# NAUTICAL ELECTRO

Genoveva steers the Torqeedo Travel 1003 electric motor on her way to the mangroves in Puya Puyal, where she usually collects piangua.


# MOBILITY

## Testing alternative business models for artisanal fishing in Colombia

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*Photos by the authors*

**At its core,** nautical electromobility involves the use of a novel technology, which means a fundamental change in propulsion systems. Compared to conventional combustion technology, there are three basic components of an electric propulsion system: a rechargeable battery serving as the energy storage, an electric motor for transforming the electric energy into thrust, and enhanced power electronics.

For our purposes, the term electromobility denotes the application of electric propulsion for waterborne transport of people and goods. Nautical electromobility is a small but rapidly growing segment of the marine market, and its potential implementation typically is discussed in the context of developed countries. In peripheral coastal and Amazon regions in Colombia, as in other Latin American countries, such innovations (with certain exceptions such as the Kara Solar Project in Ecuador) have not been implemented. The potential of small-scale innovative

Sorting piangua in order to ensure the minimum 5 cm size is respected, thus allowing smaller shells the chance to reproduce and sustain future collection in the mangroves.

technological solutions, including their connections and replicability, has been widely ignored by policy makers and underestimated in their impact on local populations. Consequently, traditional, low-level technological forms of mobility based on fossil fuels are predominant.

These traditional forms of fossil-fueled propulsion systems have been alien to processes of transformation, progress, and innovation. At the same time, the effects of fossil fuel dependency in these regions, elevated fuel prices (despite government subsidies), and negative environmental impacts (emissions, water pollution, and noise) have been taken as a given and haven't received proper attention. Without the drive to create new development pathways, these coastal and Amazon communities are prevented from participating in regional and national markets. Regardless of the environment in which it is used, mobility is a fundamental factor in the development of economic and social activities. It facilitates a strategic flow of goods, services, and people.

Most small-scale waterborne transport activities—fishing, local transport, and tourism—in the coastal areas of Colombia are still dominated by two-stroke outboard engines of between 5 and 40 hp. The use of this outdated technology is due to restricted access to fuel, the limited purchasing power of economic participants, and the historic trajectory of technology use. However, the current situation carries a profound contradiction: the restricted access to fuel also makes fossil fuels, despite local fuel subsidies, up to 50% more costly per gallon than in central regions of the country. As a result, fuel prices can reach between $4 and $5US per gallon. Fuel costs therefore are the major burden for all waterborne transport activities and the main risk for indebtedness of the local population.

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As the public and private sectors work with academia to bring affordable, intelligent, environmentally friendly, and resources saving mobility options from concept to practice, the current situation in the coastal regions has the potential to develop a model testing site. By using electromobility, operating costs can be reduced and energy efficiency can be significantly increased. Using more cost-efficient renewable energy sources also contributes to the reduction of greenhouse gases. $CO_2$ emissions can be reduced, depending on the share of renewable electricity, by up to two thirds as compared to conventional propulsion systems. The reductions of greenhouse gases and air pollutants achieved at all scales represent an important contribution to a future environmentally friendly mobility. In addition, such a solution reduces noise emissions.

## User acceptance

Mobility and energy are key areas for economic development. The challenge is to provide such services in a way that doesn't jeopardize the natural and cultural endowments of these regions. It should instead transform traditional economic activities—fishing, for example—and use existing richness and local knowledge to create competitive and sustainable livelihoods.

Acceptance and adoption of technology are key challenges, particularly in traditional societies that often are post-conflict and are in economically underdeveloped regions. Consumption patterns are highly path-dependent in these areas, but early experiences have shown that awareness of a need for more sustainable livelihoods in the regions under study is significant, and this has created an interest in new solutions. This interest is more developed among the female and economically active population, and among school children.

## The technology side

Electric outboard motors that are comparable to 5 to 40 hp. traditional outboard combustion engines are widely available in the market and have proved their practicality in the leisure and prime market segment for boating in developed countries. Therefore, the goal is to transfer the use of proven technology to new economic and social contexts. It's important to consider the overall efficiency of an electric outboard, described as the percentage share of propulsive power in comparison to input power. Current brushless electric outboards convert 44 to 56% of the input energy in thrust versus a conventional fuel engine that converts 5 to 15%.

For electric outboards, overall efficiency is a key performance indicator: Because batteries only have a small fraction of the energy density of gasoline, battery capacity is almost always the limiting factor for power and range of an electric motor. Higher overall efficiencies result in more power and range. For gasoline outboards, overall efficiency is not such an important performance indicator. Due to the high energy density of gasoline, poor efficiencies can be balanced by higher petrol consumption.

The overall efficiencies of small gasoline outboards are therefore particularly poor and tend to be in the 5% range. That is, 95% of the energy supplied to a small gasoline outboard is lost in the drivetrain and only 5% winds up propelling the boat.

Ninfa explores the different configurations and operation requirements of electric outboard motors before a trial in Macharal, Colombia.

Replacing a single four-stroke 5-hp. outboard engine will reduce $CO_2$ emissions to the equivalent of 38 diesel cars. The most common engines in these regions are two-stroke engines with higher emissions, due to low maintenance levels and age of the engines.

## Concept to practice

In Nariño, on the Pacific coast of Colombia, women collecting the black shells—called "piangua" or "curil"—live in stilt houses in small dwellings. These are spread out in the mangroves along the coast and coastal estuaries, often without any connection to land infrastructure. The women have to navigate distances of up to 7 km in canoes propelled with paddles or small two-stroke outboard engines from their home dwellings through the estuaries to reach the shell grounds in the mangroves.

Collecting piangua is a physically demanding activity. Once on site, capturing the mollusk under the mudflats requires well-developed skills and entails the risks of being bitten by snakes or stung by rays; at the same time, the women have to cope with mosquitoes and the threat of mosquito-borne diseases. Moreover, due to overexploitation, the women increasingly need to search for shell grounds at greater distances from their dwellings, thus requiring motor power as paddling is not physically feasible. The use of motor power is significantly impacting the environment, polluting air and water sources. More importantly, for these women, motorization also represents a very costly tradeoff between the possibility of collecting the shells for a small income, or not performing the activity at all due to the increase in fuel costs. The current situation poses a major threat to the livelihood of the families whose income relies mostly on piangua.

The Travel 1003 (second from the right) electric outboard sitting between two 40 h.p. engines on the resting bench at the end of a journey.

Genoveva and Emma discuss the economic benefits electric outboards will provide for them in their work.

The electromobility project targets this first mile of the logistics of artisanal fishing, proposing a solution composed of an electric outboard motor and a set of batteries.

Women from the community council "Esfuerzo Pescador" in Santa Barbara de Iscuandé, Nariño, on the Pacific coast of Colombia, were the first recipients of the technology under a pilot study developed by the Universidad de los Andes, along with HTW Berlin, Calidris Association, WWF Colombia and the national fishing authority (AUNAP) and co-funded by iNNpulsa and the BMBF. In November 2018, the first fishing association was equipped with a 1,000 W short-shaft electric outboard motor (Torqeedo Travel 1003) replacing their traditional 15 and 5 hp. two-stroke outboard engines. This pilot was extended to four women's fishing associations in February 2019. Each outboard motor is equipped with two exchangeable and 915 Wh Li-Ion batteries. The recharging of the batteries during the pilot is done using the public grid in the villages.

The autonomy for travel, defined by the available battery capacity, was a main concern of the fisherwomen as they need to reach their shell harvesting grounds. These can be as distant as 7 km and part of the journey is against the currents because of the tidal changes on the Pacific coast.

Tests conducted in the Puya Puyal area in Nariño showed that, as expected, an increase in the use of power and speed leads to a decrease in autonomy and reach (distance in kilometers). Furthermore, the results suggest that 400-600 watts of power use (of the maximum available 1000 w) are the optimal values for efficient operation, delivering speeds in the range of 5.5 to 6.8 km/h.

Therefore, the necessary average electrical power requirement for the fishing boats during the activity was assumed to be 600 w, with the maximum peak power being 1000 w. To ensure sufficient energy autonomy, we hypothesize a maximum navigating time to reach and return from the shell collecting grounds of two hours. We also add an extra margin of one hour considering the effect of tidal changes, currents, maneuvering, and possible emergencies. Therefore, the fisherwomen needed to be equipped with sufficient battery power to sustain navigation for three hours. This means that the energy consumption per trip that the batteries have to provide is equal to the average power (550 w) for a total time of three hours to guarantee a safe and energy sufficient voyage. Considering these elements, the available battery capacity has to be greater than 1,650 Wh.

Based on the on site tests and considering the hypothesis, the shell collecting grounds are within safe reach when using the two exchangeable 915 w batteries for a total of 1,830 Wh.

## Reduced operating cost

Beyond the technical feasibility, the operating costs of the fisherwomen in terms of fossil fuels reduce to zero, as they charge the batteries using the photovoltaic panels at the local school or the public grid. Compared to using a 5 hp. two-stroke outboard engine, this results in savings of $2-$3US per fishing trip. Each woman collects an average of approximately 100 shells per trip, with a current local market value of $5-$7US. Therefore, adopting this new technology offers the fisherwomen savings of up to 40% or better and an increase in net earnings of the same figure per trip, depending on the number of fisherwomen per boat (usually from one to four).

The monitoring also shows that the members of the association not only use the electric outboard engines for their main economic activity, but also are increasingly using the solution for other activities. These include getting supplies (for example, ice for cooling of caught fish from the neighboring villages), attending community meetings, and social and recreational activities such as visiting friends and family in adjacent dwellings. As a result, the burden of fuel costs is eliminated for all these activities, on the one hand creating

*The tested nautical electromobility alternatives have great scalability and transferability to other scenarios in Colombia.*

financial relief for the families and on the other facilitating greater mobility and social interaction.

Given these first positive results and depending on the further monitoring results of the first six months pilot, the pilot is continuing in order to gather more information to convert this into a long-term solution. In Colombia, the benefits of this new mobility technology are starting to receive wider recognition in the socio-political system after successful pilot programs by academic research groups. Further, work is underway to prepare possible market and incentive schemes, not only to raise awareness and information about the project, but also to scale up the implementation of electric propulsion for fishing activities. This is being accompanied by developing concepts for the necessary renewable energy systems and charging infrastructure with the public sector such as the national fishing authority (AUNAP), the Transport Ministry, and the National Planning Department.

An improved mobility concept, based on electric propulsion with a similar or even greater geographical reach, enables collection of the mollusks in a broader range than the current harvesting areas, which are limited by time and tide dynamics, and as a result are only reaching nearby mangroves. Nautical electromobility can help with the rotation of harvesting areas, promoting species recruitment and ecosystems preservation, improving working conditions, and limiting the impacts of motorization of the fishing fleet. Additionally, this economic activity has the potential to ensure the sustainability of artisanal fishing supply chains in the region.

Three instruments for driving the adoption of this innovative technology are currently being evaluated in Colombia. The first is early purchases of electric vehicles by public bodies in order to start up a market; second is the promotion of regional networks to test in practice and to demonstrate their viability; and third is the launch of mobility services based on electric outboard motors (for example, ecotourism in national parks).

Stimulation of the market will be key for success. Many of the nautical electrification strategies can be taken from similar efforts in other transport modes and existing government strategies. However, specific policy instruments and regulation will be required to foster the adoption of this technology.

Procurement of publicly available infrastructure for access to electricity in the coastal and remote regions is one way of indirectly stimulating possible demand. This includes the construction of charging stations or battery banks along with the general electrification in these regions. Government agencies at the various territorial levels—local, regional, and national—will have to collaborate as dominant agents for implementing such strategies.

## Development outlook

Nautical electromobility solutions can serve as a key element to engender regional social and economic development, and at the same time protect the fragile biodiversity in post-conflict and peripheral regions in Colombia, as well as similar regions in other countries.

The tested nautical electromobility alternatives have great scalability and transferability to other scenarios in Colombia. The results give new insights into the potential for upscaling such electromobility solutions within the fishery sector and other small-scale water transport economic activities such as ecotourism, freight transport, inland waterways, and agricultural production in areas accessible only by water.

A modular solutions portfolio that adapts to the particular conditions and requirements of the different activities and local geographical and service characteristics is currently being studied. For example, in national natural parks in Colombia, the main mobility needs are related to ecotourism, which requires boats that travel through calm waters at low speed with the purpose of fauna sightings, which means low power but high autonomy for daily trips. Conversely, freight transport and fishing activities both require motors with increased power in order to maneuver in high tide and wind conditions as well as high reliability and autonomy to endure harsh conditions in the open sea.

The synergy of marine technology linked to outboard engines and productive activities in peripheral regions in Colombia has the potential to transform the livelihood of local communities. Decoupling transportation from fossil fuels provides a novel solution to economic, social, and environmental challenges, leading to the commercialization of local products, ecotourism, increased revenue, and increased conservation efforts. It can therefore give artisanal, local, and responsible workers in formerly marginalized areas the ability to provide high-quality products, local flavors, and culinary traditions to the marketplace. It also can increase awareness of the cultural and ecological diversity of a region and ultimately serve as a gateway for communities to thrive and do their part to help reduce climate change emissions.

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