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Plugging into green growth: Towards e-mobility and renewable energy integration in Lao PDR

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ABSTRACT

The majority of transport decarbonisation pathways rely on the parallel electrification of the majority of modes of surface transport and significant expansion in renewable electricity generation. Whilst the integration of these two previously siloed sectors – electricity and transport – can benefit the low-carbon transition, there are barriers presenting their realisation. These issues are highly geographically contextual, and little research has been conducted in Lao PDR and the wider Southeast Asia region. To fill this research gap, this paper presents a study of how the barriers to, and enablers for, e-mobility and renewable energy integration in Lao PDR and the wider Southeast Asian region are viewed by different groups of stakeholders. Through engagement with 41 expert stakeholders from a wide range of backgrounds at both the international and national level, we present analysis of the difference in importance assigned to different barriers and enablers. Several differences were identified between how international and country-level stakeholders interpret these issues; generally, international stakeholders identify broad 'top down' barriers and enablers whereas country-level stakeholders identify with higher-resolution issues. By bringing their views together, the stakeholder interviews were analysed to support a set of 19 recommendations to international organisations, national governments, financial institutions and the private sector, in fostering e-mobility and renewable energy integration in Lao PDR to support low-carbon growth in the region.

1. Introduction

The aim of this paper is to present in-depth analysis of the issues pertaining to e-mobility and renewable energy integration in Lao PDR and Southeast Asia, and how they are viewed by different groups of stakeholders in the region. By using the results of interviews with these stakeholder groups, the paper presents a set of recommendations towards realising the benefits of this joined-up transition.

The transport sector contributes 16% of global emissions [1], but only 8% of Nationally Determined Contributions (NDCs) to the 2015 Paris Agreement contain transport-specific greenhouse gas (GHG) reduction targets as of November 2021 [2]. There are no countries in Southeast Asia with transport-specific GHG reduction targets [3]. To avoid irreversible climate breakdown, deep and drastic cuts to GHG emissions are needed: for this, high-emitting sectors like transport must be specifically addressed in nations' NDCs.

E-mobility and renewable energy integration links the electrification of transport with growth in renewable electricity generation. This can be mutually beneficial to the transport and electricity sectors, and can thus help support countries' transitions towards low-carbon, low-cost and high-reliability transport energy systems. This is because:

- The charging of battery electric vehicles (EVs), including passenger cars, 2- and 3- wheelers, mini-buses, buses and trains, can act as an 'anchor load' [4], creating a consistent electricity demand to incentivise the development of generation and grid infrastructure, thus improving reliability of service provision [5].
- The flexibility of charging demand, whether provided through battery swap stations or EV charge points, naturally favours low-cost variable renewable energy sources such as wind and solar [6] as it can maximise these sources' utilisation when supply is high or other demands are low [7]. EV charging can also respond in real time – potentially bidirectionally [8] – to provide grid services, such as frequency response, supporting systems with high penetrations of renewable energy sources [9,10].

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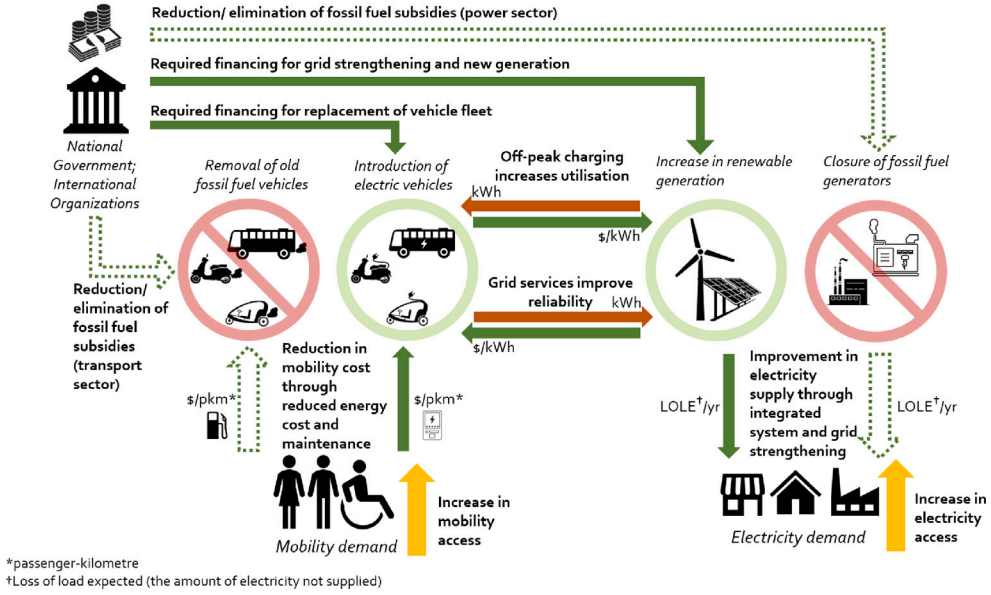

Fig. 1. Conceptual illustration of e-mobility and renewable energy integration, and relevant benefits.

Table 1
Renewable electricity and electric vehicle adoption/ICE phase-out targets by ASEAN country (as of 2022).

Country	Renewable electricity target	EV adoption/ICE phase-out target
Brunei Darussalam	10% of generation mix from renewable sources by 2035 [18]	60% sales of new vehicles to be electric by 2035 [19]
Cambodia	20% of generation mix from renewables by 2023 [20]	40% of car/bus fleet, 70% of 2 wheeler fleet to be electric by 2050 [21]
Indonesia	23% of generation mix from renewables by 2025 [22]	Uptake targets of 2200 electric cars and 2.1 million E2Ws by 2050 [23]
Lao PDR	30% of generation mix from renewables by 2025 [24]	1% of vehicle sales to be electric by 2025, rising to 30% by 2030 [25]
Malaysia	31% of installed capacity renewable by 2025 [26]	No specific target (EV roadmap to be announced in 2022 [27])
Myanmar	62% of generation mix from renewables by 2030 [15]	No specific target
Philippines	35% of generation mix from renewables by 2030 [28]	No specific target
Singapore	3% of generation mix from solar by 2030 [14]	Phase-out of ICE vehicles by 2040 [29]
Thailand	30% of generation mix from renewables by 2036 [30]	Phase-out of ICE vehicles by 2035 [31]
Viet Nam	21% of installed capacity renewable by 2030 [32]	No specific target

In practice, e-mobility and renewable energy can be integrated in the same time and place, such as battery swap stations for electric 2-wheelers providing battery storage to the grid [11]; integration can also occur at a higher level through linking supply chains and financing for e-mobility and renewable energy projects [12]. These proposed benefits can be realised for both grid-connected and off-grid circumstances. The differences are likely to be the appropriate scale of the integration, including how any grid services are implemented: for example, large grid-connected systems will be more likely to benefit from the provision of frequency response, whereas off-grid implementations would see greater value from back-up power supply.

The concept of, and proposed benefits of, e-mobility and renewable energy integration are illustrated in Fig. 1.

Southeast Asia has significant potential for renewable energy production, and all countries of the Association of South East Asian Nations (ASEAN) – Brunei, Cambodia, Indonesia, Lao PDR, Malaysia, Myanmar, the Philippines, Singapore, Thailand and Viet Nam – have targets to increase the share of renewable generation in their electricity mixes [13]; the ambition of these targets ranges from 3% of electricity generation from solar in Singapore by 2030 [14] to 62% from all renewable sources in Myanmar by the same year [15]. As well as a growing policy backbone in setting transport electrification targets across ASEAN countries, more countries are seeing expansion in e-mobility, including the development of electric bus rapid transit (BRT) systems in Lao PDR [16] and the rapid expansion of the electric 2-wheeler market in Viet Nam [17]. The ASEAN country targets are summarised in Table 1.

As demonstrated in the literature review (Section 2), there is a lack of research into e-mobility and renewable energy integration in Lao PDR and the Southeast Asian region generally. In particular, to the authors' knowledge, there has been no work to date on comparing perceptions of the e-mobility or renewables transition between international- and national-level actors. To address this gap, this paper presents a study of how the barriers to, and enablers for, e-mobility and renewable energy integration in Lao PDR and the wider Southeast Asian region are viewed between different groups of stakeholders.

Specifically, the research questions of this study are:

1. How do national-level stakeholders view barriers to, and enablers for, e-mobility and renewable energy integration in Lao PDR?
2. How do international-level stakeholders view barriers to, and enablers for, e-mobility and renewable energy integration in Lao PDR?
3. How do the perceptions between national and international stakeholders differ, and how do these differences impact the plausibility of country- or region-specific policy recommendations for growth in low-carbon transport and energy systems?

To address these questions, we initially conducted a workshop with 25 stakeholders consisting of development financial institutions (DFIs) active in Asia & the Pacific, international development organisations (IDOs) and academic practitioners, followed by 6 one-to-one interviews with subject experts, before honing into the case study country of Lao PDR where 11 one-to-one interviews were conducted with varying stakeholder groups. These included government representatives, transport service providers, electricity system operators and academia. This latter part helped to (i) derive country-specific recommendations for the acceleration of the low-carbon transition in transport and electricity in Lao PDR, a country with significant potential for clean energy

resources, and (ii) investigate whether the relative importance assigned to particular barriers and enablers by the DFI align with those of in-country stakeholders.

The data collection for this research was conducted in the period 2021 to 2022. The original workshop was held in October 2021; one-to-one interviews were conducted with international subject experts in February and March 2022; one-to-one interviews were conducted with national stakeholders in May–June 2022. The data collection was done by the authors.

The rest of this paper is organised as follows: Section 2 presents a review of relevant literature on the subject; Section 3 presents a description of the methodologies employed in this study; Section 4 presents and discusses the results; Section 5 presents a set of recommendations supported by analysis of the interviews with both international and Lao PDR-based participants; Section 6 presents conclusions from the research and recommendations for future work.

2. Literature review

2.1. E-mobility landscape in Southeast Asia

Transportation is the second largest energy consumption sector in ASEAN countries and contributes to approximately 30% of total final energy consumption in the region [33]. As transportation in many ASEAN countries is heavily dependent on imported petroleum, electrifying transportation has been raised as a potentially effective measure to enhance energy security and reduce environmental risk in the region [19]. Although some ASEAN countries have already set individual targets for the deployment of electric vehicles [19,34], there are still considerable gaps in EV support policies and penetration rates between ASEAN countries compared to other Asian countries such as South Korea and China [35]. Jamaludin et al. [35] indicate that EV adoption in Southeast Asia, in general, is still in a very early stage that requires significant input in policy implementation and EV charging infrastructure deployment. Another study in ASEAN countries by Li and Chang [36] suggests that compared to promoting EVs alone, the combination of EV support policies with higher fuel economy standards and a higher percentage of renewable energy in the power sector can decarbonise transportation much more effectively. This suggests that in order to decarbonise transport in Southeast Asia, EV deployment should not be a stand-alone effort. The integration between electrifying transport and tapping into the enormous potential for renewable energy generation in the region [13] is therefore a critical step for ASEAN countries to catch up and even 'leapfrog' [37] more established EV markets in terms of decarbonising transport.

2.2. E-mobility and renewable energy integration in Lao PDR

Due to the rapid GDP growth in Lao PDR in recent years, energy demand has significantly increased. To meet this growing demand, fossil fuel imports grew by 6.5% annually, with 96% being consumed in the transport sector [38]. This growing import of petroleum induces severe trade deficits and puts strain on Lao PDR' national economy due to the fuel subsidies deemed necessary to make fuel less unaffordable than it would be otherwise [39,40]. On the other hand, Lao PDR has a high potential for renewable energy generation, especially for hydropower, which can enable an affordable transition to e-mobility. The country has set targets to achieve 30% renewables in primary energy supply and a 98% electrification rate by 2025 [13]. These ambitious targets are backed up by over 80 hydropower plants that are producing electricity more than 30 times the domestic demand [40]. Based on this power generation capacity, the Laotian government positions the country as the 'battery of Southeast Asia' [41] that is capable of not only meeting domestic energy demands but also exporting surplus electricity to neighbouring countries such as Thailand [42]. The abundance of hydropower in Lao PDR opens up an ideal opportunity to integrate renewable energy with the electrification of transport and achieve a zero-emission transport system. This could reduce annual transport-related emissions by 503 $ktCO_2$ by 2050 [41]. Moreover, due to the temporal fluctuation of hydropower generation and other renewable electricity generation in Lao PDR, EVs can play a role in storing electricity, balancing grids, and providing domestic power demand to consume excessive power generated [43].

Whilst there is clearly an abundance of hydropower generation in Laos, given that it is currently exported to the wider region, additional renewable generation is necessary due to the significant increase in electricity demand from the electrification of transport. Of course, this is not specific to Lao PDR; by integrating e-mobility and renewables, Laos can realise the benefits noted in Fig. 2. Notably, wind and solar are virtually absent in the Laotian electricity mix. By facilitating effective e-mobility and renewable energy integration, Laos can unlock the potential resource from wind and solar and further diversify its electricity mix, thereby increasing the resilience of its low-carbon transition.

The current state of the EV market in Laos is nascent. Local media reported in February 2023 that the Department for Energy and Mines has stated that there are 3201 private electric vehicles in the country, comprising 1428 cars and 1773 motorcycles [44]. Compared to the overall vehicle fleet of 131,950 cars and 1,841,678 motorcycles [45], the penetration rate is very low. However, the future of the sector shows significant promise. For the past 30 years, Lao PDR has enacted liberalisation policies to increase the amount of private sector involvement in the country, including from international sources [46]. Whilst historic progress has been slow, there has been acceleration in recent years. According to the UN Conference on Trade and Development's World Investment Report [47], the inflow of direct foreign investment increased from US$557m in 2019 to US$968m in 2020, despite the economic crises triggered by the pandemic. The energy and infrastructure sectors are being promoted by the country's Investment Promotion Department [48], and according to the World Bank's Private Participation in Infrastructure (PPI) database [49], the energy and transport sectors constitute virtually all of the US$23.7bn in PPP projects in Lao PDR.

Whilst the potential benefits of e-mobility and renewable energy integration in Lao PDR are clear, there are numerous obstacles – or at least *perceived* obstacles – to growth in this area. Firstly, the high upfront costs of electric vehicles is likely to discourage the Laotian government and citizens from adopting EVs. A previous forecast study has found that compared to business as usual in the transport sector, electrifying transport in Lao PDR is likely to induce significant GDP loss in the short term due to its higher cost, although the effect on GDP loss is likely to decrease in the long run [38]. Secondly, there is concern that existing infrastructure cannot support a rapid transition to e-mobility. A study by Namba [40] found that unfavourable infrastructure environments and the lack of integration with local demand in Lao PDR was the leading cause for the lack of adoption of EVs by the Japan International Cooperation Agency (JAICA). For instance, many roads in the capital Vientiane are unpaved or have rough surfaces; this was found in two studies to at least lead to a perception amongst local stakeholders that the roads would be unsuitable for EVs [50,51]. Thirdly, there are references in the literature to adverse effects of the Lao climate: in [40], it is stated that the combination of regular flooding in wet seasons and poor drainage systems on urban roads has led to perceptions in Lao PDR that EVs and charging infrastructure could suffer electrical short circuits due to water exposure.

The lack of cooperation between the transport and energy sectors is another significant barrier to e-mobility and renewable energy integration in Lao PDR. While studies of transport-energy integration in the Laotian context are lacking, research from neighbouring countries in Southeast Asia suggests that both EV promotion policies and renewable energy policies are lacking in the region, with even less cooperation between the two [36]. It is still unclear in the literature how the energy and transport sector in Lao PDR or any other ASEAN country could cooperate. Moreover, the role of international organisations in

facilitating such cooperation across sectors is largely absent in the literature. Given the clearly significant potential for Lao PDR to realise the benefits of e-mobility and renewable energy integration, this article seeks to address these gaps by exploring the barriers and enablers of e-mobility and renewable energy integration in Lao PDR through engaging with multiple stakeholders.

3. Methodology

This section outlines the methodology of this study: data collection (Section 3.1) and data analysis (Section 3.2).

3.1. Data collection

Data collection for this study consisted of the following two steps:

- Initially, an **online workshop** was held to develop a framework of barriers and enablers for e-mobility and renewable energy integration in Asia & the Pacific. This saw the participation of 25 experts across the transport and energy sector, active in the region, from DFIs, IDOs and academic institutions. Participants were assigned to one of four breakout groups, each discussing:
    1. Benefits of e-mobility and renewable energy integration
    2. Barriers to effective e-mobility and renewable energy integration
    3. Enablers to effective e-mobility and renewable energy integration

  Building on the breakout groups, workshop participants were asked to collectively co-create a framework for the categorisation of barriers and enablers in the transition towards e-mobility and renewable energy integration.
- The development of this framework informed the **semi-structured interviews** (SSIs) that followed. There were two sets of SSIs, as characterised below according to the type of interviewee (Table 2):
    (a) **International experts**. Interviews were conducted online, consisting of six[1] senior specialists in the fields of energy, transport, private sector finance, climate financing and public–private partnerships from DFIs and international organisations (IOs). The aim was to develop recommendations for practical actions in Southeast Asia based on the framework developed during the workshop; and
    (b) **Laotian stakeholders**. Interviews were conducted in-person by researchers from the National University of Laos (NUOL), consisting of eleven stakeholders including government officials, transport service providers, electricity system operators, e-mobility users and academia in Lao PDR. These interviews were carried out to investigate whether the recommendations arising from a top-down approach applied from a framework developed by internationally active organisations would be similar to a bottom-up approach in eliciting views from in-country stakeholders.

  The SSIs lasted 45–60 min, with questions centring around the barriers and enablers relating to e-mobility and renewable energy integration in Southeast Asia [(a)] and Lao PDR [(b)], and how practical actions may be developed in establishing successful integration. They were broadly guided by the following questions (additional questions were informed by the discussion):
    1. What do you see as the greatest barriers to the integration of e-mobility and renewable energy in (Lao PDR/Southeast Asia)?
    2. What do you see as the biggest enablers to overcoming these barriers?
    3. How much do you communicate with your counterparts across (i) other departments within your organisation, (ii) actors across the public & private sectors and (iii) consumers concerning the integration of e-mobility and renewable energy in (Lao PDR/Southeast Asia)?
    4. What is the role of your organisation, or stakeholder perspective, in establishing integration of e-mobility and renewable energy in (Lao PDR/Southeast Asia)?
    5. Are you aware of any case studies in the region where growth in electricity demand (whether from e-mobility or not) has been used to promote growth in electricity system infrastructure? If so, please give a brief description of these case studies. What were the barriers in each case, and how were these overcome?

It should be noted that it cannot be ensured that answers to these questions are representative of an individual's stakeholder type (Table 2). However, these SSI questions were designed in a way that forces individuals to draw on their experiences working in particular roles within their organisations (for example, questions 3 and 4). Furthermore, their position in their organisation will have a significant influence on how they might see barriers, enablers and case studies (questions 1, 2 and 5).

The study participant breakdown is given in Table 2.

To ensure the study's integrity, a risk and ethics assessment following the Medical Sciences Interdivisional Research Ethics Committee at the University of Oxford in accordance with the procedures laid down by the University for Ethical Approval for all research involving human participants was completed and approved with reference: R74082/RE001.

3.2. Data analysis

The interviews were transcribed, and where applicable translated from Lao to English, for analysis. The framework in Fig. 2 (Section 4.1) was used for *deductive coding* of the transcript data, whereby the text was coded according to the categories and subcategories of barriers and enablers as per the framework (Fig. 2). Analysis was carried out using NVivo software.

To minimise variation in the results, all data were coded to a common methodology by the same researcher.

4. Results and discussion

4.1. Framework of e-mobility and renewable energy integration

Based on the outcome of the online workshop, we present a framework for the categorisation of barriers to – and enablers for – e-mobility and renewable energy integration (Fig. 2). This framework underpins the discussion that follows.

In essence, the framework sets out three categories of barriers to integration: (i) that these solutions have a high **upfront cost**; (ii) that systems of **locked-in governance** give preferential treatment to fossil fuel-based incumbent solutions; and (iii) that **technology uptake** can be constrained by the limited growth in adjacent sectors, such as battery manufacturing or charging infrastructure deployment.

The framework then sets out four categories of enablers to the transition:

(i) **Business model** enablers represent innovative solutions to link growth in demand from e-mobility to growth in the supply of renewable electricity generation; (ii) these business models are in turn supported

[1] One person that attended the workshop was also interviewed.

Table 2
Study participants by organisation/stakeholder type.

Organisation/stakeholder type	Online workshop	International interviews	Lao PDR interviews
Development financial institution (DFI)	19	5[a]	–
International development organisation (IDO)	2	–	–
International organisation (IO)	–	1	–
National government (NG)	–	–	5
E-mobility service provider (EVP)	–	–	2
Public transit operator (PT)	–	–	1
E-mobility user (EVU)	–	–	1
Electricity system operator (ESO)	–	–	1
Academia (A)	4	–	1
Total	25	6	11

[a]One person that participated in the online workshop also took part in the face-to-face interviews. Anonymous quotes are used to support the ascertains made in the text using acronyms and a numerical identifier.

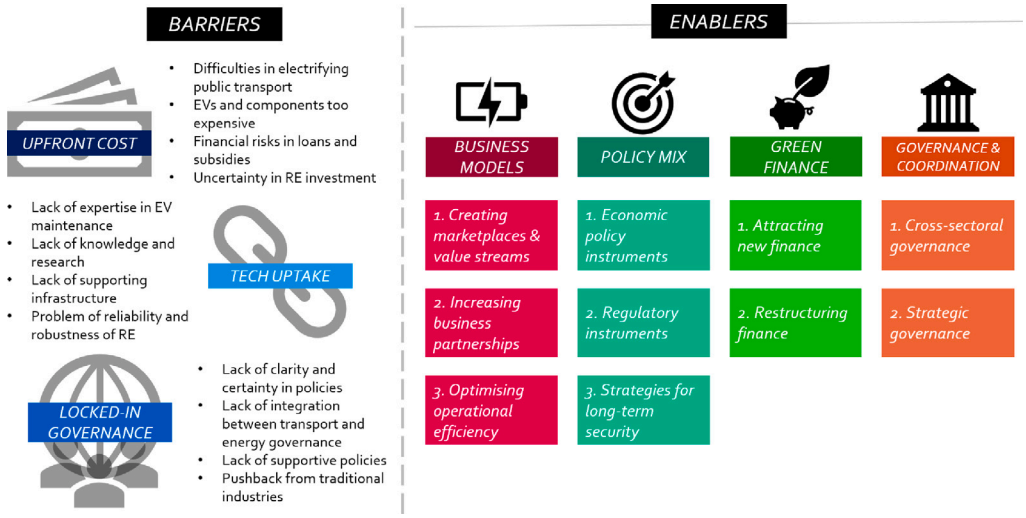

Fig. 2. Framework of barrier and enabler categories relating to e-mobility and renewable energy integration.

by **policy mixes** that favour innovative solutions; (iii) **green financing** is brought in to support the development and deployment of solutions; (iv) **governance** provides the **strategic coordination** such that effective policy mixes and financing can be effectively targeted in supporting these innovations.

The framework in Fig. 2 is intended to provide a platform for the identification of specific actions that can be taken in promoting e-mobility and renewable energy integration as an accelerant to the low-carbon transition.

4.2. Barriers to e-mobility and renewable energy integration

4.2.1. Summary

From the interviews, a number of barriers were identified using the broad categories from the framework: upfront cost, technology uptake, and locked in governance. Generally, the barriers in the framework (Fig. 2) are upheld in the interviews. Interestingly, there are several commonalities and several points of divergence in perceptions of these barriers between different types of interviewee (international/Lao PDR-based; different areas of expertise). The latter are summarised here and further discussed in Sections 4.2.2 and 4.2.3.

Fig. 3 shows analysis of the coded interviews with both the international experts and Laotian stakeholders. The doughnut chart shows the number of mentions of each barrier type: the inner doughnut represents the international interviewees; the outer doughnut represents the Lao PDR-based interviewees. Notable quotes are displayed around the chart in boxes whose border colour corresponds to the barrier type.

Whereas locked-in governance was the largest barrier category by far for the international interviewees (44% of total mentions), concern amongst Lao PDR-based interviewees was more evenly spread across the barrier categories. It is also demonstrated how the different groups identify with different challenges within each barrier category. For example, both groups identify an issue surrounding the high upfront cost of vehicles: as articulated by an international interviewee, "*for someone who's used to buying a vehicle for $1000 it will be quite a leap for [them to buy a vehicle for] $6000*" (DFI4), and as articulated by a Lao PDR interviewee, "*the price of EV in Lao market [is] still very high if compared with neighbouring countries like Thailand and Vietnam*" (EVU1).

In general, the concerns raised by the international interviewees pertain to high-level issues including national fiscal constraints ("*it wouldn't be responsible to just lend the money if it didn't make sense in a [...] holistic perspective*" (DFI2)) and hurdles faced by financial institutions ("*you can't bank on unknown future conversions of consumers from petrol bikes to e-bikes, so it's kind of hard to make that viable [for banks]*" (DFI3)). On the other hand, concerns raised by Lao PDR-based interviewees focused on issues at a higher resolution, such as issues relating to access to concessional finance ("*there is no [...] assistance to get a low-interest loan*" (EVP2)). This hypothesis of international interviewees' concerns being 'top-down' in comparison to in-country interviewees' concerns is supported across the barrier categories. For technology uptake barriers, international interviewees are shown to be concerned with the "*additional installed capacity*" (IO1) required for transport electrification; Lao PDR-based interviewees are concerned with how poor road surfaces might affect the viability of EVs ("*infrastructure has not yet responded to electric car [...] alley road is still not smooth*" (EVU1)), as was also found in earlier studies [50,51].

The commonalities identifiable across the international and Lao PDR-based interviewees surround the concern that advancements in

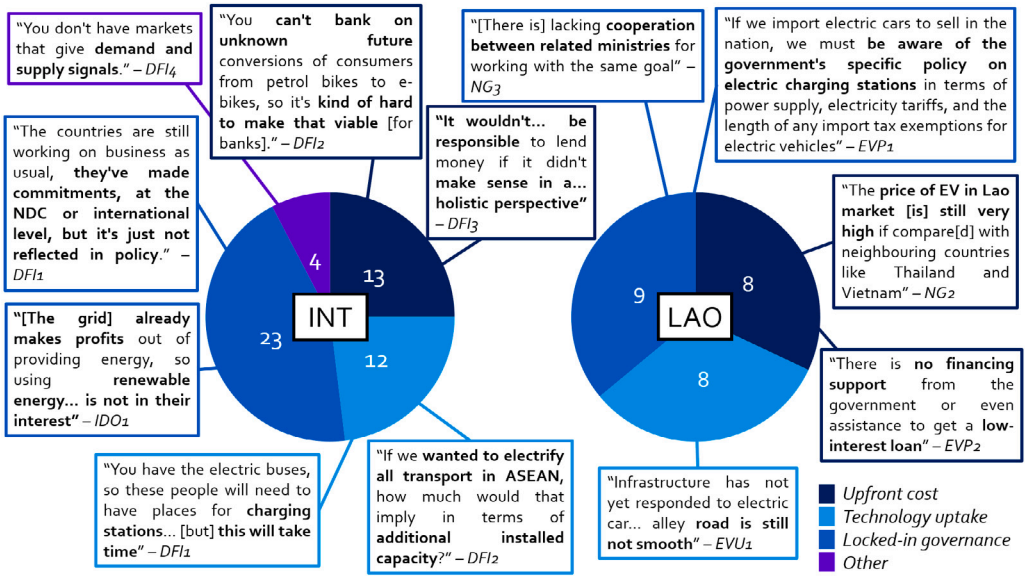

Fig. 3. Doughnut chart showing barriers to e-mobility and renewable energy integration in Southeast Asia and Lao PDR: analysis from interviews from expert stakeholders. The inner doughnut shows the number of mentions of each type of barrier in the international interviews; the outer doughnut shows the number of mentions of each type of barrier in the Lao PDR interviews. Key quotes are shown in boxes coloured according to the barrier type; each quote is designated according to the interviewee type (see Table 2).

some sectors may not be able to match advancements in others: in-country interviewees identify the "*lack of maintenance and service of EVs [...] [and the] lack of charging stations*" (NG4); international interviewees identify the lack of coordination between the electricity sector (vis-a-vis the aforementioned concern regarding installed capacity) and the ability of the maintenance sector to evolve ("*if it's a new technology [...] how do I fix it?*" (DFI2)). The lack of coordination between sectors – and the barriers presented by silos existing between them – emerges as a strong similarity between in-country and international interviewees in the locked-in governance barriers. Both sets of interviewees identify issues surrounding siloed government departments: as a Lao PDR-based interviewee puts it, "*[there is] lacking coordination between related ministries for [...] the same goal*" (NG3); an international interviewee voices concerns that while commitments are made at the "*NDC or international level [...] it's not reflected in policy*" (DFI1).

4.2.2. Detailed analysis of differences in perceived barriers between international and Lao PDR-based interviewees

To enable further analysis into the barriers, the mentions of each barrier subcategory (as shown in Fig. 2), was normalised against the total number of mentions of all codes in each interview. The results, that further illustrate the relative importance afforded to different types of barrier, are shown in Fig. 4.

Overall, international interviewees mentioned locked-in governance and upfront cost more frequently as compared with the local respondents in Lao PDR. On the contrary, local respondents were more concerned with technology uptake in general. This might reflect higher level of local concerns regarding the technological and infrastructural aspect of EV uptake, such as lack of expertise and lack of infrastructure support.

In terms of specific problems, both international and local respondents expressed considerable concern (standardised score >0.1) over 'lack of clarity and certainty in policies', 'lack of supporting infrastructure', and 'EVs and components too expensive'. Notably, 'EVs and components too expensive' is most frequently mentioned by both international and in-country interviewees. These are likely to be some of the most pressing issues blocking the integration between e-mobility and renewable energy in Lao PDR, which echoes results previously identified in the literature [38].

Overall, international interviewees were more likely to discuss a wide range of specific issues when talking about barriers. Conversely, local respondents were relatively more focused, concentrating their discussion on lack of technological support and the high price of EV. None of the local respondents had touched upon issues related to the renewable energy grid, financial risks, and difficulties of electrifying public transport. On the other hand, while international respondents talked about a diverse range of barriers, they ignored 'lack of knowledge and research', which local respondents expressed considerable extent of attention upon.

4.2.3. Detailed analysis of differences in perceived barriers between interviewees of different backgrounds and areas of expertise

Fig. 5 shows the same data as Fig. 4, but rather than showing the difference between the international and Lao PDR-based interviewees, it shows the differences between professionals of 5 different fields, plus an EV user. It should be noted that only one EV user was found to be co-operative in Lao PDR for this study.

In Fig. 5, the categorisation of interviewees is as follows:

- The energy experts comprised of 2 energy experts from the international interviewees plus a representative of the Lao electricity system operator.
- The transport experts comprised of a transport expert from the international interviewees, plus a representative from the public transport operator and an academician in Lao PDR.
- The finance experts comprised climate financing, private finance and PPP experts from the international interviewees.
- The government officials were entirely Lao PDR-based, which as before were representing the Ministry of Public Works and Transport, the Ministry of Planning and Investment, the Ministry of Natural Resources and Environment, the Ministry of Energy and Mines, and the Department of Energy Efficiency.
- The EV suppliers comprised of 2 e-mobility service providers in Lao PDR.
- The EV user was an electric car owner in Lao PDR.

Fig. 5 depicts a split in the relative importance of barriers between different groups. Energy experts, finance experts and EV users were most concerned with 'upfront cost'; government officials were also concerned with 'upfront cost', but they were also very concerned with 'technology uptake'; transport experts were most concerned with 'technology uptake'; and EV suppliers were most concerned with 'locked-in governance; the EV user was most concerned with upfront cost.

		Int interviewee	Lao interviewee
Upfront cost	1 : difficulties of electrifying public transport	0.083	0.000
	2 : EVs and components too expensive	0.170	0.344
	3 : financial risks in loans and subsidy	0.116	0.000
	4 : uncertainty of investing in renewable energy	0.090	0.000
	SUM	0.459	0.344
Technology uptake	1 : lack of expertise in EV maintenance	0.042	0.074
	2 : lack of knowledge and research	0.000	0.139
	3 : lack of supporting infrastructure	0.104	0.182
	4 : problem of reliability and robustness of the renewable energy grid	0.063	0.000
	SUM	0.208	0.395
Locked-in governance	1 : lack of clarity and certainty in policies	0.135	0.114
	2 : lack of integration between transport and energy departments	0.052	0.018
	3 : lack of supportive policies	0.063	0.129
	4 : pushback from traditional industries	0.083	0.000
	SUM	0.332	0.261

Fig. 4. Normalised mentions of each barrier subcategory in international and Lao PDR-based interviews.

		Energy experts	Transport experts	Finance experts	Government officials	EV suppliers	EV user
Upfront cost	1 : difficulties of electrifying public transport	0.167	0.000	0.000	0.000	0.000	0.000
	2 : EVs and components too expensive	0.333	0.083	0.321	0.373	0.000	0.667
	3 : financial risks in loans and subsidy	0.042	0.000	0.286	0.000	0.000	0.000
	4 : uncertainty of investing in renewable energy	0.125	0.056	0.000	0.000	0.000	0.000
	SUM	0.667	0.139	0.607	0.373	0.000	0.667
Technology uptake	1 : lack of expertise in EV maintenance	0.000	0.000	0.000	0.113	0.125	0.000
	2 : lack of knowledge and research	0.000	0.250	0.000	0.107	0.125	0.000
	3 : lack of supporting infrastructure	0.000	0.250	0.250	0.133	0.125	0.333
	4 : problem of reliability and robustness of the renewable energy grid	0.125	0.000	0.000	0.000	0.000	0.000
	SUM	0.125	0.500	0.250	0.353	0.375	0.333
Locked-in governance	1 : lack of clarity and certainty in policies	0.083	0.056	0.071	0.100	0.375	0.000
	2 : lack of integration between transport and energy departments	0.000	0.056	0.071	0.040	0.000	0.000
	3 : lack of supportive policies	0.125	0.083	0.000	0.133	0.250	0.000
	4 : pushback from traditional industries	0.000	0.167	0.000	0.000	0.000	0.000
	SUM	0.208	0.361	0.143	0.273	0.625	0.000

Fig. 5. Normalised mentions of each barrier subcategory in interviews with interviewees categorised into types.

- **Energy experts** were very concerned with the 'upfront cost' of EVs. They raised concerns regarding 'difficulties in electrifying public transport' and 'uncertainties in investing in renewable energy', which other respondents rarely talked about. A case study in Fiji was given to illustrate the high economic cost of electrifying public transport, and how difficult it might be to make the case for this investment when transport service provision may not change as a result ("*in Fiji where they have buses that are probably 40 years old. We're looking at replacing with electric bus[es], which will probably cost twice as much as a new diesel bus and six times that of a 25 year old diesel bus but still meeting service standards*" (DFI4)). Another case study of Jeepneys in Manila was given to suggest the social cost of electrifying public transport associated with employment substitution and loss of a cultural symbol ("*[People don't want] to move from these very old buses which are totally impractical [...] but just culturally a symbol of Manila*" (DFI1)). Notably, the latter barrier does not naturally fit into the three barrier categories established in the framework. For this reason, the 'other' category was established (see Fig. 3).
- **Transport experts** were mostly concerned with 'technology uptake' and 'locked-in governance'. Notably, they mentioned the pushback from traditional industries, which none of the other experts talked about. Pushback from incumbent industries is a historically observable phenomenon, contributing to 'technological lock-in' that favours established solutions over new technologies, including e-mobility [52].
- **Finance experts** focused much on upfront cost. They discussed the financial risks associated with EV-specific loans and subsidies, especially the lack of incentive and future certainty in providing supporting loans in Lao PDR.
- **Government officials** were aware of various problems with locked-in governance. As aforementioned, a representative of one ministry articulated that there is "*lacking cooperation between related ministries for working with the same goal*" (NG3).
- **EV suppliers** were the only group of respondents who were most concerned about 'locked-in governance', which potentially suggests that EV suppliers in Lao PDR are suffering from some local policies. Specifically, they suffer from both the lack of supportive policies and the lack of clarity in EV-related policies. One interviewee decried the "*lack of infrastructure, [such as] charging stations and service centres, tax and custom regulations, and necessary policies to support electric cars*" (EVP1), and another business owner calls for open policy and regulation: "*if we import electric cars to sell in the nation, we must be aware of the government's specific policy on electric charging stations*" (EVP2).
- The only **EV user** interviewed was concerned with high price of EVs and components when compared to the low running costs, stating that "*now we do not use [...] gasoline car because electrical energy for electric car [is] much cheaper than gasoline fuel*" (EVU1). They also mentioned technology uptake and infrastructure support by voicing concerns about the lack of charging infrastructure, stating that they have to charge at home.

4.3. Enablers for e-mobility and renewable energy integration

4.3.1. Summary

To translate the analysis in this study to useful results, the analysis of enablers in this section is taken forward to generate a set of recommendations for policymakers, finance institutions and international organisations (Section 5).

Fig. 6 shows analysis of the coded interviews with both sets of individuals. The doughnut chart shows the number of mentions of each barrier type: the inner doughnut represents the international interviewees; the outer doughnut represents the Lao PDR-based interviewees.

4.3.2. Detailed analysis of differences in perceived enablers between international and Lao PDR-based interviewees

Figs. 7 and 8 present data analogous to that shown in Figs. 4 and 5, but this time for analysis of mentions of enablers. As before, the

Fig. 6. Doughnut charts showing enablers for e-mobility and renewable energy integration in Southeast Asia and Lao PDR: analysis from interviews from expert stakeholders. The inner doughnuts show the number of mentions of each type of barrier in the international interviews; the outer doughnuts show the number of mentions of each type of barrier in the Lao PDR interviews.

numbers in each cell represent the number of mentions of that enabler subcategory divided by the total number of mentions of all codes in the framework (Fig. 2) per interview.

International respondents spoke more about 'business model' enablers and 'green finance' enablers, whereas local respondents prioritised 'governance' and 'policy mix' enablers. Notably, 'green finance enablers' were rarely mentioned by local respondents, which suggests that compared to international respondents, local interviewees were less aware of potential finance tools and opportunities.

In terms of specific aspects of enablers, both international respondents and local respondents demonstrated considerable attention (standardised score > 0.1) over 'increasing business partnerships' and 'cross-sectoral governance'. 'Cross-sectoral governance' received a very significant high standardised score. International respondents have touched upon all aspects of enablers as outlined in the framework. In comparison, none of the local respondents discussed 'optimising operation efficiency' and 'restructuring finance'. Both of these two enablers require a considerable extent of cooperation and assistance on the transnational scale, so it is reasonable that they were not discussed by local respondents.

4.3.3. Detailed analysis of differences in perceived enablers between interviewees of different backgrounds and areas of expertise

As shown in Fig. 8, energy experts and transport experts were most concerned with 'governance' enablers; finance experts and EV suppliers were most concerned with 'business model' enablers; government officials and the EV user were most concerned with both 'governance' and 'policy mix' enablers.

In terms of specific enablers:

- Within '**governance**' cross-sectoral governance' was frequently discussed (standardised score > 0.1) by all participants except for the EV user. Most discussions centred around strengthening the cooperation between the transport and the energy sectors.
- '**Green finance**' enablers, especially 'restructuring finance', is rarely touched upon by most experts except for finance experts.
- In terms of '**policy mix**', 'economic policy instruments' is discussed more frequently by finance experts and government officials, whereas 'regulatory instruments' is discussed more by transport experts. Both transport experts and government officials also viewed 'strategies for long-term security', especially long-term plans to facilitate local EV manufacturing in Lao PDR, as an important enabler.

Energy experts and transport experts focused on similar aspects when talking about enablers. Both demonstrated considerable emphasis on cross-sectoral governance, which suggests that experts from both sides see the opportunity and necessity to work together with the other side. Government officials focused quite exclusively on governance and policy-related enablers, while mostly ignoring business model enablers and completely ignoring green finance enablers. It is possible that opportunities for green finance have not been made clear and visible to government officials in Lao PDR. EV suppliers focused their discussion of enablers on business models. They were most interested in increasing business partnerships, especially in cooperating with the public transport sector and the energy sector.

5. Recommendations

In analysing the interviews for their mentions of enablers, it was possible to arrive at a set of 19 recommendations for accelerating the integration of e-mobility and renewable energy in Lao PDR and the wider Southeast Asian region. These recommendations are presented in Fig. 9, organised according to enabler categories as per the framework (Fig. 2). Each recommendation is assigned a set of parties[2] to whom that recommendation is directed: 'G' = governments; 'I' = international organisations; 'F' = financial institutions; 'P' = private sector. These recommendations are justified based on analysis of interviews in Sections 5.1–5.4.

5.1. Business models

- **Establish the potential size of markets in e-mobility and renewable energy.**
  It was widely recognised amongst international interviewees that bringing in private sector investment can unlock economic growth in both the e-mobility and renewable energy sectors. However, without knowledge of the size of the market – for example, the demand for EVs expected in a given region over a particular time period and the corresponding growth in electricity demand or storage provision – it is difficult to make a business case for investment. One international interviewee points to a need to understand the potential market size to drum up 'excitement' amongst suppliers: "*what's the size of the market […]. That's what will probably get manufacturers or suppliers excited about it.*" (DFI3) As another interviewee explains, the perception of value of these business cases from the point of view of investors is important: "*for that big bang kind of transition to happen you need to be able*

[2] Governments includes national and sub-national public sector bodies. In Fig. 2, international organisations include multilateral development banks, intergovernmental organisations and non-governmental organisations. Financial institutions include retail banks, central banks, credit unions, investment banks, and insurance companies. Private sector refers to all other for-profit companies operating in this space.

		Int interviewee	Lao interviewee
Business model	1 : Creating marketplaces and value streams	0.053	0.115
	2 : Increasing business partnerships	0.192	0.176
	3 : Optimizing operational efficiency	0.047	0.000
	SUM	0.292	0.291
Policy mix	1 : Economic policy instruments	0.076	0.130
	2 : Regulatory instruments	0.086	0.064
	3 : Strategies for long term security	0.080	0.145
	SUM	0.242	0.339
Green finance	1 : Attracting new finance	0.071	0.023
	2 : Restructuring finance	0.089	0.000
	SUM	0.160	0.023
Governance	1 : Cross-sectional governance	0.253	0.302
	2 : Strategic governance	0.054	0.045
	SUM	0.307	0.347

Fig. 7. Normalised mentions of each enabler subcategory in international and Lao PDR-based interviews.

		Energy experts	Transport experts	Finance experts	Government officials	EV suppliers	EV user
Business model	1 : Creating marketplaces and value streams	0.105	0.167	0.050	0.033	0.250	0.000
	2 : Increasing business partnerships	0.166	0.194	0.241	0.100	0.400	0.000
	3 : Optimizing operational efficiency	0.027	0.000	0.100	0.000	0.000	0.000
	SUM	0.298	0.361	0.391	0.133	0.650	0.000
Policy mix	1 : Economic policy instruments	0.054	0.111	0.141	0.200	0.000	0.000
	2 : Regulatory instruments	0.099	0.111	0.000	0.033	0.100	0.000
	3 : Strategies for long term security	0.120	0.042	0.045	0.200	0.000	0.500
	SUM	0.273	0.264	0.186	0.433	0.100	0.500
Green finance	1 : Attracting new finance	0.048	0.000	0.141	0.000	0.125	0.000
	2 : Restructuring finance	0.048	0.000	0.141	0.000	0.000	0.000
	SUM	0.095	0.000	0.282	0.000	0.125	0.000
Governance	1 : Cross-sectional governance	0.299	0.375	0.141	0.433	0.125	0.000
	2 : Strategic governance	0.034	0.000	0.000	0.000	0.000	0.500
	SUM	0.333	0.375	0.141	0.433	0.125	0.500

Fig. 8. Normalised mentions of each enabler subcategory in interviews with interviewees categorised into types.

to get the key stakeholders to see value in this." (DFI5) Interviewees also highlighted the potential positive reinforcement effect offered by private sector involvement in promoting public sector involvement: "*the larger markets [are] driving this because larger and more mature markets will have an active vibrant private sector. There will be competition, there is transparency, and therefore the government will always look at this from a perspective of 'if this is something that the private sector can deliver, let them do it'.*" (IO1)

In-country interviewees were more sparing with their calls for establishing the size of markets, though they did on several occasions stress the need for concerted planning across adjacent sectors to meet the need of the transition. For example, one interviewee states that "*we must research the economic viability of public electric vehicle charging stations*" (EVP1), which would include establishing the potential size of the public charging market. Another interviewee described evolving relationships between the electricity system operator and an EV supplier to "*define where would [be] suitable to install public electric charging station[s]*" (NG2).

- **Support business models based on bringing in disruptive low-carbon technologies.**

  Business models centred around the introduction of new and disruptive technologies were frequently mentioned. In e-mobility and renewable energy integration these technologies have two key aspects: (i) grid-side solutions, such as smart charging, vehicle-to-grid (V2G), and peer-to-peer (P2P) energy trading; and (ii) mobility-side solutions, including shared mobility and the use of artificial intelligence in predicting the movement of vehicles around a city or region (and thus the location and timing of both electricity demand and potential storage from vehicle batteries). Bringing these technologies together in innovative business models that support the integration of these sectors was seen as a way of advancing innovations to markets, as emphasised by two interviewees. An international interviewee focuses on the ability of smart technologies to enable e-mobility and renewable energy integration ("*a lot of charging [happens] at peak hours, and so [there is value in using] smart technologies to smooth that out*" (DFI1); "*there [are] a lot of projects increasingly that were looking at the combination of renewables but also digital technologies and artificial intelligence.* (IO1)")

- **Support integrated business models across e-mobility and renewables.**

  Business models such as battery-as-a-service (or battery leasing), in which the customer buys only the vehicle shell upfront and pays a rental fee for the battery, were raised as potential incentives for EV uptake by international interviewees: "*the company that we're studying in Viet Nam [is using] the battery leasing model. This is frequently used as incentive for the customer to buy an EV upfront and then incur battery cost later on during the use [of the EV].*" (IO1) Battery-as-a-service naturally lends itself to battery swapping solutions. One interviewee was quick to point out the co-benefits of battery swap infrastructure in being able to (i) better optimise the power flows to and from multiple batteries at a single point source (rather than a distributed set of individual batteries) and (ii) better manage the collection and recycling of batteries: "*[In a battery swapping system] you can ensure the batteries are better managed… It's also easier to manage all the recycling and collection of these batteries.*" (DFI5)

  For the integration of revenue streams in business models to work, solutions must be viewed through the lens of the consumer. This was well-articulated by one of the international interviewees: "*it's really about trying to not look at solutions with the lens of a single sector but trying to understand this in terms of what does it mean for the end customer who is going to be using that service? It is not just about buying a vehicle but what's the value chain like, who's going to produce it, who's going to service it, how to charge it.*" (DFI4)

Fig. 9. Recommendations, including responsible parties, for promoting e-mobility and renewable energy integration in Lao PDR and Southeast Asia.

- **Ensure environmental sustainability of business models through effective regulation.**
  Full transport electrification could result in disastrous consequences for the environment if environmental sustainability is not mandated in the development of business models in the sector. A large part of this relates to batteries, and how they are processed at the end of their useful life. As one international interviewee articulated: "*circular economies [...] battery disposal, recycling and reuse will become important as we reach full electrification [...] Otherwise we will have an environmental problem on our hands*" (DFI1).

Notably, this was not brought up by in-country interviewees. This recommendation applies to the business models, but enforcing regulations must be carried out by appropriate authorities.

5.2. Policy mix

- **Develop long-term transport electrification and renewables growth strategies.**
  The importance of setting long-term strategies for transport electrification and renewables growth was highlighted by both international and Lao PDR-based stakeholders. International interviewees emphasised the importance of setting policy that linked the transport and electricity sectors, such as the requirement for a cross-sectoral "*5-year plan, 10-year plan or a 15-year plan in terms of what needs to be [built] to meet [...] demand*" (DFI3). Particular to the case of Lao PDR, which has a high proportion of electricity generated from hydropower, it was expressed by one interviewee that "*hydropower, solar power [...] is ready to serve to the customer*" (NG1). This signifies the recognition of the 'readiness' of Lao PDR for a renewables-driven e-mobility transition amongst in-country stakeholders. Lao PDR-based interviewees, including those within the national government, were also keen to emphasise the need for government support to de-risk business activity in the sector, including the need for "*the government [to] set policies to promote electric cars*" (NG2), including a "*structure of car prices and electricity prices*" (NG1) that favours e-mobility, to "*reduce cost or attract investor[s] of electric vehicles and renewable energy*" (ESO1).
- **Electrify government fleets and integrate with renewable energy.**
  International interviewees in particular identified the introduction of EVs into government fleets as a first practical step that could be taken to pilot and promote e-mobility in the rest of the country. As one interviewee highlighted, the *"push towards getting government fleets to electric vehicles [...] is helping to build some kind of initial momentum"* (IO1). It was also stressed that this needs careful planning: if e-mobility in government fleets is to promote the use of EVs in the country, it is imperative that the transition is supported by sufficient infrastructure (in terms of electricity networks and EV charging equipment).
- **Include transport-specific targets in NDCs and establish national transport strategies to convert ambitions to policies on the ground.**
  As of November 2021, only 8% of NDCs include transport-specific mitigation measures [2]. Furthermore, once countries do include mitigation measures in their NDCs, there is often a disconnect between ambitious pledges and lacklustre or non-existent policies [53]. It is therefore of paramount importance to set out transport targets in NDCs and ensure that is reflected in policy. As highlighted by an international interviewee, "*there needs to be a policy dialogue of all these things that [Southeast Asian countries] put in their NDCs, how they're going to implement them, where do they need funding from abroad, because some of these things are conditional on getting that funding from the developed countries.*" (DFI1) Positively, Lao PDR-based interviewees were able to refer to policy documents that contain e-mobility targets (in particular, the fleet and charging station targets build on the previously cited targets in Table 1): "*to achieve 14% of EVs in the country's vehicle fleet and 500 charging stations nationwide by 2030*" (NG5).
- **Develop standards for e-mobility and renewables integration at national and sub-national levels.**
  Interviewees were keen to emphasise the need for "*associated standards*" – for charge points, communications systems and grids – in ensuring that the integration of e-mobility and renewable energy works effectively and does not produce unwanted emergent behaviours. For international interviewees, this was seen as particularly important in enabling "*smart [grids] to be able to manage this adequately [..., with] 70 or 80% renewable energy resources.*" (DFI1) Lao PDR-based interviewees expressed similar points, that "*to ensure the secure and effective operation of charging stations and vehicles [...] international standards must be met*" (A1).
- **Upgrade electricity grids and communications infrastructure in parallel to facilitate e-mobility transition.**
  Part of the integration of transport and electricity sectors that is necessitated by the electrification of transport is that growth in e-mobility must be matched by a sufficiently strong electricity grid. Otherwise, a poor supply of electricity would result in a poor supply of mobility. 'Smart' technologies, including smart charging to manage the impact on the grid, and V2G to unlock potential benefits of distributed battery storage assets offered by EVs, require significant embedded communications infrastructure in the grid. The need to ensure that grid infrastructure can keep pace with e-mobility was articulated by one international interviewee: "*Grids will need to be upgraded and expanded to respond to increased electrification of the transport sector*"; "*Smart digital technologies [...] require upgrade[s] of ICT infrastructure in parallel*" (DFI3).

5.3. Green finance

- **Provide concessional loans for potential e-mobility customers.**
  Concessional loans were seen by both international and Lao PDR-based interviewees as ways of overcoming the frequently-mentioned barrier of the high upfront costs associated with e-mobility. Lao PDR-based interviewees stressed the importance of "*low-interest loan[s] for those interest[ed] to implement [e-mobility] businesses*" (EVP2) and the importance of concessional finance in "*assist[ing] the rapid growth*" (EVP2) of the e-mobility sector. It was identified by some international interviewees that IOs and DFIs could be "*working with local commercial banks to offer lower interest loans*" (DFI1). This was seen as having the potential to cause a 'snowball' effect of affordable finance — it was stated by one international interviewee that once DFIs "*help the local banks [...] to finance these areas that [local banks] probably wouldn't*" (DFI2), there can be a "change in mindset" in the provision of low-cost finance in these growth areas.
- **Promote blended finance for integrated e-mobility and renewable energy projects.**
  Blended finance – the strategic use of development finance to mobilise the flow of private capital – was highlighted by international interviewees on several occasions, but was not touched upon by Lao PDR-based interviewees. While this may speak to the relative level of exposure to such mechanisms between the groups, the importance of this as raised by international interviewees merits its inclusion as a recommendation. International interviewees referred to specific country cases ("*if you're talking about millions of dollars of investment for Lao PDR or for Thailand, then we can't do it without the private sector, so that's where [DFIs] come in*") and specific organisations ("*we try to bring a number of stakeholders to bring through blended finance so we can bring some money from the Green Climate Fund, some from donors like the UK, and IO money to structure it in a way that can support the government's needs*") in highlighting the importance of blended finance in supporting e-mobility and renewable energy integration. In actioning the need for blended finance, it was suggested by one international interviewee that IOs and DFIs could help "*build a pipeline of projects by setting up a facility [for] local banks to finance e-mobility and renewable energy*" (DFI5).
- **Align finance streams from e-mobility and renewable energy.**
  It was identified by international interviewees that aligning finance streams (both costs and revenues) for e-mobility and renewable energy can serve to "*broaden capital markets*" (DFI2), increasing the appeal for banks, governments, and private sector

companies. One interviewee referred to a case study of e-ferry deployment in Thailand to demonstrate how the finances of a project can be re-structured to maximise its viability: *"[the e-ferry owner] was having difficulty raising funds from the commercial banks due to the ridership risk and the technology risk that is foreseen in the project. Without this financing, the company is facing difficulty in managing their project and liquidity. So, that's why we decided to… structure the deal so that it is feasible for the commercial banks and some development financial institution to join hands with us"* (DFI5).

- **Include financing commitments in long-term decarbonisation strategies, including the need for international finance.**
  International interviewees highlighted that financing commitments can be used to enhance long-term policy strategies and to help deliver security for private companies, such as e-mobility providers, charging infrastructure operations, and other key actors in the e-mobility and renewable energy sectors. It was stated that for a limited time – "*the first 5 or 10 years*" – national governments and DFIs can help "*through climate funding… to kickstart [the transition]*" (IO1). The need for international finance from high-income countries was seen as particularly stark; one international interviewee emphasised that countries implementing their NDCs was "*conditional on getting the funding from developed countries*" (DFI1).
- **Use green bonds to support integration of e-mobility and renewable energy.**
  It was raised by international interviewees that financing can be used as a tool for making this happen. Specifically, it was raised that *"in a few Pacific countries there have been discussions about the green bond, which means you should not just electrify transport; you also want to ensure that the energy that goes into it is relatively clean"* (DFI4).

5.4. Governance & coordination

- **Align decarbonisation policies across transport and electricity sectors.**
  Bringing together decarbonisation policies across multiple sectors, such as transport and electricity, was consistently brought up by both international and Lao PDR-based interviewees as an important way of ensuring e-mobility and renewable energy integration meets its stated aims: *"from a transport perspective you now have to look at the energy source… it's just not enough that you just could say we're going to replace a number of internal combustion engines… We have to look at the long-term sustainability and look at how the country is decarbonising"* (DFI1). One international interviewee credited progress in Southeast Asian countries where siloed government departments are beginning to communicate in bringing together joined-up decarbonisation strategies: "*Silos [are] being broken in government and consequently… there's also that interest to try and see how can we solve this problem by bringing various schemes together. The new policy is increasingly moving away from conventional energy-based solutions*" (DFI3).
- **Integrate management of projects across transport and electricity sectors.**
  E-mobility and renewable energy projects can be integrated across their respective sectors to streamline their financing. While experience of doing so in the e-mobility and renewables space is relatively low, case studies exist. For example, drawing on the wider Asian context, one interviewee referred to the integration of floating solar and agricultural energy demand in streamlining the production of a multi-purpose facility: *"in Kiribati and Tuvalu where we're looking at floating solar platforms that will also help with marine aquaculture, so it's about identifying certain areas where you can have a combination of resources, both energy and agricultural output, being produced"* (DFI4). Another international interviewee stated that their DFI are no longer working on *"pure energy projects"*, implying that there are consistently ties to other sectors. They illustrated this point using an example of integrating ocean thermal energy conversion with desalination needs: "*For a long time now we're actually not doing pure energy projects. In places like [the] Pacific […] we [are] looking at work on ocean thermal [energy conversion], and what does that mean from meeting desalination needs and things like that*" (DFI3).
- **Support integrated governance of transport and electricity through inter-departmental integration.**
  The merging of government departments, or the creation of new government departments that sit over existing departments, were both talked about as means of promoting joined-up policy across interacting sectors, including transport and electricity. This has been an effective tool across other sectors (for example, floating solar and agriculture, as previously discussed) and is already happening in Southeast Asia and Lao PDR. For example, two separate divisions of government have been merged to work on integrated transport–energy projects in South Asia ("*in… South Asia we see the transport, the energy, the urban development divisions [coming] together to do work on… industrial corridors, which [is] no longer just a single-sector focused intervention*" (DFI4)). Similarly, an "*EV Forum*", where the Ministry of Energy and Mines, the Ministry of Public Works and Transport, and the Ministry of Natural Resources and Environment presented "*visions and potentials to promote using EVs in the country*" (NG3). Aside from integrated governance at national government level, the importance of employing the same practices in IOs and DFIs was highlighted by one interviewee: "*In China for example, the energy and transport divisions [of the DFI] have actually merged into a sustainable structure division to meet demands from the Chinese government*" (DFI4).
- **Support international working groups to address cross-sectoral challenges.**
  Interviewees consistently raised the idea of creating international working groups in addressing the challenges in e-mobility and renewable energy growth and the integration of the two sectors. One of the Lao PDR-based interviewees referred to an electric bus trial in Vientiane, Lao PDR, under the cooperation between the Ministry of Natural Resources and Environment, Lao PDR, and the Ministry of Ecology, China isexemplifying the positive outcomes associated with international co-operation in the expansion of new sectors. One international interviewee stated that international working groups with the aim of bringing together stakeholders across projects are already active in China and India: "*we are inviting [companies] to these working groups. [In] the electric 2 and 3-wheeler working group we have invited a private sector [company] in India, a Chinese company, and <redacted> to be part of this global working group on electric mobility*" (DFI5).
- **Context-specific solutions**
  A final, overarching recommendation is added to Fig. 9 to emphasise the need for all parties to consider geographical context when designing solutions for e-mobility and renewable energy [54]. It has been demonstrated through the analysis in this paper that there are considerable differences between perceptions of the barriers to, and enablers for, e-mobility and renewable energy integration. Whilst the recommendations in Fig. 9 are designed to be general, it is clear that local contexts are crucial in designing effective solutions in this space.

6. Conclusion

In this paper, expert stakeholders including senior staff at a DFI and an IO active in Lao PDR and the wider Southeast Asian region and a range of stakeholders in Lao PDR were interviewed to generate learning on the barriers to, and enablers for, e-mobility and renewable energy integration in Lao PDR and provide analysis that would show

how barriers and enablers were viewed differently at the international (DFI and IO) and country (Lao PDR) levels.

It was found that there were some key differences between how international and country-level stakeholders interpret these issues; generally, international stakeholders identify broad 'top down' barriers and enablers whereas country-level stakeholders identify with higher-resolution issues. By bringing their views together, the stakeholder interviews were analysed to support a set of 19 recommendations to international organisations, national governments, financial institutions and the private sector, in fostering e-mobility and renewable energy integration in Lao PDR to support low-carbon growth in the region. As evidenced through the discursive points in Section 5, these recommendations have been drawn through discussions with stakeholders. In most cases, the recommendations were made by both international and Lao PDR-based interviewees.

These recommendations are aimed at supporting business models that integrate the e-mobility and renewable energy sectors in Lao PDR, a nation with significant potential to realise the benefits of the transition. The sectors can be brought together in the same time and place, such as a battery swap station for electric 2-wheelers providing grid services from vehicle-to-grid (V2G), or they can be brought together at a higher level, such as by linking supply chains and financing for e-mobility and renewable energy projects. The ways in which these business models can be supported relates to policy, financing, and governance. It was shown that through effective policy setting, long-term strategies can help de-risk investment in e-mobility and renewable energy integration by allowing businesses to establish the size of potential markets and de-risk their expansion plans. Furthermore, green finance can play a role by aligning streams of finance across these adjoining sectors. Governance can provide effective coordination to these efforts.

A recurring theme in the interviews was one of silos, and the need to break them. Consistently, interviewees at both the international and national levels referred to barriers resulting from the lack of coordination between government departments and the lack of development of co-dependent sectors. It was raised repeatedly that there are unwanted silos between sectors. Likewise, interviewees consistently talked about breaking these silos as enablers to the transition.

The Laotian context was described in Section 2. Given the country's plentiful renewable resources, the relative abundance of inexpensive electricity and its relatively recent openness to international investment, Lao PDR is a prime candidate for e-mobility and renewable energy integration in accelerating the transition to low-carbon economic development. However, to progress the research agenda on e-mobility and renewable energy integration in Lao PDR and Southeast Asia, it is recommended that (i) the benefits of this joined up transition be further quantified and evidenced to further characterise the issues explored in this paper and (ii) the relative feasibility of following the recommendations presented be weighed up against one another, taking into account the Laotian context as mentioned above.

CRediT authorship contribution statement

James Dixon: Conceptualization, Methodology, Investigation, Data curation, Formal analysis, Writing – original draft, Writing – review & editing. **Zhaoqi Zhou:** Investigation, Data curation, Formal analysis, Writing – original draft. **Sounthisack Phommachanh:** Conceptualization, Investigation, Writing – original draft. **Sengratry Kythavone:** Conceptualization, Investigation, Writing – original draft. **Phongsavanh Inthavongsa:** Conceptualization, Investigation, Writing – original draft. **Stephanie A. Hirmer:** Conceptualization, Data curation, Writing – original draft, Writing – review & editing.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: James Dixon reports financial support was provided by Foreign Commonwealth & Development Office.

Data availability

The data that has been used is confidential

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To ensure the study's integrity, a risk and ethics assessment following the Medical Sciences Interdivisional Research Ethics Committee at the University of Oxford in accordance with the procedures laid down by the University for Ethical Approval for all research involving human participants was completed and approved with reference: R74082/RE001.

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