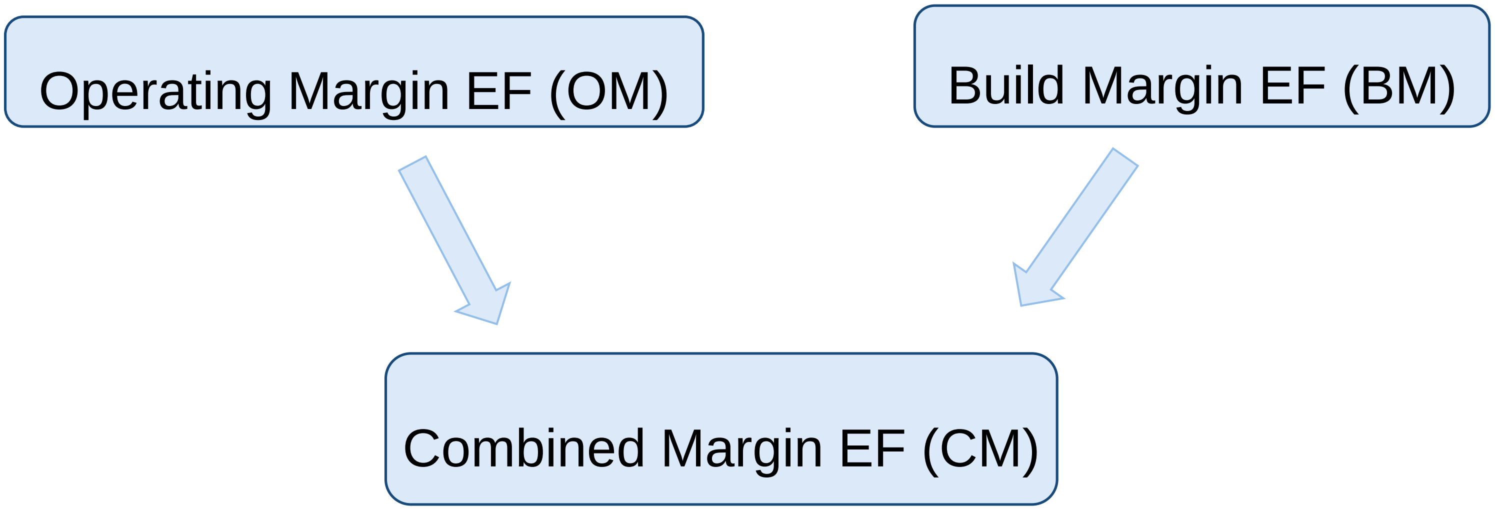
Application of the grid tool

Step 6: Calculating the combined margin (CM) emission factor



Application of the grid tool

Step 6: Calculating the combined margin (CM) emission factor



CM = w x OM + y x BM (w +y =100%)

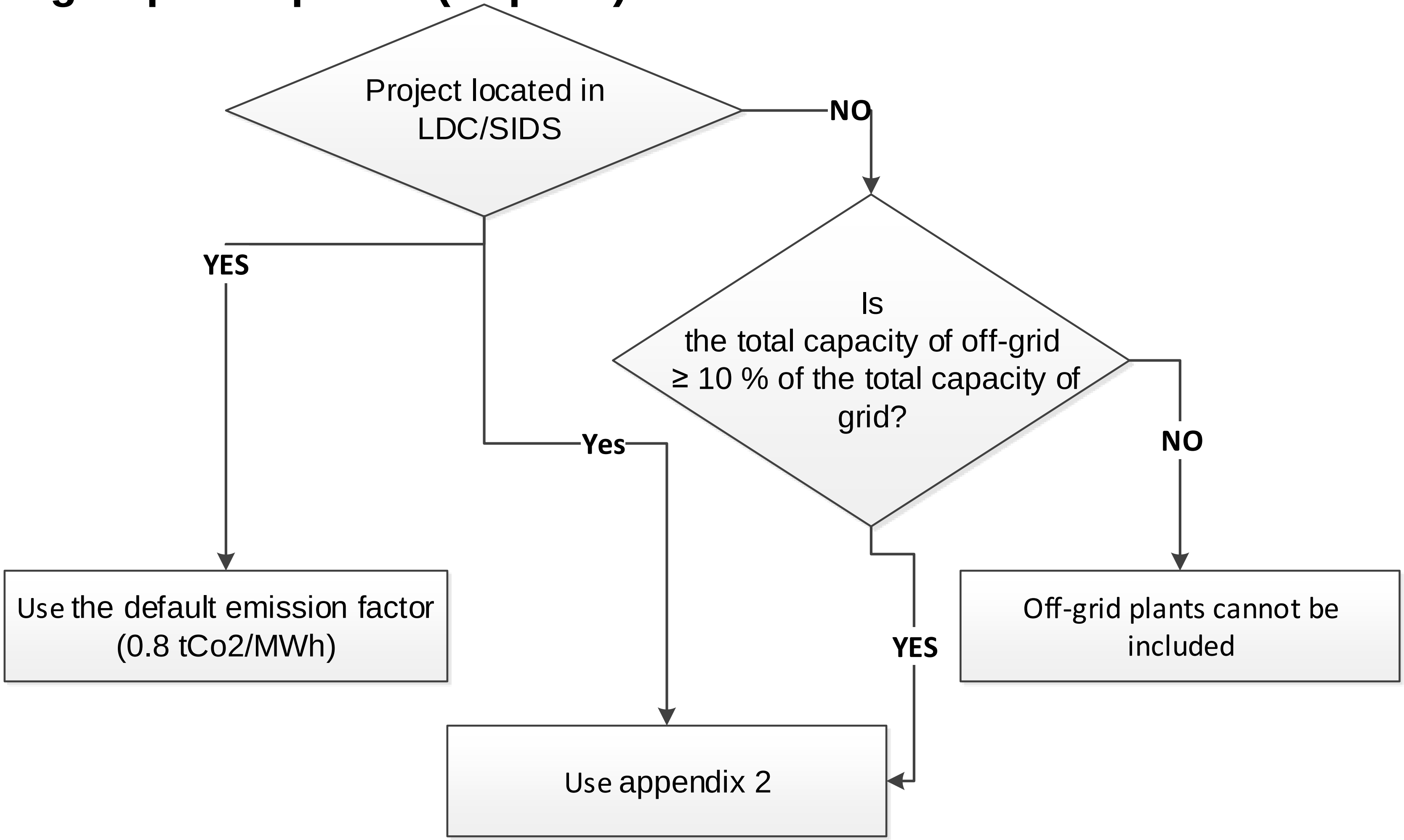
w = 75% and y= 25% (Wind & Solar)

w = 50% and y= 50% (Other projects - hydro, fossil fuel)

Simplified Options

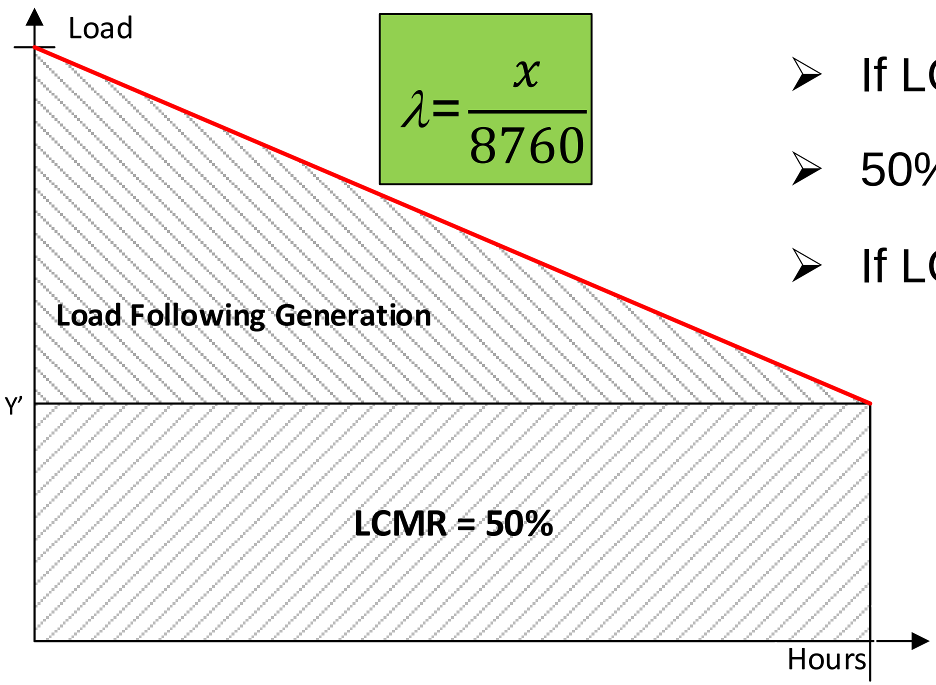
Simplified Options

Off-grid power plants (Captive)



Simplified Options

Simple Adjusted OM



$$\lambda = \frac{x}{8760}$$

- If LCMR <50%, then λ_y =0
- 50%< LCMR< 100% λ_y= default values
- If LCMR = 100%, then λ_y =1

share of LCMR	lambda
99.87% to100.00%	1
99.50% to 99.87%	0.95
98.87% to 99.50%	0.9
97.98% to 98.87%	0.85
96.85% to 97.98%	0.8
95.47% to 96.85%	0.75
93.83% to 95.47%	0.7
91.94% to 93.83%	0.65
89.80% to 91.94%	0.6
87.41% to 89.80%	0.55
84.76% to 87.41%	0.5
81.86% to 84.76%	0.45
78.72% to 81.86%	0.4
75.32% to 78.72%	0.35
71.66% to 75.32%	0.3
67.76% to 71.66%	0.25
63.60% to 67.76%	0.2
59.20% to 63.60%	0.15
54.54% to 59.20%	0.1
50% to 54.54%	0.05
0% to 50%	0

Condition:

If Min load= 33% of Max load over 5 years

Simplified Options

Simplified Combined Margin EF

- **Conditions**:
  - Data for BM is not available
  - RE share ≤ 20%
- **Use Default BM EF** depends on availability of NG
  - BM = **0.326** tCO_2/MWh (no NG used), else
  - BM = **0.568** tCO_2/MWh
- **Determine Simplified CM** = w x OM + y x BM (w +y =100%)

  w = 75% and y= 25% (Wind & Solar); w = 50% and y= 50% (Other projects - hydro, fossil fuel

Simplified Options

Simplified Combined Margin EF

- **Conditions:**
  - Data for BM is not available
  - RE share ≥ 20%
- Apply default BM EF = 0
- **Determine Simplified CM** = w x OM + y x BM (w +y =100%)

  w = 75% and y= 25% (Wind & Solar); w = 50% and y= 50% (Other projects - hydro, fossil fuel

Simplified Options

Simplified Combined Margin EF [LDCs/SIDS/ URCs]

**** URC: Countries < 10 registered CDM projects***

- **<u>Conditions</u>:**
  - Data for BM is not available
  - If **LDCs/SIDS/ URCs**
- **Apply** weight for BM= 0
- Determine Simplified CM = w x OM + y x BM (w +y =100%)
  - w = 100% and y= 0%
  - OM = Average OM

QUIZ

1. Go to menti.com
2. Type Code ….

Data requirements

KEY DATA REQUIREMENTS TO DETERMINE GEF

	Dispatch data OM	Simple adjusted OM	Simple OM	Average OM	Build margin
Power generation per plant		✓	✓		✓
Power generation aggregated			✓	✓	
Fuel consumption per plant		✓	✓		✓
Fuel type and technology		✓	✓		✓
Fuel consumption aggregated			✓	✓	
Hourly power generation and fuel consumption per plant	✓				
Hourly load of the grid		✓			
Date of commissioning of power plants/units					✓

Data requirements

Electricity generation (MWh)

- Net electricity generation by power plant provided by utility, or government, other official publication
- Hourly values (dispatch analysis OM)
- One or three most recent year (Simple OM, Simple adjusted OM, Build Margin)

Data requirements

Fuel consumption (mass or volume unit)

- Fuel consumed by power plant provided by utility, or government, other official publication
- Hourly values (dispatch analysis OM)
- One or three most recent year (Simple OM, Simple adjusted OM, Build Margin)

Data requirements

Net calorific value (GJ/mass or volume unit)

<u>Source:</u>

- Fuel supplier
- Regional or national average values
- IPCC default values (Table 1.2 of Chapter 1 of Vol. 2 (Energy) of the 2006 IPCC Guidelines on National GHG Inventories)

Data requirements

CO_2 emission factor of fuel (GJ/mass or volume unit)

<u>Source:</u>

- Fuel supplier
- Regional or national average values
- IPCC default values (table 1.4 of Chapter1 of Vol. 2 (Energy) of the 2006 IPCC Guidelines on National GHG Inventories)

QUIZ

1. Go to menti.com
2. Type Code ….

Recurring issues on development of grid emission factor

Common Issues

- **Delineation of the power system**
  - Transmission constraints not always being checked properly
  - Shared energy resources (e.g., hydro)
  - Name convention for power units is not consistent
- **Co-generation units**
  - Fuel consumption is not allocated. Leads to enormously high EF
- **Fuel properties**
  - Sources are not recorded
  - Units are not properly converted

Data quality issues and QA/QC aspects

CLEAN DEVELOPMENT MECHANISM

CDM-EB66-A49-GUID

Guideline

Quality assurance and quality control of data used in the establishment of standardized baselines

Version 02.0

Key lessons learned on quality control/quality assurance of data

- No assessment report: No assessment report required for the SBs where no data collection/processing required (e.g. LFG destruction SBs).
- Data templates: Very important for DNA to get converse with. This decides the quality of data collected.
- Stakeholder consultation and transparency: There can be various means adopted for this including direct meetings, inviting written comments, communication through DNA webpage etc.
- QA/QC system: Although recommended to be available in documented form, minimum requirement is that DNA should be able to justify the adherence to quality objectives of QA/QC guideline.
- QC report: QC report is the key for DNA to explain how they comply with QA/QC objectives.

Examples

Examples

Country	Status	Combined margin EF (tCO_2/MWh)
Belize	approved	0.1521
The Dominican Republic	approved	0.4887
Grenada, Grenada	approved	0.634
Grenada, Carriacou	approved	0.675
Grenada, Petit Martinique	approved	0.890
St Lucia	WIP	
Antigua and Barbuda	WIP	
St Vincent and Grenadines	WIP	
Haiti	WIP	

Examples

Grenada. Data

- Three islands
  - Grenada
  - Carriacou
  - Petit Martinique
- Three isolated grids
- One diesel per island
- Fuel consumption
- Electricity generation
- Commissioning dates <u>not available</u>

Examples

Grenada. Analysis

- Delineation of the system: Three islands – three GEFs
- Method for OM:
  - One power plant - dispatch analysis OM not applicable
  - No RE – LCMR =0%
  - Simple OM or Average OM applies
- Data for BM not available
- Country status - SIDS: simplified option for CM applies

Examples

Grenada. Application

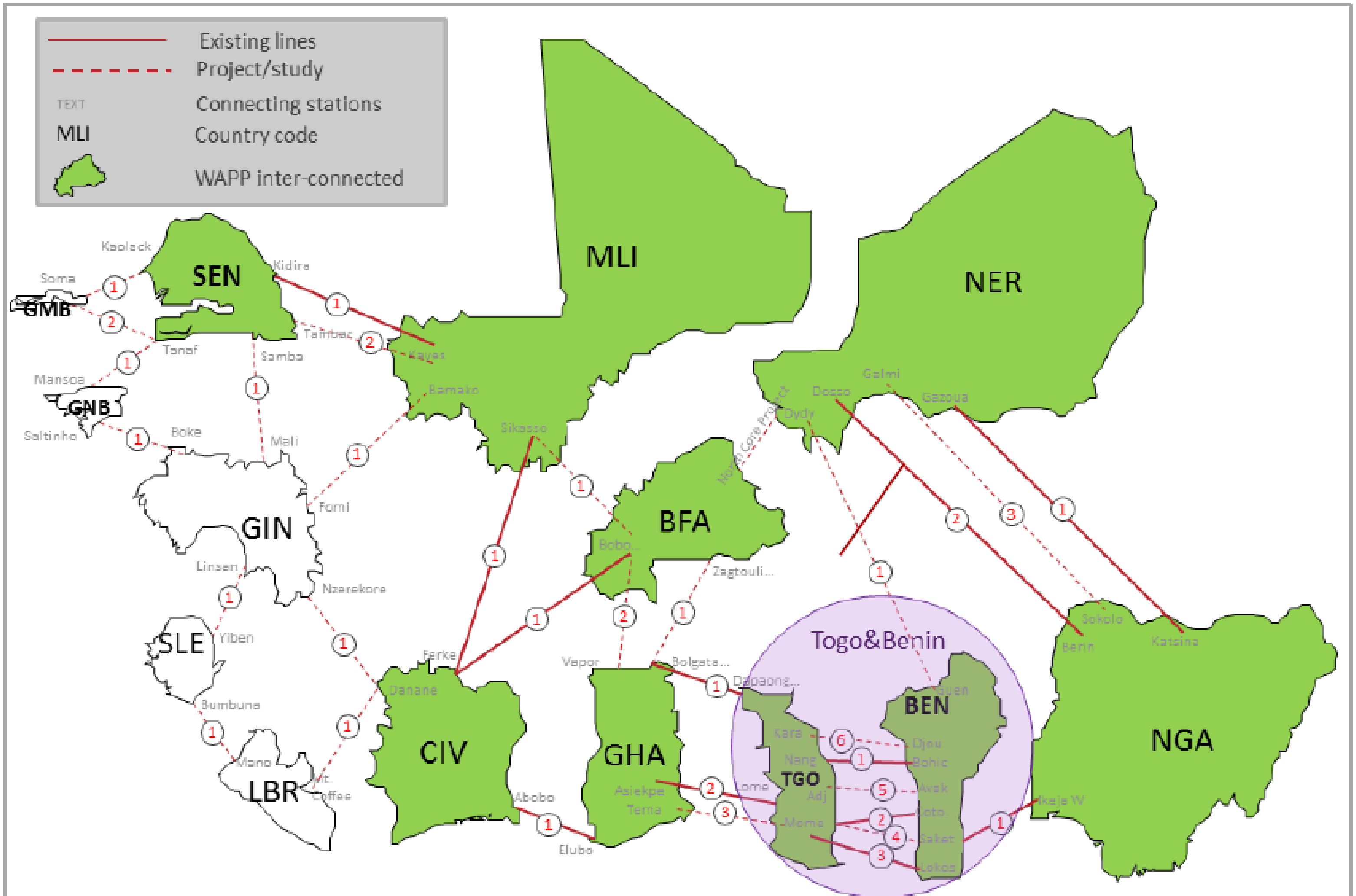
Power Plant *m*	Electric System (Island)	Year	Electricity Generated (GWh) A	Fuel consumed (Gg) B	Fuel type	NCV fuel (TJ/Gg) C	$EF_{CO2, diesel}$ (tCO_2e/TJ) D	$EF_{EL, Queen's Park, y}$ (tCO_2e/MWh) E = B x C x D / A	OM 2010-2012 (average)
Queen's Park Power Plant	Grenada	2010	193.4737	40.23	Diesel	42.60	72.60	120,909	0.634
		2011	188.8839	39.05	Diesel	42.28	72.60	117,359	
		2012	185.3488	37.53	Diesel	42.40	72.60	112,799	

OM EF = 0.634 tCO2/MWh

Simplified CM = 100%*OM EF+0% * BM EF = 0.634 tCO2/MWh

Examples

West African Power Pool. Data



Examples

West African Power Pool. Data

Table 1. Generating (available) capacity (MW) within the WAPP members[a]

Country	Oil	Coal	Gas	Hydro	Total
Burkina Faso	146	0	0	23	169
Cote d'Ivoire	0	0	765	585	1,350
Gambia	49	0	0	0	49
Ghana	700	0	180	1,380	2,260
Guinea	19	0	0	95	114
Guinea-Bissau	4	0	0	0	4
Liberia	13	0	0	0	13
Mali	114	0	20	153	287
Niger	15	32	20	0	67
Nigeria	0	0	3,858	1,358	5,216
Senegal	395	0	49	68	512
Sierra Leone	44	0	0	56	100
Togo/Benin	57	0	0	65	122
Total	1,410	32	4,892	3,760	10,094

Examples

West African Power Pool. Data

Table 5. Overview of the existing interconnected transmission lines in the WAPP (WAPP Secretariat 2014)[17]

Country 1	Country 2	Line Voltage in kV	Line Capacity in MW (Aggregated)
Nigeria	Niger	132 x 2	169
Nigeria	Togo & Benin	330	686
Ghana	Togo & Benin	161 x 2	300
Ghana	Cote d'Ivoire	225	327
Cote d'Ivoire	Burkina Faso	225	327
Cote d'Ivoire	Mali	225	327
Burkina Faso	Niger	330	637
Mali	Senegal	225	100

Examples

West African Power Pool. Application

		Ivory Coast		Niger		Mali		Senegal		Burkina Faso		Benin & Togo	
	MW in 2012	line capacity (MW)	condition of 10% from the tool (Y/NO)	line capacity (MW)	condition of 10% from the tool (Y/NO)	line capacity (MW)	condition of 10% from the tool (Y/NO)	line capacity (MW)	condition of 10% from the tool (Y/NO)	line capacity (MW)	condition of 10% from the tool (Y/NO)	line capacity (MW)	condition of 10% from the tool (Y/NO)
Nigeria	5507.00			169	Y							686	Y
Ghana	550.00	327	Y									300	Y
Ivory Coast	1421.00					327	Y			327	Y		
Burkina Faso	173.75			637	Y								
Benin	0.00												
Niger	61.31												
Mali	417.45							100	Y				
Senegal	585.10												
Togo	146.38												
Benin & Togo	109.00												

Examples

West African Power Pool. Application

Table 6. WAPP trade analysis; Transmission constraint check within the WAPP interconnected network 2012-2013

Export From	Line No.	Import To	Line Voltage (kV)	Maximum load capacity (MW)	Power transmission (MWh)		Operational Load Factor		Transmission constraint check (<90%)	
					2012	2013	2012	2013	2012	2013
NGA	1	NER	132	40	151,963	160,953	43%	46%	OK	OK
NGA	2	NER	132	80	468,311	383,764	67%	55%	OK	OK
NGA	1	BEN/TGO	330	630	1,184,352	1,374,976	21%	25%	OK	OK
NER	1	NGA	132	40	0	0	0%	0%	OK	OK
NER	2	NGA	132	80	0	0	0%	0%	OK	OK
TGO/BEN	1	NGA	330	630	0	0	0%	0%	OK	OK
TGO/BEN	1	GHA	34	30	0	0	0%	0%	OK	OK
TGO/BEN	2	GHA	2x161	300	0	0	0%	0%	OK	OK
GHA	1	TGO/BEN	34	30	0	0	0%	0%	OK	OK
GHA	2	TGO/BEN	2x161	300	599,765	560,007	23%	21%	OK	OK
GHA	1	CIV	225	220	54,275	616,377	3%	32%	OK	OK
BFA	1	CIV	225	121	0	0	0%	0%	OK	OK

Examples

West African Power Pool. Application

	2009	2010	2011	2012	2013	AVG
Total WAPP	32,308,569	37,511,738	40,325,218	43,815,473	43,456,615	39,483,523
LCMR (GWh)	10,918,990	10,310,250	9,819,152	9,647,729	9,124,477	9,964,119
Share of LCMR (%)	33.80%	27.49%	24.35%	22.02%	21.00%	25.24%
5yr average Low cost / must run:	25.24%	Simple OM Possible?		YES		

Examples

West African Power Pool. Application

213 power plants/units for 2013

Years	2011	2012	2013	Period 2011-2013
WAPP Connected Total Yearly Energy Production for OM	30,506,066	34,167,745	34,332,138	99,005,949
WAPP Connected Total Yearly emissions for OM (tCO_2)	17,031,115	19,233,002	19,105,598	55,369,714
WAPP Connected Year Specific Operating Margin (Simple OM)	0.5583	0.5629	0.5565	
WAPP Connected Yearly Share of generation 2010-2013	30.81%	34.51%	34.68%	100.00%
Weighted Simple OM				**0.5593**

Examples

West African Power Pool. Application

Total Generation	39,072,991	
2013	SET 5 units	SET 20%
Total Power generation for BM (MWh)	2,099,784	7,957,852
Emissions for BM (tCO2)	792,914	4,494,026
Build Margin excl. off-grid	0.3776	0.5647
BM (tCO2/MWh)	**0.5647**	

Examples

West African Power Pool. Application

Project types	1st crediting period				
	OM	BM	CM	Wom	Wbm
Solar and Wind power project	0.5593	0.5647	**0.561**	0.75	0.25
Other renewables	0.5593	0.5647	**0.562**	0.5	0.5
Other projects	0.5593	0.5647	**0.562**	0.5	0.5

Project types	2nd or 3rd crediting period				
	OM	BM	CM	Wom	Wbm
Solar and Wind power project	0.5593	0.5647	**0.561**	0.75	0.25
Other renewables	0.5593	0.5647	**0.563**	0.25	0.75
Other projects	0.5593	0.5647	**0.563**	0.25	0.75