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FACILITATION OF TRANSPORT AND TRADE IN LATIN AMERICA AND THE CARIBBEAN

Energy Efficiency and Electric-Powered Mobility by River: Sustainable Solutions for Amazonia

Background

Reducing non-renewable energy consumption and exploring alternatives for energy generation are priority topics of much debate around the world. The quest for affordable and non-polluting energy is one of the 17 Sustainable Development Goals adopted by the United Nations in September 2015. One of the targets of Goal 7 is to expand infrastructure and upgrade technology for supplying modern and sustainable energy services for all in developing countries, in particular least developed countries, small island developing States, and landlocked developing countries, in accordance with their respective programmes of support.

We are passing through a historic stage that is opening the way to uncoupling mobility from dependence on oil and other fossil fuels. The use of renewable energy presents an opportunity within this paradigm shift and makes it possible to build a closer relationship between the economy, society and nature. Passenger and freight mobility demands great quantities of energy, accounting for some 19% of the world's final consumption of energy in 2013. That sector will represent 97% of the increase in worldwide oil use between 2013 and 2030 (Kreuzer and Wilmsmeier, 2014). In terms of efficiency, energy security, greenhouse gas emissions, and local-impact emissions (particulate matter, NOx and SOx among others) there is a clear need to reduce the consumption of fossil fuels in general: when it comes to choosing a starting point, this sector would be the most strategic one at the local, national and global levels.

The mobility of people and freight, in terms of volume and structure, carries significant weight in the context of sustainable development because of its environmental, social and economic implications. Thus, mobility is crucial

This issue of the *FAL Bulletin* is devoted to seeking sustainable solutions to mobility in remote areas of the region such as Amazonia.

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UNITED NATIONS

ECLAC

consideration in efforts to achieve the majority of the Sustainable Development Goals, even if sustainable mobility is not itself covered by a particular Sustainable Development Goal. Mobility is a key element in linking rural areas and giving them access to domestic and regional markets (Goals 1 and 10), to health services (Goal 3) and to educational institutions (Goal 4), based on access to sustainable energy sources (Goal 7). As for transport infrastructure (Goal 9), this will endure for decades, which means that decisions taken now by local and national governments will have lasting effects on development and on the environment.

In the more remote areas of Latin America and the Caribbean, where lakes and rivers form the only natural communication routes, the search for comprehensive alternatives in energy and mobility matters is of the first priority. Mobility in these areas today demands major efforts on the part of users, not only in terms of costs but also in terms of time, quality and accessibility. One of the main challenges facing residents of those areas is the scarcity of infrastructure and services, which limits opportunities for economic and social development.

This paper presents a series of recommendations concerning innovations that could contribute to progress in integrating the Amazon basin, and it includes some suggestions regarding government policies and strategies that could strengthen and expand the initiatives now under way. With the availability of innovative mobility options, where infrastructure, means of transport, passengers, goods and the environment are increasingly intertwined, the objective must be to achieve a permanent uncoupling of mobility from oil consumption.

I. The context and the relationship between basic mobility and energy services

The shortages of basic services such as energy and mobility have until now been addressed with separate strategies for each sector. The ministries and institutions that develop and implement public policies for improving mobility or the electrification of rural areas tend to pursue their efforts independently with minimal collaboration. For example, the "Light for All" programme[1] launched by the Brazilian government seeks to electrify the entire country, including rural areas, but it does not consider mobility as a further basic necessity.

The lack of access to (renewable) energy sources poses a series of challenges for communities in these areas, resulting in the following situations:

- people cannot move about freely
- people are constrained in their pursuit of potentially productive activities
- people feel an incentive to migrate and move to population centres with better services
- societies are isolated and without communication
- access to medical and educational services is restricted and uneven
- opportunities for sustainable rural development are limited
- opportunities for social, cultural and recreational development are limited
- women face greater obstacles in developing alternative forms of productive and independent work.

Below is a review of some examples of government tools that have emerged in Latin American countries that could eventually ensure a joint approach to addressing the lack of basic necessities such as mobility and energy, with funding sources that encourage comprehensive projects, recognizing that isolated initiatives are essentially band-aid solutions that lack a long-term vision and will fail to improve the overall quality of life for the citizenry.

In several countries of Latin America, the legislation now emerging starts from the premise that mobility is a basic right. The state of Mexico, for example, has adopted a law on the right to mobility (EDOMEX, 2016). That law defines mobility as the right that every person enjoys to travel within the state, regardless of place of residence, condition, or form of transport used. Among the stakeholders responsible for mobility priorities are the municipalities. These priorities include supporting and participating in state-developed programmes to foster a mobility culture and education. In terms of sustainability, the law calls for gearing actions to ensure respect and priority attention for the right to mobility, analysing their impact on social, economic and environmental development, in order not to compromise the needs of future generations. Under this law, accessibility is defined as an essential condition of public services that allows the entire population to move readily in any external or internal space or environment. Moreover, it calls for institutional strengthening through the creation of a mobility secretariat and the allocation of funds for transportation infrastructure.

Ecuador has implemented the National Plan for Living Well (Government of Ecuador, 2013) with the general objective of transforming the country's economic and productive structure. The plan contains aspects relating to:

- satisfaction of needs
- quality of life
- dignified death
- the right to love and be loved

[1] https://www.mme.gov.br/luzparatodos/Asp/o_programa.asp.

- healthy flourishing for all in harmony with nature
- indefinite prolongation of cultures
- free time for contemplation
- emancipation and expansion of freedoms, capacities and potentials.

Under these broad objectives, the ECLAC-supported Inland Waterway Mobility Policy is currently under consideration by the Ministry of Transport and Public Works as a means of linking the Living Well plan to the concrete needs of Ecuador's more rural areas.

The Inland Waterway Mobility Policy is aligned with the 2008 Constitution of Ecuador, in particular its articles 391, 392 and 394, as well as with the 2013-2027 National Plan for Living Well and the previous one. Within the body of Ecuadorian legislation, it is based on the following legal instruments:

> ***Constitution of the Republic***
>
> *Article 11. The exercise of rights shall be governed by the following principles: all persons are equal and shall enjoy the same rights, duties and opportunities.*
>
> *Article 391. The State shall draft and implement demographic policies that contribute to balanced territorial and intergenerational development and guarantee protection of the environment and security of the population, in the framework of respect for self-determination of persons and diversity.*
>
> *Article 394. The State shall guarantee the freedom of overland, air, sea and river transport within the country's territory, without privileges of any kind. The promotion of mass public transportation and the adoption of a policy for differentiated transportation rates shall be a priority. The State shall regulate overland, air and water transportation and airport and seaport activities.*

In both cases, the state of Mexico and the Government of Ecuador have based their legislation and policies on a more integrated viewpoint of the principles of sustainability and accessibility. This approach forms the basis for including other sectors and ministries at different levels of government in order to generate and implement comprehensive activities, such as facilitating and implementing electrification and electric mobility projects.

Electric-powered mobility by river can be an important part of the solution to the complex problem of travel over short and intermediate distances in Amazonia. The principles of electrical mobility underpin all the recommendations for mobility and logistics policies (Jaimurzina, Pérez-Salas and Sánchez, 2015) and those contained in the Inland Waterway Mobility Policy for Ecuador prepared by ECLAC together with the Ministry of Transport and Public Works.

The policy takes a transdisciplinary and comprehensive approach to inland waterway mobility, recognizing the way in which economic, social and environmental topics are interlinked and creating a space for seeking concrete solutions to local and global problems.

Moreover, there is an Amazonian identity common to all the countries, making for an environment conducive to the development of innovative activities with a focus on the global market for sustainable Amazonian services and products (bananas, yucca, coffee, palm oil, and species for pharmaceutical use), ecotourism, wood and non-wood products with certificate of origin, as well as cooperative systems for environmental monitoring and surveillance, in businesses and activities that should be developed in the form of transnational production chains and local information and communication networks (Bara Neto, Sánchez and Wilmsmeier, 2006).

Within the context of sustainable mobility, and with the backing of entities such as the major automotive manufacturers, innovative firms in the field of mobility, and non-governmental organizations (NGOs) dedicated to sustainability, electromobility has emerged forcefully in discussions about urban mobility, focusing primarily on mobility by land. The benefits of electro-mobility in urban areas flow from the possibility of uncoupling mobility from non-renewable fuel consumption, and reducing noise and emissions – benefits that are also of direct relevance and importance in a rural context.

The issue of mobility must be resolved as a matter of urgency in order to start improving the quality of life for citizens, as lack of mobility significantly limits their participation in economic activities and their access to education and other basic services. A comprehensive solution must include uncoupling mobility from dependence on non-renewable energy sources such as fuel. At the present time, there have been advances in electrical mobility by land through innovations such as automobiles, trains and electrical bicycles, but there has been little progress with mobility by inland waterways, due in part to the low level of economic development in areas that are dependent on this type of mobility.

Some of the main difficulties in Amazonia could be overcome to a large extent with electrification through the installation of stand-alone solar power systems in communities (Gómez and De Campos Silveira, 2010; Giannini Pereira, Sena, Vasconcelos Freitas, and Fidelis da Silva, 2011; and Coelho and Goldemberg, 2013) and improved mobility and accessibility for the region (Bara Neto, Sánchez and Wilmsmeier, 2006). The introduction of electric-powered vessels that use photovoltaic power to recharge their batteries presents an important opportunity for progress in the social and economic integration of communities in the more remote regions of Amazonia.

Electrification and mobility strategies can be complementary in combination and can help meet basic needs as well as exerting a "leapfrog" effect in poor peripheral areas toward sustainable and highly innovative energy and mobility systems. Below we examine:

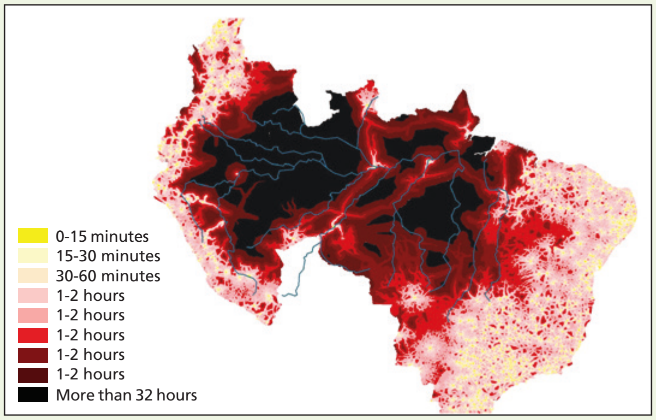
- the restrictive nature of mobility in the Amazon basin
- the need for electrification
- the potential for electrical mobility, citing examples of pilot projects that are currently under way in the Amazon basin
- the broader prospects for electric-powered river travel as part of a comprehensive and sustainable policy for inland navigation.

II. The restrictive nature of mobility in the Amazon basin

River travel in Amazonia is one of the most important features of daily life. It is one of the most important forms of communication for the majority of inhabitants, and a central component of the Amazonian identity. Moreover, it represents the most suitable mode of transport for purposes of environmental preservation. Having a system of river mobility that is efficient, accessible, equitable, effective, safe and sustainable and that meets the mobility needs and requirements of people and freight will facilitate the development of a diversified production matrix and will promote territorial, economic and social integration in remote areas – the very kind of development that the United Nations seeks to promote. With the exception of river travel, the region's accessibility by land-based transportation is very low, as can be appreciated in the following map (Bara Neto, Sánchez and Wilmsmeier, 2006).

In this situation, river travel in the Amazonian region is the most widely used form of transport, given the lack of roads and the limited availability of air transport between widely separated populations centres: 90% of transportation takes place on navigable waterways (Bara Neto, Sánchez and Wilmsmeier, 2006). Despite the lack of accessibility, Amazonia is home to a sizable, if scattered, population. People tend to be grouped in villages along the rivers because, in the absence of physical infrastructure, the rivers are the prime means of communication in the region.

Map 1
Amazonian accessibility in terms of physical infrastructure



Source: prepared by the authors on the basis of ECLAC data.

III. The potential for electrical mobility based on acupuncture projects

Certain Amazonian communities are currently engaged in acupuncture projects designed to overcome the lack of electricity and mobility problems, while uncoupling mobility from dependence on non-renewable fuels.

A case in Ecuador's Amazonia can serve as an example of the kind of project that seeks solutions to the lack of electrification and mobility in outlying areas. These problems can be overcome to a large extent with electrification through the installation of stand-alone solar power systems or through micro-networks with generation centralized in each community, and improved mobility and accessibility in the region.

In Amazonia, any initiative to replace conventional fossil fuel-powered motors with battery-driven electric motors will face the problem of how to recharge the batteries, given the lack of conventional electric power in isolated areas without electrification. In this context, there is a very important role to be played by power distribution utilities, which by law must provide electric power to dwellings and families within their service area (Guzmán, Ordoñez, Espinoza and Jara-Alvear, 2015)

In the Ecuadorian Amazon, the power utility Empresa Eléctrica Quito (EEQ) has undertaken a solar-powered river mobility project as part of the support provided to the Sucumbíos National Electricity Corporation (CNEL), based on a management contract under which EEQ has developed its "Light for Sumak Kwasay" programme. That programme is designed to provide electrical service to isolated communities, either by installing individual solar power systems in every dwelling or, in communities where houses are clustered around a square with perhaps a school, a health post or community hall, by installing hybrid (solar-thermal) generation with mini distribution networks. In the first phase, six communities belonging to the parish of Puerto Rodríguez in the canton of Putumayo, Sucumbíos Province, have been equipped with stand-alone 390 watt (W) photovoltaic solar power systems and solar-powered street lighting and water pumping systems.

The technical and commercial management model developed by CNEL and EEQ as the firms responsible for power supply is intended to ensure sustainability over time. This model is based on pre-payment systems in which the electrical service is the responsibility of the distribution company and not of the community. Experience with previous projects shows that maintenance and management of such services cannot be delegated either to the communities or to NGOs. The prepaid system allows consumers to pay for their electricity at the nearest agency or office and, using a portable memory key, to purchase days of power month by month. When connected to the PRE CASH system installed in the distributor's agencies, the key downloads operational data for the solar power system on site and if it detects a technical problem in the system it reports this and a maintenance technician is sent to review the situation. This enables remote monitoring and avoids power cuts in the photovoltaic solar systems.

The experiment with solar-powered mobility reflects the understanding that energy is the vector for a people's development, and that productive uses must be found for communities that already have electricity. At the same time, the authors' own experience shows that working in hard-to-reach Amazonian communities demands time-intensive coordination and entails high costs because of problems with land, air and river transport.

In the northern Amazonia of Ecuador, NGOs, local governments and the electric power utility itself have been carrying out isolated and decentralized rural electrification projects by installing generating systems that take advantage of local resources, primarily photovoltaic solar energy, in districts and communities that cannot be supplied with power through the conventional electricity networks. The National Plan for Living Well (Government of Ecuador, 2013) decrees that basic services, including electricity, must be provided to the entire population.

The projects completed to date by EEQ have followed a sustainability model that takes full account of the social, cultural and environmental conditions of the area and its highly diverse and dispersed population, which embraces 6 of the country's 10 indigenous peoples —Kichwa, Cofán, Siona, Secoya, Shuar and Huaorani.

The Ecuadorian Amazon is no exception. In Amazonia the majority of communities are located in the interior, where there are no land routes offering mobility. The inhabitants move between communities by river, in canoes powered by two-stroke motors. Typically, they will travel to the larger centres to supply themselves with products that cannot be obtained locally. These trips also serve for marketing their forest-grown products, and for collecting benefits under the Human Development Bonus Programme.[2]

Inhabitants generally travel by motorized boats that have greater power than the canoes traditionally used in the zone. These boats are fast and are widely used by the oil industry for accessing worksites. In communities along the Putumayo River, speedboats offer quick passage between Puerto Mestanza and Puerto Asís in Colombia. In Amazonia, tourism is the economic activity with the greatest weight and highest profile, and boats are typically used to access eco-lodges, hostels and hotels and to transport tourists, staff and supplies.

Currently, the education sector in Ecuador is also using boats to move students and teachers by river. With the reorganization of educational infrastructure in Ecuador, one-room schools in communities with few pupils have been closed, and the State has built schools in larger communities where the Ministry of Education has concentrated pupils. In order to make these institutions more accessible, river transport systems have been introduced to carry students between their remote communities and their assigned schools.

Access to fuel, without which the commonly used conventional motors will not function, is perhaps the main mobility problem in remote areas. Access to fuel varies by region and depends on geographic characteristics: fuel shortages of course affect the possibilities of travel in the zone. Along the Putumayo, a river on the frontier with Colombia, where even higher fuel costs result in cross-border smuggling, fuel purchases require authorization and are rationed. These measures were implemented to prevent smuggling and the use of gasoline for illicit purposes, and the cost per gallon can be as much as four times the normal cost.

In the provinces of Pastaza and Morona Santiago, fuel is transported by light plane from Shell or Macas plants to communities in the forest, and from there by boat, resulting in excessively high costs. On the Napo River, by contrast, fuel is transported as far as Nuevo Rocafuerte by river tanker.

The aforementioned six communities along the Putumayo River have a community-owned fibreglass boat donated

[2] The Human Development Bonus is a programme to transfer economic resources, for investment in education and health, aimed at the poorest households in Ecuador.

by the Provincial Council of Sucumbíos, powered by a Yamaha 40 horsepower (hp) motor, with which people can travel between communities or further afield to Puerto El Carmen, the cantonal seat, from where they can take vehicle transport to Lago Agrio or another city. Because it is a border zone, it has a major problem with fuel shortages, as there is only one service station run by the Ecuadorian army. The cost of fuel is much higher on the Colombian side, and this encourages fuel smuggling from Ecuador. To purchase fuel one must justify its use, a cumbersome and time-consuming procedure. In this context, finding an alternative to fuel for the boats is very important, quite apart from the problem of environmental pollution through the emission of gases into the air, pollution of the river through the leakage of oil used in the two-stroke engines, and damage to docking facilities.

The following table shows communities with their travel distances and times from Puerto El Carmen using a conventional boat powered by a fuel-burning 40 hp short-leg motor, which is the most widely used motor on the Putumayo, and consumption of the gasoline-oil blend of fuel used in two-stroke engines. The most common form of transport between communities or population centres is via river, using boats with a two-stroke fuel-driven engine.

Table 1
Putumayo: distances, times and energy consumption

Puerto el Carmen	Distance	Travel time	Fuel consumption	
To	*(km)*	Motorized canoe	Gasoline	Oil
		(Hours)	*(Gallons)*	*(Litres)*
Nuevo Sinaí	40	1:30	14	2
Buen Samaritano	52	2:10	18	3
Puerto Rodríguez	60	2:40	20	4
Bajo Rodríguez	64	3:00	22	4
Mushuc Kayari	70	3:20	23	5
Tres Fronteras	81	3:40	27	6

Source: EEQ, 2016.

IV. The technological solution

Electric motor technology has made great strides worldwide in recent years, apace with the development of electric vehicles, which are now produced by nearly all the major brands. In Colombia and Ecuador, the government has exempted electric vehicles from taxes to encourage this form of mobility. In contrast to electric-powered mobility in the cities, which involves automobiles, motorcycles and electric bicycles, electric-powered mobility and technical solutions available for river transport have received little or no attention or strategic support. The technology for electric boat motors, both outboard and inboard, has been tested in many places in the world, but there is also experience in Latin America to which this FAL refers. Generally speaking, there are two possible power sources for electric motors: (i) onboard solar panels that generate continuous energy (for example, the Kara Solar project), and (ii) portable batteries that use land-based solar power (or other sources) for recharging. Both options present important opportunities for promoting the social and economic integration of Amazonian communities. The components of the system are the following:

- Electric motor: this transforms the electricity received from a system of onboard batteries or solar panels into mechanical energy and transmits it to a propeller, which in turn provides the thrust necessary to move the vessel.
- Bank of batteries: this stores the energy needed to drive the motor. There are various types of batteries: open lead-acid, sealed lead-acid, absorbed glass mat (AGM), gel and lithium batteries. Of these, it is the last one that offers the best energy density (kilowatt hours/kilogram) and efficiency to full discharge. Lead batteries are also used in electrical mobility, but their efficiency and their maintenance needs are limiting factors when it comes to operating a solar-powered vessel. The number and type batteries used must be chosen in accordance with the navigation routes and times and the type of vessel in order to guarantee safe and autonomous navigation.
- Generator/battery charger: the energy stored in the batteries must be expended in any case, and for this purpose various options are mentioned above. Depending on the navigation requirements, a system based on two lithium batteries requires a photovoltaic generating system of at least 800 to 1000 "Watt-peak" or peak power.
  - Energy can be drawn directly from an "electroliner" electrical socket at the dock. For example, a recharging system could be located in a community kiosk, where the jump leads for the batteries and the regulator that will control the recharging of the batteries, as well as the prepayment system mentioned earlier could be housed in panels and compartments.
  - Power generated by solar photovoltaic panels mounted on a hut next to the dock, or on houses in each community.
  - Power generated by solar panels installed on the roof of the vessel.
  - Power generated using a 5 kW hydrokinetic turbine immersed in the river. The idea is that its energy will recharge the batteries, and the leftover power will be fed into the community's hybrid system.

- Charge regulator. This is crucial for the proper charging and discharging of the batteries, and in particular to preserve their useful life. It is better to use regulators that can programme the charge and discharge limits according to the type and model of the battery.
- Speed controller. This device controls the consumption of the motor in accordance with the needed velocity; the greater the speed, the greater the passage of electric current that will be allowed. This component can be built into the outboard motor, or it can be a stand-alone device.

This concept calls for use of an electric outboard motor, which combines a propeller, the electric motor and the speed regulator in a single piece of equipment, in a manner similar to the gasoline outboard motors now in use, with the difference that the motor is submerged in water and connected directly to the propeller, thus avoiding the need for gears or complicated transmission systems and thereby reducing maintenance work and the risk of damage, while improving the system's efficiency.

A. Electro-mobility tests in the Ecuadorian Amazon

In May 2015, representatives of ECLAC, the Ministry of Transport and Public Works and EEQ/CNEL, conducted three days of testing in the communities of Nuevo Sinaí, Buen Samaritano, Puerto Rodríguez, Bajo Rodríguez, Mushuk Kallarí and Tres Fronteras, along the Putumayo River, in the presence of leaders of the communities involved and the president of the parish board of Puerto Rodríguez. School transportation was successfully provided by the electric vessels, and this aroused great interest among the six communities of the area and their representatives.

The project was launched and the tests were conducted in the light of the need to pool the region's efforts at electrification through photovoltaic solar systems, which had previously been installed in the communities by EEQ/CNEL, and to complement these with the search for productive uses of this type of energy.

Two boats were used in these tests, a conventional boat powered by a gasoline engine, and a boat powered by an electrical motor, and it was found that, given the characteristics of the community boats and the current of the Putumayo River, an electric motor of 4 kW, or the equivalent of a 20 hp gasoline engine, was needed for propulsion. A motor with two batteries was used for the run between Puerto El Carmen and Puerto Rodríguez. The distance of 60 km was covered in 3 hours and 40 minutes, at an average speed of 16.3 km/h, using a wooden hull.

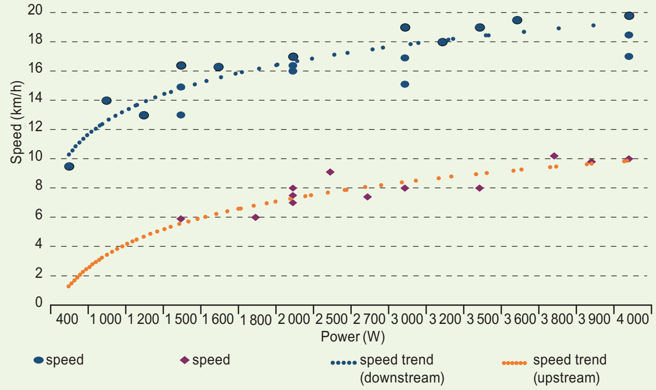
Figure 1 shows how the wooden-hull boats performed during the tests in terms of the speed/power ratio.

Table 2
Technical configuration of the tests

Motor	4 kW Torqeedo Cruise 4.0 RS/RL electric motor.
Batteries	Power 26-104: 2 685 Wh weighing 25 kg.
Recharge	The batteries were recharged using Torqeedo chargers of 120/220V 60Hz, and a normal power network, with a maximum recharge time of 11 hours, to take the battery from 0 to 100% of capacity.

Source: Authors.

Figure 1
Speed-power performance of an electric-powered boat on the Rio Putumayo



Source: authors.

Of the two pairs of batteries used in this test, the first pair were totally depleted (they gave out upon reaching 10% of their charge), and the second pair were used to 50% of their charge. When running with the current, a speed of up to 20 km/h was achieved at maximum power, and 16.5 km/h at medium power, with the boat used for the tests (six-person, 12 m boat). When running against the current, a speed of up to 10 km/h was achieved at maximum power, and 7.5 km/h at medium power, indicating that the impact of the current is up to 10% greater when navigating upstream. In this test, the velocity of the river was between 5 km/h and 6 km/h. The consumption and required power generation data are shown in table 3, as a function of the speed of navigation, the distance covered, and the cruising range of the batteries.

The electro-mobility tests for the school transport service are based on the objectives of overcoming the current challenges in providing this service. These challenges include the limited availability and high cost of fuel (up to US$ 5 per gallon), which lead to great irregularity in the school transport service. Moreover, the fuel is not handled under proper conditions, and this poses a high risk of water pollution. The use of a two-stroke motor exposes the driver and the children to very high noise levels during the trip, and over time this can be harmful. Finally, the boat used has no roof to protect against rain and the sun's rays, nor is it equipped with life jackets for the children. The boat currently operates with a two-stroke 20 hp outboard motor. The school run covers 10 km, 50% of which is upstream and 50% with the current. The time needed to fetch the children was 40 minutes, similar to the time required with a conventional motor, at an average speed of 13.5 km/h. The delivery of the service consumed 38% of the power of the two batteries: in other words, it is possible to make a round trip with the children using a single charge of the two batteries.

Table 3
Technical results of the tests

Two batteries	Direction of current	Speed *(km/h)*	Distance *(km)*	Cruising range *(hours)*	Energy *(kWh/day)*
Maximum speed	Upstream	10	15	1:30	5
	Downstream	20	30	1:30	5
Medium speed	Upstream	7	20	3:00	5
	Downstream	16	45	3:00	5
Low speed	Upstream	4	30	8:00	5
	Downstream	12	90	8:00	5

Source: authors.

Image 1
The Puerto Rodríguez school canoe, Putumayo

Source: authors.

During the test with the school boat (4-person, 6 m long boat), greater speeds were achieved with less power, thanks primarily to the design and weight of the vessel.

Map 2
Route to the school, and stops: Puerto Rodríguez, Putumayo

Source: authors.

The results show that it is technically feasible to provide a service with these characteristics. Moreover, the solution improves the regularity of the service, eliminates or at least reduces atmospheric emissions, and eradicates noise pollution and the risk of polluting the water through improper handling of fuels.

In addition to these tests, there are other examples of electro-mobility in Latin America, presented in Table 4.

In electro-mobility projects, the integration of the energy and mobility sectors plays a very important role. For all the projects, a suitable model for managing the socioeconomic, cultural and ethnic characteristics is key to ensuring sustainability of the project itself and for management during the useful life of the equipment and of the small, isolated electrical systems, whether these are stand-alone or connected to a mini distribution network. The sustainability model is the most important thing for managing these isolated systems, for it will determine whether the power supply is continuous and whether the service lives up to users' expectations.

Table 4
Electro-mobility projects in Colombia, Ecuador and Peru

Executing agency	Photovoltaics Peru	Solano Corporation and Smart Hydro Power
Year	2015	2015
Place	Tapiche River, Peru	Caquetá River in Araracuara (Municipality of Solano, Department of Caquetá), Colombia
Project objective	To establish a sustainable mobility system for residents along the Tapiche River within a wildlife sanctuary. To minimize transport costs using renewable energy (electric motor and stand-alone solar power system).	To provide economical electric-powered river transport to indigenous communities in a forested zone of Amazonia
Description of the solution applied	Kayaks typical of the river region were outfitted with electrical propulsion systems from the German manufacturer Torqeedo, consisting of the 4 hp "Travel 1003" electric outboard motor and the related batteries and accessories. The project seeks to establish a sustainable and competitive form of transport and a logistics system for riparian residents. Users of the electric kayaks live along the river and use boats for their daily transport and logistics tasks, including the transportation of students to and from school. The electric boats can also be used for any type of transport in the communities, either for passengers or for freight.	With funding from the non-profit NGO, MIVA, the Solano Corporation acquired: • 2 electric outboard motors • 8 batteries • 8 chargers • 1 fibreglass boat, 7 m in length These inputs were acquired with a view to replacing the outboard motors traditionally used by the community. The logistics involved in delivering gasoline to Araracuara for operating two-stroke outboard motors are very complicated, as there are no roads and air transport is very costly. The village of Araracuara is an enclave in the middle of the Amazon forest, and it faces a great energy shortage. It is located within the buffer zone of the world's largest land-based national park, Chiribiquete. This is a highly innovative project of renewable energy technology that is unique in all of Latin America. The electric boat makes it much easier and more economical for indigenous communities to transport their merchandise and agricultural products and fish on the Caquetá River and to attend the health post and the Fray Javier de Barcelona boarding school in Araracuara and Puerto Santander. Electro-mobility by river serves in this case as a sustainable tool for rural development in a very remote area. In addition, through the use of renewable energy, the project helps to preserve the quality of water in the Caquetá River and to protect the global climate.
Power system	The main town has installed an off-grid solar power plant to recharge the batteries.	In order to charge the boat's lithium-ion batteries a hybrid renewable energy system was installed in Araracuara on the Caquetá River, consisting of a 5 kW/peak photovoltaic plant with its respective inverters, a bank of rechargeable lead-gel batteries of 30 kW/h (all mounted on a 12 m long and 6 m wide steel river pontoon), as well as two Smart Hydro Power monofloat floating hydrokinetic turbines with a nominal power of 4 kW each. This river pontoon with the electricity supply kiosk was designed and built in Colombia for recharging the boat's batteries, supplying electric lighting to a boarding school for indigenous students, recharging lamps and cell phones for indigenous households, and operating and maintaining the floating turbines.
Current project status	The project is still under way and has been functioning successfully for a year and a half. For the moment there are seven boats, and there are plans to add more in the near future.	The project is still under way and has been functioning successfully for a year and a half

Table 4 (concluded)

Executing agency	World Wildlife Fund for Nature	Nacionalidad Achuar del Ecuador (NAE)
Year	2013	2013-2014
Place	Galapagos Islands, Ecuador	Pastaza River (tested on the Aguarico River)
Name of the boat	Solaris	n/a
Aim of the project	To instil a new cultural and technological concept among the inhabitants of the Galapagos, in order to promote a shift in traditional thinking about the use of renewable energy in sea transport in the Galapagos Islands, with a view to supporting the general objective of eliminating dependency on fossil fuels so as to conserve the islands and mitigate the effects of climate change.	To establish a cooperative river-transport system managed by the indigenous communities living along the banks of the Pastaza River, and to reduce operating costs by eliminating the use of fossil fuel and its transport to the communities.
Description of the solution applied	Solaris was designed to operate in Tintoreras Bay on Isabela Island, using a solar electric propulsion system, in order to demonstrate the feasibility of powering the boats using solar power and connection to the electric grid as a replacement for fossil fuel. Solaris was built using a boat that was confiscated for illegal fishing in the islands. The boat was adapted to receive the Torqeedo electric propulsion system and the solar photovoltaic generator needed to produce the power to drive the boat. The results show that the use of solar powered boats for bay transport in the Galapagos Islands is commercially feasible. Solaris uses a highly efficient outboard motor, which allows for a carrying capacity of up to 4 tonnes, combined with a bank of safe and efficient marine-grade lithium batteries. The boat can run for 10 hours at a speed of 2 knots between charges. See a video of the test at https://www.youtube.com/watch?v=jsoCxzLa_Ok	Participation in the design of the boats to be built for this project; this will be done by the indigenous organization (client), which has experience in the manufacture of fibreglass boats for the rivers of Amazonia. Full advisory services to establish propulsion needs as well as the cruising range of the batteries for the different boats that will navigate each planned route, according to river conditions, trip distance, speed and expected load. Detailed design of the electrical connections and data, and fixed recharging systems to be installed in specific ports, thus allowing sufficient cruising range for navigating all the routes. The project, which consists of various phases, is still under development, but a number of tests concerning the construction and the electrical connections have been performed with successful outcomes. In particular, the test conducted on the Aguarico River, which is more complicated and faster-flowing than the Pastaza, exceeded the design specifications (maximum speed of 26 km/h, average speed of 7 km/h, 3 tonne load), thus guaranteeing the desired speed and confidence level for the project. See a video of the tests at https://www.dropbox.com/ sh/rmdld7g8eg0cvg3/ AADR2NMArkoVH6beOGsMsJwia

Source: authors, based on information from Wagner, E. and Jara-Alvera, J.

V. Conclusions

This FAL describes the possible linkage between electrification from renewable energy and mobility in isolated regions of South America, and demonstrates the technical feasibility of implementing electro-mobility systems on the basis of field tests and existing projects in the region. To date, these have all been isolated and small or acupuncture projects. In order to make the most of the advantages and the complementarity of these projects they will have to be supported and combined with integrated energy and mobility strategies. The solutions described offer a high degree of intersectoral integration and represent a paradigm shift in the provision of basic services (energy, water and mobility), as this new form of mobility makes it possible to uncouple the growing demand for mobility from the demand for fossil fuels. In addition, these solutions reduce atmospheric emissions, they eliminate noise from the boats, and they contribute directly to reducing the risk of water pollution through inept fuel handling. Lastly, giventhese advantages, electro-mobility offers a greater quality of service and an opportunity to implement it in the tourism, agricultural and small-scale fishing sectors.

To ensure that these mobility projects are viable, they should be built and connected to existing and future electrification projects through, for example, the installation of isolated photovoltaic or hydrokinetic systems.

Freight volumes in Amazonia, whether in transit or for local delivery, are low, although they offer some interesting potential. To seize this potential in the future will require investments in infrastructure and in improving the quality and quantity of services over the transportation and logistics network, in order to overcome the current inertia in the zone's development. Communities have shown great interest in adopting this new propulsion system, but they require financial assistance to cover the needed initial investment.

This case study in the Ecuadorian Amazon has shown that it is feasible to install electric-powered canoes using renewable energy in the rivers of Amazonia, when there is an interest and commitment on the part of the communities in undertaking projects of this kind. The designs and weights of the current canoes will have to be reviewed to make them more efficient for use on Amazonian rivers. Electrically-powered river mobility must be part of integrated and sustainable policies for inland navigation and the energy sector. Moreover, they could become an important and complementary part of existing mobility options. The government, working through the power distribution companies, should continue to supply electricity service to Amazonian communities for both residential and productive use, employing generation systems based on renewable energy, and in this way support the implementation of electro-mobility projects.

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