Energy Blueprint for the Galápagos Islands

August 2001

Revised October 2001

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Galápagos at a Glance

- 13 Major Islands and more than 115 smaller ones located 600 miles off the coast of Ecuador
- 95% of the Galápagos Islands' biodiversity is still intact
- Three quarters of the land birds and 97% of the reptiles and mammals are found nowhere else on Earth
- Home to giant tortoises that live to 150 years and weigh more than 400 pounds
- World's only seagoing lizards—marine iguanas
- Unique bird species include flightless cormorants, tool-using finches and Galápagos hawks
- Threatened by invasive species, pollution, illegal harvesting of sea cucumbers, shark finning and overfishing

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Energy Blueprint

A Message from the President

World Wildlife Fund is delighted to release this Energy Blueprint for the Galápagos Islands. Although we have been a force for conserving these unique islands for four decades, we still feel pressed to find a superlative that does them justice. The Galápagos have been called "nature in its innocence"—a place where birds and wildlife show little fear of humans due to an absence of predators. They are the cradle of our understanding of evolution, through the work of Charles Darwin. And they are truly an icon of global conservation.

But the Galápagos ecosystem is as fragile as it is unique. The *Jessica* oil spill in January 2001 underscored the vulnerability of these islands and their surrounding waters to fossil energy transport. Finding ways to reduce the impacts of energy use on the islands has become a conservation priority. The Galápagos Energy Blueprint seeks to meet this need with an ambitious vision: to move the archipelago to a clean, sustainable energy system over the next 10 years.

The implications of the Energy Blueprint, however, reach far beyond the environment of an archipelago in the Pacific. Moving the Galápagos to a carbon-free energy future is a compelling model, not just for its immediate conservation benefits to the islands, but for what it suggests may be possible, at much larger scales, in tackling the causes of global climate change.

How fitting that a major conceptual step in the energy transition needed to solve climate change could come in this natural laboratory. The Galápagos Islands, whose famous finches taught us about adaptation and evolution in nature, may show us how human society, given the will and wisdom, can change as well.

Kathryn S. Fuller

President

World Wildlife Fund

WWF®

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Energy Blueprint

Executive Summary

This energy blueprint for the Galápagos is directed at transforming all high pollution energy systems now in use in the archipelago to sustainable, clean ones using demonstrated and cost effective environmentally sensitive technologies. Four energy sectors are analyzed with detailed proposed actions over the next decade specified for each:

- Electric power[1]
- Transportation
- Fishing
- Tourism

Approximately 10 steps for each sector will complete the transformation from the present to the sustainable future configuration by 2010. At that time a final transition to a hydrogen-based energy economy may be possible assuming it to be cost effective.

Actions included are of four types:

- Regulatory
- Technical
- Economic
- Environmental

The gross cost of the entire transformation is estimated to be $20–25 million over 10 years including new personnel, facilities and equipment. Donations of equipment are very likely and could reduce the ultimate net cost to well below this gross cost.

Mission Statement

The mission of this energy plan is to achieve, in 10 years, an integrated sustainable energy system[2] for the Galápagos using the best available technologies with a bridge to still better future technologies.

This document describes the background and importance of energy systems in the Galápagos, how the mission can be accomplished within realistic time lines, feasible systems and competitive costs, and the preferred approach using tested and well understood approaches. There is a clear need to minimize the many impacts of energy on the fragile and unique ecosystem of the Galápagos Islands. This can best be done using simple, reliable and tested approaches described in this document. This first 10-year blueprint ends with an energy economy in all sectors that will be ready for achieving a hydrogen based economy at its end.

There are a number of critical actions that need immediate attention. They are noted in the final section of this document.

1. The Ecuadorian government has recognized the importance of reducing the use of polluting energies in Galápagos. There are two projects that are being jointly promoted by the Ministry of Energy and the Ministry of the Environment: (1) Project ECU/02/G35, titled "Renewable Electrification of the Galápagos Islands", sponsored by the Ministry of Energy and the Ministry of the Environment with the support of the United Nations Development Program; this project promotes the use of clean energy in Galápagos and the gradual reduction of dependence on energy systems that rely on fossil fuels; (2) the "Fuel Distribution in the Galápagos Islands" project, sponsored by Petroecuador and the Ministries of Energy and the Environment. The latter project seeks to modernize the storage, management, and distribution systems in key sites in the four inhabited islands.
2. An "integrated system" means one that uses various forms of clean energy production — wind power, solar power, synthetic diesel — working together and substitutable for each other within one island, island by island in the archipelago. Integrated systems have lower cost, better efficiency and good economies of scale.

Introduction

Energy is the "go" of things. It makes cars, trucks and boats move, lights light, computers run, and telephones work. No modern society can function without reliable supplies of energy. There are two ways to supply useful energy:

- **Traditional, often high emission** approaches such as diesel power plants[3] and two-cycle gasoline motors[4] for motorcycles and boats, or
- **Renewable and sustainable** energy approaches that are far cleaner and less hurtful to delicate environments such as those found in the Galápagos; these approaches include solar energy[5] for electricity and heat, wind generators[6] for electricity, four-cycle gasoline engines[7] for boats and diesel engines using synthetic diesel[8] for clean power production, along with truck and bus engines using the same clean fuel.

Energy is used in the Galápagos as shown in the table below.

Table 1 Overview of Energy Sources in the Galápagos – 2001

Energy Usage	Energy Source	Comment on Present System
Electric power	Diesel fueled generators	Uses traditional, high sulfur diesel fuel; fuel is spilled, contaminating the water supplies; sulfur in fuel when burned results in gross particulate emissions which have been shown to be a significant respiratory threat. In addition, ozone emissions which are released as a result of this process have been linked to inhibited respiratory systems development in children.
Outboard boat motors for fishing	Gasoline mixed with oil	Two-cycle gasoline motors are the most polluting of all internal combustion engines; unburned, poisonous gasoline and oil are introduced into both water and air.
Inboard boat motors for fishing and tourism	Diesel engines	Uses high sulfur diesel fuel; fuel is spilled, contaminating the water supplies; sulfur in fuel causes significant air pollution that damages human health. Spilled diesel fuel is toxic to aquatic life.
Motorcycle motors	Gasoline mixed with oil	Two-cycle gasoline motors are the dirtiest engines; unburned, poisonous gasoline and oil are introduced into the air.
Truck and car motors	Gasoline	Gasoline in the Galápagos is mixed with a great deal of water during shipment from the mainland; water and gasoline do not mix nor burn efficiently — engines are out of tune and pollute the air and damage human health as a result.
Truck and bus motors	Diesel fuel	Uses high sulfur diesel fuel; fuel is spilled, contaminating the water supplies; sulfur in fuel causes significant air pollution that damages human health.
Tourist hotels	Primarily diesel generated electricity	Uses high sulfur diesel fuel; fuel is spilled, contaminating the water supplies; sulfur in fuel causes significant air pollution.

All gasoline and diesel systems in use in the islands are highly contaminated with water and are very high in sulfur (>9,000 parts per million). Fuels of this nature not only result in high emissions from traditional equipment, but moreover, prohibit the use of new low-emissions advanced technologies.

3 A diesel power plant uses internal combustion engines that burn "fuel oil" called diesel fuel to spin generators that produce electric power. These engines have hundreds of moving parts and require continuous, expensive maintenance. Air pollution from sulfur oxides, unburned hydrocarbons, carbon monoxide and particulates is significant.

4 "Two-cycle" refers to the way in which the engine intakes gas/air mixtures and exhausts burned fuel; it is a very dirty approach that emits high levels of visible ("blue oil smoke") and invisible pollution; it is the dirtiest engine commonly available, by far. Details are given later in the text.

5 Solar energy converts rays of sunlight to either electricity using solar cells or to heat using solar collectors. Few if any moving parts are involved.

6 Wind generators or windmills use large rotating blades to spin generators that produce electricity. They are available in sizes from one kilowatt up to a few megawatts.

7 "Four-cycle gasoline engines" use a much cleaner intake and exhaust approach than do two-cycle engines; air pollution can be almost zero and efficiency significantly greater than for two-cycle devices. They cost up to 40% more than two-cycle engines.

8 "Synthetic diesel" is essentially free of sulfur, aromatics and metal, produced from natural gas, and can be used in diesel engines, both old and new. Production of synthetic fuel will begin during 2004 from a gas-to-liquids (GTL) plant under development in northwest Peru. It will be commercially competitive with ultra-low sulfur, ultra-clean diesel fuel.

Some of the problems with traditional approaches now used in the Galápagos include:

- Water pollution from diesel fuel spills; traditional diesel fuel[9] used for power production and bus transportation is toxic and persistent in the environment on both land and in the water. Contaminated water causes serious human illness including cancer.
- Traditional energy systems that use oil and natural gas deplete the finite supplies that exist on earth.
- Water pollution from two-cycle fishing boat outboard motors is significant and long lasting; both the fuel that is incompletely burned and the oil that is mixed with two-cycle gasoline are toxic to humans and marine life.
- Air and water table pollution from polychlorinated biphenyls (PCBs); this is one of the most toxic and carcinogenic compounds on earth; it appears to be used in Galápagos electric power transformers that are leaking it into the environment and ground water. The water supplies may be very contaminated with serious threats to human and animal health.
- Poisonous by-products and residual "leftovers" from power plants, cars, trucks, motorcycles, fishing boat motors. These include used oil, discarded mechanical parts containing heavy metals, such as lead and mercury, and other materials that are part of traditional energy uses; now they all make their way into the ecosystem where they are persistent. Most of these substances are toxic to humans and wildlife even in extremely small quantities.
- Traditional methods of energy conversion (e.g., converting diesel fuel to electricity) are not very efficient and create both local air pollution and greenhouse gases. This increases global warming over the long term causing a rise in the sea level and the disruption of traditional weather patterns, potentially including ocean currents.

Benefits of renewable and sustainable[10] energies include the following:

- Solar and wind energy are completely clean, creating no air or water pollution.
- Solar and wind systems do not create any greenhouse gases and do not contribute to global warming.
- Clean engines such as four-cycle gasoline boat motors and modern diesel engines running on synthetic fuel (both are described in detail below) are much cleaner than two-cycle and traditional diesel engines. They do not pollute the air and water to any extent comparable to old two-cycle and traditional diesel engines.
- Solar and wind systems have very few parts that create disposal problems at the end of their useful lives; poisonous residuals such as used oil and heavy metals are not present.
- Modern diesel fuel called "synthetic diesel fuel" is biodegradable, contains no sulfur (one of the chief contaminants of traditional diesel fuel), and has no long-term, adverse effects on the environment.
- Modern four-cycle gasoline engines and synthetic diesel engines are more efficient, use less fuel, are much cleaner and are cheaper to operate than traditional prime movers.

9 "Traditional diesel fuel" is number 2 diesel fuel; it is used in all diesel engines now in the Galápagos. Because it contains high amounts of sulfur and trace amounts of other chemical compounds, it is toxic to humans and wildlife.

10 When we use the term "renewable" this refers to the fact that these energy sources do not deplete any fuel supplies; rather these energy supplies are renewed forever from the sun. "Sustainable" energy refers to energy forms that can be created using processes that do not necessarily deplete finite oil and gas supplies. Sustainable and renewable power is sometimes called "green power."

- Hydrogen operated fuel cells can be easily integrated into a clean energy system. Fuel cells[11] are beyond the 10-year time horizon of this energy blueprint but the energy systems put in place in the next 10 years will work well with hydrogen fuel cells.

Therefore, we see that there is a significant need and opportunity to produce clean energy in the Galápagos. The rest of this document explains how this will be done.

The Current Situation

Feasible indigenous, renewable energy sources in the archipelago include wind and solar power. Biogas[12] could be generated in limited quantities from solid waste. None of these energy sources are used to any appreciable extent today. Instead, diesel fuel, gasoline and liquefied petroleum gas (LPG[13]) are the top three energy resources. All are imported from the Ecuadorian mainland. The magnitude of the renewable energy resource[14] needs to be established as an early action item. This will allow the sizing of wind and solar systems that are expected to be major energy sources. Certain energy end uses are not compatible with wind or solar power; for those, clean synthetic diesel and synthetic gasoline will be used. Energy end uses on the Galápagos shown in Table 1 include the following list along with clean and renewable supply possibilities:

- Electricity for buildings (can be produced from solar and wind energy or clean, synthetic diesel power plants),
- Fishing and tourism boat propulsion by engines (fuels will be either synthetic gasoline or synthetic diesel fuel as described earlier),
- Heat for water heating (can be produced from the sun using solar collectors), and
- Land vehicle propulsion (cars, trucks, buses) using liquid fuels (fuels will be either clean hydrocarbon fuel or synthetic diesel fuel as described earlier).

Fuel handling and distribution today is a serious environmental problem for all sectors. Between the loading of diesel fuel tankers and the ultimate consumption in tourist boats, power plants or vehicles, the diesel fuel[15] is handled and stored several times, at each stage of which leaks occur. Power plant sites are particularly polluted by ongoing diesel fuel spillage. The principal tank farm where diesel fuel is stored on Baltra:

(1) is located on sloping ground with tanks held in place by a few rocks,

(2) has no secondary containment[16] should a spill occur,

(3) is located very close to the sea,

(4) does not use dry-break connections[17] and

(5) uses unsupported piping laying on the ground.

If a spill should occur on Baltra, the volume of oil released could be well in excess of that released on January 16, 2001, when the *Jessica* ran aground. Diesel fuel spills onshore pollute ground water, and spills offshore kill marine life. The Baltra tank farm is an example of an immediate and urgent problem for the Galápagos.

11 Fuel cells use natural gas or hydrogen to produce electricity with few moving parts and very high efficiency (40–60% efficient) compared to diesel generators which have an efficiency of about 30% and use high sulfur fuel. Fuel cells typically do not produce pollution; diesel generators can produce high levels of air pollution.

12 Biogas is methane produced by fermenting organic waste in the presence of certain bacteria.

13 LPG is compressed propane, a heavier form of gaseous fuel similar to natural gas.

14 "The renewable energy resource" refers to how much the wind blows and how intense the solar radiation is at various locations.

15 Gasoline transport and storage has exactly the same problems as diesel fuel.

16 "Secondary containment" refers to a basin that surrounds fuel tanks; it is large enough to hold all oil that could be spilled if a tank should rupture or leak.

17 "Dry break connections" are used in liquid transfer lines to avoid spillage when connecting a hose from one tank or receptacle to another; a mechanical device shuts off the hose before it is disconnected or reconnected thereby eliminating spillage.

Diesel fuel conversion to electricity or usage for transport (land and water) is inefficient and dirty. This situation can be significantly improved by using synthetic diesel fuel. Synthetic diesel is the preferred replacement fuel because:

1. It can be made from natural gas which is plentiful on the mainland; it will be available in the time frame of this energy blueprint.
2. It will be available at a cost competitive with ultra-clean conventional diesel.
3. It is biodegradable and will not kill marine life.
4. It produces no sulfur or complex hydrocarbon air pollution that is dangerous to human health.
5. It is a cleaner fuel thereby reducing maintenance costs.
6. It is directly substitutable ("drop in replacement") for traditional diesel fuel.

Fishing boats use approximately 450 two-cycle engines; motorcycles and mopeds are predominantly two-cycle as well. These engines are among the most inefficient and polluting designs available. Light vehicles (cars and pickups) using gasoline are generally out of tune and release considerable unburned hydrocarbons and other pollutants to the ecosphere. The engine service and maintenance infrastructure is essentially nonexistent.

Specifically, two-cycle engines expel as much as 30% of their incoming fuel/air mixture unburned. A two-hour boat trip can release up to three gallons of gas-oil mixture into the water according to a study of the U.S. National Park Service. The same study observes that a **four-stroke engine of the type to be used in the Galápagos is 16 times cleaner** than a two-cycle engine[18] of the same size.

Although fresh water is not directly an energy sector factor, it has been indirectly impacted by the energy sector. The planned or unplanned disposal of waste from various energy sectors impacts ground water quality directly and unfavorably today; reinjection of human waste into ground water is commonplace. This occurs when sewage is disposed of by virtue of the widespread practice of dumping it back into subsurface cracks in the volcanic soil from which it enters the shallow ground water system. Only two hotels purify their own water; bottled water is imported from the mainland for drinking purposes.

Electric power systems using diesel fuel leak toxic diesel fuel into ground water which is the prevalent, local source of drinking water in the Galápagos. Ground water must be clean for good human health. Fuel oil contamination is carcinogenic. Bottled water is a poor substitute because it is expensive, must be transported from the mainland and is not a sustainable water resource.

In view of the present critical Galápagos energy situation, many studies by various entities and several expensive demonstration projects have been created. A clear message from the WWF visit in July–August 2001 is that the studies and demonstrations phase of energy development is nearly complete. There are perhaps just a few necessary additional demonstrations of new technologies. A new era in which major, cost effective projects aimed at solving clear problems on a large scale has begun.

18 They emit 100–300 grams of pollution per kWh of power produced.

The Sectors

Four key sectors consume energy today:

- Electric power
- Transport
- Fishing
- Tourism

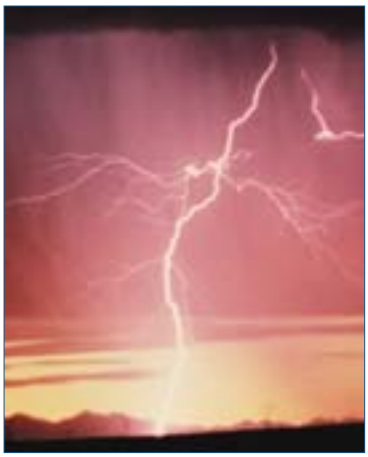
For each sector a trajectory leading to a permanent, clean energy future is described briefly below. Each uses best available practices in keeping with the Mission Statement. Needed planning regulatory actions are summarized at the end of this section.

The time line for all energy activities is included after the four sector action descriptions. Note that a general training facility and program crossing all sectors is proposed to reduce cost and to maximize technical expertise of technicians in the Galápagos.

These actions must be undertaken in the order shown because one necessarily follows the other from a logical, technical viewpoint.

Electric Power Sector

The main power generation facilities are located on San Cristobal and Santa Cruz with smaller plants on Isabela and Floreana. The 10-year transformation of the energy sector consists of these steps to be undertaken in order:



1. The Galápagos planning agency INGALA (Instituto Nacional de Galápagos) has formally requested input to their energy planning document for energy within 60 days. This input must be structured in such a way that all planned electricity generation technologies do not encounter regulatory barriers that would prohibit implementation while requiring best available practices and regulatory procedures. The situation is simpler than in the U.S., for example, because systems are small and will be new. The only barriers expected have to do with electricity transmission and distribution along with final termination in buildings.
2. Determine state of renewable resources — wind and solar; install data acquisition systems on each island; collect historical data from Charles Darwin Research Station (CDRS). This is an ongoing, multi-year project that needs to be started soon.
3. The present fuel and lubricant handling systems will be upgraded at all ports; systems for waste handling and transport of used oil, discarded mechanical equipment and other wastes to the mainland will be instituted.
4. Fuel distribution from port facilities to power plants will be sealed up and leak proofed; manual fuel handling systems in tanker trucks will be replaced by state-of-the-art dry-break systems (defined above) with secondary containment basins at all generating plant fuel tank farms. Ballast water[19] separation systems are required. Actions 3 and 4 are needed because of the high probability of serious spills from present tank farms and crude piping networks.

19 For ship stability purposes, empty fuel holds on some ships are filled with sea water for return trips to the mainland; this water significantly contaminates the next load of fuel. Poor engine performance (diesel or gasoline) in the archipelago is attributed to water-contaminated fuels.

5. The present electricity transmission and distribution (T&D) systems[20] on Santa Cruz, San Cristobal and Isabela will be stabilized by installing proper grounding, short circuit protection, transformer coolants (remove all PCBs from the archipelago) and properly supporting and insulating all transmission lines. This action is needed because modern generators and renewable energy systems require stable transmission systems.

6. Create training program for operation and maintenance personnel for current and future generation plants including conventional diesel, synthetic diesel, solar photovoltaic and wind power. Training must be completed to coincide with the start of operation of synthetic diesel plants and renewable energy plants. Electric sector training will be part of a general training activity including the transportation and fishing sectors. This is an early action item because of significant lead time.
7. Conventional diesel will be replaced by synthetic diesel for power generation. This will require retrofit of existing engines or replacement with new clean diesel-compatible generators. Tankers without water ballasting of fuel tanks are required.[21] The transition to synthetic diesel can begin in 2002 with careful introduction of ultra-low sulfur diesel. A complete changeover to synthetic diesel will occur as rapidly as possible during the following years.
8. Install grid monitoring system that measures power flow; this is needed for power dispatch that allows integration of renewable energy generation systems with synthetic diesel systems. This action will require significant effort to commission after the T&D system upgrade noted above.
9. Develop sector consensus on magnitude, siting and scheduling of renewable power systems. The costs are extensive; therefore, careful planning is needed.
10. Install green power systems.
11. Assess fuel cell systems for first installation in 2010. Include costs for base load plants, hydrogen infrastructure and fuel cell O&M. Fuel cells ultimately replacing diesel generators along with green power systems will comprise the ultimate electrical sector plants and will conclude the transition to clean power for the Galápagos. This will be done near the end of the 10-year plan when the new utility system is operating per design.

Transport Sector

The transport sector includes land transportation (bicycles, mopeds, motorcycles, cars, light trucks, heavy trucks, non-fishing outboard powered boats). The present situation is described completely in Cardenas (2001). Oceangoing tourism and fishing ships are not included in this sector but in the separate fishing and tourism sectors. Transformation of the transport sector will be accomplished as follows:

1. Quantify the situation—vehicle count, age, fuel using Cardenas (2001) as a starting point. This is the first action because all other items depend on the inventory that will result from this step.
2. Create incentives for significantly increased bicycle use, bike paths and publicly owned bicycles usable by anyone in major towns.

20 These are the wires that carry electricity from the generation plants to end uses in buildings. Transformers to match voltage levels to building needs are part of the T&D system.

21 A careful study of the need for a new tanker for clean diesel compared to cleaning up an old tanker to synthetic diesel standards is required. Synthetic diesel cannot be exposed to ballast water because it will change chemically and be unusable for fuel.

3. Create training program and training facility for service of modern, computer controlled light vehicles, for four-cycle motorcycles and mopeds and for synthetic diesel fueled trucks and buses. This is an early action because the lead time is significant.
4. The present fuel and lubricant handling systems will be stabilized at all ports; state-of-the-art waste handling and transport to the mainland will be instituted. See previous section for rationale for this item and items 5–7 below.
5. All transportation fuels currently in use on the archipelago suffer contamination from water and have sulfur levels exceeding 9,000 ppm. Use of these fuels increase pollution from existing equipment and prohibit the inclusion of new low-emissions technology.
6. Fuel distribution from port facilities to new centralized land and shore based fueling stations will be upgraded; manual fuel handling in drums, open containers with uncontrolled pumps and leaky fuel lines, and tanker trucks will all be replaced by fueling stations for the land and water transport.
7. Secondary containment (defined earlier) will be installed at all fuel tank farms and distribution stations to control spills and environmental damage.
8. Ballast water separation systems are required. They are necessary because engines using fuel without water will last longer, run more efficiently, need less maintenance and pollute the air and water less.
9. Create central land vehicle repair facility. Transport sector boat repair facility will be part of fishing sector transformation activity described below. Transport sector training will be part of a general training activity including the electric generation and fishing sectors.
10. Provide realistic market based program to migrate entire fleet on all islands to vehicles meeting California Air Resources Board (CARB) Low Emission Vehicle II (LEV II) standards for Ultra Low Emissions Vehicles (ULEV) or Super Ultra Low Emission Vehicles (SULEV). These low emission levels are appropriate for the Galápagos because they represent the cleanest vehicles available for protection of the fragile environment, are available at little extra cost, and are reliable and more easily maintained than the present vehicle fleet.
11. Preferential treatment should be afforded those designs which demonstrate the lowest emissions. This last recommendation includes four-cycle gasoline engines for all mopeds and motorcycles, synthetic diesel for all heavy trucks and buses. (Outboard motor transition described in following section.)

Hybrid vehicles are available now.

Measures to be put in place as part of the transport sector transformation include:

- Develop relationship with car manufacturer to implement transport sector transformation. This connection is essential for the obvious purpose of acquiring vehicles; however, training, transport co-op fleet experience and old vehicle removal would also be a part of this relationship.
- Control of imports to assure that only ULEVs are allowed.
- Register and track all vehicles.
- Create and staff annual safety and emissions inspection program.
- Recover, remove from the islands and recycle all non-compliant current vehicle stock.
- Institute ride share programs via co-ops; reduce vehicle count.
- Undertake market study of neighborhood electric vehicles (NEVs) for general use in town.
- Provide market mechanisms to encourage the introduction of Super Ultra Low Emissions Vehicles (SULEV) and more advanced technologies as they become available throughout the Americas.
- Develop funding mechanisms to provide hybrid/electric buses for all economic sectors.

Fishing Sector

From an energy viewpoint the fishing sector includes approximately 450 artisanal fishing boats, fish handling facilities and transport facilities. Measures to transform the fishing sector are:

1. Quantify the situation — boat count, size, engine age. Needed precursor to all following actions.
2. Create training program and training facility for service of four-cycle outboard motors and synthetic diesel fueled inboard boat motors. To be integrated with transport sector service training and service facilities to the extent possible. Significant lead time requires early action.
3. Undertake business case development for central refrigerated fish storage on Santa Cruz. Determine who will own and operate storage. Construct central storage if business case can be made. There is presently no publicly available refrigerated storage for fish on Santa Cruz. Early action with quick economic payback demonstration of energy efficiency. Useful fish delivery should double based on similar projects undertaken in Central America.

4. The present fuel and lubricant handling systems will be upgraded to the same level as the transport sector; state-of-the-art waste handling and transport to the mainland will be integrated with the transport sector facilities.
5. Fuel distribution from port fuel off-loading facilities to new shore-located fueling stations will be upgraded; the present manual fuel handling in drums, open containers with uncontrolled pumps and leaky fuel lines, and gasoline tanker trucks will all be replaced by fueling stations for the land and water transport. This is the only way to control uncontrolled spillage that occurs today.
6. Secondary containment will be installed at all fuel tank farms and distribution stations.
7. Create central outboard engine repair and maintenance facility. Include sufficient capacity for non-fishing outboards in transport sector and for diesel inboard motors. Fishing sector training will be part of a general training activity including the transportation and electric generation sectors. A central facility will include one recycling location for used oil and used mechanical parts thereby reducing environmental impact. Small facilities in each town cannot be cost justified when compared to the economies of scale of a central facility.
8. Replace entire two-cycle gasoline motor fleet on all islands with four-cycle gasoline engines in three-year period. Measures to be put in place include:
   - Create new financing mechanism for engine upgrades (and fuel purchase) instead of current fish-for-engine or fish-for-fuel financing.
   - Develop relationship with outboard engine manufacturer to implement fishing sector transformation.
   - Register and track all boats and motors.
   - Recycle two-cycle engine stock.
9. Upgrade and eventually replace inboard diesel engines in fishing boats that are now running on high-sulfur diesel, so that they can run on synthetic diesel.

Tourism Sector

The tourism sector includes two key energy consumers — hotels and tourism boats. Transformation of the boat sector is the same as that described for the fishing sector; both inboard diesel and outboard motors are involved in the tourism sector. Hotels have the following energy actions[22]:

1. Assess the magnitude of energy use by tourism hotels — electricity, LP Gas, diesel fuel for onsite electrical generation. Precursor to all actions below.
2. Upgrade diesel fuel and LPG handling as described in transport sector above. Consider use of LPG transport truck on Santa Cruz to avoid handling of small LPG tanks.
3. Where economically feasible upgrade building mechanical systems (water heating, pool water treatment, air conditioning) to reduce energy consumption; case-by-case studies will be made. These actions cost little and have fast payback.
4. Put in place training program for building systems maintenance — water heating, air conditioning, solar thermal, solar photovoltaic, wind; integrate with training for electric power sector to extent possible. Building sector training will be part of a general training activity including the transport, electric generation and fishing sectors. Significant lead time mandates that this occur early as with all other sectors.
5. Install solar thermal systems[23] for water heating where economically feasible. Economic feasibility compares the cost of the solar heat with the value of conventional fuel saved because it will be replaced by solar heat. If the solar heat is cheaper, then it is adopted.
6. Install solar electric power systems[24] for lighting and other electrical end uses where economically feasible. Economic feasibility compares the cost of the PV system with the value of electric energy saved because grid electricity from existing power plants will not be needed. If the solar electricity is cheaper, then it is adopted.
7. Evaluate local wind power systems for hotels remote from utility grid; install systems as economically feasible on a case-by-case basis. If the wind electricity is cheapest, then it is adopted.

Other Sectors – Recycling

A comprehensive recycling plan is needed to augment current efforts. For each species or recyclable material the following aspects will be included:

1. Local collection
2. Centralized collection and sorting
3. Transport from the archipelago
4. Ultimate green disposal on mainland
5. Present landfills on all islands to be dug up and contents removed from the archipelago

Materials to be recycled include but are not necessarily limited to:

1. Fuels and lubricants from electric power, transport and fishing sectors
2. Municipal solid waste from residences, hotels, tourism ships, institutional buildings, shops
3. Used mechanical equipment from all sectors
4. Used vehicles; two-cycle powered vehicles and boat motors
5. Lead acid batteries from boats, ships and land vehicles
6. Toxic waste from all sectors
7. All other solid waste
8. All other liquid waste

22 The hotel actions will also be undertaken for institutional buildings including provincial and municipal buildings, schools and other public buildings.

23 Solar thermal systems produce hot water by absorbing sunlight on black metal panels through which water flows. They are an old, reliable technology.

24 Solar electric systems produce electricity using photovoltaic (PV) panels that are wired together. There are no moving parts in these systems that can produce either direct or alternating current.

Regulatory and Planning Actions

Priority Planning Topics (INGALA)

The Galápagos planning agency INGALA will soon issue a document stating aspects of the energy plan for the Galápagos. It is very important that this document not exclude any of the blueprint action items in the previous 13 pages. Otherwise, the transformation of the energy economy to a sustainable and clean one will be compromised. INGALA has formally requested assistance in its planning effort from the World Wildlife Fund USA and from the authors of this blueprint. A memorandum of understanding (MOU) is being drafted for this purpose.

It is critical that that document include the following:

1. All import duties on any renewable energy system components or replacement parts for the Galápagos are 100% waived and eliminated.
2. All import duties on other equipment mandated in this blueprint (excluding that for green energy production) that is to be used to implement the Energy Blueprint for the Galápagos will be reduced to 20% of the normal level.
3. All equipment needed to implement the Energy Blueprint for the Galápagos will be cleared through Ecuadorian customs within 48 hours.
4. Wording that specifically does not preclude any sustainable energy system (present or future) from installation in the archipelago for reasons other than safety or ecosystem preservation; all green energy systems are to be specifically enabled by the INGALA plan.
5. Wording that enables all measures in this Energy Blueprint — include Energy Blueprint as part of the INGALA energy planning document.
6. Clarification of the electrical utility deregulation process so that mistakes made in California and other states and countries are not repeated in the Galápagos.
7. Renewable energy set aside as integral part of deregulation. Whoever acquires the existing Galápagos diesel generation assets will be required to replace 10% of the conventional, diesel-based generation per year with either wind or solar power systems until 70% of the generation in the archipelago is from renewables.
8. Bonuses for good performance of the generating companies beyond contractual minimums are recommended.
9. Establish firm limits to number of vehicles on each island — necessity must be demonstrated for each vehicle that will increase vehicle count in the archipelago.
10. Licensing fees for all vehicles, boats and ships are recommended.
11. Unimpeded solar access to be assured in areas where solar buildings exist or may exist in the future.
12. Annual safety inspections for all land vehicles are required.
13. Ultra low emission vehicles (ULEV), super ultra low emission vehicles (SULEV) and zero emission vehicles (ZEV) will be defined relative to their emission levels under standard test conditions. These definitions will be used to determine which vehicles are permitted in the Galápagos.

Priority Regulatory Topics

In order to assure compliance with actions listed above, these regulatory actions are required at a minimum:

1. Adopt interconnection safety standards for green power systems integrated with the grid. Refer to Institute of Electronic and Electrical Engineers standard number 1547 which describes how to safely interconnect solar, wind and diesel power systems.
2. Adopt building, electrical and energy codes and standards for all sectors. Refer to Uniform Building Code, National Electrical Code and Model Energy Code for an approach to ensuring that minimum standards for construction, safety and energy conservation are adhered to in new and existing buildings.
3. Adopt state-of-the-art fuel handling and storage standards as described earlier (containment basins, dry break connections, no use of drums for manual transport).
4. Adopt vehicle inspection and emissions testing program to assure safety and allowable emission levels.
5. Adopt fuel quality standards so that engines will operate efficiently and will require lower maintenance.
6. Phase out chlorofluorocarbon (CFC) refrigerants to conform with Montreal protocols to avoid atmospheric ozone depletion and global warming. Most of the world has agreed with the Montreal protocol.
7. Adopt zero sum vehicle replacement rules so that no new vehicle can be imported into the Galápagos without one being removed. This stabilizes vehicle impact.
8. Institute certification program for all boat, ship, land vehicle and building mechanical system mechanics; only certified mechanics are permitted to make repairs on vehicles and building systems because systems are complex in modern vehicles and only trained technicians are permitted to service them.

Critical Near-Term Actions

The Energy Blueprint is a 10-year plan to accomplish the Mission Statement. However, there are a few actions that must be made immediately:

1. Transmit input to INGALA planning document within deadline for inclusion in Galápagos planning document (see preceding page for details).
2. Stabilize and protect fuel tank farm near the harbor on Baltra Island.
3. Remove leaking transformers from Santa Cruz central power plant site; install ballast water separator recycling system.

Publicity and Information

Factual and correct information on all aspects of the energy transformation is necessary so that citizens of the Galápagos understand from the very beginning what is proposed for each. This is called out as an activity for each of the sectors and begins with descriptive materials on the present situation, proposed solutions and follow-up on successes in each sector.

Energy Blueprint

Time Lines

This section contains schedules by activity with the key sectors for accomplishing the Mission Statement by the end of 2010.

Sector	Task	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
Electric Power	Finalize INGALA planning document – URGENT	•									
	Stabilize Baltra Fuel Tanks – URGENT	•	•								
	Remove XFMRS from Santa Cruz power plant – URGENT	•	•								
	Install ballast water separator recycling system – URGENT	•	•								
	Install and operate weather monitoring stations	•	•	•	•	•	•	•	•	•	•
	Stabilize T&D systems on Santa Cruz, San Cristobal and Isabela		•	•	•	•					
	Stabilize fuel and lubricant handling systems – incoming, outgoing		•	•	•	•					
	Create and operate power plant O&M training program – all types			•	•	•	•	•	•	•	•
	Convert generators to synthetic diesel fueling (30% of total generation capacity)			•	•	•					
	Install and operate electric grid monitoring system		•	•	•	•	•	•	•	•	•
	Install and operate green power systems – wind and solar (70% of total generation capacity)				•	•	•	•	•	•	•
	Evaluate fuel cells for baseload power to replace diesel										•
Transport	Quantify transport situation with future projections		•	•							
	Create and operate training program and facility			•	•	•	•	•	•	•	•
	Stabilize fuel and lubricant handling systems – coordinate with power sector activity		•	•	•	•					
	Initiate bicycle programs			•	•						
	Create and operate central land vehicle repair facility				•	•	•	•	•	•	•
	Replace entire fleet on all islands with modern vehicles				•	•					

Sector	Task	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
Fishing	Quantify the situation – boat motors and engines	●	● ●								
	Create and operate training program and central training facility		● ● ●	● ● ●	● ● ●	● ● ●	● ● ●	● ● ●	● ● ●	● ● ●	● ● ●
	Develop business case for central refrigerated fish storage		●								
	Update fuel and lubricant handling systems		● ● ●								
	Create and operate central engine repair and maintenance facility		● ● ●	● ● ●	● ● ●	● ● ●	● ● ●	● ● ●	● ● ●	● ● ●	● ● ●
	Replace entire two-cycle gasoline motor fleet		● ● ●	● ● ●	● ● ●						
	Upgrade diesel engines to run on synthetic diesel fuel		● ●	● ● ●							
Tourism	Assess the magnitude of energy use by tourism hotels		●	● ● ●							
	Upgrade diesel fuel and LPG handling		● ● ●	●							
	Upgrade building mechanical systems			● ● ●	● ● ●						
	Initiate and operate building systems maintenance training			● ● ●	● ● ●	● ● ●	● ● ●	● ● ●	● ● ●	● ● ●	● ● ●
	Install solar thermal systems for water heating			● ●	● ● ●						
	Install solar electric power systems for lighting, etc.						● ● ●	● ● ●			
	Evaluate local wind power systems for hotels; begin installation				● ● ●	● ● ●	● ● ●	●			
Other	Design, implement and operate recycling programs on all islands		●	● ● ●	● ● ●	● ● ●	● ● ●	● ● ●	● ● ●	● ● ●	● ● ●

Energy Blueprint

Cost Estimate

The cost of achieving all of the Blueprint actions is shown below.

Sector	Task	Initial	$/Year	Years	Total Ongoing	Grand Total
Electric Power	Finalize INGALA planning document – URGENT	$0	$0	0*	$0	$0
	Stabilize Baltra Fuel Tanks – URGENT	$100,000	$0	0*	$0	$100,000
	Remove XFMRS from Santa Cruz power plant – URGENT	$15,000	$0	0*	$0	$15,000
	Install ballast water separator recycling system – URGENT	$20,000	$0	0*	$0	$20,000
	Install and operate weather monitoring stations	$60,000	$20,000	9	$180,000	$240,000
	Stabilize T&D systems on Santa Cruz, San Cristobal and Isabela	$1,000,000	$0	1.75	$0	$1,000,000
	Stabilize fuel and lubricant handling systems – incoming, outgoing	$1,000,000	$0	2.25	$0	$1,000,000
	Create and operate power plant O&M training program – all types	$450,000	$50,000	8.5	$425,000	$875,000
	Convert generators to synthetic diesel fueling (30% of total generation capacity)	$500,000	$65,000	1.5	$0	$500,000
	Install and operate electric grid monitoring system	$50,000	$20,000	9	$180,000	$230,000
	Install and operate green power systems – wind and solar (70% of total generation capacity)	$4,900,000	$98,000	8	$588,000	$5,488,000
	Evaluate fuel cells for baseload power to replace diesel	$25,000	$0	1	$0	$25,000
Transport	Quantify transport situation with future projections	$50,000	$0	0*	$0	$50,000
	Create and operate training program and facility	$450,000	$50,000	8.5	$425,000	$875,000
	Stabilize fuel and lubricant handling systems – coordinate with power sector activity	$0	$0	2.25	$0	$0
	Initiate bicycle programs	$50,000	$20,000	1	$190,000	$240,000
	Create and operate central land vehicle repair facility	$150,000	$100,000	8	$800,000	$950,000
	Replace entire fleet on all islands with modern vehicles	$0	$1,666,667	3	$5,000,000	$5,000,000
Fishing	Quantify the situation – boat motors and engines	$50,000	$0	0*	$0	$50,000
	Create and operate training program and central training facility	$150,000	$50,000	9	$450,000	$600,000
	Develop business case for central refrigerated fish storage	$20,000	$0	0*	$0	$20,000
	Update fuel and lubricant handling systems	$500,000	$0	1	$0	$500,000
	Create and operate central engine repair and maintenance facility	$150,000	$50,000	9	$450,000	$600,000
	Replace entire two-cycle gasoline motor fleet	$0	$250,000	3	$750,000	$750,000
	Upgrade diesel engines to run on synthetic diesel fuel	$500,000	$0	1	$0	$500,000
Tourism	Assess the magnitude of energy use by tourism hotels	$50,000	$0	1	$0	$50,000
	Upgrade diesel fuel and LPG handling	$0	$0	1	$0	$0
	Upgrade building mechanical systems	$500,000	$0	1.5	$0	$500,000
	Initiate and operate building systems maintenance training	$100,000	$50,000	8	$400,000	$500,000
	Install solar thermal systems for water heating	$0	$166,667	1.5	$250,000	$250,000
	Install solar electric power systems for lighting, etc.	$20,000	$285,714	1.75	$500,000	$520,000
	Evaluate local wind power systems for hotels; begin installation	$25,000	$233,333	3.25	$700,000	$725,000
Other	Design, implement and operate recycling programs on all islands	$100,000	$20,000	8.5	$170,000	$270,000
		On-Site Mgr.	$200,000	9	$1,800,000	$1,800,000
						$24,243,000

* 0 = Immediate

Key References

Cardenas, Susan (2001) “A Study of Transport and Energy in the Galápagos Islands,” World Wildlife Fund Internal Report. This report contains the latest available information on energy consumption for all sectors with considerable detail as to end uses.

United Nations Development Program (1999). *Energy as a Tool for Sustainable Development*, United Nations, New York. Survey of renewable energy for African, Caribbean and Pacific countries.

National Park Service (1999). “Water Quality Concerns Related to Personal Watercraft Usage,” Washington, D.C. Contains data on high pollution levels produced by two-stroke outboard motors and an extensive list of references.

Biographies

Jan F. Kreider – Biographical Sketch

Dr. Jan F. Kreider is Founding Director of the University of Colorado's Joint Center for Energy Management and Professor of Engineering. He is a co-founder of the Building Systems Program at CU and has written eight textbooks on renewable energy and energy efficiency, four books on efficient building energy systems and other energy related topics and nearly 200 technical papers. For 10 years he was a technical editor of the ASME Transactions.

Beginning in 1980, he created distributed generation systems involving wind, solar and internal combustion engines; the first system was connected to the Public Service of Colorado grid in 1981. From that time onward he has specialized in hybrid and renewable energy research and development all over the world including Central America, India, Europe, Mexico and the USA. His projects have won several Owens Corning Energy Conservation Awards.

During the past decade Dr. Kreider has directed more than $5 million in energy related research and development. His work on renewable energy, thermal analysis of buildings, building performance monitoring, building diagnostics along with his distributed resource research is known all over the world. Among his major accomplishments are the first applications of neural networks to building control, energy management and systems identification and of applied artificial intelligence approaches for building design and operation. He has also assisted governments and universities worldwide in establishing renewable energy and energy efficiency programs and projects since the 1970s. He is a Fellow of the American Society of Mechanical Engineers, a registered professional engineer and member of several honorary and professional societies. Dr. Kreider recently received ASHRAE's E. K. Campbell Award of Merit and the University of Colorado's Outstanding Researcher Award (College of Engineering, Boulder) and the Distinguished Engineering Alumnus Award, the College's highest honor.

Dr. Kreider received his BS degree (*magna cum laude*) from Case Institute of Technology, and his MS and PhD degrees in engineering from the University of Colorado. He was employed by General Motors for several years in the design and testing of automotive power trains, and heating and air conditioning systems.

William Reinert — Biographical Sketch

Mr. Bill Reinert is National Manager for Toyota Motor Sales Advanced Technology Group. Within that role he is responsible for product planning of Battery Electric Vehicles, Hybrid Vehicles, CNG products, Fuel Cell Vehicles, and advanced transportation concepts including Intelligent Transportation Systems.

Prior to his current role, Mr. Reinert was National Manager in charge of Toyota's investigation of the market for distributed generation including stationary fuel cells and microturbine systems.

He currently serves on the Board of Technical Advisors for the National Fuel Cell Research Center and is a member of the Alternative Fuels Delphi Group for the Energy Information Agency.

Mr. Reinert has an MS in Engineering from the University of Colorado and lives in Rancho Santa Margarita, California, with his wife Pam.

WWF in the Galápagos

Since 1961 World Wildlife Fund (WWF) has worked with local partners, including the Galápagos National Park and the Charles Darwin Foundation, to preserve and protect the Galápagos Islands. To date, WWF has supported more than $3 million of conservation actions in the Galápagos including: research, policy, protected area management, species research and protection, and environmental education.

In one of the first grants in its history, WWF contributed funds for the construction of the Charles Darwin Research Station (CDRS). Three years later, WWF contributed funds to CDRS for the conversion of a fishing boat into the station's first research vessel, *Beagle II*, which was eventually followed by an upgraded vessel, *Beagle III*. WWF has continued to provide support for the maintenance and improvement of the CDRS, supporting construction of a visitor's center and lecture hall (Van Straelen Hall), expansion of the station's facilities, and installation of a computer system to facilitate data collection, research and administrative tasks.

Control of introduced animals and plants has been a focus for staff of the CDRS since it began to promote conservation in the Galápagos Islands. Along with efforts to eliminate the threats posed by introduced animals, WWF has sponsored captive breeding and repatriation programs and related conservation activities designed to bolster threatened species, including land iguanas, tortoises, marine turtles, sea and lagoon birds, and the dark rumped petrel.

Educational activities supported by WWF have included: providing teaching materials for local schools; holding training courses for teachers; publishing informational materials directed towards the public, colonists and tourists; and providing a means for Ecuadorian university students to conduct research on conservation-related topics. WWF also provided funding for the establishment of a Galápagos information center in the Ecuadorian capital, Quito.

In 1987, WWF negotiated a major debt-for-nature swap to secure long-term funding for conservation in Ecuador. In 1998, WWF joined with other conservation organizations and the Galápagos National Park Service to craft sweeping new legislation—the Galápagos Special Law—that establishes a 40-mile marine sanctuary free of industrial-scale fishing and ensures that tourist revenues support conservation. In 2001, WWF committed $295,000 to help with the aftermath of the *Jessica* oil spill.

Other conservation achievements include:

- Supporting, since 1987, the participatory process to define the marine management plan for the Marine Reserve
- Working to promote sustainable fisheries, including fishery certification in the Galápagos
- Developing a "Biodiversity Vision" for the islands with the Charles Darwin Foundation and 50 of the world's leading Galápagos scientists
- Providing ongoing support to the Galápagos National Park Service for the vigilant protection of the Islands by securing donations from companies such as Motorola ($200,000 for communications equipment) and other companies (for boat repairs and overflight time to monitor illegal fishing and harvesting of sea cucumbers)
- Publishing the annual *Galápagos Report* with Fundacion Natura, which identifies and tracks key indicators of the environmental, social, economic, political and institutional aspects of the Galápagos Islands

WWF is the world's largest and most experienced independent conservation organization. We have 4.7 million supporters and a global network active in 96 countries.

WWF's mission is to stop the degradation of the planet's natural environment and to build a future in which humans live in harmony with nature by:

- conserving the world's biological diversity
- ensuring that the use of renewable natural resources is sustainable
- promoting the reduction of pollution and wasteful consumption

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