IMPACT DATA METHODOLOGY OVERVIEW

Introduction

The green and sustainable bond market faces a critical challenge: inconsistent impact reporting. Issuers take wildly different approaches to measuring and attributing impact - some report precise metrics for individual projects, others bundle impacts across their entire portfolio across an unclear time frame, and many fall somewhere in between with partial or inconsistent data. This makes it difficult for asset managers to accurately assess and report environmental impact.

Our solution is a standardised methodology that transforms diverse impact reports into comparable datasets. At its core is a universal metric: annual greenhouse gas emissions avoided per million USD invested (tCO_2e/$1M). This approach enables direct comparison across bonds regardless of size, currency, or project type, while adhering to market standards for climate impact assessment.

To derive tCO_2e/$1M, we extract the specific projects financed by each bond by allocation and their geographic locations. By applying consistent assumptions, baselines, and business-as-usual scenarios, we convert varied reporting formats into actionable insights that help asset managers evaluate their investments' environmental outcomes.

Based on our comprehensive analysis of green bond documentation and impact reports, green bonds currently finance projects across the ICMA Green Bond Principle categories:

1. Renewable Energy
2. Energy Efficiency
3. Pollution Prevention & Control
4. Environmentally Sustainable Management of Living Natural Resources & Land Use
5. Terrestrial & Aquatic Biodiversity Conservation
6. Sustainable Water & Wastewater Management
7. Clean Transportation
8. Climate Change Adaptation
9. Eco-efficient & Circular Economy Adapted Products, Production Technologies & Processes
10. Green Buildings

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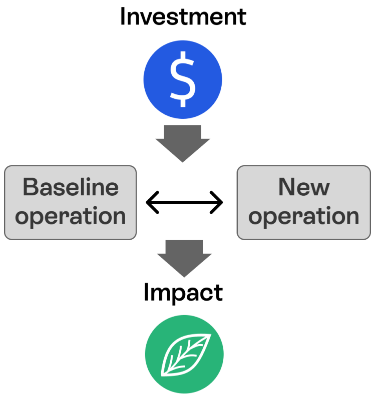
Methodology

The methodology measures the environmental impact of investments by calculating avoided emissions - the difference between business-as-usual (BAU) emissions and emissions after implementing new operational models. We use energy-related emissions changes and careful attribution of impact to specific investments, which allows us to incorporate geography-specific grid intensities, as well as maintain consistency in approach.



Core metric: Annual greenhouse gas emissions avoided per million USD invested (tCO_2e/$1M)

Calculation Process:

1. Project-Level Impact Assessment
   a. Baseline Measurement: Calculate business-as-usual annual emissions without $ 1 million in investment
   b. Post-Implementation Measurement: Calculate new annual emissions attributable to $ 1 million in investment
   c. Project Impact: BAU Emissions - Post-Implementation Emissions = Project Impact
2. Adjust for Bond Allocation
   a. Impact per $million × Percentage Allocated in Bond = Attributed Impact
3. Total Bond Impact
   a. Sum the attributed impacts across all projects: Bond's Impact/$million = $\Sigma(\text{Project}_1 \text{ Impact} \times \text{Allocation}_1\% + \text{Project}_2 \text{ Impact} \times \text{Allocation}_2\% + \ldots)$

In the Annex, you can find all of our exact equations to calculate these baselines, as well as the sources where we derived all of our assumptions.

Case Study: Tatra Banka - SK4000022034

For this case study, we selected Tatra Banka's €200 million green bond issued in October 2021. While our analysis framework can account for multi-country projects (which represent 39% of green bonds and require incorporating region-specific factors), this bond serves as an ideal example since all its funded projects are located in Slovakia. This single-country focus allows us to demonstrate the full range of project categories while keeping the analysis straightforward

Project Allocations

- Commercial Buildings (46.5%)
- Residential Buildings (46.5%)
- Solar (5.4%)
- Hydropower (0.6%)
- Electric Vehicles and Infrastructure (1.0%)

Location and Grid Carbon Intensity:

- Slovakia (100%)
- Grid carbon intensity: 0.142 tCO_2e/MWh

Calculating Impact:

- Commercial Buildings (46.5%)
  - Energy savings: 30 MWh/$1M invested
  - Impact: 30 MWh × 0.142 tCO_2e/MWh = 4.26 tCO_2e/$1M
- Residential Buildings (46.5%)
  - Energy savings: 23 MWh/$1M invested
  - Impact: 23 MWh × 0.142 tCO_2e/MWh = 3.27 tCO_2e/$1M
- Solar (5.4%)
  - Energy generation: 1,184.6 MWh/$1M
  - Impact: 1,184.6 MWh × 0.142 tCO_2e/MWh = 168.13 tCO_2e/$1M
- Hydropower (0.6%)
  - Energy generation: 1,561 MWh/$1M
  - Impact: 1,561 MWh × 0.142 tCO_2e/MWh = 221.66 tCO_2e/$1M
- Electric Vehicles and Infrastructure (1.0%)
  - Petrol cars emissions - EV energy use × 0.142 tCO_2e/MWh
  - Net emissions reduction: 33.92tCO_2e/$1M

Total Bond Impact:

(4.26 × 46.5%) + (3.27 × 46.5%) + (168.13 × 5.4%) + (221.66 × 0.6%) + (33.92 × 1.0%)

= 14.2 tCO_2e/$1M

Annex: Derived Impact Base Values

Our methodology for calculating environmental impact centers on determining avoided emissions per million dollars invested in green technologies, compared to business-as-usual scenarios. To ensure accuracy across different geographical contexts, we incorporate location-specific carbon intensity data in our calculations.

For grid carbon intensity values, we rely on the Energy Institute Statistical Review. When working with projects where only regional information is available, we apply regional averaging. In cases where neither country nor region is specified, we default to global average carbon intensity values.

Renewable Energy

Our emissions reduction calculations are based on the principle of direct displacement: every unit of clean energy added to the grid displaces an equivalent unit of carbon-intensive power. This 1:1 replacement model allows us to quantify emissions reduction by examining the interaction between new clean energy generation and existing grid carbon intensity.

Category	Equation	Assumptions
Renewables (unspecified)	[1,556 MWh/$1M]*[Country's electricity carbon intensity in CO_2e/MWh] = CO_2e/$1M	• Average of hydropower, wind, solar as these are the most common types of renewable investments
Onshore Wind	2,541 MWh/$1M × [Country's electricity carbon intensity in CO_2e/MWh] = CO_2e/$1M	• Capacity factor: 0.37 • 862 kW per $1M (Energy Intelligence)
Offshore wind	1,134 MWh/$1M×[Country's electricity carbon intensity in CO_2e/MWh] = CO_2e/$1M	• Capacity factor: 0.37 • 285.7 kW per $1M (Energy Intelligence)
Hydropower	1,561 MWh/$1M × [Country's carbon intensity of electricity in CO_2e/MWh] = CO_2e/$1M	• Capacity factor: 0.50 • 2,809 USD/kW (IRENA 2023)
Solar	[Country's MWh/$1M] × [Country's electricity carbon intensity in CO_2e/MWh] = CO_2e/$1M	• Capacity factor: Country Specific, based on local PV potential (World Bank PV Potential Data)

		○ Ex: India: 0.22, USA: 0.20, Norway: 0.11 • 0.957 MW per \$1M (2024, Energy Intelligence)
Nuclear	1,270 MWh/\$1M × [Country's carbon intensity of electricity in CO_2e/MWh] = CO_2e/\$1M	• Capacity factor: 0.95 • Cost: \$4,500-\$8,600/kWe, OECD avg: 152.7 MW/\$1B
Geothermal	Standard: 2,154 MWh/\$1M × [Country's carbon intensity of electricity in CO_2e/MWh] = CO_2e/\$1M For Turkey, Italy, USA, New Zealand : (2,154 MWh/\$1M × [Country's carbon intensity of electricity in CO_2e/MWh]) - 198 tCO_2e/\$1M = CO_2e/\$1M	• Capacity factor: 0.85 • Cost: 289 MW/\$1B (IRENA 2023) • • Special consideration for high-emitting regions*: 122 g CO_2e/kW (WorldBank), converted to 198 tCO_2e/\$1M factor
Biomass	(1,623 MWh/\$1M × [Country's carbon intensity of electricity in CO_2e/MWh]) - 373 = CO_2e/\$1M	• Capacity factor = 0.75 • Cost: 0.13 USD/kWh (Thundersaid Energy) • Median lifecycle emissions of dedicated biomass firing: 230g CO_2e/KWh (IPCC), converted to 373 tCO_2e/\$1M factor[1]
Hydrogen	(6,342.86 MWh/\$1M × [Country's carbon intensity of electricity in CO_2e/MWh]) - 2,380 = CO_2e/\$1M	• Average production costs: 5.25 USD /kg (IRENA) • Average energy produced: 33.3KWh/kg (H2) • Average CO_2e emissions from hydrogen: 12.5 kg CO_2-eq/kg (IEA)

[1] 230g CO_2e/KWh is the median lifecycle emissions according to the IPCC for dedicated biomass firing. We assumed that this would be the most likely biomass investment. It is worth noting the IPCC points out that co-firing biomass has a median lifecycle emissions that is much higher, at 740g CO_2e/KWh.

Marine Renewables + Other Renewables	N/A[2]	

Energy Efficiency

Energy efficiency encompasses various project types like retrofits, district heating/cooling, industrial improvements, smart grids, storage, and cogeneration. For now, we've focused on three categories: grid, ICT improvement, and all other general energy efficiency improvements. Our general efficiency improvements use assumptions similar to commercial building processes, as these projects typically yield comparable emissions reductions. In the future we will add more specific categories.

Category	Equation	Assumptions
Battery Storage + Grid Improvements	7.2 MWh/$1M × [Country's carbon intensity of electricity in CO_2e/MWh]) = CO_2e/$1M	• Energy capacity for lithium ion batteries: 139 USD per KWh (Statista) • We assume that grid improvements are adding capacity directly to the grid by reducing lost energy[3]
ICT & Telecoms & Other Efficiency Upgrades	(125MWh/$1M) × (Country's grid CO_2e/MWh)	• Telia case study (Impact Report 2023): • They invested 600m EUR in energy efficiency (~$634m) • They achieved a saving of 79 GWh/year (from shutting down energy-intensive copper networks)
General Energy Efficiency	[Country's Commercial MWh saved/$1M estimate] × [Country's carbon intensity of	• 40% higher energy use than residential (EU) • Same country-specific cost factors

[2] Marine renewables and other niche renewables types have minimal to no allocation as of yet. Once there is wider spread investment and demand for these renewable types, we will add estimates.

[3] This bundled approach creates a conservative estimate since it's benchmarked to the costlier battery storage figures while excluding the likely higher returns from grid improvements and secondary benefits like improved reliability and peak demand reduction.

	electricity in CO_2e/MWh] = CO_2e/\$1M	• Same 30% energy reduction assumption

Pollution Prevention and Control

Waste management investments reduce methane emissions by diverting biogenic waste from landfills, showing high impact potential. Our metric is based on recycling facilities, which represent most waste investments in green bonds, but the same emissions reduction logic applies to all waste diversion projects.

Category	Equation	Assumptions
Waste Management (general)	1,170 tCO_2e avoided/ \$1M	• Landfill emissions: 298 kg CO_2e per ton (Teichmann & Schemppl)[4] • Recycling rate: 32% (EPA) • Recycling CO_2e avoided: 0.050 kg CO_2e per ton • Operating Cost per tonne: 45.48 USD/tonne (Olafasakin, et al.) • \$80m for 175,000 tonnes / year (Let's Recycle) • 20 year lifespan (Olafasakin, et al.)

Environmentally Sustainable Management of Living Natural Resources & Land Use

Land-based investments require a distinct approach due to their complexity. Unlike other green projects with clear baselines, they involve multiple variables including local ecosystems, existing practices, and intervention types. To address this complexity, we used Manulife as a case study, as their real-world data across various ecological contexts and management approaches provides reliable, trustable impact metrics.

Category	Equation	Assumptions
Sustainable Land Use (General)	14.5 tCO_2e per year/\$1M	• Manulife sustainable agriculture investment case study (Manulife

[4] Fully compliant landfill with methane capture.

		Sustainable Agriculture Report 2022)[5] • 58,138 - two year average net annual sequestration in CO_2e • 4 billion in certified sustainable agriculture investments
Sustainable Forestry	162 tCO_2e per year/$1M	• Manulife timber investment life case study (Manulife Sustainable Timber Report 2022)[6] • 11,069 million in forestry assets • 1,791,934 - annual net sequestration in tCO_2e

Terrestrial & Aquatic Biodiversity Conservation
No estimation methodology yet for these types of projects.

Sustainable Water & Wastewater Management
Not a significant source of emissions reductions.

Clean Transportation

Most clean transportation investments reduce emissions by replacing fossil fuel vehicles with electric alternatives. The emissions impact per $1 million invested varies by local grid carbon intensity, vehicle usage patterns, and infrastructure costs. Our calculations account for both vehicle and infrastructure investment costs. Hybrid vehicles and maritime transport follow different calculation methods, detailed in the footnotes.

[5] Manulife's portfolio provides a comprehensive benchmark as it includes diverse sustainable agricultural practices - from integrated pest management and regenerative farming to biodiversity conservation and soil carbon management. These practices serve as a reliable proxy for sustainable land management investments in green portfolios. While most portfolios focus on agriculture, other land management approaches use similar techniques. Additionally, Manulife's projects span multiple regions including North America, Oceania, and South America, giving us data across different ecological contexts.

[6] Manulife's certified sustainable forestry portfolio operates across three continents with a wide range of tree species, from Australia to Canada to Brazil. Manulife's portfolio is almost exclusively commercially managed timberland. Currently, the vast majority of forestry projects financed by green bonds are sustainably managed timberland.

Category	Equation	Assumptions

Rail (Trains and Infrastructure)	135.2 - ([Country's grid intensity in tCO_2e/MWh] × 152.3) = tCO_2e/$1M	• Utility: 337,920km/year (OGAB)
		• Number of electric trains per track: 88, from UK rail assets (ORR):[7]
		  ○ 15,849km of route (31,258 of single-track-kilometer)
		  ○ 39% electrified
		  ○ 15,107 railway vehicles (assuming cars/carriages)
		  ○ 71% electric
		• Cost: $2.1M per carriage/car/vehicle (Transport Watch)
		• Electrification cost estimate globally is $1.28m/stk (single-track-kilometer) (Ria GB)
		• Diesel train: 5,000 tons CO_2e/km (ORR)
		• Diesel train emissions: 7.1 $kgCO_2e$/km (OGAB)
		• Electric train: [country_grid_emissions]*8 kWh/km (OGAB)

Electric Vehicles (Passenger vehicles and infrastructure)	32.3 - ([Country's Carbon intensity of electricity in CO_2e/MWh] × 25.2-5.2)= CO_2e avoided per $1M[8]	• Annual distance: 8,000km (OECD) • Vehicle manufacturing cost: $60,000 per EV(Azo Cleantech)

[7]This calculation applies to both freight and passenger rail operations. While freight and passenger trains have different energy consumption patterns, electrified infrastructure serves both purposes effectively. The energy usage variations tend to balance out across the network. Future versions of this methodology may separate these categories if project requirements and stakeholder needs indicate such detail would be valuable.

[8] Petrol Vehicle Emissions being replaced in tCO_2e - Emissions from Electric Vehicles from electricity - Emissions from Batteries.

		• Life-cycle GHG emissions: ICE: 250 gCO_2e/km (ICCT) • Life-cycle GHG emissions: BEV: [country_grid_emissions]*0.2 kWh/km + 40 gCO_2e/km (ICCT) • EV energy use: 0.195kWh/km (ICCT) • Level 1 charging cost, or ⅕ share of a level 2: $2000
Hybrid Vehicles	6.46 tCO_2e avoided/$1M[9]	• 20% reduction from petrol cars (ICCT) • Same assumptions on petrol cars emissions as above

Electric Buses	279.6 - (Country's grid CO_2e/MWh × 123.0) - 14.0 = tCO_2e/$1M[10]	• Bus Utility Rate: 75,000km/year (Zemo)
		• Vehicle cost: Electric bus: $519,828 (VEV)
		• Electric buses use 0.88 kWh/km (Pelican)
		• Life-cycle GHG emissions: (ICCT)
		    ○ Diesel: 2.0 $kgCO_2e$/km
		    ○ BEV:[country_grid_emissions]*0.88 kWh/km + 100 gCO_2e/km (embedded)
		• Infrastructure is an extra 3.2% for cost ($0.5m of

[9] For hybrid vehicles, we apply a uniform 20% emissions reduction compared to conventional petrol vehicles, based on ICCT data. Unlike electric vehicles where emissions vary significantly by regional grid mix, hybrid emissions show consistent reductions from reduced fuel consumption alone.

[10] Petrol Buses Emissions being replaced in tCO_2e - Emissions from Electric Buses from electricity - emissions from batteries.

		charging infrastructure for 15 buses)
Shipping, Maritime Transport	2.27 tCO_2e avoided/ $1M	• Cost: $40B/year by 2030 to transition 5% of the market to methanol and ammonia (UN) • Shipping: 706 Mt CO_2e in 2023 (Statista) • Methanol and ammonia reduction potential: 90% in 30 years, assuming wide availability of green ammonia and green methanol (Sphera, Methanol Institute) • Ship lifespan: ~40 years (SSI) • HFO emissions: 95.5 gCO_2e/MJ (Maritime.gov) • Ammonia: 2.4 t CO_2/t (IEA) • Methanol: 3.06 t CO_2/t (IRENA) • HFO: 40 MJ/kg (Aronietis et al.) • Ammonia: 18.6 MJ/kg (Black and Veatch) • Methanol: 22 MJ/kg (Methanology) • Methanol and ammonia (50/50) split is 46% higher in emissions than HFO

Climate Change Adaptation

No estimation methodology yet for these types of projects.

Eco-efficient & Circular Economy Adapted Products, Production Technologies & Processes

No estimation methodology yet for these types of projects.

Green Buildings

Almost all green building investments target building efficiency and reduce energy consumption compared to business-as-usual scenarios. Our methodology calculates emissions avoided per $1M invested, with impact varying by local climate and construction costs. We treat commercial building efficiency measures similarly to general energy efficiency investments, which typically involve upgrading multiple buildings.

Category	Equation	Assumptions
Green Buildings (unspecified)	[Avg. of Country's Res. and Comm. MWh saved/$1M estimate] × [Country's carbon intensity of electricity in CO_2e/MWh] = CO_2e/$1M	• In the case that the type of building is unspecified between residential and commercial, we use an average of the two. More detail on these values below
Residential	[Country's Res. MWh saved/$1M estimate] × [Country's carbon intensity of electricity in CO_2e/MWh] = CO_2e/$1M	• Energy baseline (kWh/m²/year):[11] ○ Average temperatures (World Population Review) ○ Income levels (World Bank) ○ Validated against actual usage data from EU, US, China building energy surveys

[11]We developed a classification system combining temperature zones (low/medium/high) with World Bank income levels to estimate energy usage, creating 9 categories with distinct energy intensities. Examples: High-income hot countries (e.g., Singapore, Saudi Arabia) use ~0.23 MWh/m² due to air conditioning needs. High-income temperate/cold regions (e.g. Europe, USA) average 0.14 MWh/m². Low-income countries maintain minimal usage at 0.03 MWh/m² across all temperature zones.

		• Construction costs ($/m²):[12] ○ Used 20 USD/m² from largest economies, representative smaller economies ○ GDP per capita baseline (World Bank) to estimate data gaps ○ Spot-checked in new areas • 30% energy reduction from renovations or new builds.[13] ○ Heat pumps can have an improvement of 75% (Energy Savings Trust.) ○ Other energy improvements can be more modest, at just 10% ○ 30% assumed as an estimate
Commercial Buildings	[Country's Commercial MWh saved/$1M estimate] × [Country's carbon intensity of electricity in CO_2e/MWh] = CO_2e/$1M	• 40% higher energy use than residential (EU) • Same country-specific cost factors • Same 30% energy reduction assumption

[12]Using benchmark data from 20 countries, we developed a GDP per capita correlation model to estimate global construction costs. This allowed us to extrapolate costs worldwide. Some examples range from 3,750 USD/m² in Switzerland to 250 USD/m² in India, with the US (1,650 USD/m²) and China (800 USD/m²) as key reference points.

[13] While renovation and new construction costs and purposes can differ significantly, post-issuance reports often aggregate both under a general "Green Building" category. For this analysis, due to data limitations and inability to distinguish between renovations and new builds in aggregate reporting, we assume all construction costs represent new builds.

Note: There are no estimates for every single eligible category because not all are receiving significant financing at scale. For example, this methodology is missing new technologies like SAF and decarbonization solutions exist for hard-to-abate sectors like steel and concrete production. As such, they are not included in this initial version of the methodology. We will incorporate impact calculations for these project types as they begin receiving meaningful financial investment.