## 2 The Potential of e-Mobility in Small Island States: Energy and Policy Considerations

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in:

# Towards Sustainable Transport and Mobility

## Perspectives on Travelling and Commuting in Small Island States

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# Contents

## Part I Transition in Personal Transportation Solutions

## Part II Digitalisation of Transport and Mobility

## Part III Non-Motorised Mobility

## Part IV Planning and Measuring Public Transport

# 2 The Potential of e-Mobility in Small Island States: Energy and Policy Considerations

*G. King and B. Maharaj*

Populated islands with a small land area, such as many of those in the South Pacific, the Indian Ocean, the Mediterranean and the Caribbean regions, are generally well suited to the adoption of e-mobility (O'Neill-Carrillo, Lave, & Haines, 2021). It can form an important part of making transport more sustainable and accessible. Energy efficiency is particularly important in SISs, which often have vulnerable electricity grids with generation based on imported fuels (Mahadeo, G.; Bahadoorsingh, S.; Sharma, 2017).In the global phenomenon of vehicle electrification, SISs can benefit very significantly from the deployment of Battery Electric Vehicles (BEVs) and there are some different barriers to adoption. Most islands lag behind developed markets in the deployment of BEVs, with some notable exceptions such as Barbados (Sophie Hares, 2018) and Waiheke Island in Auckland (Dobson, 2018).

In this chapter, we aim to highlight the potential benefits that could be gained by accelerated deployment of e-mobility in SISs. We focus on Light Duty Vehicles (LDVs) and buses since space did not permit discussion of the potential of electric micro-transport or two- and three-wheeled vehicles. An overview of the world market sets the context; general opportunities and challenges that arise from the geo-political characteristics of SISs are surveyed; and suggestions for policy approaches are discussed. The chapter concludes with recommendations for an effective transition.

## Global Trends and Issues in e-Mobility

Battery electric powertrains are more efficient, are quieter in operation, and can give better performance than internal combustion engines (ICE), all with zero harmful tailpipe exhaust emissions. Even when a BEV is charged on a grid that is powered by fossil fuels, the reduction in carbon emissions per km of travel can be significant, up to 60 % when combined cycle natural gas power generation is in use (Nealer, Reichmuth, & Anair, 2015). As the proportion of electricity is generated from renewable sources increases on a national grid, BEVs become relatively more carbon efficient (IEA, 2019).

The current global stock of passenger car BEVs is about 12 million, and there are about 600,000 buses. Around 44 % of global 2- and 3-wheeler vehicle sales are BEVs, with penetration reaching 25 % of the global fleet mostly in India and China. Aggressive growth is expected to continue, driven by government incentives and policy decisions; proliferation of BEV models available on the market; and the advance of battery technology and manufacturing economies of scale that improve performance and reduces cost.

Policy makers around the world are using legislative instruments to encourage and accelerate the transition to BEVs, with countries making policy commitments to phase out the sale of new combustion engine LDVs from as early as 2025. Many governments are offering cash incentives to customers buying new BEVs or attractive rates for the scrappage of old ICE vehicles. Support is being provided for charging infrastructure (Lieven, 2015).

Advances in battery technology, stabilised supply chains, and economies of scale have led to a nine-fold reduction in battery prices over the last 10 years (BloombergNEF, 2021). Batteries being the most expensive component in a BEV, this cost reduction has been germane to the growth in BEV sales.

BEV buses are growing in importance. China is the leading market with 27 % of new bus registrations being EVs in 2020 (IEA, 2021; Song, Liu, Gao, & Li, 2020). The global stock of BEV buses was approximately 600,000 in 2020, 99 % of which are in China. BEVs are ideally suited to start-stop duty cycles, with significant energy recovery through careful driving; reduced and simpler maintenance; and favourable vehicle architecture, improving the functionality of the bus. Heavy-duty vehicles (HDVs), using mainly compression ignition engines powered by diesel fuel, account for 24 % of GHGs in the US (US EPA, 2021) and up to 70 % of tailpipe emissions of NOx and PM pollutants. BEV HDVs can bring significant life cycle cost and environmental benefits (Sen, Ercan, & Tatari, 2017). The availability of electric heavy-duty vehicle models lags behind LDVs and buses, but models of different classes are gradually starting to appear on the market. Light and medium commercial vehicles sector, often used in urban areas for transporting equipment and materials and deliveries, are well suited to electrification. For instance, in the UK, over half of all panel vans remain within 24 km of their base on a typical day (UK Department of Transport, 2021), and have frequent stops and starts for deliveries. Most vans used for business purposes return to a base at the end of each day, and many return to base multiple times during the day. As a result, the range requirement for electric transport and delivery vans is lower than that for passenger cars, allowing them to use smaller batteries and making them more affordable.

Passenger cars, including SUVs and light duty electric pickup trucks, is the sector in which electrification has taken strongest hold. In 2019, there were 72 BEV models available in the US. Exponential growth in BEVs is expected in the coming decade. Only 2.3 % of LDV sales in the US in 2020 were BEVs, but global sales grew by 43 % year-on-year in 2020, and by 98 % year-on-year in 2021[1] (Figure 2.1).

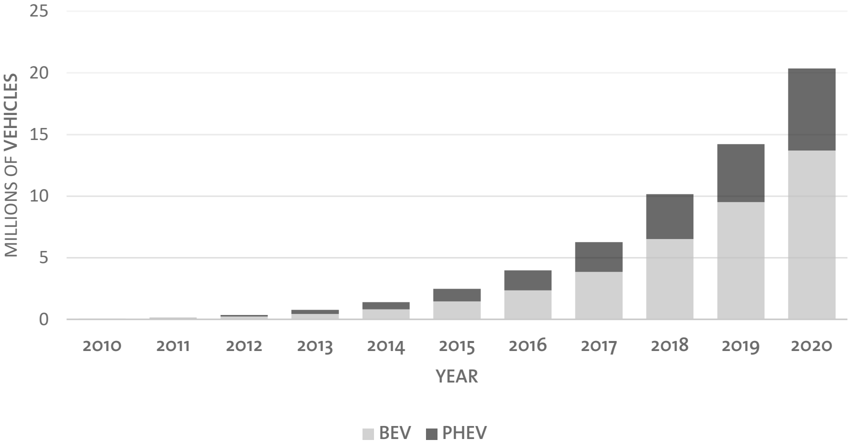

Figure 2.1 Global Electric Vehicle Stock by Powertrain Type 2010–2020
*Note: Data Source IEA EV Global Outlook 2021. Compiled by authors*

Supply of raw materials, such as cobalt and lithium, may prove to be a constraint on the growth of BEV sales. Production capacity will continue to expand as new supply sources are developed, but it is uncertain whether supply can meet demand (UNCTAD, 2020). Demand competition for battery raw materials is not only generated by BEVs but also by the burgeoning energy storage industry, in support of renewable energy installations. Supply constraints may cause BEV manufacturers to focus on products and markets that maximise returns.

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[1] Estimated.

## General Opportunities and Challenges for BEVs in SIS

Distinctive characteristics of SISs, and in particular SIDS, provide opportunities and challenges for EV deployment that are different from those of continental countries. This section identifies some key characteristics of an island context, and their implications for EV usage. A sample set of Caribbean SISs has been selected for analysis: Antigua; Aruba; Bahamas; Curaçao; Dominican Republic; Jamaica; Puerto Rico; St. Kitts; St. Lucia; St. Vincent; and Trinidad & Tobago. Additional more developed SISs were added to the analysis for comparison purposes: Cyprus; Malta; Mauritius; Singapore, and Taiwan. While not all the opportunities and challenges identified here are relevant to all islands, those discussed provide an important backdrop that can inform island-specific EV policy.

### *Low Point-to-Point Trip Lengths*

In SISs, inter-city road trips are uncommon. Daily average trip distances can be similar to those in continental markets; for instance, survey results indicate that the average daily mileage in Trinidad and Tobago is 57 km[2]; but the frequency of longer drives will be much lower. Therefore, range anxiety that has historically slowed BEV adoption in larger markets is not a consideration in a SIS. Even though the daily journey of new light duty vehicle users is approximately 58 km in the UK[2] (UK Government: Department for Transport, 2020) 47 km in the Beijing area of China[2] (Cox, 2021) and 80 km in the US[2] (USOHP, 2020), range is a valid concern since longer road trips between cities are common. In a continental context, the range of a BEV is as important as other factors, such as performance or comfort to purchasers (Nie, Wang, Guo, & Shen, 2018). While high speed DC charging technologies, a growing charging infrastructure, and customer experience are helping to mitigate range anxiety in the major markets, they will remain very important factors that drive e-mobility policy.

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[2] Calculated by dividing the average annual mileage for light vehicles by 282 days per year of usage.

Table 2.1 Examples of Small Island Maximum Point-to-Point Journey Distances and Estimated Travel Time

| ISLAND | POINT A | POINT B | DISTANCE (KM) | TRAVEL TIME (HOURS) | AVERAGE SPEED (KM/H) | CHARGES ENROUTE | DESTINATION CHARGING FOR RETURN? |
|---|---|---|---|---|---|---|---|
| Antigua | Devil's Bridge National Park | Jolly Beach | 29 | 0.82 | 36 | 0 | N |
| Aruba | San Nicolas | Arashi Beach | 35 | 0.75 | 47 | 0 | N |
| Bahamas | Crown Haven | Sandy Point | 171 | 2.15 | 80 | 0 | Y |
| Curaçao | Newport | Sabana Westpunt | 62 | 1.17 | 53 | 0 | N |
| Dominican Republic | Punta Cana | Monte Cristi | 457 | 6.05 | 76 | 2 | Y |
| Jamaica | Negril | Happy Grove | 309 | 6.48 | 48 | 1 | Y |
| Malta | San Lawrenz | Birżebbuġa | 54 | 1.12 | 48 | 0 | N |
| Mauritus | Cap Malheureux | Souillac | 77 | 1.30 | 59 | 0 | N |
| Puerto Rico | Rincon | Ceiba | 246 | 3.20 | 77 | 1 | Y |
| Singapore | Singapore Changi Airport | Tuas | 52 | 1.00 | 52 | 0 | N |
| St. Kitts | Heldens | Banana Bay | 38 | 0.77 | 50 | 0 | N |
| St. Lucia | Gros Islet | Hewanorra Inter'l Airport | 65 | 1.55 | 42 | 0 | N |
| St. Vincent | Kingstown | Owia | 46 | 1.47 | 31 | 0 | N |
| Trinidad & Tobago | Matelot | Icacos | 217 | 4.90 | 44 | 1 | N |

*Note. Estimated travel time calculated by Google Maps Travel Planner. Charges required based on an estimated BEV driving range of 200 km. Malta travel time does not include ferry crossing. Compiled by authors*

For most of the smaller islands in the sample set presented in Table 2.1, even a round trip between the farthest points on the island would require neither en-route nor destination charging. Minimal public charging networks in these islands would be sufficient for the use of private and light commercial vehicles. Larger islands such as Dominican Republic, Puerto Rico, Jamaica, and Trinidad and Tobago require strategically located public charging to support limit case longer journeys. A reasonable assumption is that most journeys on these small islands start and end at the same place, either a home or a workplace, and that charging is possible at that location.

Therefore, the low point-to-point distances on small islands lend themselves to the use of BEVs. Range anxiety should not be a factor in most cases. Minimal public charging infrastructure is needed, once home or workplace charging is possible.

### *Low Average Vehicle Speeds*

Coupled with low average point-to-point distances, average vehicle speeds in SISs tend to be slow. The estimated journey times presented in Table 2.1 were calculated using the Google Maps using its journey planner feature. The corresponding calculated average speeds in many cases, are below 50 km/h. Except for highly urbanised Singapore, the routes plotted on these small islands are primarily rural and the journey times suggest winding, narrow and, in some cases, mountainous roads. Coastal roads pass through sporadic settlements, which will also require slower speeds.

Unlike ICE vehicles, BEVs are more efficient at variable low speeds than at highway speeds. Regenerative braking allows for the recovery of energy when slowing is required, improving efficiency and extending the range. When stopped in traffic or at a road junction, BEVs use minimal energy, unlike combustion engine vehicles that enter an idling cycle.

Therefore, low average vehicle speeds on small islands also lend themselves to the use of BEVs and the efficiency and range of these vehicles may even be greater than their published WLTP certification test results, since higher speed driving conditions are less common than represented in the certification test (UK Vehicle Certification Agency, 2021).

### *Concerted Efforts to Phase out Fossil Fuels*

By their very nature, SISs must import any goods that cannot be extracted or produced domestically. Most SISs have no natural fossil fuel energy resources, yet historically they have relied on imported fossil fuels for their energy needs: smaller islands have relied on diesel generators for power generation (IRENA, 2018); larger islands have used a combination of coal, fuel oil, and natural gas. Some legacy coal power stations are still in operation. There are some notable exceptions, such as Trinidad and Tobago, which started transitioning to local natural gas power generation in 1976 and has been entirely reliant on natural gas since 1999 (Espinasa & Humpert, 2016).

Reliance on imported fossil fuels for transportation and electricity generation has several drawbacks for SISs:

### High Cost of Importing Fossil Fuels, which Translates into Elevated Prices of Electricity and Transportation

SISs, being small markets, are often unable to command competitive pricing for fossil fuels and are subject to prevailing market rates. High energy prices increase industrial and commercial operating costs, increasing the cost of living and potentially elevating wages to compensate. Locally manufactured products can be more expensive than imported equivalents, and exports from the manufacturing sector will struggle with cost competitiveness in international markets (Briguglio, 1995).

### Volatile Energy Costs Due to Fluctuations in Market Price of Key Fuels such as Oil

Not only do SISs have to deal with high energy costs, they also tend to be less able to finance hedging of fuel for stable internal pricing.

### Air Pollution from Combustion

Many SISs lack the institutional robustness to regulate emissions from the power generation and transportation sectors. Particularly in SIDS, poor fuel quality, maintenance standards and vehicle roadworthiness testing can lead to some vehicles becoming highly polluting. Air quality is degraded in urban centres and in the proximity to roadways, a phenomenon that is exacerbated in islands that suffer from severe traffic congestion such as Barbados, Mauritius and Trinidad and Tobago.

### Transportation Contributes to Greenhouse Gas Emissions

Transport tends to be the second highest contributor to $CO_2e$ emissions in SISs, after electricity production. Table 2.2 shows the oil consumption and $CO_2e$ from transportation, for example, SISs. Reducing transport $CO_2$ can have a significant impact on the national carbon emissions.

Table 2.2 Contribution of Transportation to Oil Consumption and $CO_2$e Emissions in Small Island Examples

| COUNTRY | OIL CONSUMPTION FROM TRANSPORT (KTOE) | $CO_2$E FROM TRANSPORT (MILLION T) | TRANSPORT (KG $CO_2$E/ CAPITA) |
|---|---|---|---|
| Curaçao | 355 | 1.09 | 6.90 |
| Cyprus | 665 | 2.04 | 2.33 |
| Dominican Republic | 2441 | 7.50 | 0.70 |
| Haiti | 487 | 1.50 | 0.13 |
| Iceland | 337 | 1.04 | 2.90 |
| Jamaica | 778 | 2.39 | 0.81 |
| Malta | 222 | 0.68 | 1.36 |
| Mauritius | 379 | 1.16 | 0.92 |
| Singapore | 2279 | 7.00 | 1.23 |
| Taiwan | 11964 | 36.7 | 1.56 |
| Trinidad & Tobago | 839 | 2.5 | 1.85 |

*Note. Oil Consumption from Transportation Data Source IEA,* https://www.iea.org/countries *(Accessed 18 Sept 2021). Compiled by authors*

Table 2.3 Examples of Small Island Electricity Production by Source

| COUNTRY | COAL | OIL | NATURAL GAS | NUCLEAR | BIOFUELS | HYDRO | GEOTHERMAL | WIND | SOLAR PV | WASTE | RENEWABLES (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Curaçao | | 71 % | | | | | | 27 % | 2 % | | 29.2 % |
| Cyprus | | 90 % | | | 1 % | | | 5 % | 4 % | | 10.0 % |
| Dominican Republic | 12 % | 50 % | 24 % | | 1 % | 9 % | | 3 % | 1 % | | 13.8 % |
| Haiti | | 81 % | | | | 19 % | | | | | 18.9 % |
| Iceland | | | | | | 69 % | 31 % | | | | 100.0 % |
| Jamaica | | 78 % | 11 % | | | 4 % | | 7 % | | | 11.5 % |
| Malta | | 1 % | 88 % | | | | | | 10 % | | 10.2 % |
| Mauritius | 40 % | 39 % | | | 15 % | 4 % | | | 2 % | | 20.7 % |
| Singapore | 1 % | | 95 % | | | | | | 1 % | 2 % | 5.1 % |
| Taiwan | 46 % | 2 % | 33 % | 12 % | | 3 % | | 1 % | 2 % | 1 % | 8.1 % |
| Trinidad & Tobago | | | 100 % | | | | | | | | 0.1 % |

*Note. Data for 2018–2019, Derived from IAE* https://www.iea.org/countries *(Accessed 18 Sept 2021). Compiled by authors*

Sustainability Goals SDG7 (Affordable and Clean Energy) and SDG13 (Climate Action) are very relevant for SISs, and most are seeking to transition to an increased proportion of renewable electricity production; some such as Barbados, aggressively so (Government of Barbados, 2019). The current electricity generation mix for examples of SISs is shown in Table 2.3.

Efforts to replace fossil fuels with renewable energy synchronises with accelerating the adoption of BEVs. Combined with renewable electricity production, transitioning to BEVs multiplies any reduction in fossil fuel use. Table 2.4 illustrates this fact for four countries that rely heavily on oil for power generation. Substituting 10 % of the existing vehicle fleet with BEVs, assuming that the additional electrical energy demand came from oil electricity generation, yields a saving of 5 % on net oil demand. However, when 10 % of existing oil electricity generation capacity is substituted with renewable sources, a saving of 21 %-29 % is shown (Table 2.4). An exception is Curaçao, which has a surprisingly high oil consumption from transport: based on a national vehicle fleet of 80,000 vehicles, and assuming an average fuel consumption of 10 litres/100km, annual mileage per vehicle is more than 46,000 km, which is very unlikely for such a small island. As a result, the estimated incremental electrical power demand by adopting BEVs is higher than expected, exceeding what is produced by adding 10 % renewables in place of oil generation. It is possible that there is some confusion in the data reporting and that the oil consumption from transportation includes exported refined petroleum products.

Table 2.4 Savings from Combined Action of Introducing 10 % EVs and Increasing Renewable Power Generation 10 %

| COUNTRY | OIL CONSUMPTION SAVED FROM TRANSPORT (KTOE) | TRANSPORT OIL SAVED (KTOE) | GENERATION OIL SAVED (KTOE) | TOTAL OIL SAVED (KTOE) | % OIL SAVED |
|---|---|---|---|---|---|
| Curaçao | 355 | 36 | 8 | 43 | 12 % |
| Cyprus | 665 | 67 | 113 | 180 | 27 % |
| Dominican Republic | 2441 | 244 | 438 | 683 | 28 % |
| Jamaica | 778 | 78 | 86 | 164 | 21 % |
| Mauritius | 379 | 38 | 70 | 108 | 29 % |

*Note. Assuming: average combustion engine vehicle fuel consumption of 10 litres/100 km; average energy consumption of a BEV of 16 kWh/100 km; that renewable generation displaces 10 % of oil electricity generation; and a generation efficiency of 0.297 GWh/ktoe. Compiled by authors*

For SISs that are making a strategic switch to renewable electricity generation, a complementary BEV adoption policy to accelerate uptake will have the effect of multiplying the potential savings in oil imports.

### *Vulnerability to Climate Change Effects Creating an Impetus to Exemplify Carbon Emissions Reduction Efforts*

The contribution of SISs to global carbon emissions and climate change is negligible, but these nations number among its most severe victims. Sea level rise causes coastal erosion and increased instances of flooding threatening especially low-lying SISs such as The Maldives, Tuvalu and Kiribati. Hurricanes or cyclones to which SISs are periodically subjected are becoming more frequent and intense, an example being the destruction of the island of Barbuda by Hurricane Irma in 2017. Changing rainfall patterns are leading to regular drought and flooding, both of which undermine agricultural security.

Advocacy by political leaders of SISs for decisive global action on climate change can be effectively substantiated by demonstrating their own commitment to reduce carbon emissions (Roper, 2005; UNEP, 2021). The adoption of BEVs can form an important element of a carbon reduction strategy.

Table 2.5 Assumed Specific $CO_2e$ Emissions for Power Generation with Various Energy Sources

| ENERGY SOURCE | LIFECYCLE $CO_2e$ (G/KWH) | FUEL ONLY $CO_2e$ (G/KWH) |
|---|---|---|
| Coal | 900 | 850 |
| Oil | 750 | 720 |
| Natural gas | 433 | 430 |
| Nuclear | 7 | 0 |
| Biofuels | 180 | 0 |
| Hydro | 10 | 0 |
| Geothermal | 35 | 0 |
| Wind | 10 | 0 |
| Solar PV | 75 | 0 |
| Waste | 100 | 0 |

*Note. Compiled by authors*

Table 2.6 Vehicle and Charging Energy Efficiency Assumptions

| PARAMETER | ASSUMPTION | JUSTIFICATION |
|---|---|---|
| Grid Transmission Loss | 12 % | |
| BEV Charging Loss | 12 % | |
| BEV Operating Efficiency | 160 Wh/km | WLTP Values |
| Real-world economy measurements | 7 | 0 |
| Gasoline Vehicle Fuel Consumption | 10 litres/100km | Real-world economy measurements |

*Note. Compiled by authors*

Based on the specific current energy mix for each island (Table 2.3), the specific $CO_2$e emissions from electricity generation with different energy sources (Table 2.5), and certain generalised assumptions (Table 2.6), the $CO_2$e savings from the introduction of BEVs are calculated in Table 2.7. The savings are higher in nations with a lower carbon electricity mix. At the extreme, the carbon savings in Iceland will be 100 % since all electricity is renewable. $CO_2$e savings in SISs with a heavy dependence on natural gas (Malta, Singapore and Trinidad and Tobago) is between 61 % and 65 %. The lowest savings will be yielded to Cyprus (oil dependent electricity) and Mauritius (coal and oil), but a $CO_2$e reduction of more than 40 % is still achieved.

Table 2.7 BEV Estimated g $CO_2$e/km Compared with an Equivalent Gasoline Vehicle for Example SISs

| COUNTRY | AT PLUG g $CO_2$e/kWh | BEV IN BATTERY g $CO_2$e/kWh | BEV g $CO_2$e/kWh | GASOLINE g $CO_2$e/km | SAVING g $CO_2$e/km |
|---|---|---|---|---|---|
| Curaçao | 510 | 658 | 105 | 229 | 54 % |
| Cyprus | 648 | 837 | 134 | 229 | 42 % |
| Dominican Republic | 566 | 730 | 117 | 229 | 49 % |
| Haiti | 584 | 754 | 121 | 229 | 47 % |
| Iceland | 0 | 0 | 0 | 229 | 100 % |
| Jamaica | 606 | 782 | 125 | 229 | 45 % |
| Malta | 390 | 504 | 81 | 229 | 65 % |
| Mauritius | 623 | 805 | 129 | 229 | 44 % |
| Singapore | 423 | 546 | 87 | 229 | 62 % |
| Taiwan | 550 | 710 | 114 | 229 | 50 % |
| Trinidad & Tobago | 431 | 556 | 89 | 229 | 61 % |

*Note. Compiled by authors*

Therefore, implementing an accelerated BEV adoption strategy is fully aligned with, and supportive of, the efforts of SISs to exemplify carbon reduction actions.

### *Underdeveloped Public Transportation Systems*

SIDS tend to suffer with weak public transportation infrastructure and organisation. In more developed SISs, such as Taiwan and Singapore, public transportation is very effective. Cause and effect are in operation here – a poorly organised or resourced public transport network increases the attractiveness of personal vehicle ownership and use. For instance, Cyprus, by the early 2010s, had seen a 93 % reduction in bus rides and a corresponding 300 % increase in private vehicle ownership over 30 years, leading to predictable traffic gridlocks (Papageorgiou, Maimaris, & Petros, 2015).

Electric buses provide an opportunity for SISs to upgrade their public transport infrastructure and marketing. Quiet, smooth, and comfortable, the passenger experience of an electric bus tends to be more pleasant than a diesel or CNG equivalent. Reducing tailpipe emissions and ambient noise in urban and suburban environments can help to improve quality of life, and the percentage of $CO_2e$ reduction achieved by replacing a diesel or even CNG bus with a BEV equivalent is similar to what can be achieved by light BEVs. Modern BEV buses can be equipped with tracking software to allow centralised control of the fleet. Combining the introduction of BEV buses with a Rapid Bus Transit system can maximise the benefits of electrification and make public transport more attractive (Papageorgiou et al., 2015).

Commercial vehicles such as buses have much more demanding duty cycles than private vehicles, so get less benefit from the short point-to-point trips on SISs. Providing sufficient range for normal, unrestricted shift operations is a critical success factor for successful deployment of BEV buses. This might require capital investment in innovative charging solutions, such as overhead gantry charging or battery swapping, as has been demonstrated in China and the UK (Miles & Potter, 2014; Song et al., 2020). The large battery packs required by BEV buses make them a very expensive proposition but a lower total cost of operation over the lifecycle of the bus can help to mitigate the upfront cost (Burnham et al., 2021), as can creative financing plans and public-private partnerships for transportation solutions.

## Discussion: Policies to Accelerate the Adoption of e-Mobility

In the previous section, it has been established that BEVs are particularly well suited to SISs, but their deployment is not without some challenges. They are beneficial economically, allowing for a reduction in fossil fuel imports; they improve energy security, especially when coupled with an increasing share of renewable energy for electricity generation; and they lead to a reduction in carbon emissions, especially when coupled to renewables. In this section, we provide perspectives on ways in which SISs could take decisive policy actions to overcome significant barriers to the rapid adoption of BEVs, increase their market penetration, and maximise the long-term benefits of electrification potential in their nations.

### *Availability of BEVs from Distributors*

Vehicle models made available by manufacturers to small markets, such as SISs, have historically been limited. For SISs that use right-hand drive vehicles, model availability might be further limited. Distributors are mindful of their responsibility to provide technical and parts stock support for any models that they sell and can be reticent to import vehicles that they do not believe will sell in sufficient numbers to make support economically viable. Sending a strong, clear message about its intention to transition to BEVs will encourage manufacturers to supply BEVs to a SIS.

By proclaiming an approved policy to promote the sale and support of BEVs, a SIS will signal that it is committed to a transition to electrified transportation and give manufacturers and dealers the confidence to supply BEVs to the market and invest in supporting training and infrastructure. To strengthen this policy action, a clear date after which the import and sale of combustion engine vehicles will be prohibited can be declared. Barbados has led the way by declaring that by 2030, 100 % of its vehicles will be BEVs or run on alternative fuels (Lo, 2021). Barbados is also catalysing demand by immediately starting the process of electrifying the government fleet (Atwell, 2021). Simply making such declarations of intent can cause manufacturers to adjust their vehicle allocations and make more BEVs available to an SIS.

### *Scepticism Towards BEVs Among Vehicle Purchasers*

Most customers have only had previous experience in purchasing an ICE new or used vehicle. Transitioning to a BEV is a step into the unknown. Reticence to take a ‘risk’ with a BEV is understandable since a vehicle is the second largest investment that householders make after property. For commercial purchasers, the practical business case for BEVs is usually untested. Apart from the high cost, primary concerns are about range and the ease and reliability of recharging (Rezvani, Jansson, & Bodin, 2015). Action is required to educate the public on the operation and benefits of BEVs.

Policy responses that can address scepticism towards BEVs can start with something as simple as a public information campaign to educate the public about BEVs. The media and local experts can be engaged in this activity. Commercial purchasers can be supported in their business planning for BEV purchases, in particular calculations of specific total cost of ownership for their use case. BEVs can be taught in the school curriculum along with science and geography topics such as climate change and renewable energy to sensitise young people to the importance of transport electrification.

### *Affordability of BEVs*

It is still early in the adoption 'S-curve' of BEVs globally, with annual sales currently growing exponentially. Although the technology will gradually become affordable relative to ICE vehicles, BEVs currently have a substantial purchase price premium–about 30 %-40 % for buses and in the region of 20 %-50 % for light vehicles. However, total cost of ownership of a BEV in developed markets is expected to be lower than combustion engine vehicles by 2022 (Murray, 2019; Nunno, 2018). In some SISs, total cost of ownership for a small passenger BEV is lower than that for an equivalent ICE vehicle (Maharaj & King, 2020). An additional cost for a BEV is the home or base station-charging infrastructure. For commercial customers, this might be a significant outlay. In many countries, a cash rebate for the purchase of a BEV has been a favoured approach, but this is expensive and not found to be significantly more effective than other measures (Lieven, 2015).

Suggested policy responses to address the affordability of BEVs are generally fiscal and start with mitigating the taxation on the vehicles. SIS governments should ensure that the total amount of taxation applied to BEVs does not exceed the cash amount applied to an equivalent combustion engine vehicle and possibly provide short-term tax and duty relief on non-luxury BEVs to encourage accelerated adoption. Since the purchase price of BEVs is higher than equivalent ICE vehicles, fixed duty and VAT rates can multiply the tax paid, making these vehicles even more expensive in SIS markets. Purchase can be supported using financing schemes, underwritten by governments, for electric commercial vehicles, HDVs, and buses to make purchase more affordable. Tax incentives could be used to encourage financial institutions to offer favourable schemes for the purchase of BEVs; tax and duty relief can be offered on equipment for a charging infrastructure.

### *Technical Skills to Support BEV Service, Repair, and Emergency Response*

Specific skills are required to maintain and repair BEVs. High voltage, high power systems pose safety challenges that are important for automotive technicians and emergency responders alike. Many vehicle manufacturers will not allow BEVs to be sold in a market unless technicians have received specific certification in EV technologies. It is important to encourage the acquisition of these skills in SISs to accelerate BEV adoption.

Therefore, government policy should ensure that technical standards for installation of EV chargers have been established. They should provide encouragement to automotive technical training colleges to start offering EV training courses, provide funding for this training, and set targets for the numbers of automotive technicians certified in the technology. Governments can also broker train-the-trainer arrangements to ensure that local skills training institutes are able to provide the training and certification.

### *Charging Infrastructure and Electrical Grid Robustness*

While charging infrastructure is not the limiting factor for accelerated adoption of BEVs in SISs as it is in most other markets, a basic level of public charging infrastructure must be made available and home base charging supported by the electrical grid. Two elements of grid capacity must be considered: generation and distribution. Generation capacity must be expanded to account for additional demand from BEV charging. Distribution is important particularly at the neighbourhood level, where transformer capacity might be a limiting factor if several neighbours all purchase BEVs and charge at the same time (Meetoo, Bahadoorsingh, & Sharma, 2019).

Government policy support for the establishment of charging infrastructure can include enlisting electrical utility companies in planning for e-mobility. For the utilities, it should be a business development opportunity. Beyond planning, utilities should be actively involved in facilitating and promoting public and private charging (Viscidi, Graham, Madrigal, Masson, & Prado, 2020). Detailed studies should be commissioned to determine the optimum locations for high-speed pubic charging. Incentivises should be offered for the installation of off-grid solar charging parking garages at workplaces and shopping centres.

### *Loss of Tax Revenues from Fossil Fuel Sales*

In some SISs, taxation from the sale of fossil fuels makes a significant contribution to the national purse. As these sales decline, that revenue stream will be lost, potentially causing some hesitancy from governments in accelerating the e-mobility transition.

Governments should respond by including the expected loss of revenue into their medium- and long-term budget planning. The formation of an e-mobility transition fund, financed by additional taxation on the purchase of ICE vehicles, can be considered. Alongside purchase taxes or duties, increasing taxation of fossil fuels, strategically and gradually during the transition period to mitigate the rate of revenue loss, can form part of the answer.

### *Stock of Legacy Combustion Engine Vehicles in the National Vehicle Stock*

Even if BEV sales start to increase and ICE vehicle sales are entirely banned by, say, 2030, the legacy stock of ICE vehicles will remain. Equity of access to transport is an important consideration, as BEVs are currently expensive, reducing affordability.

Mitigating policy actions aimed at reducing the stock of legacy ICE vehicles can include investment in the public transportation system, focusing on increasing its attractiveness and accessibility, and finding solutions for the 'last mile' of journeys. Opportunities exist to promote conversion of legacy cars and buses to electric powertrains. This is a growing sector globally. Many countries around the world, at various times, have instituted a scrappage policy – for instance, that all vehicles more than 15 years old must be scrapped, exported, or converted to zero carbon energy – this could also be part of the solution. However, underpinning these actions is the setting of a date for the complete prohibition on the sale of fossil fuels in the public market. This will allow the free market to catalyse BEV sales.

## Conclusion

At the start of this chapter, we hypothesised that SISs are generally well suited to the adoption of e-mobility and that it can help to make transport more sustainable and accessible. We have shown that the global trends in electrification of different classes of vehicles, supported by government policies and manufacturers' plans, present a tremendous opportunity for SISs to seize the benefits of the electrification of transport by accelerating the deployment of e-mobility.

There are several characteristics of SISs that would encourage accelerated deployment of BEVs: low point-to-point trip lengths; low average vehicle speeds; a concerted effort to eliminate the use of fossil fuels; their vulnerability to climate change that creates an impetus to exemplify an emphatic approach to reducing of carbon emissions; and underdeveloped public transportation systems that could be modernised using e-mobility.

Despite the opportunities that BEVs present to SISs, there are significant challenges in their deployment. These include the availability of BEVs, especially new cars; scepticism on the part of vehicle purchasers due to lack of knowledge and experience of BEVs; affordability; skilled technicians for maintenance and repair; a public charging infrastructure is needed; taxes may be lost from fossil fuel sales; and even if BEV sales grow, the stock of ICE vehicles will take years to deplete. Concerted policy actions from SIS governments are necessary if the challenges are to be overcome and the opportunities are to be realised.

A proactive approach to encouraging the rapid adoption of BEVs, in tandem with a transition to renewable electrical energy, can be achieved using a range of policy instruments. These should include tax relief on BEVs and equipment to support them, which could be paid for by incremental taxation on fossil fuels. Taxation incentives need only be transitional until mass-market dynamics predominate (IEA, 2020).

Encouraging an aggressive transition to e-mobility requires clear, strong, and consistent messaging from the governments of SISs. In the opinion of these authors, the most effective policy action to accelerate adoption of BEVs is to declare an early phase-out date for the sale of ICE vehicles, as is being done in a growing list of countries. Barbados stands out as a SIS having taken a particularly bold position, which can provide a benchmark for others.

Actions should be focused on the establishment of an organised, integrated e-mobility based transportation system using BEVs. A particular focus should be on buses for public transport, so that benefits can be maximised and to create an accessible transportation system that avoids the proliferation of private cars as the *de facto* preferred transport solution. Challenges in adoption of BEVs on a large scale are real but can be overcome by strategic and financed policy actions. Not all the policy responses suggested here will be politically feasible in every SIS, but they give some structure for policy planners.

Further investigation is warranted into the potential of electric micro-transport solutions, including two- and three-wheeled vehicles for SISs. These emergent vehicles could become increasingly important, especially in urban environments, offer greater energy savings than electrified cars and buses, and can be accessible a wider socio-economic spread.

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