Rural Energy Development in Chile: An Illustrative Case Study

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Chile's National Context

- Goal: Electrify 90% of the population in each region
- CNE sponsors all rural energy programs, regional governments or utilities submit project proposals, which are then evaluated and awarded guaranteeing a set return for the 20 year project life.
- UNDP Grant given to CNE to develop the use of renewable technologies in rural electrification (tackle national level barriers)
- The Chiloe Islands project is the flagship program

Chiloe Region

- Comprised of large central island, Grand Chiloe, which protects a gulf containing more than 40 islands in southern Chile.
- Project designed to electrify 32 of these islands using renewable based technology.
- Wealth varies considerably among islands with an economies based on commercial fishing operations, animal husbandry, and farming.
- Each island community includes a school, church, health clinic, and in some cases, police and other social services.

The Chiloe Islands

- Islands tend to be a patchwork of farms, fields, and forests.
- Between 12 and 453 homes per island
- Some islands have existing diesel gensets in the larger communities that run several hours per day
- Most larger islands have roads or trails but transport is a problem
- Expected loads of 17 to 1004 kWh/day
- Access is difficult in the winter due to the weather
- Minimal port facilities exist on each island

Program Plan

Initial Feasibility Study - Determined base line information on the approach and usefulness of renewable technologies

Pilot Project - Demonstration system installed to provide insight into the system operation & maintenance

Detailed Project Analysis – All data used in the initial analysis validated, refined & supplemented for more detailed analysis

System Implementation and Support – Replication activities, oversight of system installations & operation

Feasibility Study

Study demonstrated the economic viability of electrifying the islands with wind-diesel systems, used in discussions with local and federal officials to determine scope and funding level for project.

Study used to:

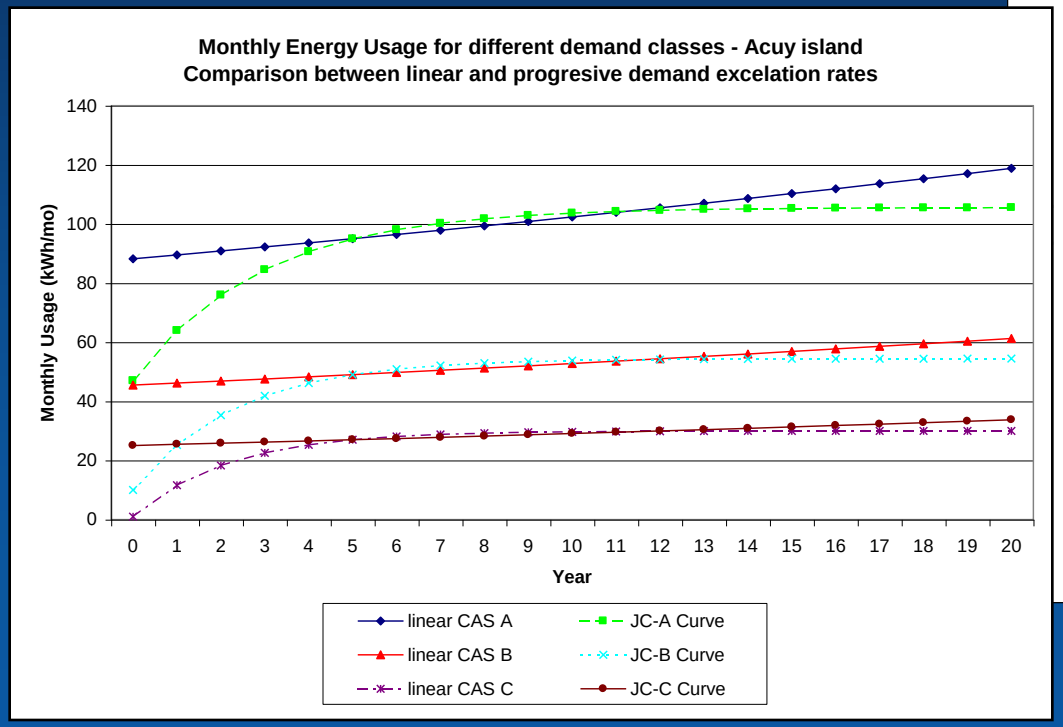
- Design distribution system and estimate costs
- Evaluate electrification options (Grid, battery charging, independent power systems)
- Analyze system design
- Estimate project's life cycle costs
- Analyze social benefits

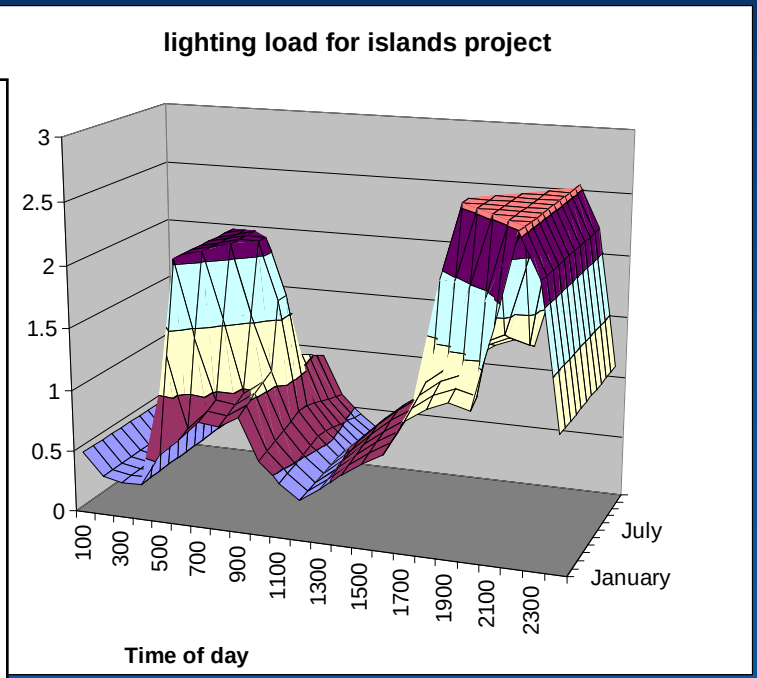
Implementation of Isla Tac Pilot Project

- Information on local consumption
- Cost of system implementation
- Cost of operation and maintenance
- Equipment problems
- Local acceptance and understanding
- Publicity and visibility

Detailed Data Collection

Very little was known about the energy needs and resources in this area. Project lifetime, seasonal and daily load profiles, population, economic data, local electric usage and the Isla Tac Pilot project.





Socioeconomic analysis

BUTACHAUQUES

COMUNA DE QUEMCHI

DATOS GENERALES	
INHABITANTS (aprox.)	*1000*
FAMILIES	*205*
GROWTH POPULATION	*0*
SCHOOLS	*2*
POST	*1*
CHURCHES	*1*
SALMONERAS	*2*
CLASSIFICATION	**3 a 4**

Realizado por : *Hernán*
Drago Ba

DATOS GEOGRAFICOS	
CARACTERISTICAS	*Island of great extension and one of the far away, 2 hrs. navigating from Q*
SECTORES DE LA ISLA	***Metahue**, Maluco, Coneb, San José, Nayahue.*
AIR STRIP	*Yes, in good state.*
ROADS	*Bad in Winter, it lacks rubble and canalization of waters, there is a lot of mud when it rains.*
ACCESSES	*Via marine, it is dangerous with strong winds. Ramp in sector Metahue.*
RIVERS	*If, there are 3 profitable rivers, with flows of more than 100 lts/seg in Wint*
LAGOONS	*No.*

PERSONAS CLAVES	*nombre*	*teléfono*	*servicios*
PDTE. JUNTA DE VECINOS	*Luis Bascur*	*09-6437627*	*Lodging, food, transfers (qu and 2 Jeeps to move inside Island).*
ENCARGADA REG. CIVIL	*Gloria Ojeda*		
DUEÑA DE SUPERMERCADO	*Marcela Vidal*	*09-6443546*	*Lodging, foods.*

ECONOMIA			
ACTIVIDADES PRODUCTIVAS	*Most works around the salmoneras, the other ones are devoted to the fish little to the cattle raising. They are also devoted to the gathering of algae a*		
FAMILIAS POR SECTOR	*Maluco*	17	Low level
	Coneb	33	Low level
	San Jose	31	medium level
	Nayahue	32	medium level
	Metahue	76	High level

Socioeconomic evaluation completed on most islands

Socio-economic standing of the population of Islands

Island Name	Percent of population of each social economic class level		
	Class A (CAS 3)	Class B (CAS 2)	Class C (CAS 1)
Acuy	0%	90%	10%
Ahullini	14%	62%	24%
Alao	3%	37%	60%
Añihue	9%	66%	25%
Apiao	14%	62%	24%
Aulin	50%	50%	0%
Butachauques	9%	75%	16%
Caguache	6%	68%	26%
Cailin	14%	51%	35%
Chaulinec	5%	65%	30%
Chaullin	14%	62%	24%
Chelin	28%	50%	22%
Cheniao	7%	67%	26%

Loads Assessment Completed

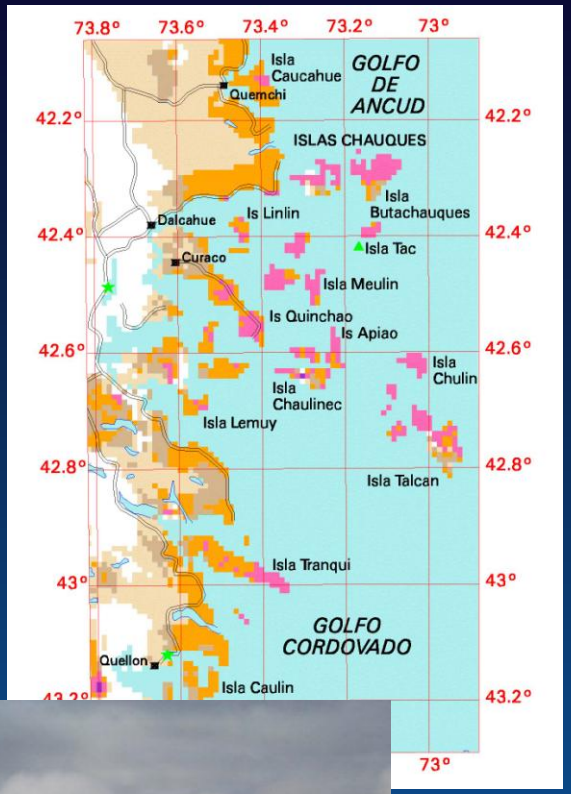
DEMAND ASSESSMENT					Island: **Acuy**
Parameters and Assumptions					File: Chiloe3a modified.xls
					Date: 30-Jul-02
					E.I. Baring-Gould
DESIGN PARAMETERS					**Notes**
Population Growth:	0.0%				Based on information from Javier Castillo, and Health Post worker.
Connection Growth:	**0.27%**				Calculated based on 90% to 95% growth over 20 years (below), the number of users connected increases over time.
Consumption Growth (kWh):	1.5%				Based on information from Javier Castillo, for mainland Chile
Demand Growth (kW):	3.0%				No information from Chile. 3% Reasonable for RE in Bolivia. Aprox. 6% historically for rural Cochabamba, Bolivia.
Load Factor:	0.3				Range in Bolivia from 0.18 (lowest RE area) to 0.60 (industrial area).
Analysis Horizon:	20 years				Chilean government requires a 20 year analysis horizon for non-conventional electrification projects.
Assumptions	**Year 0**	**Year 1**	**Year 10**	**Year 20**	**Notes**
Losses	10%	10%	10%	10%	With a new system and a loss control program 10% is realistic, but this can climb if not controlled.
Coverage	90%	90	94%	95%	Initial coverage in Bolivia typically from 50% to 65%. After a year of operation on Isla Tac, there is a 92.4% coverage rate.
USERS	**Year 0**	**Year 1**	**Year 10**	**Year 20**	Percent of User Type From Drago's Survey
Total Population	**23**	**23**	**23**	**23**	**100%**
Type A - Serviced	**0**	**0**	**0**	**0**	**0%**
Type B - Serviced	**19**	**19**	**19**	**20**	**90%**
Type C - Serviced	**2**	**2**	**2**	**2**	**10%**
Total Serviced Users	**21**	**21**	**21**	**22**	**91%**
Usage and Demand Calculations					**Notes**
The following calculations are based on Drago Bartulin's field survey of users in the Chiloe islands area. It is important to note that many of these users have been connected to diesel grid power for some time, and have acquired numerous appliances. The					
Usage					Year zero numbers taken from Drago's surveys.
Type A usage (kWh/usr/mo)	88	**64**	**104**	**105**	
Type B usage (kWh/usr/mo)	45	**25**	**54**	**54**	
Type C usage (kWh/usr/mo)	25	**12**	**30**	**30**	
Total Est. Cons. (kWh/mo)	**192**	**503**	**1135**	**1149**	Total monthly island usage FROM "Dem" sheet, using J. Castillo's demand curves.
Demand					These data are taken FROM the Demand Proj. sheet, where REA formulas are used to calculate the demand.
User Type A (kW/usr)	**0.0**	**0.0**	**0.0**	**0.0**	
User Type B (kW/usr)	**1.2**	**2.8**	**5.6**	**5.7**	
User Type C (kW/usr)	**0.0**	**0.3**	**0.7**	**0.7**	
Total Demand (kW)	**1.3**	**3.1**	**6.4**	**6.4**	Includes losses.

The following calculations are based on NRECA field experience and illustrate one simple approach to monthly energy usage calculations.

Island	# Homes	Community Energy Usage	Average household energy usage	Average individual energy usage	System Capacity	Average household demand
		kWh/day	kWh/day	kWh/month	kW	W/house
Acuy	23	42	1.8	54.9	6	280
Ahullini	25	50	2.0	61.1	8	301
Alao	122	176	1.4	43.8	22	181
Añihue	77	139	1.8	54.8	18	229
Apiao	174	333	1.9	58.1	40	227
Aulin	31	87	2.8	85.1	12	385
Butachauques	212	400	1.9	57.3	47	223
Caguache	111	194	1.7	53.1	24	216
Cailin	163	171	1.0	31.9	22	134
Chaulinec	136	297	2.2	66.5	36	264
Chaullin	22	44	2.0	61.4	7	311
Chelin	103	222	2.2	65.6	27	261
Cheniao	98	171	1.7	53.0	21	217
Chuit	29	55	1.9	57.9	8	279
Chulin	50	95	1.9	57.7	13	252
Coldita	73	130	1.8	54.2	17	228
Huar	453	1101	2.4	73.9	124	273
Laitec	124	214	1.7	52.5	26	212
Linlin	155	269	1.7	52.7	33	210
Llancahue	55	106	1.9	58.5	14	251
Llanchid	19	40	2.1	64.8	6	336
Llingua	114	231	2.0	61.5	28	245
Mechuque	140	307	2.2	66.6	36	260
Meulin	171	320	1.9	56.8	38	223
Nayahue	28	53	1.9	57.8	8	281
Quehui	267	640	2.4	72.9	73	274
Quenac	155	321	2.1	62.9	38	246
Quenu	38	71	1.9	56.8	10	260
Queullin	92	179	1.9	59.0	22	240
Tabon	126	242	1.9	58.4	29	232
Talcan	45	86	1.9	58.1	12	257
Tauculon (Incl. Voigue)	34	60	1.8	53.3	9	251

Resource Data Re-assessed

- Detailed wind resource assessment
- Data collected from local weather stations to complete an additional assessment
- Re-analysis by EdF basically confirmed original wind map.



Detailed cost data collected

- Data on installation of the Isla Tac systems
- Data from purchase of the Isla Tac system
- O&M cost from the Isla Tac system
- Cost data collected from different equipment manufactures
- Local fuel prices based on salmon farms

Fixed Cost

Building		$ 6,000	
Step up transformer		$ 1,300	
Other supplies		$ 1,000	
DC source center with disconnects		$ 2,800	
		$ 11,100	

Annual Operation and Maintenance Cost

Fixed Annual cost	#	Cost	
Site service	12	$ 270	$ 3,240
Transportation to site	8	$ 150	$ 1,200
Technical Administration	5	$ 500	$ 2,500
Local operator	12	$ 300	$ 3,600
			$ 10,540

Fuel price calculation (CP/L)

General fuel price	$232.60	(Castro basic fuel price 10/23/00 (P282.1/l) and 11/01 (P18
Tax rebate for prime power	-40.9	(10/23/01)
Transport to site	140	
Delivered fuel cost (CP/L)	$331.70	
Delivered Fuel Cost ($/L)	$ 0.471	
Yearly transport	$ 1,193	
Exchange rate: CP per $	704	########

Diesel Cost and Maintenance expense

Size (kW)	Capital Cost (US$	Overhaul (Major every 17(Major (60%	Minor (30%)	Combined every 8500	O&M $/hr
2.3	2069			2069	
4.8	4036			4036	
6.5	3545			3545	
7.5	6000			6000	
7.5	6000			$1,317	
10	$ 6,750	$ 4,050	$ 2,025	$ 3,038	$ 0.28
13.5	$13,799	$ 8,279	$ 4,140	$ 6,209	$ 0.28
15	$ 7,426	$ 4,456	$ 2,228	$ 3,342	$ 0.28
20	$ 8,500	$ 5,100	$ 2,550	$ 3,825	$ 0.30
25	$11,744	$ 7,047	$ 3,523	$ 5,285	$ 0.36
30	$13,286	$ 7,971	$ 3,986	$ 5,979	$ 0.40
35	$14,589	$ 8,753	$ 4,377	$ 6,565	$ 0.43
40	$15,635	$ 9,381	$ 4,691	$ 7,036	$ 0.46
50	$17,604	$10,562	$ 5,281	$ 7,922	$ 0.51
55	$18,410	$11,046	$ 5,523	$ 8,284	$ 0.54
60	$19,145	$11,487	$ 5,744	$ 8,615	$ 0.56
70	$20,448	$12,269	$ 6,134	$ 9,202	$ 0.59
80	$21,577	$12,946	$ 6,473	$ 9,710	$ 0.62
90	$22,573	$13,544	$ 6,772	$ 10,158	$ 0.65
100	$23,463	$14,078	$ 7,039	$ 10,559	$ 0.67
110	$24,269	$14,561	$ 7,281	$ 10,921	$ 0.70

Wind turbine Cost (Bergey)

Turbine	$ 18,400.00	
Tower and Grounding	$ 11,628.00	
Installation	$ 4,000.00	
Shipping	$ 2,000.00	$36,028.00
O&M	$ 200.00	year

Wind turbine Cost (Northern Power)

Turbine	$ 7,700.00	
Tower and Grounding	$ 9,328.00	
Installation	$ 2,500.00	
Shipping	$ 2,000.00	$21,528.00
O&M	$ 100.00	year

Battery bank	Unit cost	Maintenance
Trojan L-16	$ 280.00	15
SEC 6-M100-17	$ 311.00	15
SEC 6-M100-33	$ 512.00	15

Trojan L-16	40	$11,200.00
SEC 6-M100-17	120	$37,320.00
SEC 6-M100-33	0	$ -

Wind turbine Cost (Westwind 10.0)

Turbine	$ 15,560.00	
Tower and Grounding	$ 13,791.94	
Installation	$ 4,000.00	
Shipping	$ 2,000.00	$35,351.94
O&M	$ 200.00	year

Wind turbine Cost (Westwind 5)

Turbine	$ 9,544.00	
Tower and Grounding	$ 6,339.00	
Installation	$ 3,000.00	
Shipping	$ 2,000.00	$20,883.00
O&M	$ 150.00	year

Wind turbine Cost (Westwind 2.5)

Turbine	$ 4,900.00	
Tower and Grounding	$ 6,339.00	
Installation	$ 2,000.00	
Shipping	$ 2,000.00	$15,239.00
O&M	$ 100.00	year

Program Development

- Detailed cost data used to obtain subsidy funding from the Federal and Regional government.
- Numbers used to obtain $40 Million IADB loan for rural electrification activities with a focus of renewable technologies.
- The e7 international utility group became interested in the project and has worked with CNE to further develop the analysis.
- e7 would team up with a local utility to develop the project.
- Chile UNDP program is supporting further dev.
- Team approach allows better project coordination through implementation.

Implementation

- Likely funded by a combination of private, national, and international funds.
- Implemented by a team of national and international technical organizations incorporating the experience gained on the Isla Tac project.
- Operation and maintenance would be conducted by local organizations, likely under contract from a regional utility using a service boat similar to ones used in the salmon farming Industry.

Process Pro's

- Detailed staged assessment that allows all levels of government to agree on the project
- Allows for economic based decisions on project details
- Technology neutral
- Regionally focused yet nationally applied
- Based on locally available data
- Provides the type of information required by international funding and business organizations - investment opportunities
- Built in project publicity

Process Con's

- The project has never been developed
- Taken a long time to develop
  - Analysis paralysis
- Analysis requires more information and is an intensive process
- Government required to develop the project - high federal costs compared to private development.
  - Changes in the government, force changes in the project
- Partnerships are a two edged sword – each new partner wants to put their own stamp on the process
- Uses different technologies, difficult for some organizations to agree to the concept.