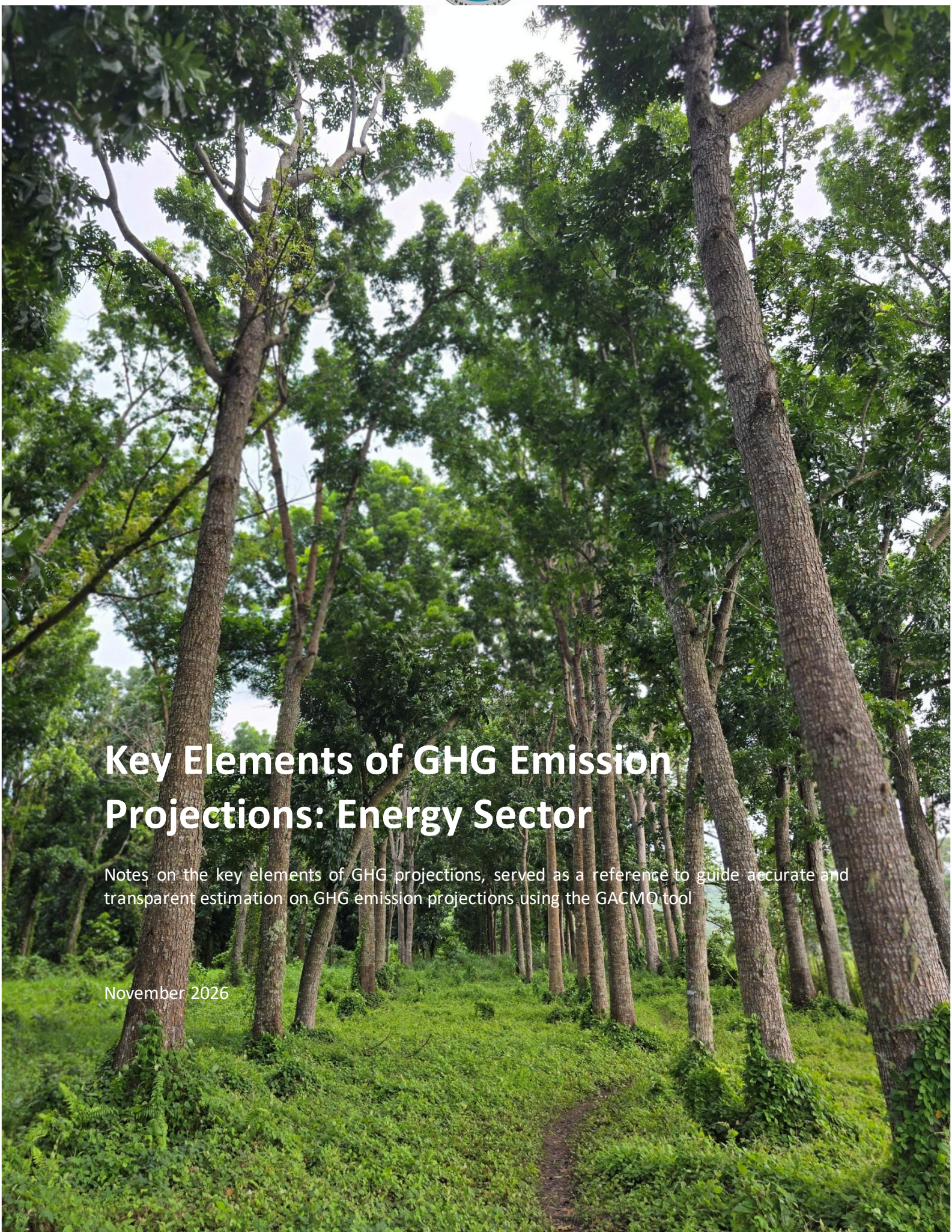


Key Elements of GHG Emission Projections: Energy Sector

Notes on the key elements of GHG projections, served as a reference to guide accurate and transparent estimation on GHG emission projections using the GACMO tool

November 2026

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Output J

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Abbreviations and Acronyms

Term	Meaning
AD	Activity Data
BTR	Biennial Transparency Report
CTF	Common Tabular Formats
EF	Emission factor
GACMO	Greenhouse Gas Abatement Cost Model
GWP	Global Warming Potential
MAC curve	Marginal Abatement Cost curve
MPGs	Modalities, Procedures and Guidelines
NCV	Net Calorific Value
PLTA	Public Land Transport Authority
SFC	Specific Fuel Consumption
VBOS	Vanuatu Bureau of Statistics
WOM / WEM / WAM	Without / With / With Additional Measures

1. Understanding GHG Projections and Their Importance

A GHG projection is a forward-looking estimate of national emissions under a defined set of assumptions about economic activity, technology and policy. Unlike the inventory, which measures what has happened, a projection describes what could happen, so its credibility rests on transparent assumptions rather than on measured data.[1]

For the energy sector, projections are used to:

- show the expected effect of implemented and planned mitigation measures, including NDC energy commitments;[2]
- indicate the gap between projected emissions and the NDC target (projections are not used to assess progress towards the NDC unless the Party has identified a reported projection as its baseline);[3]
- inform energy planning, investment priorities and climate finance proposals;
- meet reporting requirements under the Enhanced Transparency Framework (ETF).[4]

1.1 The three standard scenarios

Table 1. Projection scenarios used in ETF reporting

Scenario	What it includes	Notes
Without measures (WOM)	Emissions trajectory with no mitigation policies, usually from a chosen start year[5]	Optional under the ETF. Often called the baseline or business-as-usual (BAU) in GACMO.[6]
With measures (WEM)	Effect of policies and measures that are already implemented or adopted[7]	Required for Parties that report projections; developing countries needing flexibility are encouraged, rather than required, to report projections.[8]
With additional measures (WAM)	WEM plus policies and measures that are planned (e.g., conditional NDC measures)[9]	Optional, but useful to show the conditional NDC pathway.[10]

[1] Wartmann et al., 2021, pp. 8–10; Decision 18/CMA.1, annex, para. 93.
[2] Decision 18/CMA.1, annex, para. 93.
[3] Decision 18/CMA.1, annex, para. 93.
[4] Decision 18/CMA.1, annex, paras. 92–102.
[5] Wartmann et al., 2021, p. 10; Decision 18/CMA.1, annex, para. 94.
[6] Desgain et al., 2023, p. 16.
[7] Wartmann et al., 2021, p. 10; Decision 18/CMA.1, annex, para. 94.
[8] Decision 18/CMA.1, annex, paras. 92 and 94.
[9] Wartmann et al., 2021, p. 10; Decision 18/CMA.1, annex, para. 94.
[10] Decision 18/CMA.1, annex, para. 94.

2. Reporting requirements (ETF / MPGs)

Projections are reported in the BTR under Section III.F of the Modalities, Procedures and Guidelines (MPGs), decision 18/CMA.1, paragraphs 92–102), using the common tabular formats adopted in decision 5/CMA.3. The main requirements are summarised below.[11]

Table 2. Summary of MPG requirements for GHG projections

Element	Requirement (summary)
Scenarios	WEM projection required; WOM and WAM may be reported. Developing countries needing flexibility are encouraged to report projections.[12]
Starting point	Projections start from the most recent inventory year.[13]
Time horizon	At least 15 years beyond the next year ending in 0 or 5. Developing countries needing flexibility may instead extend to at least the end point of their NDC.[14]
Coverage	By sector and by gas, plus the national total, using the same metric as the inventory (AR5 100-year GWPs).[15]
Presentation	Presented relative to actual inventory data for preceding years, in graphical and tabular formats.[16]
Methodology	Describe the models/approaches used, key assumptions and parameters (e.g., GDP, population, fuel prices), and changes since the previous report.[17]
Sensitivity analysis	Should be provided: show how results change when key assumptions change, with a brief explanation of the methods and parameters used.[18]
Flexibility	Developing countries may report using a less detailed methodology or coverage, explaining the capacity constraint and plans to improve.[19]

[11] Decision 18/CMA.1, annex, chapter III.F; Decision 5/CMA.3, annex II, sections 7–9.
[12] Decision 18/CMA.1, annex, paras. 92 and 94.
[13] Decision 18/CMA.1, annex, para. 95.
[14] Decision 18/CMA.1, annex, para. 95.
[15] Decision 18/CMA.1, annex, paras. 37 and 98.
[16] Decision 18/CMA.1, annex, paras. 99 and 101.
[17] Decision 18/CMA.1, annex, para. 96(a)–(c).
[18] Decision 18/CMA.1, annex, para. 96(d).
[19] Decision 18/CMA.1, annex, paras. 6 and 102.

3. Energy sector emission sources to project

Projection categories should mirror the inventory structure. For Vanuatu the main energy sources are fuel combustion for electricity and transport, with smaller contributions from other sectors.[20]

Table 3. Energy sector emission sources (IPCC Sector 1) to be projected

IPCC code	Category	Main fuels	Main projection driver
1.A.1.a	Public electricity generation (concession and utility grids)	Diesel; biofuel (coconut oil)	Electricity demand, renewable share, diesel efficiency
1.A.2	Manufacturing and construction	Diesel, LPG	Industrial/construction, GDP
1.A.3.a	Domestic aviation	Jet kerosene, avgas	Domestic passengers / flights, tourism
1.A.3.b	Road transportation	Gasoline (ULP/Mogas), diesel	Vehicle fleet, population, GDP per capita
1.A.3.d	Domestic navigation (inter-island shipping)	Diesel	Inter-island trade and passengers
1.A.4.a	Commercial / institutional	Diesel, LPG	Services GDP, tourism
1.A.4.b	Residential	LPG, kerosene, fuelwood	Households, urbanisation, electrification
1.A.4.c	Agriculture / forestry / fishing	Diesel, gasoline	Agricultural output, fishing fleet
Memo	International bunkers; CO_2 from biomass	Jet kerosene, marine fuels; wood, coconut oil	Reported separately, not in totals

Gases: CO_2 dominates energy emissions. CH_4 and N_2O from combustion are small but must be included for completeness, especially for residential fuelwood (CH_4) and road transport (N_2O).[21]

4. Data requirements

Good projections need three layers of data: a reliable base year, drivers of future activity, and parameters describing technology and mitigation measures.[22]

4.1 Base-year data

- Fuel consumption by fuel and IPCC category for the latest inventory year (from the national inventory / energy balance).[23]
- Electricity generation by source (diesel, biofuel, solar, wind, hydro) and by grid, plus off-

[20] Decision 18/CMA.1, annex, para. 98; Government of Vanuatu, 2016.
[21] IPCC, 2006, Vol. 2, Ch. 2 and 3.
[22] Wartmann et al., 2021, pp. 20–21.
[23] Decision 18/CMA.1, annex, para. 95; Desgain et al., 2023, pp. 6 and 13.

grid supply.[24]

- Net electricity sales by customer class, and transmission and distribution losses.
- Emission factors and net calorific values consistent with the inventory.[25]

4.2 Socio-economic drivers

Table 4. Socio-economic drivers and possible data sources

Driver	Used to project	Possible source
Population and households	Residential energy, road transport	VBOS census and projections
GDP and sectoral value added	Industry, commercial, overall demand	VBOS, Ministry of Finance, IMF/ADB outlooks
Tourist arrivals	Aviation, commercial electricity	VBOS, Department of Tourism
Vehicle registrations	Road transport fuel	Vehicle registration records, PLTA
Electricity demand forecasts	Power generation	Department of Energy, URA, UNELCO, VUI
Fuel prices	Sensitivity analysis, cost of options	Fuel importers, URA, international outlooks

Source: drivers based on Wartmann et al. (2021), p. 20

4.3 Policy and technology parameters

- List of energy policies and NDC measures with status (implemented / adopted / planned), start year and target level.[26]
- Planned renewable capacity additions (MW), capacity factors and commissioning years.
- Diesel generator specific fuel consumption (litres/kWh) and expected efficiency changes.
- Efficiency programme targets (e.g., appliances, lighting, buildings) and transport measures (e.g., EV uptake, fuel standards).
- Costs of mitigation options (investment, O&M, fuel savings, lifetime) where a cost analysis is needed.[27]

[24] Desgain et al., 2023, p. 6.
[25] Decision 18/CMA.1, annex, para. 98.
[26] Decision 18/CMA.1, annex, para. 96(c); Government of Vanuatu, 2025.
[27] Desgain et al., 2023, pp. 20–21.

5. Calculation methods

5.1 Basic emission equation

Projected emissions use the same Tier 1 equation as the inventory, applied to projected activity data:[28]

$$Emissions\ (gas, fuel, t) = Fuel\ consumption\ (fuel, t)\ [TJ] \times EF\ (gas, fuel)\ [kg/TJ]$$

$$CO_2\text{-}eq(t) = \Sigma\ Emissions(gas) \times GWP\ (gas)$$

$$GWP\ values\ (IPCC\ AR5,\ 100\text{-}year):\ CO_2 = 1,\ CH_4 = 28,\ N_2O = 265.$$[29]

Fuel in physical units is converted to energy using net calorific values (NCV) and density, exactly as in the inventory.[30]

Table 5. Default net calorific values and CO_2 emission factors

Fuel	NCV (TJ/Gg)	CO_2 EF (kg/TJ)	Source
Diesel / gas oil	43.0	74,100	IPCC 2006, Vol. 2, Tables 1.2 & 1.4
Motor gasoline	44.3	69,300	IPCC 2006, Vol. 2, Tables 1.2 & 1.4
Jet kerosene	44.1	71,500	IPCC 2006, Vol. 2, Tables 1.2 & 1.4
LPG	47.3	63,100	IPCC 2006, Vol. 2, Tables 1.2 & 1.4

Source: IPCC (2006), Vol. 2, Ch. 1, Table 1.2 (NCV) and Table 1.4 (CO_2 emission factors).

Use country-specific factors where they exist, and keep them identical to those in the inventory so that the base year matches.[31]

5.2 Projecting activity data

(a) Growth-rate method — activity grows at a fixed annual rate g:[32]

$$AD(t) = AD\ (base) \times (1 + g)\ ^\wedge\ (t - base)$$

(b) Elasticity method — activity is linked to a driver such as GDP through an elasticity ε (e.g., ε = 0.8 means energy grows 0.8% for each 1% of GDP growth):

$$AD(t) = AD(t-1) \times (1 + \varepsilon \times g_GDP\ (t))$$

(c) Intensity method — activity is driver × intensity, e.g., households × LPG per household, or

[28] IPCC, 2006, Vol. 2, Ch. 2, Equation 2.1.
[29] IPCC, 2013, Table 8.7; Decision 18/CMA.1, annex, para. 37.
[30] IPCC, 2006, Vol. 2, Ch. 1, section 1.4.
[31] IPCC, 2006, Vol. 2, Ch. 2; Decision 18/CMA.1, annex, para. 98.
[32] Wartmann et al., 2021, p. 8; Desgain et al., 2023, p. 16.

vehicles × fuel per vehicle. Intensities can change over time to reflect efficiency.[33]

(d) Bottom-up / technology method — used for electricity: projected demand is met by a supply mix, and only the fossil-fired part generates emissions.[34]

5.3 Electricity generation (1.A.1.a)

$$Generation(t) = Sales(t) \div (1 - loss\ rate)$$

$$Diesel\ generation(t) = Generation(t) - Renewable\ generation(t)$$

$$Diesel\ use(t)\ [litres] = Diesel\ generation(t)\ [kWh] \times SFC\ [L/kWh]$$

Renewable generation for each plant = capacity (MW) × capacity factor × 8,760 hours. Coconut-oil generation is renewable: its CO_2 is a memo item, but CH_4 and N_2O are counted.[35]

5.4 Estimating the effect of mitigation measures

$$Reduction(t) = Activity\ affected(t) \times (EF_baseline - EF_measure)$$

Example: a solar plant producing electricity that would otherwise come from diesel avoids emissions equal to its output × the diesel grid emission factor (tCO_2/MWh). Avoid double counting when measures overlap - for instance, efficiency savings on a grid that is also becoming more renewable reduce emissions by less over time.[36]

Illustrative worked example (replace with national data)

Diesel generation = 50,000 MWh; SFC = 0.27 L/kWh → 13.5 million litres

Mass = 13.5 ML × 0.84 kg/L ≈ 11,340 t = 11.34 Gg → energy = 11.34 × 43.0 ≈ 487.6 TJ

CO_2 = 487.6 TJ × 74,100 kg/TJ ≈ 36,130 t CO_2[37]

$CH_4 + N_2O$ (3 and 0.6 kg/TJ) ≈ 1.46 t CH_4 and 0.29 t N_2O → ≈ 41 + 78 = 119 t CO_2-eq[38]

Total ≈ 36,250 t CO_2-eq; implied grid factor ≈ 0.725 t CO_2-eq/MWh of diesel generation

6. Applying the GACMO tool

The Greenhouse Gas Abatement Cost Model (GACMO), developed by the UNEP Copenhagen Climate Centre, is an Excel-based tool for building a baseline, adding mitigation options and calculating emission reductions and abatement costs.[39] It has been used in many countries to design and track NDCs.[40] Sheet names and layout differ between versions; the latest is version 2.3, released in October 2025.[41] The workflow below is general.

[33] Wartmann et al., 2021, pp. 8 and 12.
[34] Wartmann et al., 2021, p. 12.
[35] IPCC, 2006, Vol. 2, Ch. 2 (biomass CO_2 reported as a memo item).
[36] Desgain et al., 2023, p. 19.
[37] IPCC, 2006, Vol. 2, Ch. 1, Tables 1.2 and 1.4.
[38] IPCC, 2006, Vol. 2, Ch. 2, Table 2.2.
[39] ICAT, 2023; Desgain et al., 2023, pp. 6–7.
[40] ICAT, 2023.
[41] UNEP-CCC, 2025.

6.1 Typical workflow

1. **Set the base year** to the latest inventory year and enter energy-sector emissions and fuel use from the inventory.[42]
2. **Enter the energy balance**: fuel consumption by sector, electricity generation by source, and losses.[43]
3. **Enter growth rates**: sector- and fuel-specific growth rates for energy use, assuming no mitigation options. Population and GDP are entered only to calculate intensity indicators; they do not drive the projections.[44]
4. **Generate the baseline (WOM/BAU)** and check that base-year values reproduce the inventory.[45]
5. **Add mitigation options** from GACMO's library of 119 options (e.g., large-grid solar PV, electric cars, efficient lighting, improved cookstoves), entering the number of units, start year and local cost data.[46]
6. **Build scenarios**: group implemented options into WEM and planned/conditional options into WAM.[47]
7. **Review results**: emissions by sector and gas, reductions per option, and the marginal abatement revenue (MAR) curve, which is an inverted marginal abatement cost (MAC) curve.[48]
8. **Export and document**: transfer results to CTF projections tables and record all assumptions.[49]

6.2 Calibration check

Before adding measures, the base-year emissions in GACMO should match the inventory's energy total. Any difference should be small and explained (e.g., categories not included in the tool, rounding, different GWPs). This keeps the projections consistent with the inventory they start from.[50]

6.3 Reading the results

- **Emission pathways**: compare WOM, WEM and WAM against the NDC target year.[51]
- **Reduction per option**: shows which measures matter most (in Vanuatu, typically renewable electricity and transport).
- **MAR curve**: GACMO's inverted MAC curve. Options above the x-axis are "win-win" (they reduce emissions and save money), and the area of each option is proportional to its total emission reduction.[52]

[42] Desgain et al., 2023, pp. 6 and 13.
[43] Desgain et al., 2023, p. 6.
[44] Desgain et al., 2023, pp. 16–17.
[45] Desgain et al., 2023, p. 18.
[46] Desgain et al., 2023, pp. 7, 20 and 30–32.
[47] Desgain et al., 2023, p. 25.
[48] Desgain et al., 2023, pp. 25–26.
[49] Desgain et al., 2023, pp. 26–27; Decision 5/CMA.3, annex II, sections 7–9.
[50] Decision 18/CMA.1, annex, paras. 95 and 99; Wartmann et al., 2021, p. 22.
[51] Desgain et al., 2023, p. 25.
[52] Desgain et al., 2023, p. 26.

- **Grid emission factor over time**: falls as renewable share rises, which reduces the benefit of demand-side measures.

7. Assumptions and their documentation

Assumptions drive projection results more than any formula. Each key assumption should be stated, justified and sourced.[53]

Table 6. Key assumptions and good practice for documenting them

Assumption	Why it matters	Good practice
GDP growth	Main driver of energy demand	Use official forecasts; state the rate per period
Population growth	Residential and transport demand	Use national census projections
Elasticities / intensities	Translate growth into fuel use	Derive from historical inventory data where possible
Measure implementation timing	Determines when reductions occur	Use realistic dates; avoid assuming 100% delivery
Renewable capacity factors	Determines renewable output	Use measured plant data or project feasibility studies
Diesel SFC	Determines fuel per kWh	Use utility data; note expected improvements
Fuel prices and costs	Affect MAC results	State year and currency; give a discount rate

Source: Decision 18/CMA.1, annex, para. 96 and Wartmann et al. (2021), pp. 20–24.

7.1 Sensitivity analysis

Run at least a high and low case for the most influential assumptions (usually GDP growth and the pace of renewable deployment). Report the range alongside the central WEM projection so that readers can see how robust the conclusions are.[54]

[53] Decision 18/CMA.1, annex, para. 96(a); Wartmann et al., 2021, pp. 21 and 24.

[54] Decision 18/CMA.1, annex, para. 96(d); Wartmann et al., 2021, p. 26.

8. Quality assurance, transparency and consistency

- **Consistency with the inventory**: same categories, fuels, factors, GWPs and base-year values; recalculate projections when the inventory is recalculated.[55]
- **Time-series check**: the join between the last inventory year and the first projected year should be smooth, without unexplained jumps.[56]
- **Plausibility checks**: compare per-capita emissions, emissions per unit GDP and growth rates with historical trends.[57]
- **Avoid double counting** between overlapping measures and between sectors (e.g., electric vehicles add electricity demand).
- **Version control**: keep a dated copy of each GACMO file and data log used for reporting.[58]
- **Peer review**: have someone not involved in the modelling check inputs and results before submission.[59]

[55] Decision 18/CMA.1, annex, paras. 98–99; Wartmann et al., 2021, p. 22.
[56] IPCC, 2006, Vol. 1, Ch. 5; Decision 18/CMA.1, annex, para. 99.
[57] Wartmann et al., 2021, p. 20.
[58] Wartmann et al., 2021, p. 24.
[59] IPCC, 2006, Vol. 1, Ch. 6; Wartmann et al., 2021, p. 22.

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