A Modelling Approach to Evaluate the Economics of Electric Vehicles for Passenger Transportation in Developing Countries

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Live policy questions regarding electric mobility in developing countries that motivate research

- **Why** is electric mobility for passenger transportation relevant to the developing world?
- **When and where** does it make sense for developing countries to proactively pursue the transition?
- **How** can policymakers accelerate adoption of electric passenger vehicles?

Why is electric mobility for passenger transportation potentially relevant to the developing world?

- **Health benefits**
  - ✓Air pollution
- **Inclusive mobility**
  - ✓Affordable last mile
- **Energy security**
  - ✓Dependency on imported fuel
- **Industrial Policy**
  - ✓Economic benefits and jobs/Global value chain
- **Decarbonization**
  - ✓As part of an **integrated sustainable transport strategy**

Scoping tool to support first order decision-making on electric mobility options in developing countries

Inputs

- Global assumptions
- Country-specific data

- Typology benchmarks (fleet, oil, vehicle)

Historical Data 2000-2019

→

Modules

- Demand
  - Transport
  - Electricity
- Costs
  - Vehicle life-cycle (2W, 3W, 4W, Bus)
  - Charging infrastructure
  - Externalities

Projections 2020-2030

→

Outputs

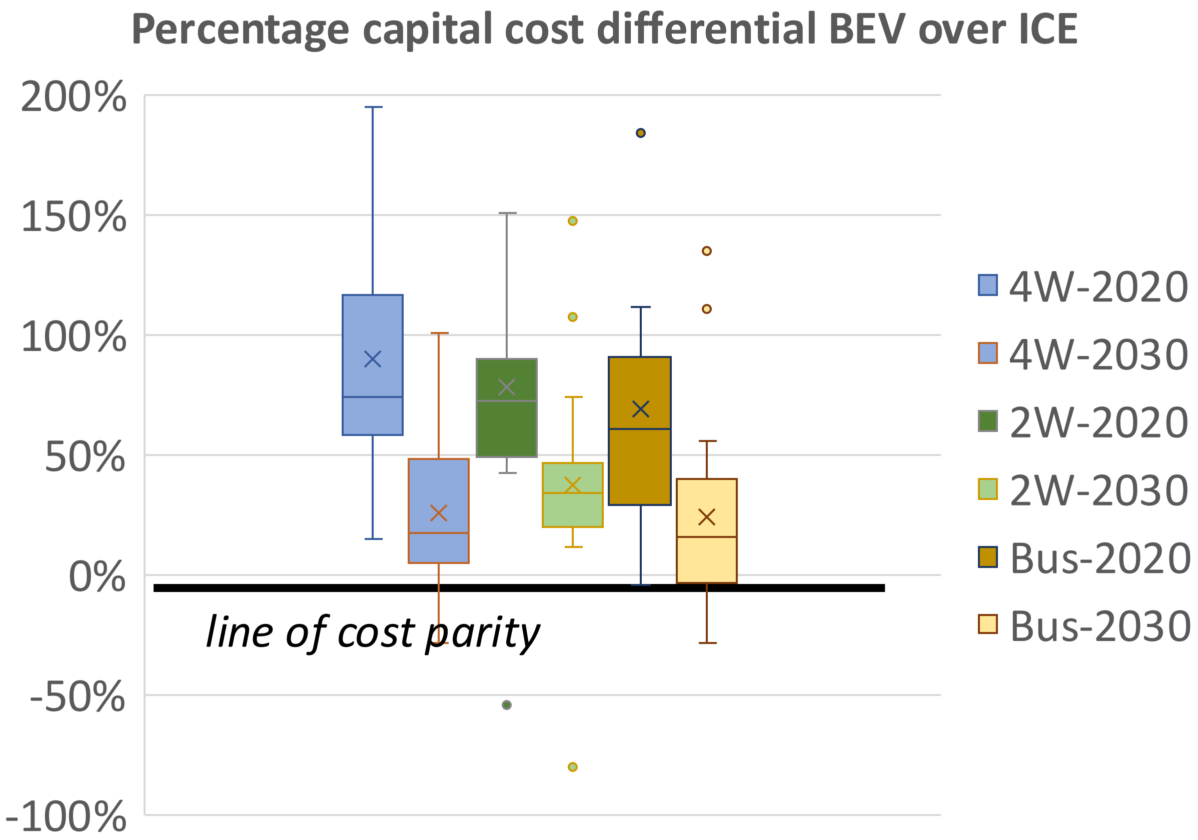
- Economic analysis
- Financial analysis
- Sensitivity analysis
- Financial implications

- Cross-country comparisons

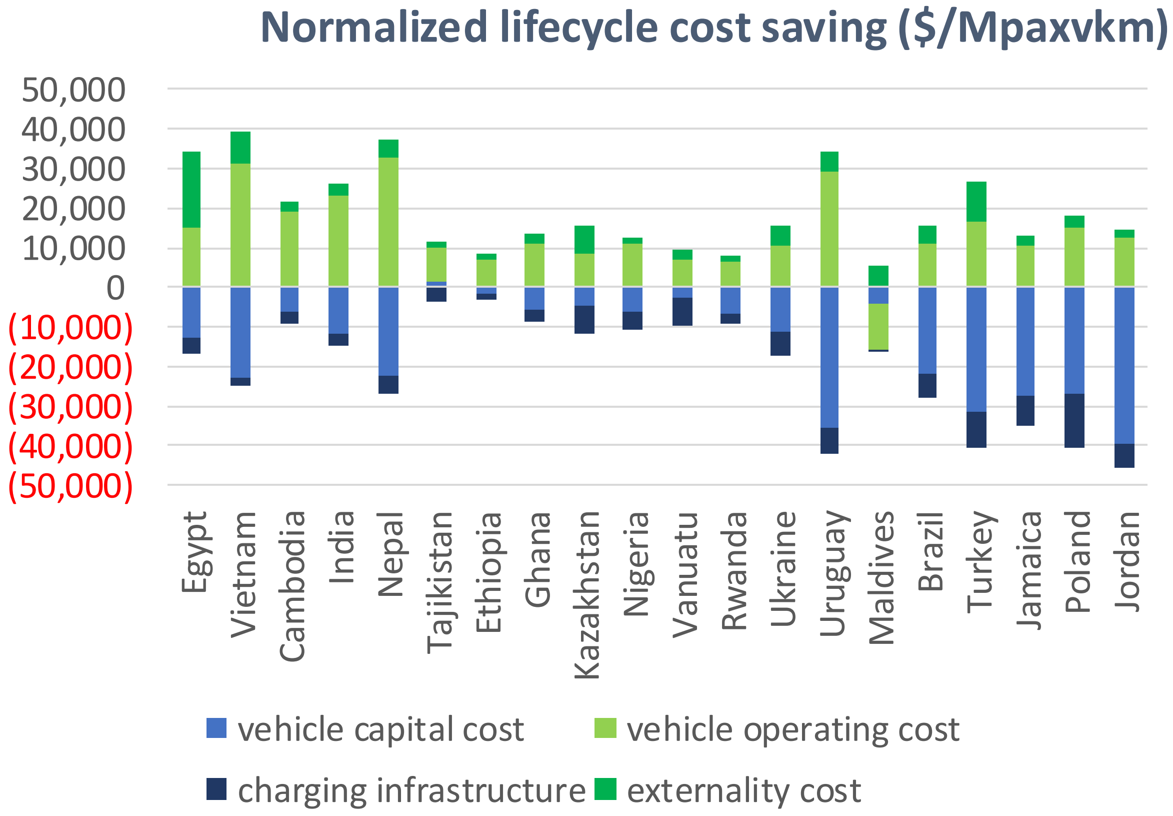
Alt. Scenario 2020-2030

Q1: Is the higher capital cost of electric vehicles compensated by lower lifecycle costs? A1: Increasingly, but context specific

Vehicle capital cost premiums high now ~80% but coming down towards to 20-40% by 2030



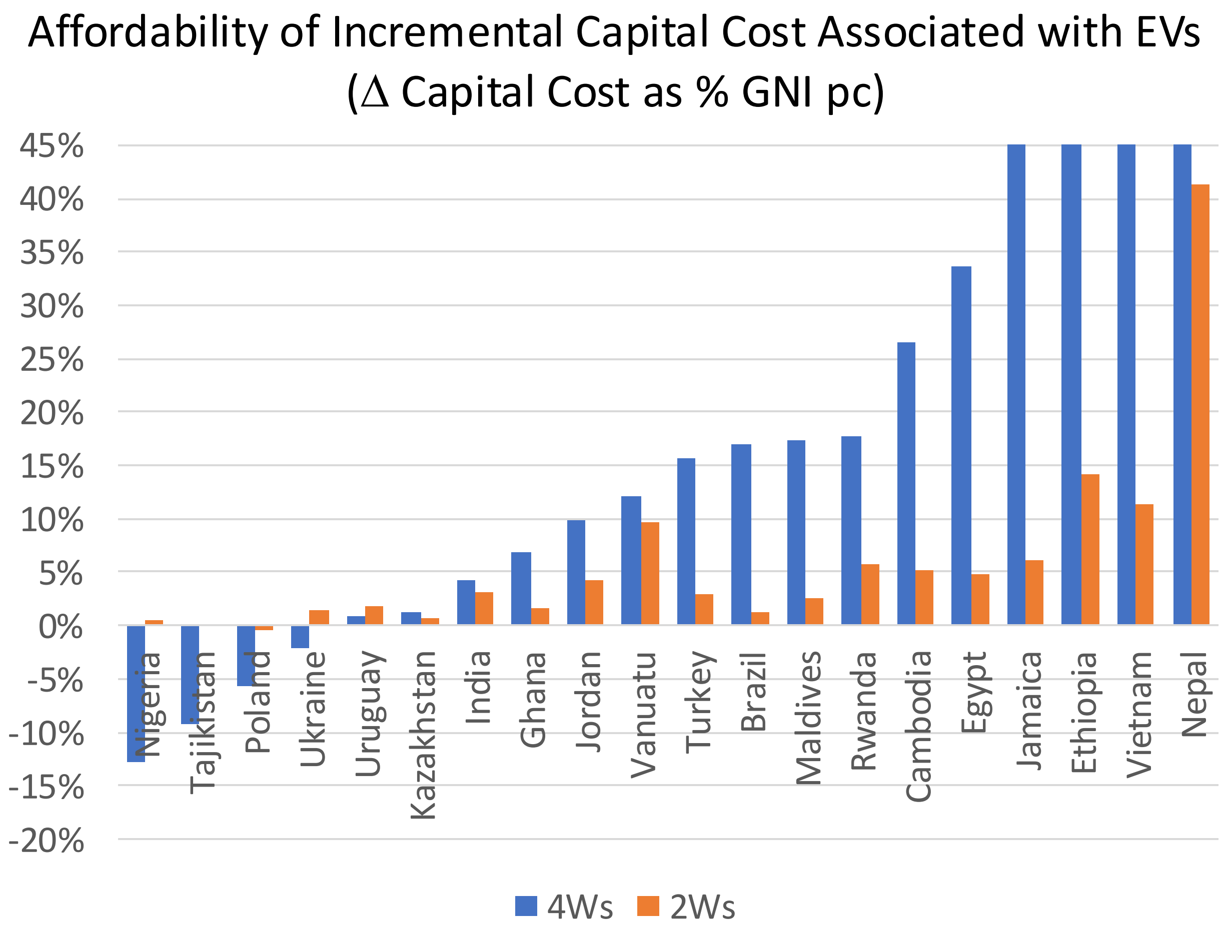
Target of 30% EVs by 2030 is economic in more than half of LMICs studied



Source: World Bank *Electric Mobility Scoping Tool*, 2022

Q2: Can consumers afford the capital cost differential associated with electric vehicles? A2: Mainly just 2Ws.

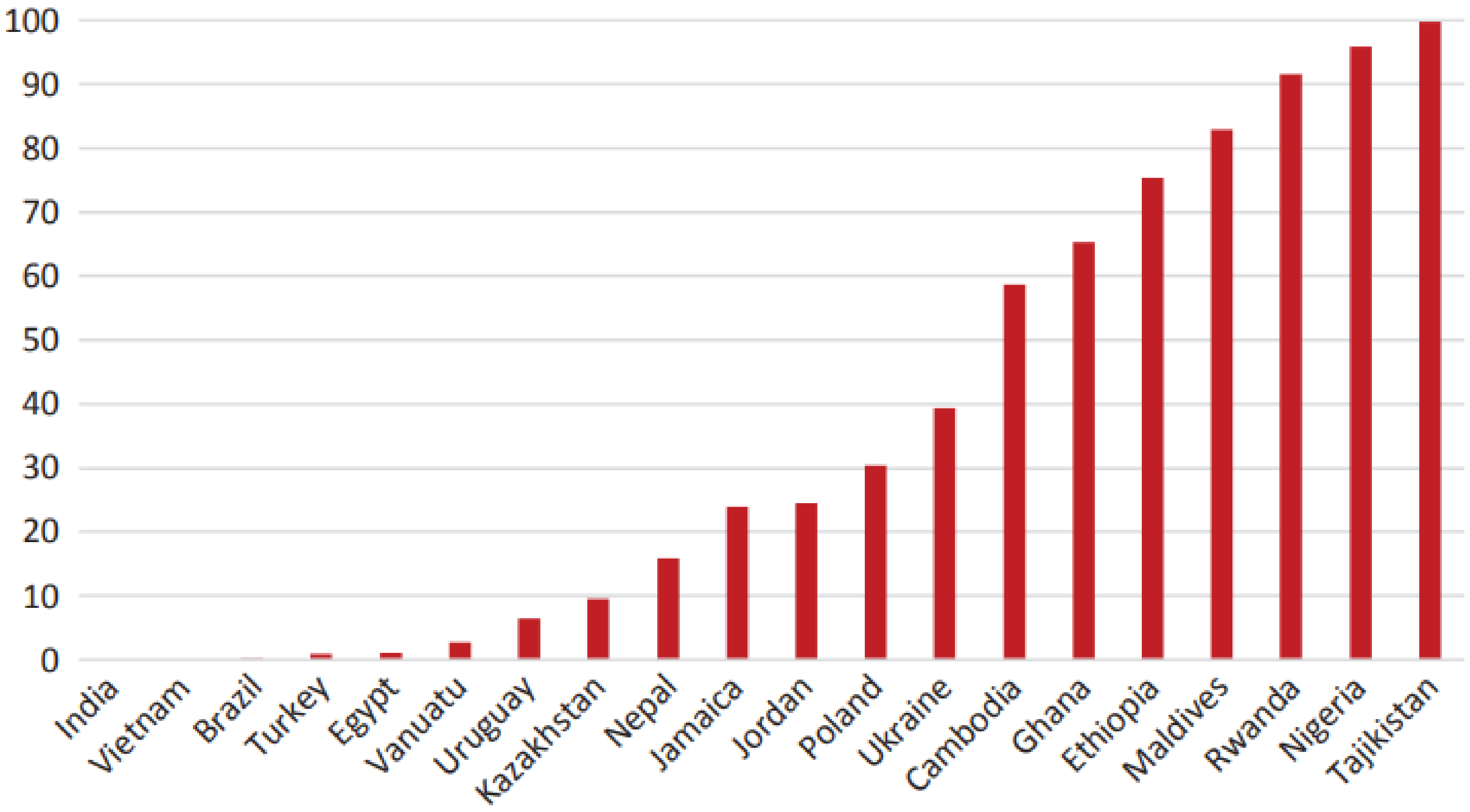
- Capital cost premium
  - ✓ 2W < 10% of GNI/pc → financeable
  - ✓ 4W ~ 15-45 % of GNI/pc → barrier
- Subsidies to E-4W widespread but costly
- Possible mechanisms to increase affordability
  - ✓ Credit lines
  - ✓ Leasing models
    - Buses
    - BaaS



Source: World Bank *Electric Mobility Scoping Tool*, 2022

Reliance on second-hand vehicle imports is particularly high in many African countries

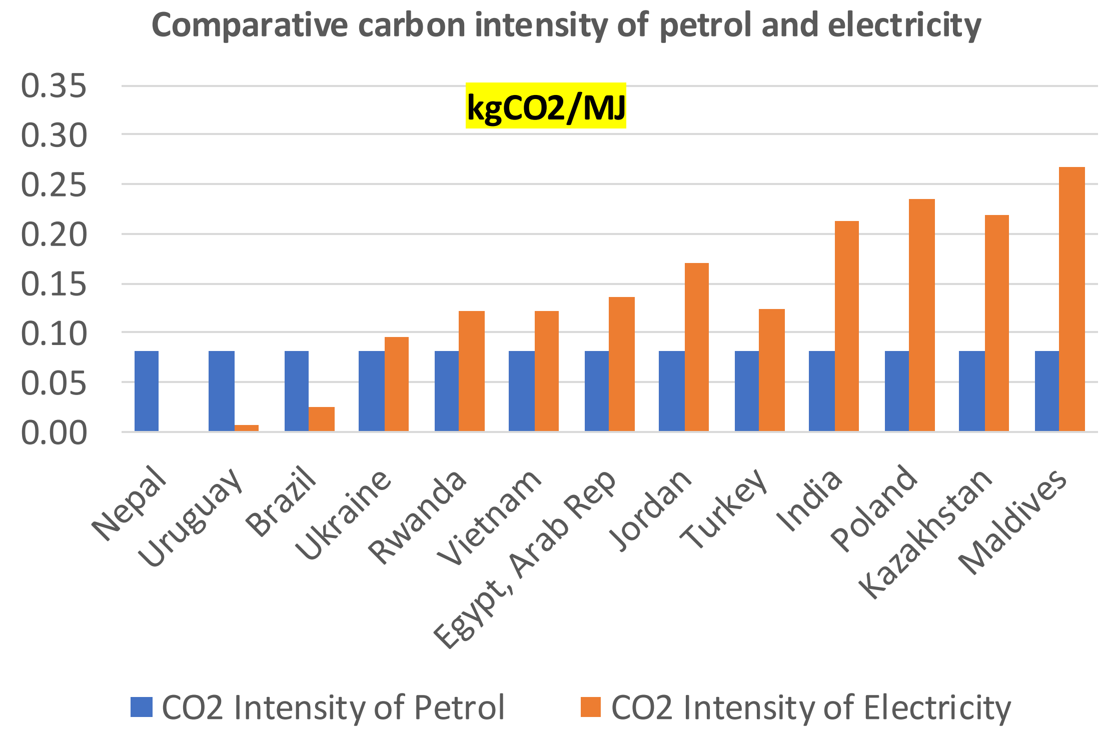
Percentage of vehicles imported second hand

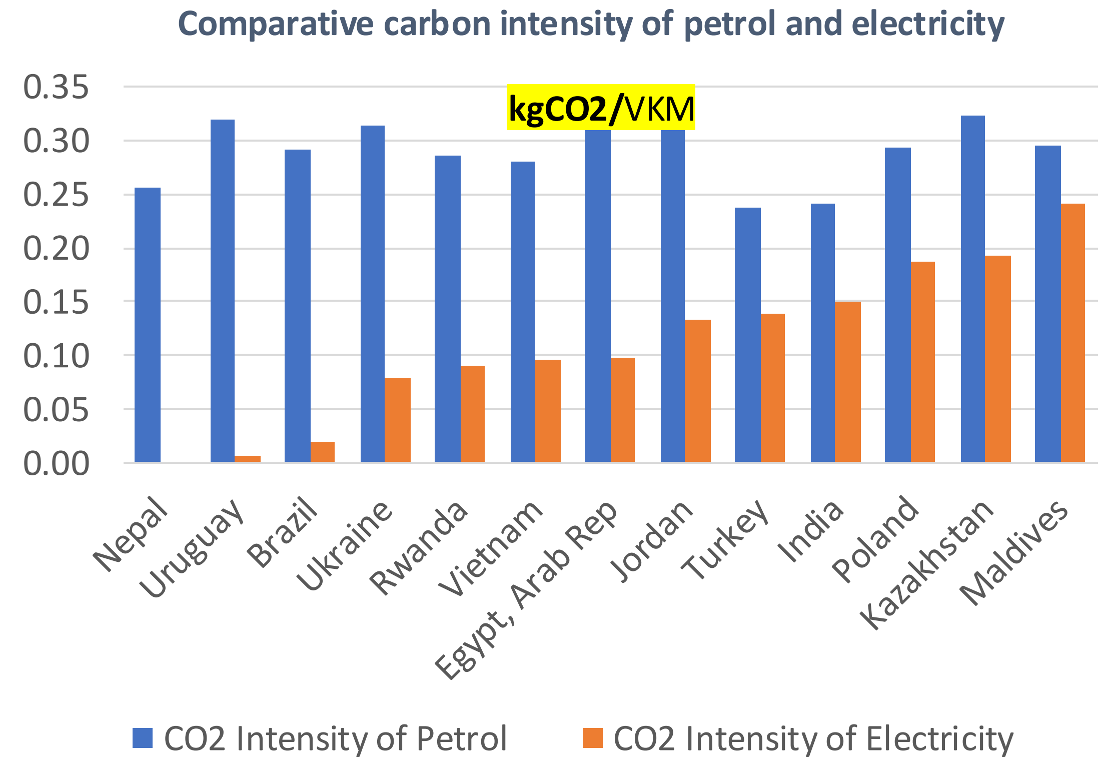


Source: World Bank *Electric Mobility Scoping Tool*, 2022

Q3: Does it make environmental sense to electrify transport before power grid is fully decarbonized? A3: Usually, yes!

Electricity may be more carbon intensive than petrol per unit of energy but NOT per vehicle-kilometer

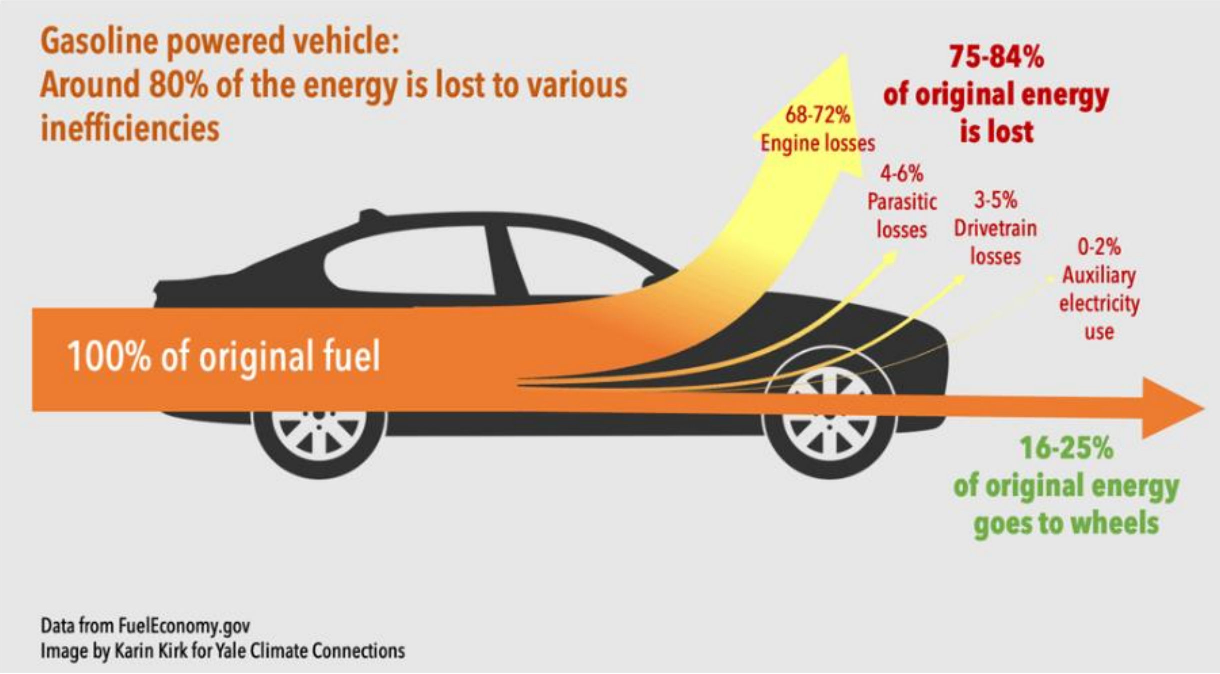


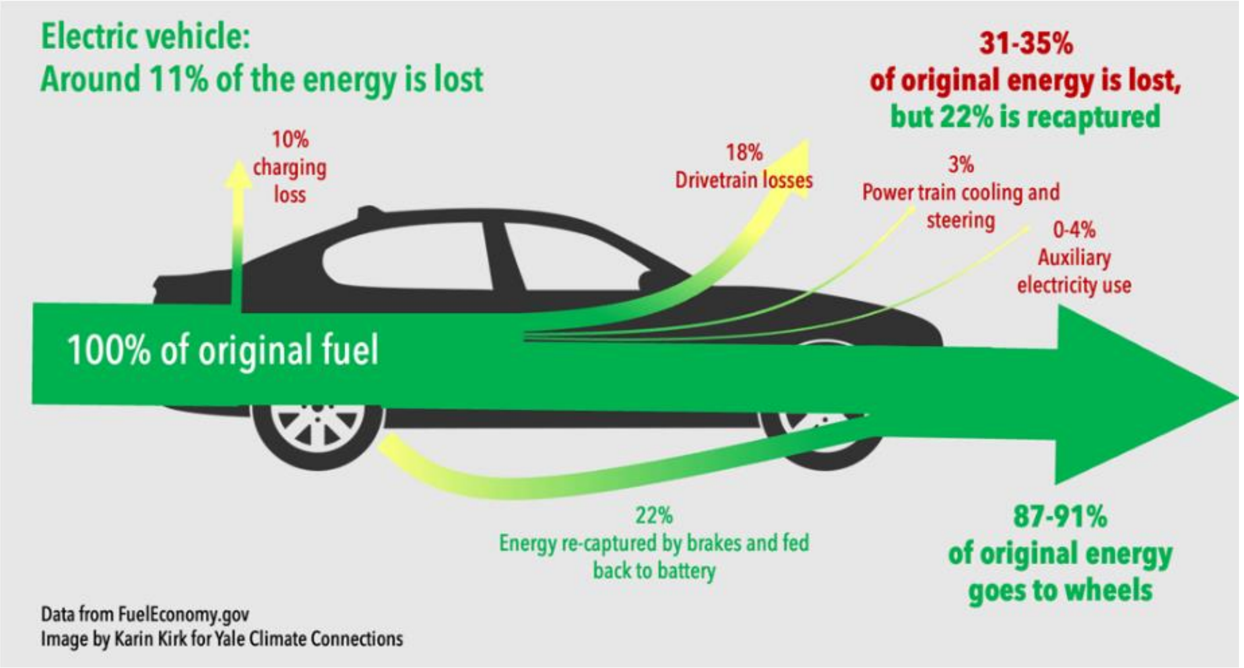


adjusting for major differences in energy efficiency

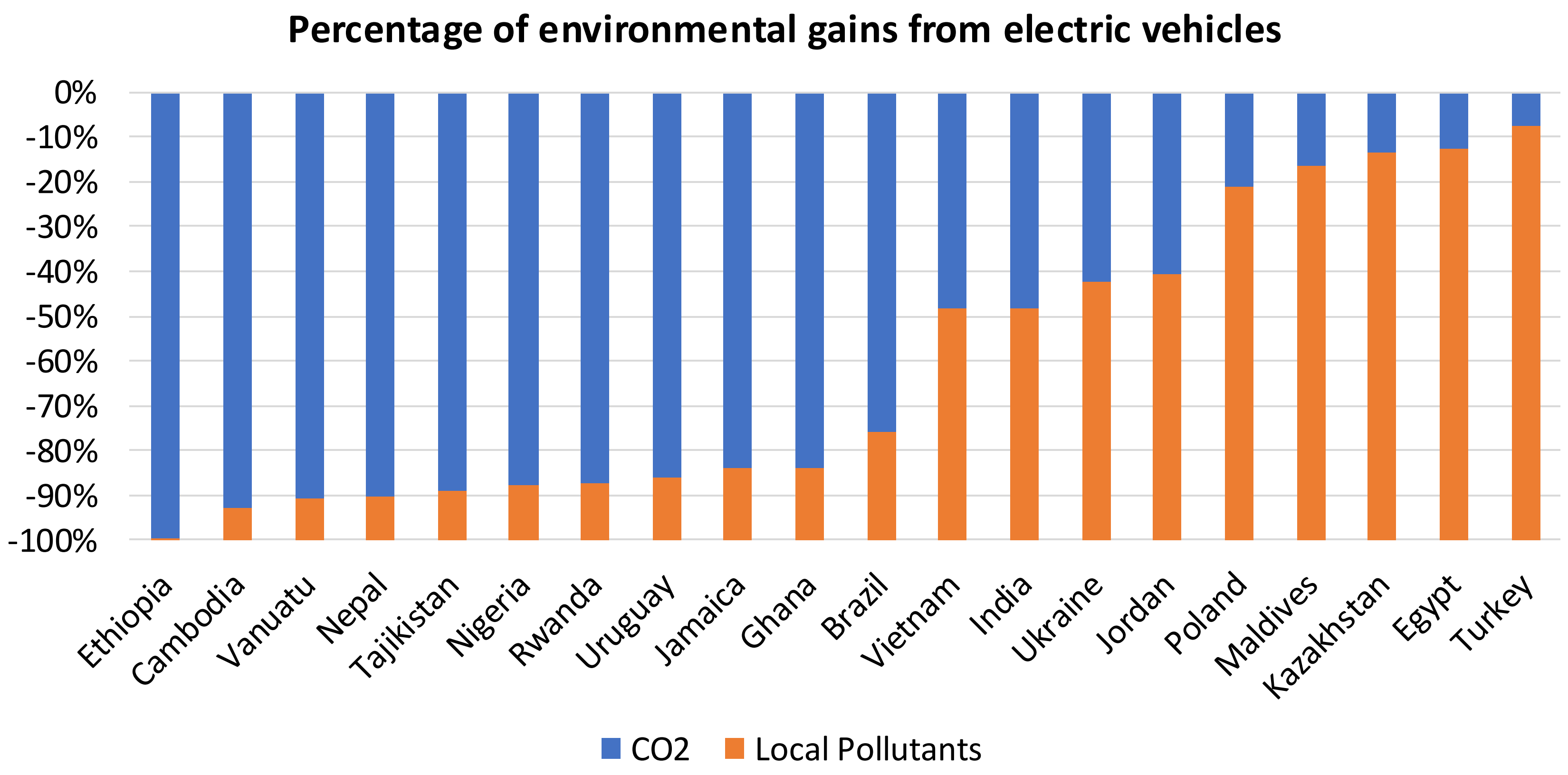
Source: World Bank *Electric Mobility Scoping Tool*, 2022

ICEVs consume four to five times as much energy per vehicle-kilometer as EVs





Q4: How important are local environmental benefits in relation to global ones? A4: Very important in many cases.

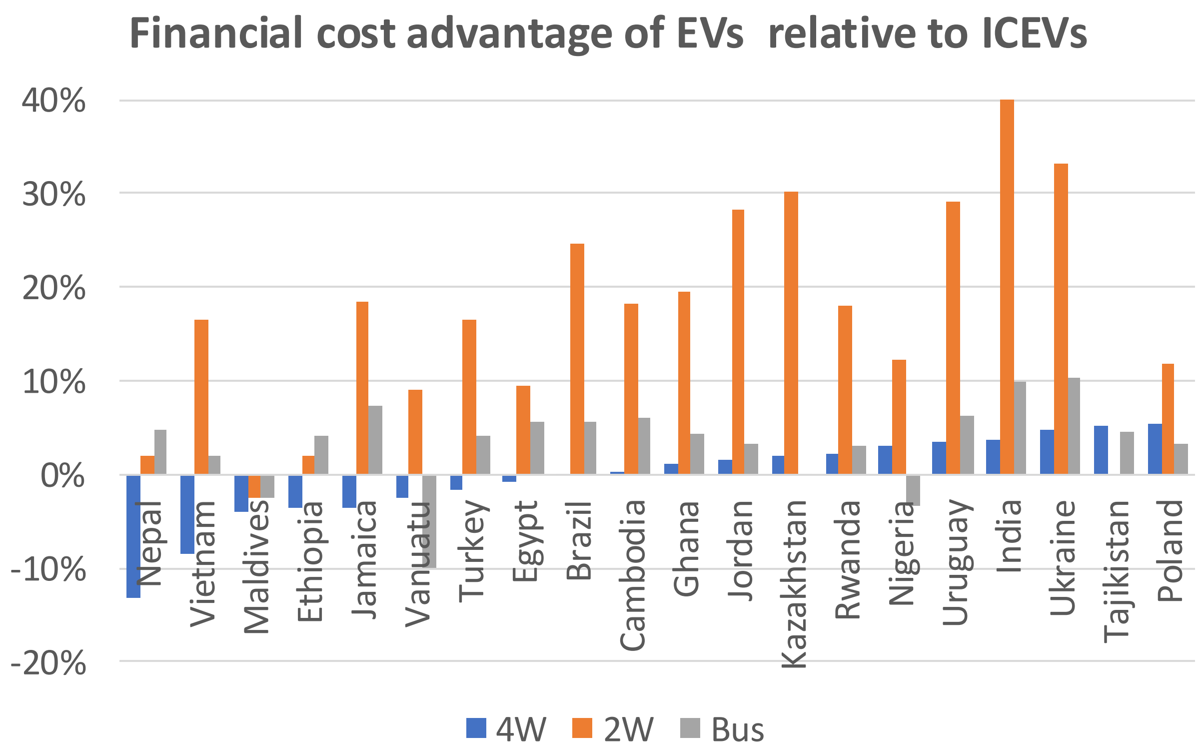


Environmental benefits associated with local air quality can be much more significant than those associated with mitigating global climate change

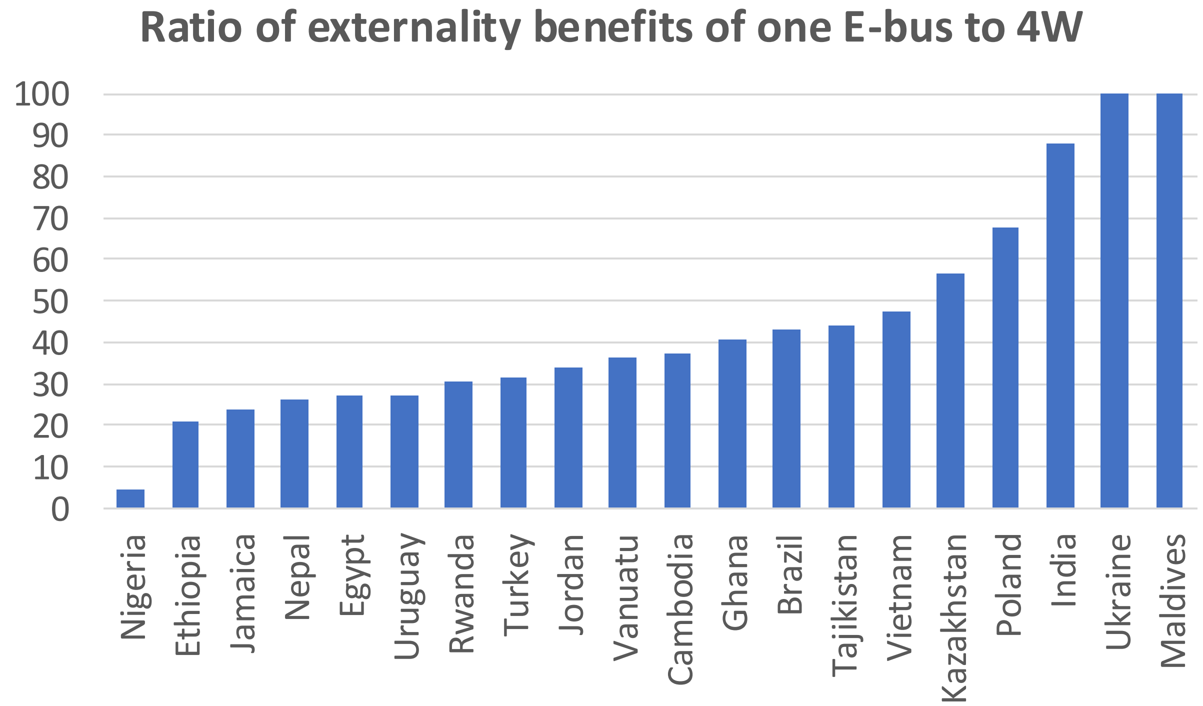
Source: World Bank *Electric Mobility Scoping Tool*, 2022

Q5: Should countries prioritize electrification of certain vehicle categories, and if so, which? A5: Yes, 2Ws and e-buses

Most promising market segments 2Ws and buses. 4Ws only in a minority of cases

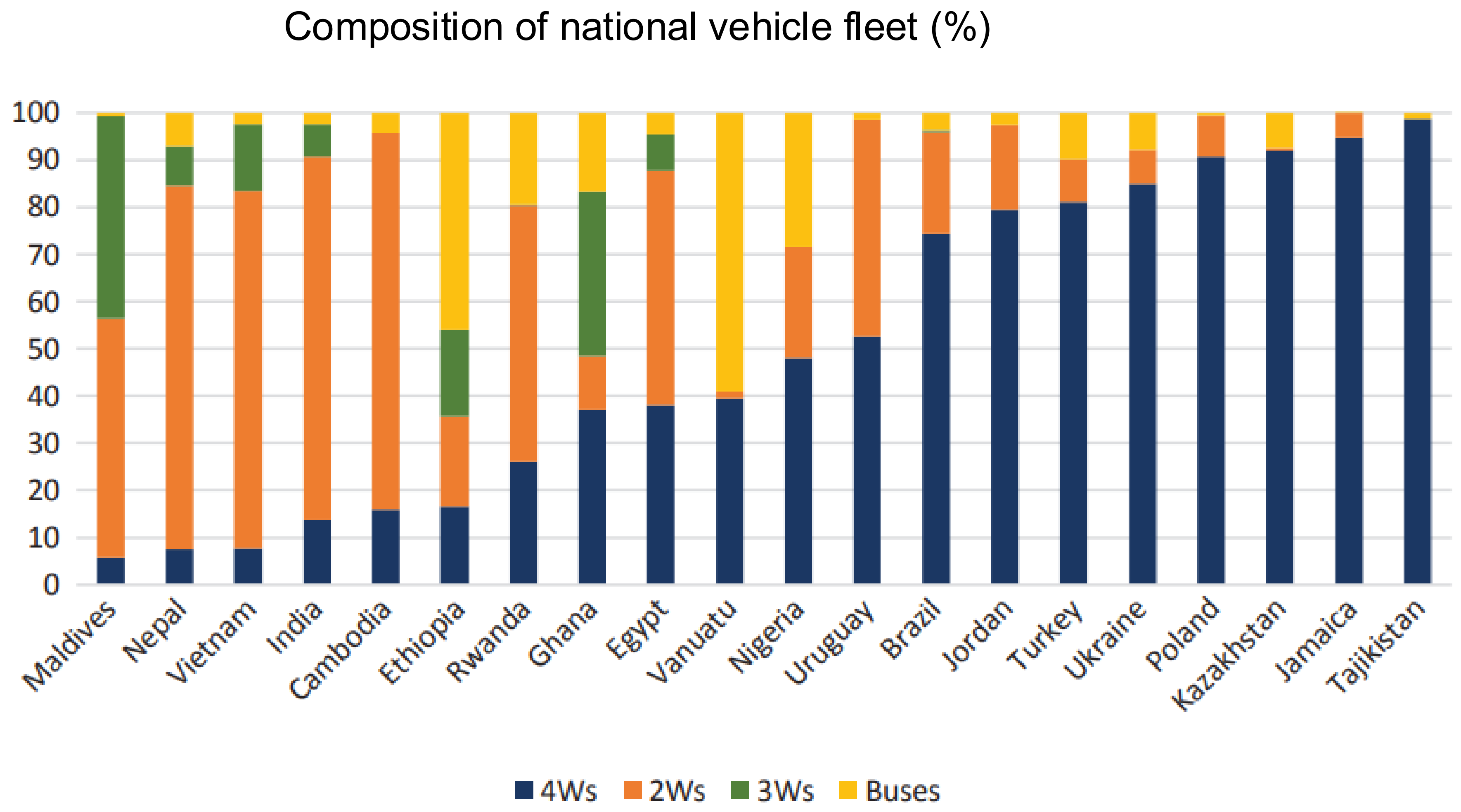


Electrifying one bus brings externality benefits that are 30x higher than electrifying one 4W



Source: World Bank *Electric Mobility Scoping Tool*, 2022

Vehicle fleet composition varies dramatically across the developing world

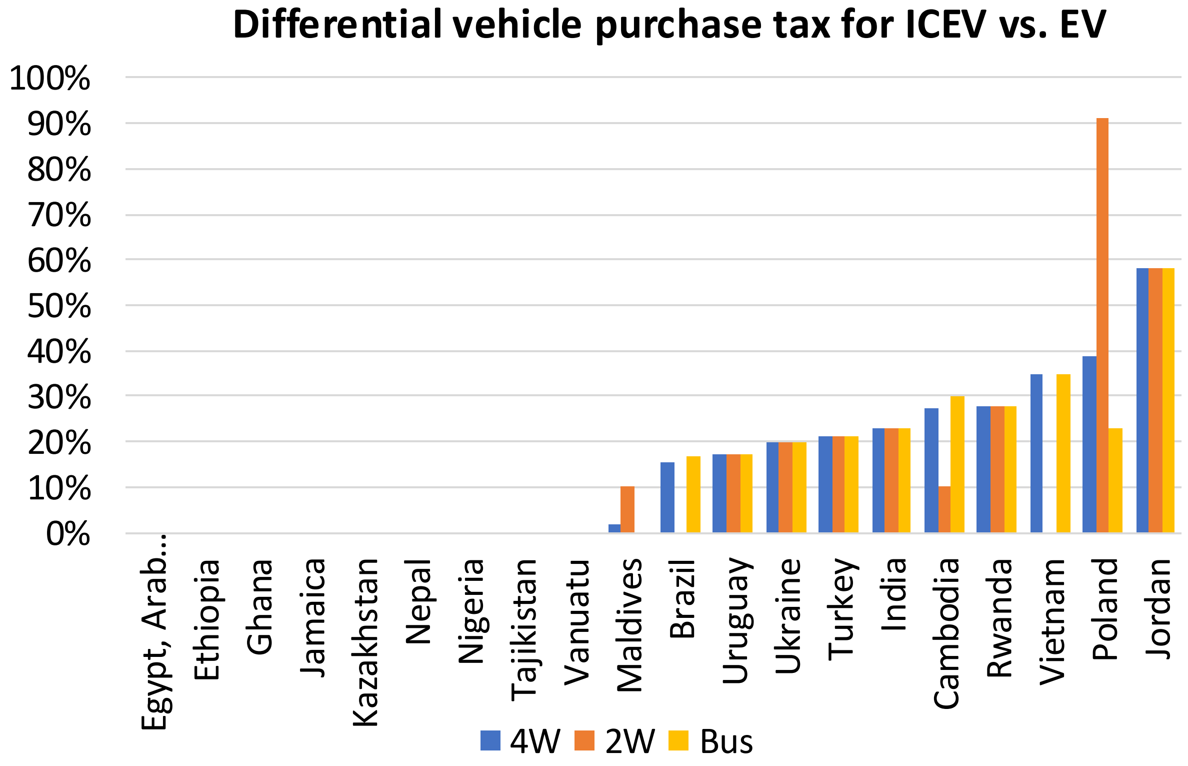


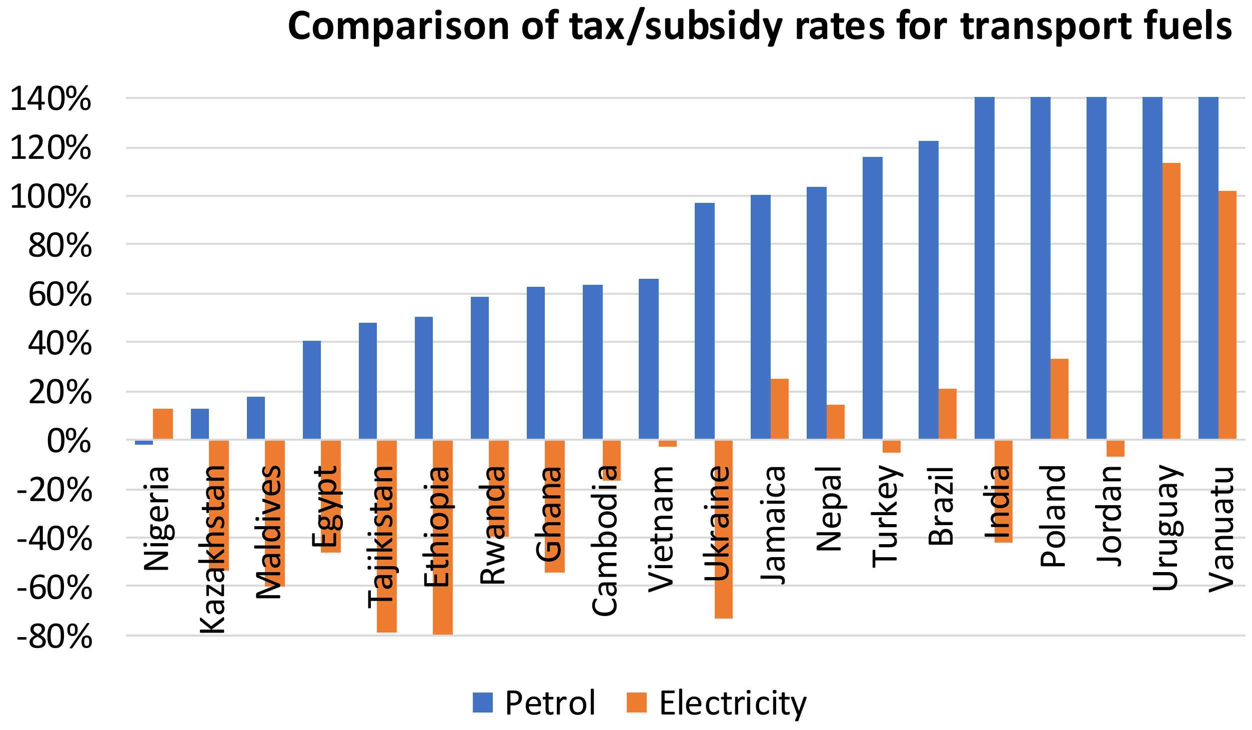
Source: World Bank *Electric Mobility Scoping Tool*, 2022

Q6: What will be the impact of electric mobility on the electric power system? A6: More distribution than generation

- Relatively small impact on generation needs
  - Demand for electricity associated with 30x30 Scenario no more than 1% of total
  - But some known cases where impacts could be higher (e.g. Ouagadougou where 5% e-2Ws penetration would consume 7% of electricity)
- Potentially significant impact on local grid
  - Potential for charging to be spatially and temporally concentrated exacerbating peaks
  - Desirable to incorporate demand management via tariff structures and/or technology (V2G)
- Possible impact on utility finances
  - Without price reforms increased sales of subsidized electricity undermine utility finances

Q7: How do taxes and subsidies affect incentives for adoption of electric vehicles? A7: Fiscal regimes often incentivize





Fiscal regime slightly discourages ICEV purchase

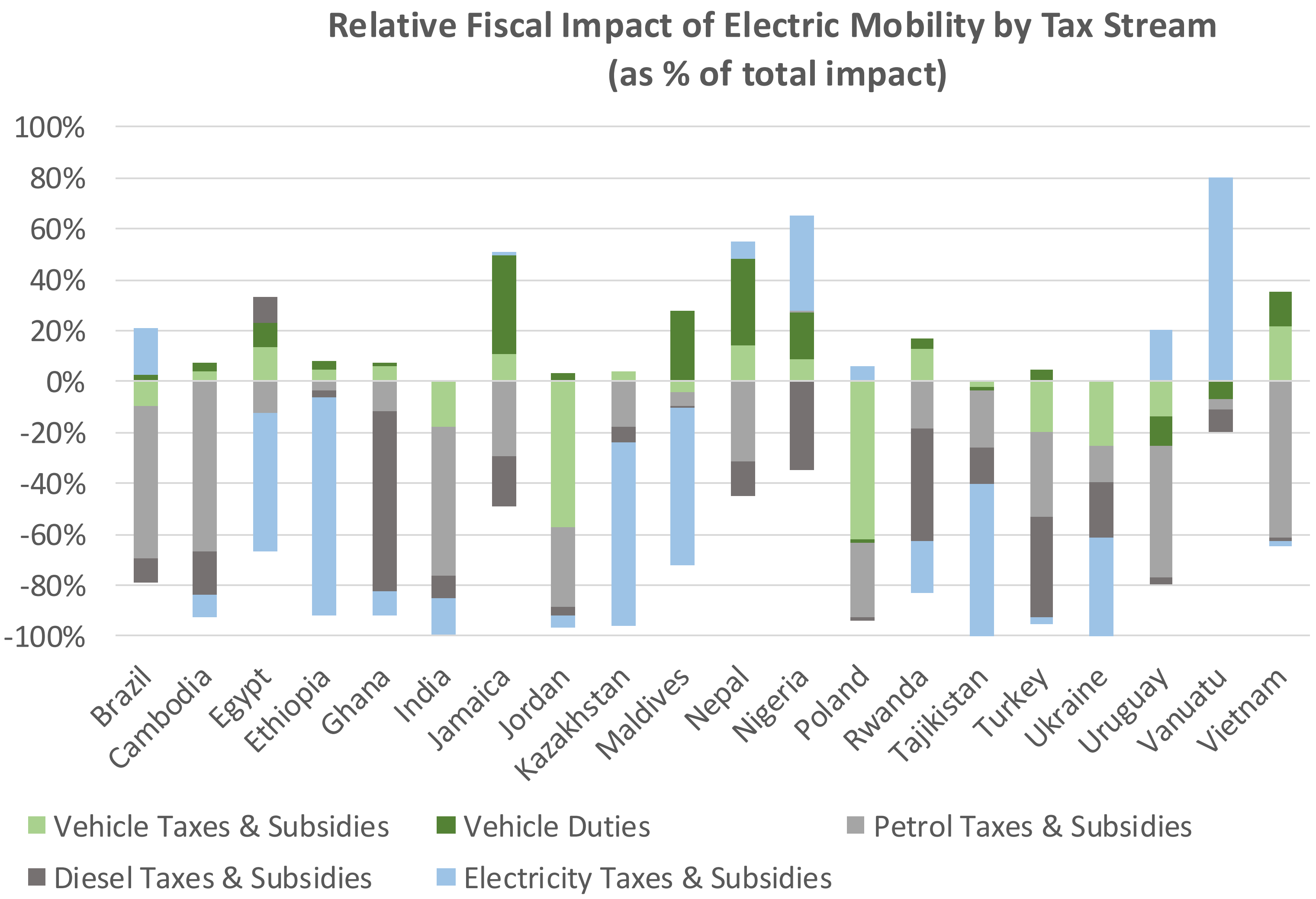
- Half the countries do not differentiate fiscally
- Half the countries penalize by just 20%

Fiscal regime makes EVs cheaper to run

- Petrol – heavily taxed (~40-120%) due to externalities
- Electricity – heavily subsidized (~40%) as basic need

Share of countries with case for electric mobility rises from 50% in economic terms to 75% in financial terms

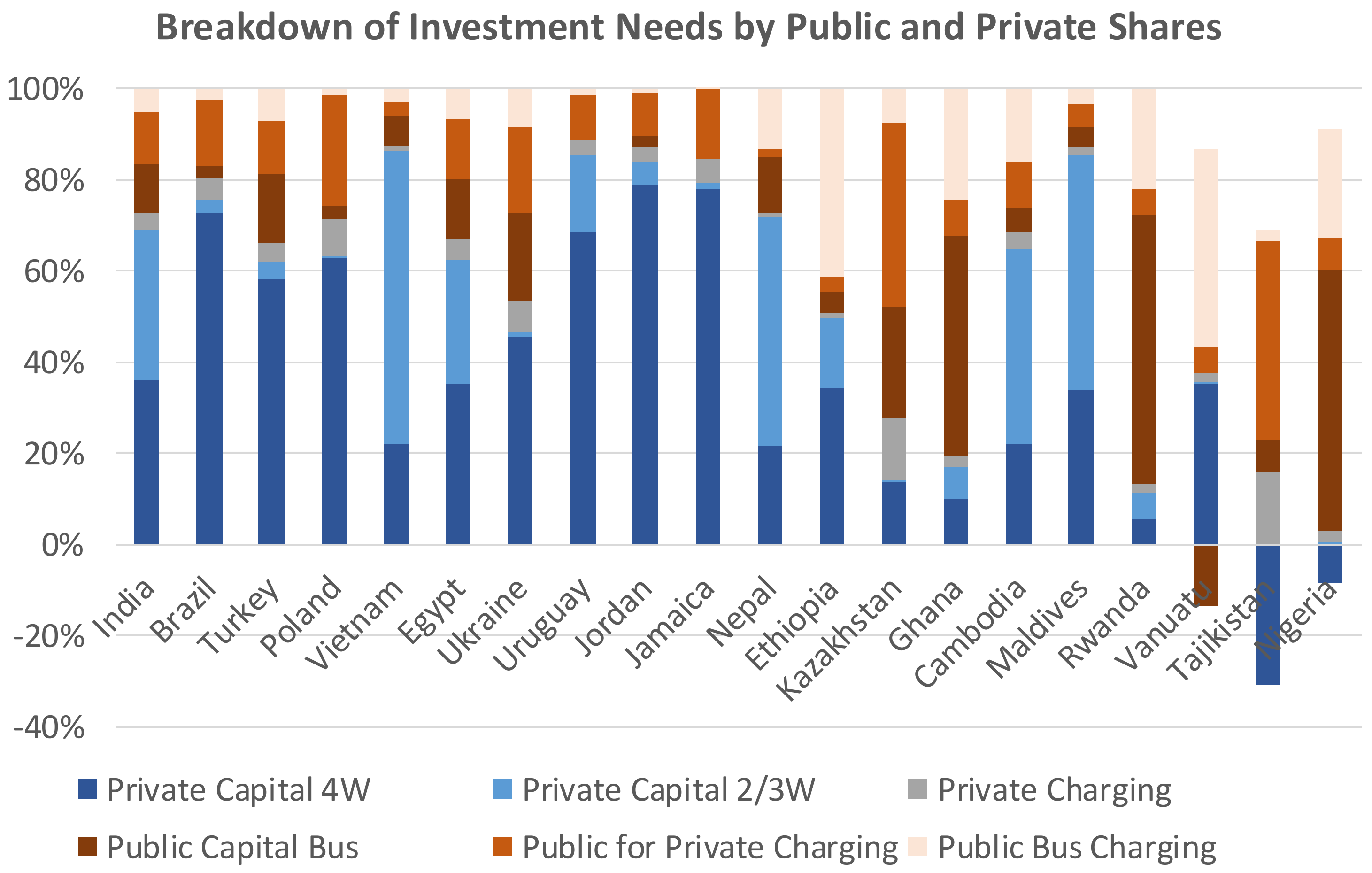
Q8: What are the fiscal implications of accelerated transition to electric mobility? A8: Fiscal implications typically negative



Source: World Bank *Electric Mobility Scoping Tool*, 2022

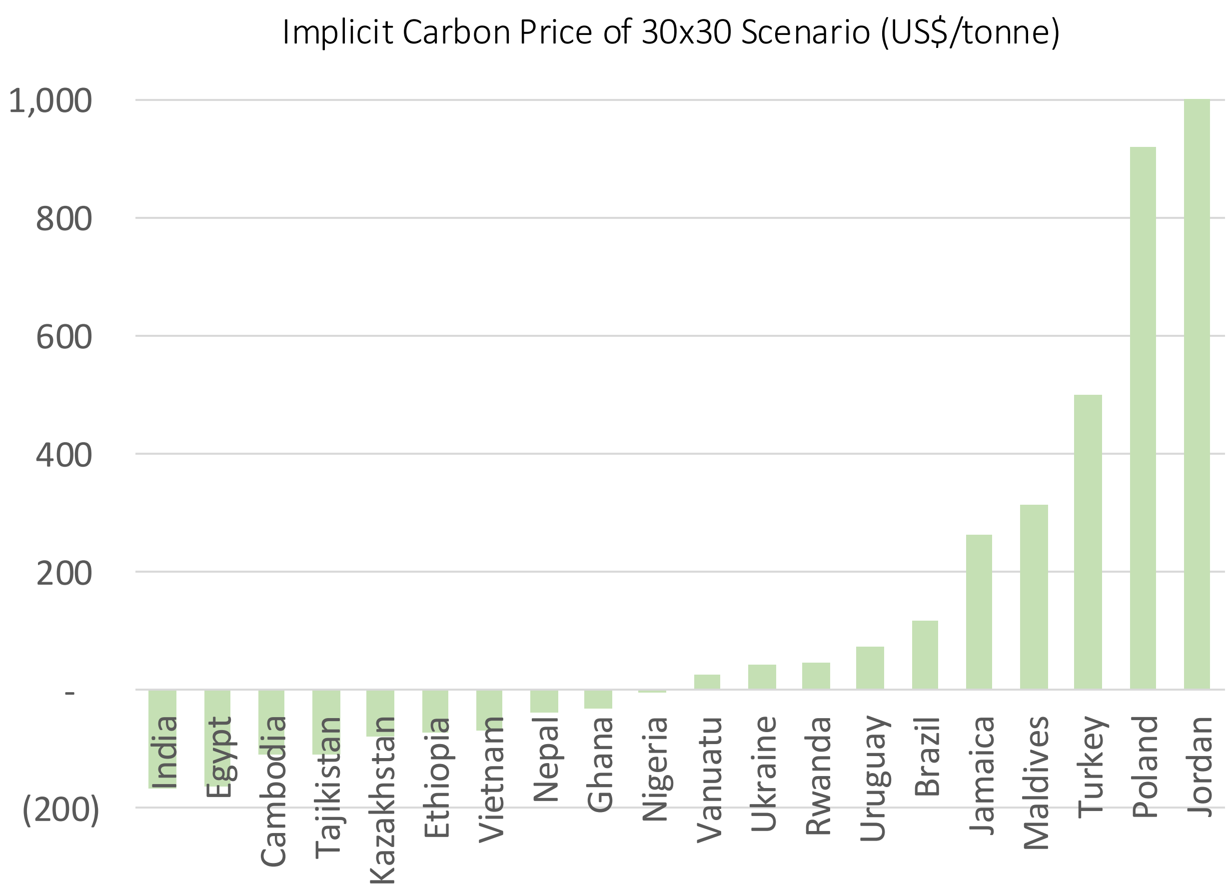
Q9: What are the investment needs associated with electric mobility and who bears them? A9: Public-private share varies

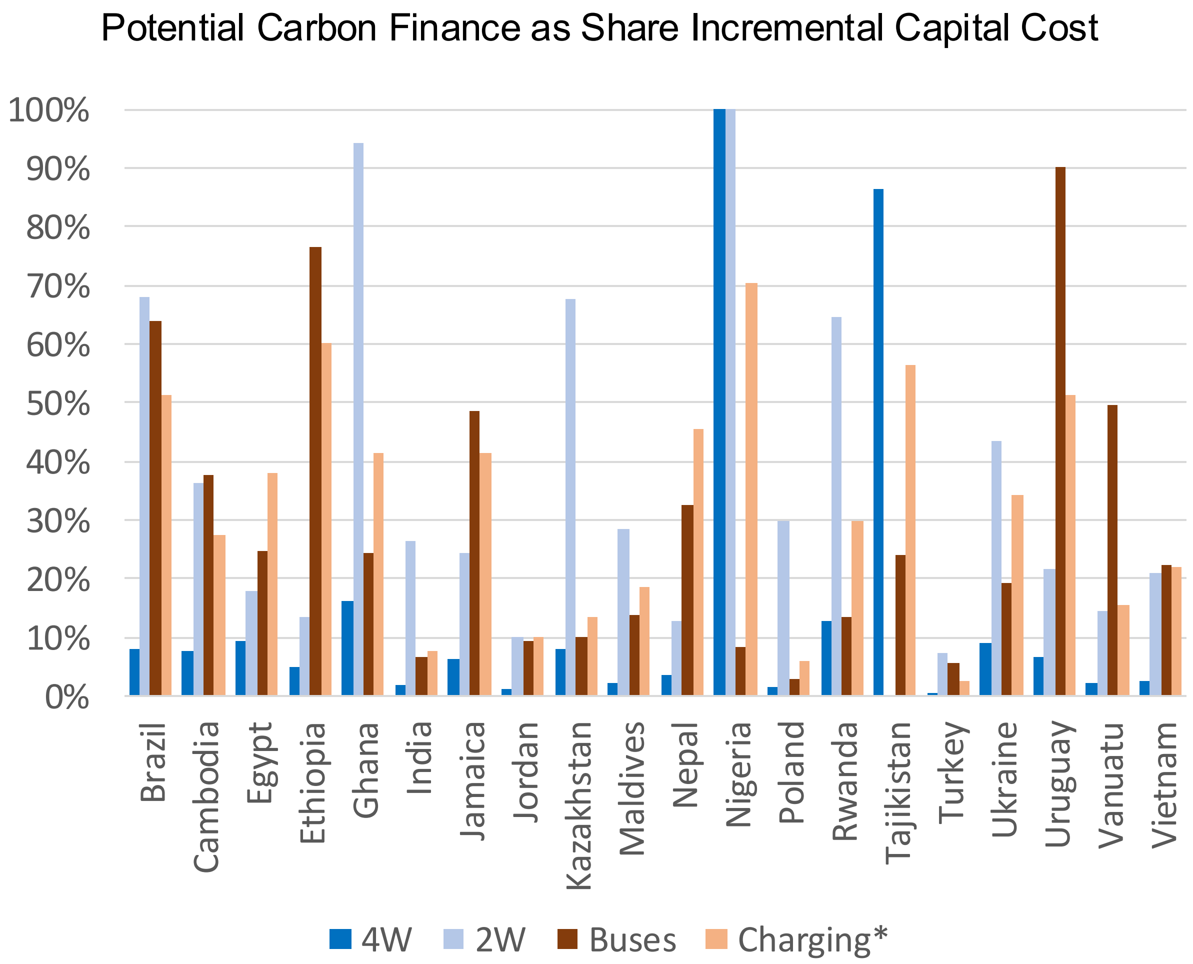
- Median investment needs are
  - 0.28% of GDP
  - (or 0.65% of tax revenues for public component)
- Investments fall on different actors
  - UMICs: largely **private**
  - LMICs: largely **public**



Source: World Bank *Electric Mobility Scoping Tool*, 2022

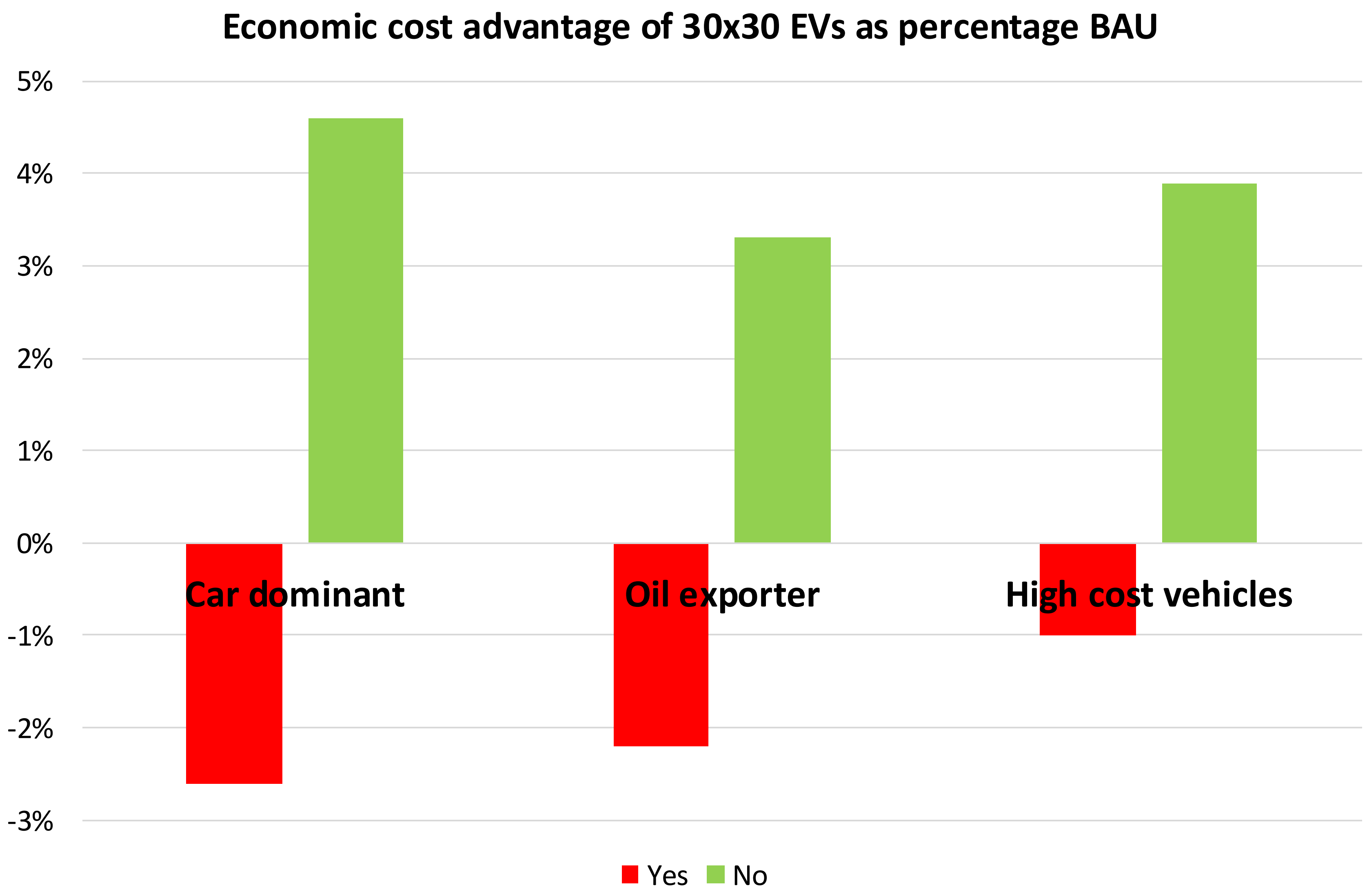
Q10: Could carbon finance play a role in financing the electric mobility transition? A10: Implicit carbon price quite low





- Median implicit carbon price of US$10 (often negative and mainly <US$100)
- Except for 4Ws, carbon finance could cover 30-60% of incremental capital costs

Simple country typology has strong explanatory power regarding outcomes of economic analysis



How can policymakers accelerate adoption of electric passenger vehicles?

Strategic Recommendations

- Identify primary motivation for pursuing electric mobility
- Position electric mobility within a wider sustainable mobility strategy
- Evaluate the case for, and timing of, electric mobility at the country level
- Establish mechanisms for institutional coordination

How can policymakers accelerate adoption of electric passenger vehicles?

Transport Sector Recommendations

- Target adoption of electric mobility towards promising vehicle types
- Prioritize use of public funds for subsidizing charging infrastructure
- Facilitate recycling of batteries for electric vehicles.
- Facilitate battery swapping models
- Adopt demand pooling mechanisms to procurement of buses

How can policymakers accelerate adoption of electric passenger vehicles?

Energy Sector Recommendations

- Integrate demand for electric mobility into power sector planning
- Adopt demand management measures to shift/flatten charging peak
- Reform electricity tariff structures to incentivize efficient charging
- Reform energy prices to ensure suitable incentives for adoption

How can policymakers accelerate adoption of electric passenger vehicles?

Finance Recommendations

- Aggregate demand and enlarge markets at national or regional scale
- Create financing mechanisms to spread higher capital costs
- Tap into carbon finance to offset public investment needs
- Adjust fiscal regime to avoid loss of public sector revenues

To download underlying report go to:

https://openknowledge.worldbank.org/handle/10986/38265

Annex

- Further Methodological Details

Framework for economic analysis

$$\Delta\ NSC = PV_{30x30}\ (Economic\ Cost) - PV_{BAU}\ (Economic\ Cost)$$

$$\Delta\ NSC = PV_{30x30}\ (CC + OC + CI - T + S + EX) - PV_{BAU}\ (CC + OC + CI - T + S + EX)$$

Or alternatively

$$\Delta\ NSC = \underbrace{\Delta PV\ (CC - T_{cap} + S_{cap})}_{\text{Capital}} + \underbrace{\Delta PV (OC - T_{ope} + S_{ope})}_{\text{Operations}} + \underbrace{\Delta PV\ (CI)}_{\text{Charging Infrastructure}} + \underbrace{\Delta PV\ (EX)}_{\text{Environmental}}$$

Δ: difference between 30x30 Scenario and BAU
PV: present value of costs
NSC: net social cost
CC: vehicle capital costs
OC: vehicle operating costs
T: taxes
S: subsidies
CI: Charging infrastructure
EX: environmental externality costs

Framework for economic analysis
(can be modified to provide financial analysis also)

$$\Delta\ NSC = PV_{30x30}\ (Economic\ Cost) - PV_{BAU}\ (Economic\ Cost)$$

$$\Delta\ NSC = PV_{30x30}\ (CC + OC + CI - T + S + EX) - PV_{BAU}\ (CC + OC + CI - T + S + EX)$$

Or alternatively

$$\Delta\ NSC = \underbrace{\Delta PV\ (CC - T_{cap} + S_{cap})}_{Capital} + \underbrace{\Delta PV(OC - T_{ope} + S_{ope})}_{Operations} + \underbrace{\Delta PV\ (CI)}_{Charging\ Infrastructure} + \underbrace{\Delta PV\ (EX)}_{Environmental}$$

Δ: difference between 30x30 Scenario and BAU
PV: present value of costs
NSC: net social cost
CC: vehicle capital costs
OC: vehicle operating costs
T: taxes
S: subsidies
CI: Charging infrastructure
EX: environmental externality costs

Data

The model draws on a wide range of available data and assumptions from public data sources.

Country Specific Data:

- Transport sector data: Vehicle stock and sales, Traffic volumes, Fuel prices, Charging infra.
- Power sector data: Generation and mix, Energy prices, Electricity capacity
- Imports: Import shares and other data for transport and power sector
- Economic data and projections: Population, GDP, Transport and power sector multipliers
- Fiscal data: Tariffs, Tax, Subsidies

General assumptions:

- Emissions: Transport emissions factors, vehicle pollutions standards and production emissions (PM, NOx, CO_2, SO_2), Power sector emissions factors (PM, NOx, CO_2, SO_2), Environmental damage coefficients
- Transport: Occupancy rates, vehicle depreciation, charging infra density assumptions, vehicle efficiency improvements
- Costs: Vehicle, powertrain, battery, and maintenance costs, power sector investment and O&M costs.

Scenarios

Base Scenarios:

- **BAU**: We set a Business as Usual (BAU) as baseline scenario, where vehicle fleet continues to evolve according to historic trends without any explicit policy to promote EV transition.
- **30x30 Scenario**: which means the national EV will reach the target of 30% of new cars/buses entering the national fleet will be EVs and 70% for the 2/3 wheelers.

Alternative Scenarios for Sensitivity Analysis:

- **Green Grid Scenario**, a country's power generation mix undergoes further decarbonization to reach higher share of renewable energy. This increases the externality benefits associated with EV adoption.
- **Scarce Minerals Scenario,** it is assumed that the cost of batteries declines more slowly (3.5% pa vs. 7% pa) than anticipated due to global shortages of rare earth minerals and their associated rising prices.
- **Efficient Bus Scenario**, we explore the possibility of further optimizing management of bus fleets to secure procurement savings (35%) and extend bus mileage to maximize operational benefits (35000, 60000, 75000).
- **High Fuel Efficiency Scenario:** To test the scenario where ICE vehicle fuel efficiency improves at a faster pace than the current projection, we assume the fuel efficiency improvement rate doubles (about 30% from 2020 to 2030.)
- **Taxi fleet Scenario** (High Efficiency 4W): consider the 4W fleet is composed by taxis, with higher occupancy and VMT. (4W VMT is 4X for each country; doubled the density of fast chargers for cars and the maintenance cost; and assumed two battery replacements during lifetime).

Exploring sensitivity of results

- **Green grid scenario:**
  - Median value of externality benefits rises by ~25%
  - However, only one country flips from unfavourable to favourable
- **Scarce minerals scenario:**
  - Median capital cost of vehicles rises by ~40%
  - Moreover, three countries flip from favourable to unfavourable
- **Fuel efficiency scenario**:
  - Three countries flip from favourable to unfavourable
- **Efficient bus scenario**:
  - Three countries flip to favourable for e-buses leaving only one unfavourable
- **Taxi fleet scenario**:
  - Three countries flip to favourable for e-4Ws but still a minority

Step 1: Transport Demand

GDP

Population

Veh. Stock

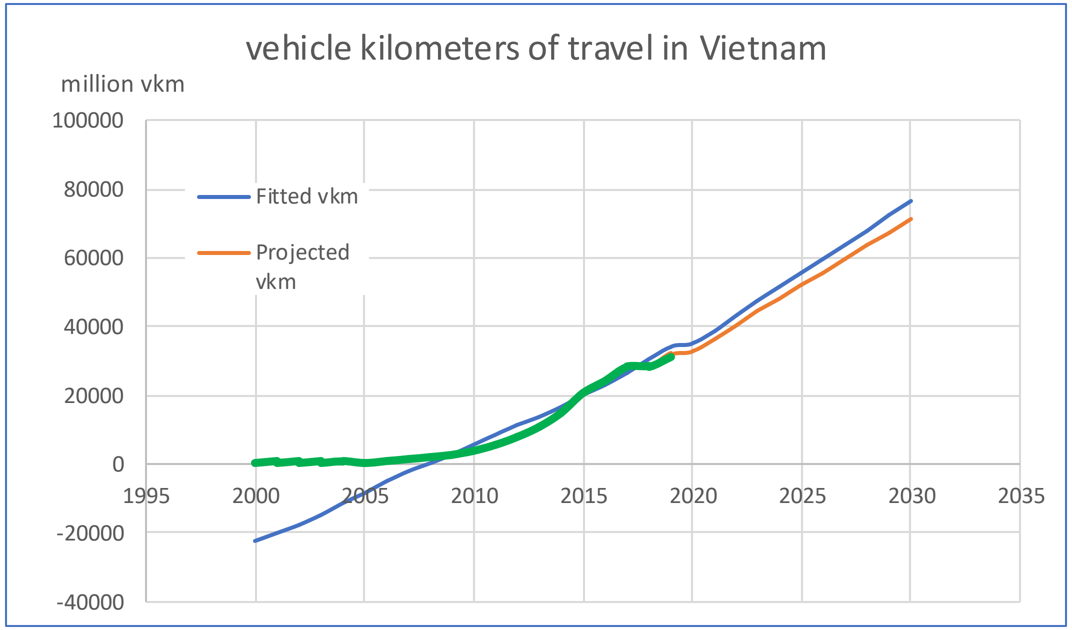
vkm per vehicle

Total vkm

$$vkm\ per\ capita_i = a_i + b_i * \ln(GDP\ per\ capita)$$

$$projected\ total\ vkm\ by\ count = vkm\ per\ capita\ * pop$$

$$total\ vehicle\ required = country\ total\ vkm\ /vkm\ per\ vehicle$$



$a_{car} = 633 \qquad b_{car} = -4636$

$R^2_{car} = 0.909$

Data Available (Bank, IMF, …)

Data from Country Specific Sources

Intermediate Results

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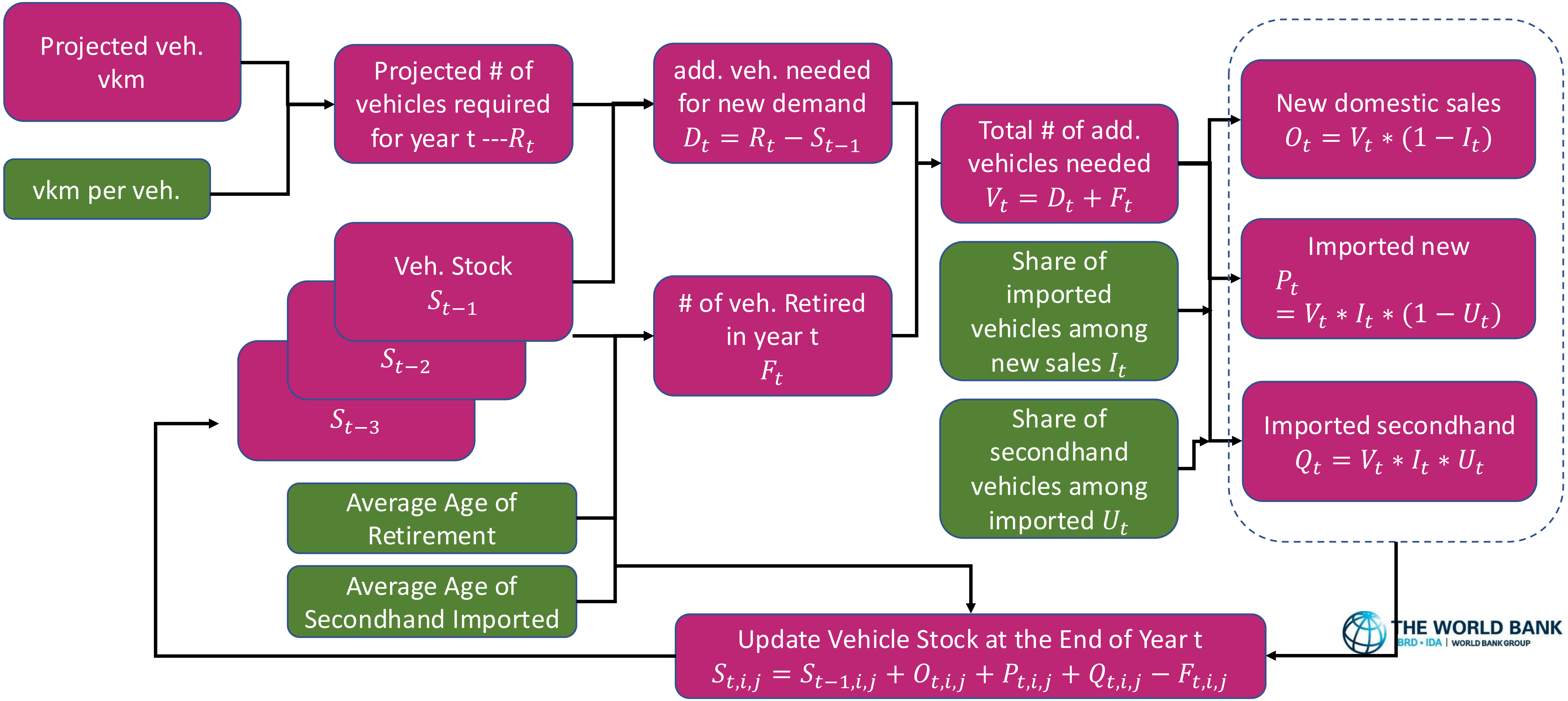
Step 2: Vehicle demand



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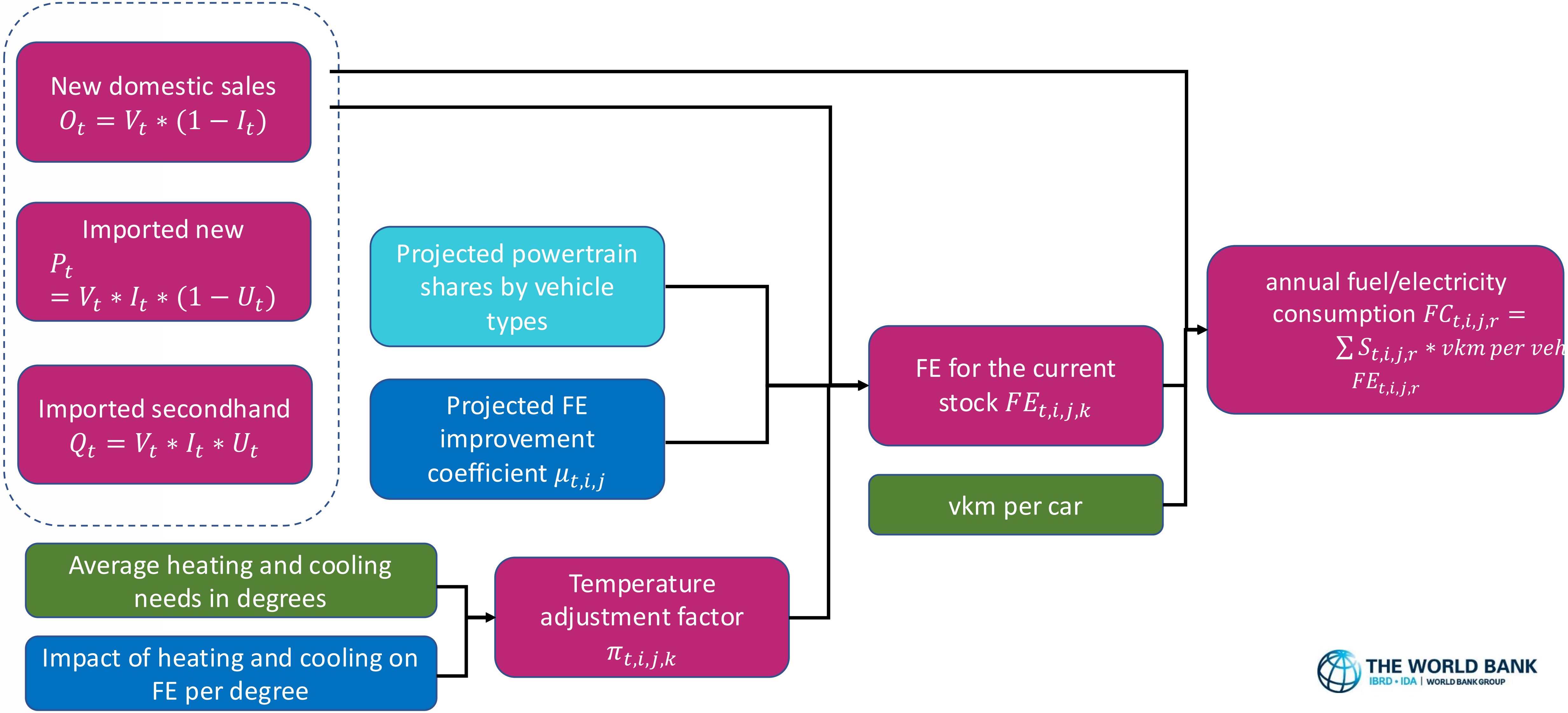
Step 3: Fuel efficiency and consumption



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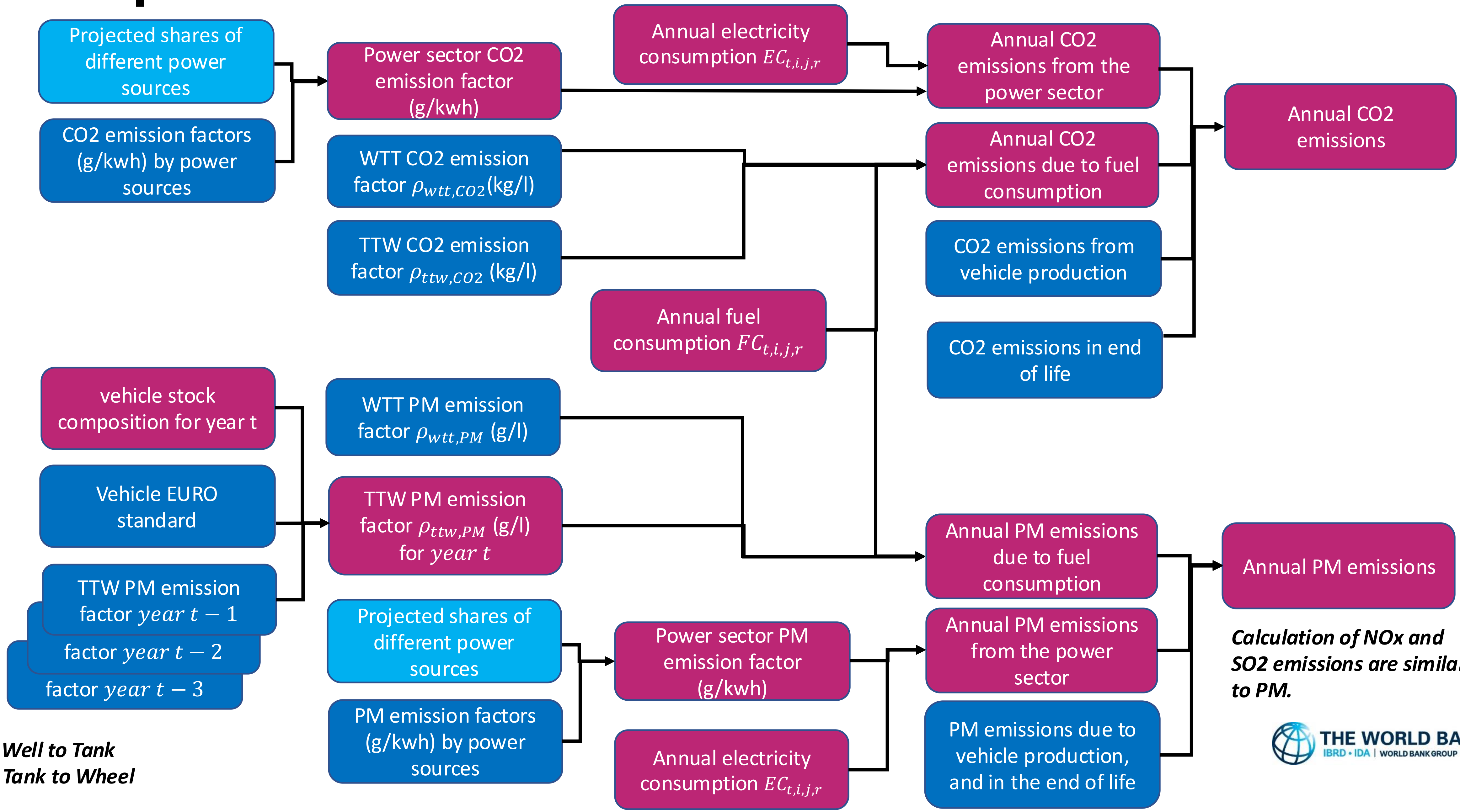
Step 4: Emissions



Calculation of NOx and SO2 emissions are similar to PM.

WTT: Well to Tank
TTW: Tank to Wheel

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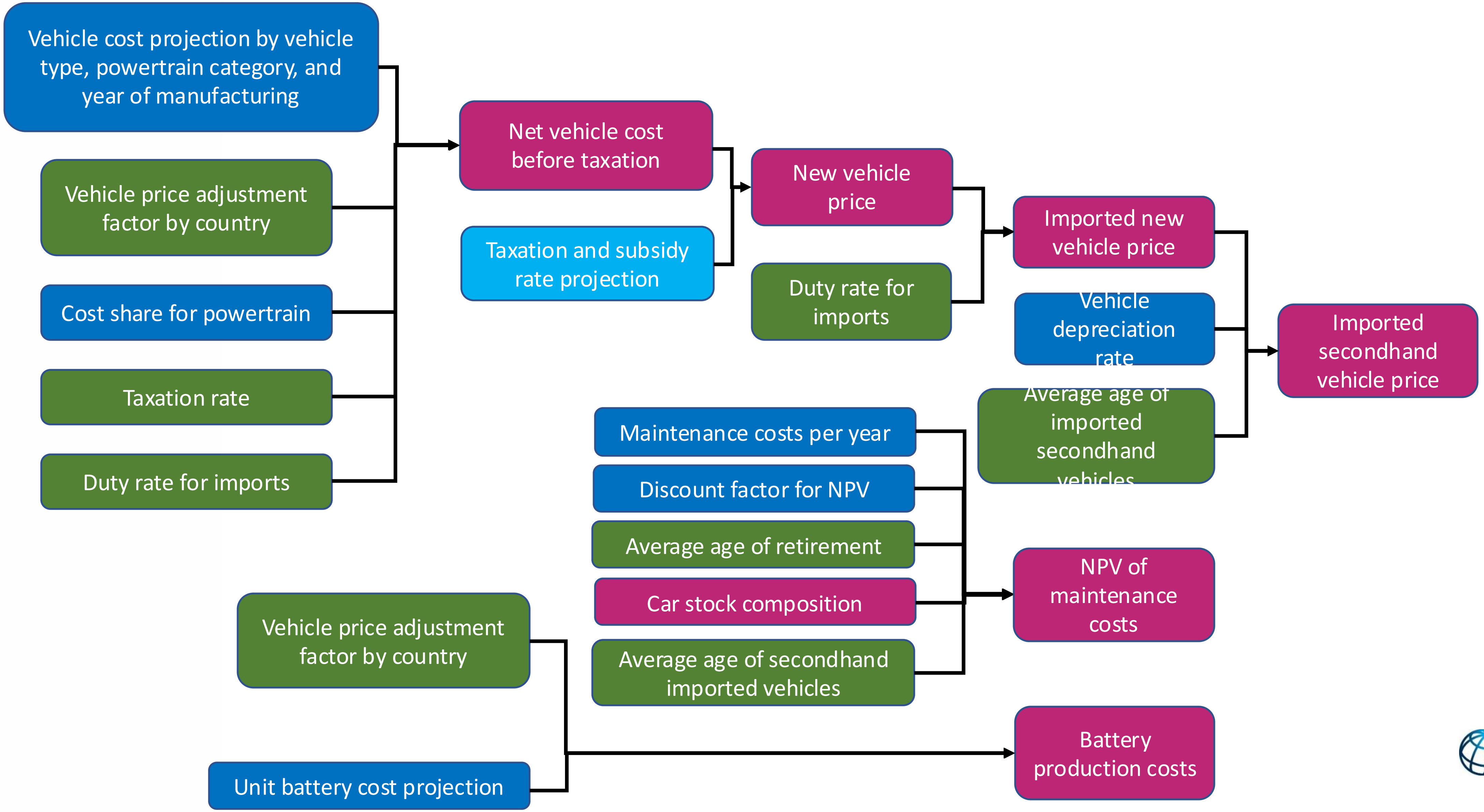
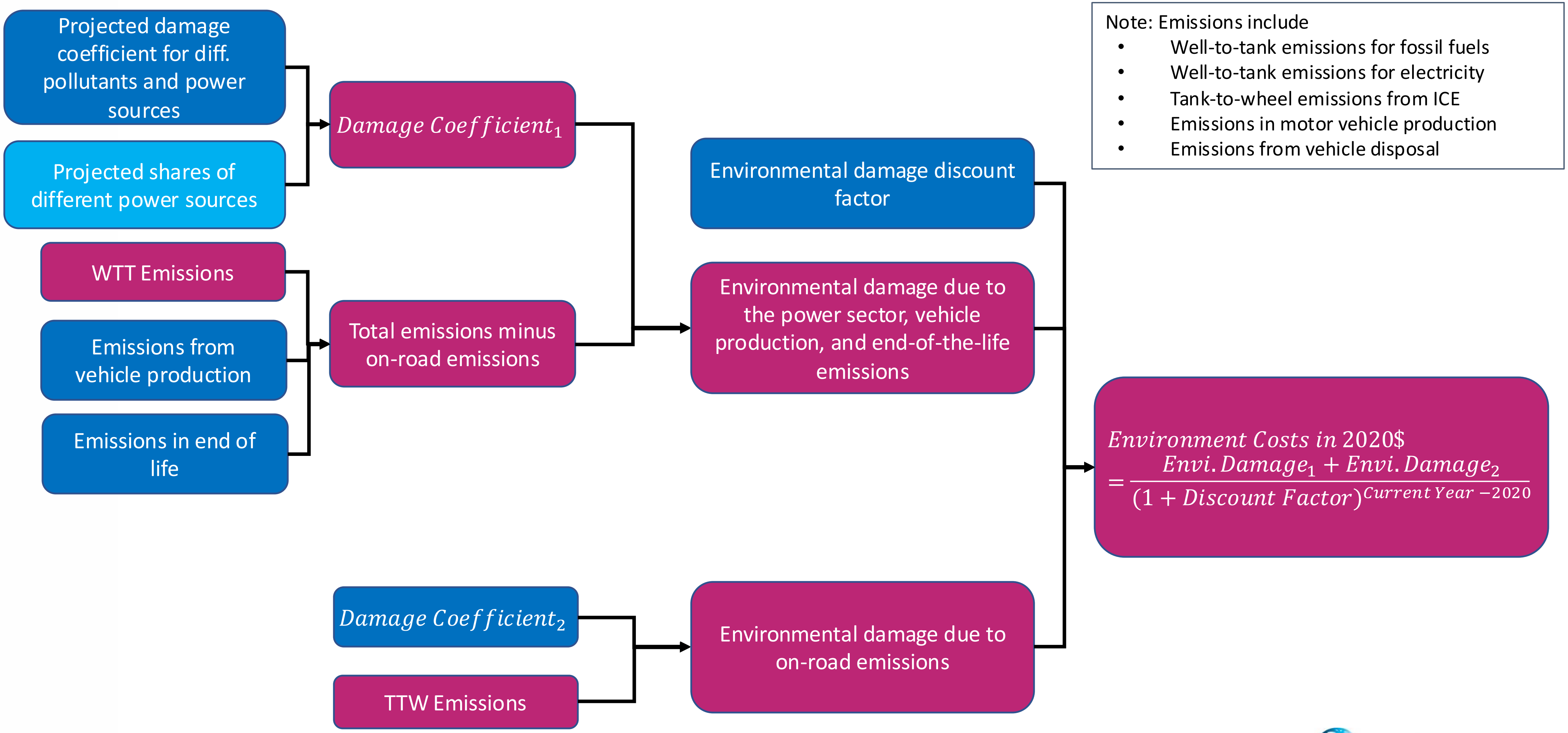
Step 5: Vehicle Cost



Step 6: Environmental Impacts



The same procedure is applied for CO2, NOx, PM, and SO2, respectively.

Overview of globally fixed model assumptions

Battery	unit	value
Batteries-share of EV total value	%	37%
Battery annual cost reduction	%	7%
EV discount rate	%	6.6%

Environmental Damage Cost	unit	min	median	max
CO2	$ per ton	80	80	80
NOx	$ per ton	5	384	8,996
PM	$ per ton	769	32,986	30,5692
SO2	$ per ton	207	3,673	22,725

Overview of country-varying model assumptions

Over whole sample of 20 countries in 2020	Mode	Unit	Min	Median	Max
Vehicle stock total	car	#	3,627	948,727	41,846,850
	2w	#	-	658,806	190,685,490
	bus	#	54	87,321	1,517,685
BEV % of total	car	%	0.00%	0.01%	8.20%
	2w	%	0.00%	0.00%	4.46%
	bus	%	0.00%	0.00%	4.49%
Average distance traveled annually per vehicle	car	km	8,029	15,224	20,000
	2w	km	3,960	7,627	12,800
	bus	km	17,799	48,092	77,380
Import share of new sales	car	%	7%	83%	100%
	2w	%	7%	83%	100%
	bus	%	7%	83%	100%
Vehicle lifetime -retirement age	car	#	15	22	35
	2w	#	7	17	34
	bus	#	20	20	20
Vehicle retail price	car	US$	$ 22,807	$ 53,915	$ 119,446
	2w	US$	$ 821	$ 1,942	$ 3,981
	bus	US$	$ 182,775	$ 205,622	$ 292,440