Appendix A2
Collection of Good Practice Reports
Part 2: NO01 - ZA01

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NO01

Name of Power Plant: Ljøsåa Hydropower Plant

Country(Country/Prefecture): Norway

Owner

Name of Owner: Småkraft AS

Type of ownership: Independent Power Producer

Type of Market: Electricity sales / International power exchange

Commissioning Year: August 2008 (New)

Project Evaluation:

Financial Viability: Recovering initial investment, Securing the cost of maintenance and management, Securing an appropriate level of profit

Economic Benefits: Tax revenue, employment opportunities

Social Aspect: Local Environment: Infrastructure improvement, river environment conservation
Local Community: Vitalization of local community, creation of leisure opportunities

Keywords: Development of a small hydropower by private water resource proprietary, Business model by professional developer, Cooperation between local landowner and professional developer, Power generation income to farmer in addition to income from traditional farming in remote areas, Effective planning and construction

Abstract

Ljøsåa power plant is a run-of-river type hydropower plant of 2.4MW capacity (commissioned in August 2008) located in the Øksendalen valley in North-West Norway (Sunndal Municipality in Møre and Romsdal County). After studying the effective usage of hydro potential in the region, the landowner decided to examine the possibility for developing a small-scale hydropower plant in cooperation with a professional engineering and investment company experienced with small hydropower development. Consultations were held with actual companies, and the landowner then entered into a consignment with

Småkraft AS in 2004. Småkraft AS, then majority-owned by Norway's biggest power utility Statkraft AS, entered into a lease contract for water rights and land usage with the landowner, then constructed the power plant and is now performing the operation and maintenance.

A unique point in the case of the Ljøsåa project is that the landowner has all necessary rights to utilize the river fall for power production and the property in which all plant facilities are located, and that it is a compact high pressure power plant situated in a rural area surrounded by high mountains. The hydro plant was planned and built effectively and with acceptable costs. The benefits obtained from power generation are shared with the landowner. This is a good example of how a small-scale hydropower plant is developed in cooperation with small communities or private individuals with a view to vitalizing the community where depopulation is a threat.

1. Outline of the Project

(1) Background

The Energy Act from 1991 opened access to the grid and the electricity market, and there was a general understanding that a small hydro plant could be a sustainable contribution to the economy and progress in rural areas by promoting settlement. From about year 2000 a new era for small-scale hydro was initiated in Norway. In 2002 the government expressed an aspiration for an increase in the number of small-scale hydropower plants in Norway. The aim was to make the process from planning to operation more systematic and efficient, and also minimizing environmental impacts. The Norwegian Water Resource and Energy Directorate (NVE) received from the Ministry of Petroleum and Energy the task of implementing a national programme to enhance small-scale hydropower development.

The idea for utilization of the Ljøsåa river fall for electricity production was conceived by Turid and Svein Stave in 1999, and the time was ripe for realization of a power plant in the background described above. Turid Stave, the only actual landowner and rights holder, entered into an inclusive consignment with Småkraft AS in 2004 for planning, financing, construction and operation of a hydropower plant.

(2) Project features

Ljøsåa power plant utilizes a head of 374 meters (between intake 447 m.a.s.l. and outlet 73 m.a.s.l.) in river Ljøsåa, which flows into river Usma. The catchment area is 5.7 km^2. The license was granted in November 2006 and the plant was completed in August 2008. The construction works were done in 15 months. The implementation of the project has been rapid and the plant was built approximately on budget.

The power plant has delivered a mean annual output of approximately 4.7 GWh/year in the period 2009-2016, while forehand stipulation was 7 GWh. This was due to the unavailability of direct flow measurements in the river or in the river Usma, to which the river Ljøsåa is a tributary, at the time of making the estimates. Flow figures for the catchment area were calculated on basis of flow measurements and flow series from other catchment areas. The difference between actual power generated at the Ljøsåa plant and the estimate shows that it is essential to have trustable flow figures for production estimates.

The intake dam is about 20 m long and 4 m high (see Photo-1) to secure ice-free intake. The intake is equipped with intake gate in front of the pipeline (penstock) inlet, breather tube downstream intake gate, intake rack and discharge gate in front of the intake rack. For environmental flow release, two separate tubes were constructed having ample capacity to release the required water flow from the pond to the river downstream from the dam.

Photo-1 Intake Dam

The penstock is approximately 1.5 km long and is entirely buried. The upper part is PE-pipeline (polyetylen) with diameter 630 mm and the lower part is cast iron type, with diameter 600 mm. Access to the penstock is 1.3 km existing forest road and then 1 km new road in the steep hillside up to the intake area. The road was made to be permanently used after the construction period and now is also used for maintenance work.

Photo-2 and Table 1 show the power station building and the project specifications, respectively. Maximum design discharge is 0.81 m³/sec. The generator capacity is 2.77 MVA. The generated power (0.7 kV) is transformed up to 22 kV and connected to existing transmission line, 40 m from the power station. The turbine is a 4-jet vertical Pelton with capacity about 2.4 MW. The power station building is made of wood and glass (see Photo-2), and the space is minimized to save construction costs. The outlet channel is approximately 5 m long, and is covered with large stones between the building and the river.

Photo-2 Power station building

Table 1 Project Specifications

Items		Specifications
Name of river/river system		Ljøsåa, tributary to river Usma
Catchment area (km^2)		5.7
Mean annual runoff (m^3/s)		0.463
Mean annual runoff (mill. m^3)		14.6
Specific runoff ($l/s/km^2$)		81.2
Installed capacity (MW)		2.4
Generator capacity (MVA)		2.8
Maximum discharge (m^3/s)		0.81
Minimum discharge (m^3/s)		0.05
Environmental flow (m^3/s)	May 1～Sep.30	0.066
	Oct.1～Apr. 30	0.030
Gross head (m)		374
Construction costs (MNOK/MUSD)		20.6/2.5
Estimated mean annual production (GWh)		7.1
Mean annual production 2009-2016 (GWh)		4.7
Type of power plant	Type of power plant	Run-of-river
	Design	Dam (about 20 m long and 4 m high) Intake (Intake gate, Sand discharge gate) Environmental flow release tubes Headrace(penstock)(Entirely buried, 1.5km) Ground power station Electro-mechanical equipment (4 jets vertical shaft Pelton) Tailrace Connection to existing transmission line (40m)
Connection type		On-grid
Water use		Power generation, Environmental flow

2. Financial Viability of the Project

When initiating planning and constructing Ljøsåa power plant, there were no actual subsidies. The Norwegian-Swedish Electricity Certificate Market was established for the purpose of promoting renewable energy utilization from 1th of January 2012, which was after commissioning of Ljøsåa power plant. In June 2015 the Parliament passed an act which stipulates that power plants that were commissioned after January 2004 can be approved for the certificate market and Ljøsåa power plant was given approval in June 2016. Normally a project is approved for 15 years. For Ljøsåa power plant the operation time before January 2012 is deducted, and last date for access to the certificate market is then February 2029.

The Electricity Certificate Market makes it possible for the renewable power producers to receive electricity certificates which can be sold to electricity suppliers and certain electricity users. Even though Ljøsåa power plant was planned and constructed independent of the certificate market, and was profitable without entering this market, the access to the certificate market gives a valuable addition to the income.

3. Economic Benefits of the Project

There are a number of positive effects beyond the company's (Småkraft) income in each of the planning, construction and operation phases. Tax revenue in the operation phase is essential, and the property tax to the municipality is rather large. This is an important contribution to the municipality's economy, and increases the ability to carry out public services. The landowner's income during renting of fall rights is also taxable. The renting of rights is important as an annual income for the landowner, and it further gives cumulative effects on the region because the landowner's spending may increase in the area. The construction phase had possibility for some local employment, and in the operation phase there is a need for local inspection and supervision.

4. Social Aspects of the Project

4.1 Local Environment

A new road was constructed from the termination of the existing road to the intake area which gives easier public access to the mountainous areas for recreation than before.

Also, NVE ensures that Ljøsåa hydropower plant is a sustainable hydropower project preserving the local environment as the result of a thorough examination and assessment of the license application and licensing procedures.

4.2 Local Community

Ljøsåa power plant is valuable for the landowner. The power plant ensures secure income for future generations, and increases the possibility for continued settlement and conservation and maintenance of the established cultivated landscape, agriculture and forestry.

Rural depopulation is a challenge in many districts in Norway, and development of small-scale hydropower has been considered to be a subsidiary income that can reduce this trend. In addition, the power plant provides added tax revenue for the hosting Sunndal municipality to use for stabilizing and improving public services.

5. Reasons for the Success

(1) Cooperation with a professional company

This case shows that a landowner or a small local community desiring to harness the potential value of the local river can establish a joint investment with a hydropower developer who has professional knowledge on project planning, design, construction and operation. This reduces the landowner's financial risk. The power plant can also be a source of tax revenue for the municipality and ensures income for future generations to increase the possibility for continued settlement, contributing to the solution of the depopulation issue.

(2) Local politicians and steering bodies

Local politicians and autonomous bodies were positive to the project.

6. Outside Comments

There are some newspaper reportages, in particular from the construction period and the period just after commissioning. The reportages emphasize the project as a promising and positive development for the district.

7. Reference

[1] *License application*. Småkraft AS, 11182005

[2] *License granted*. NVE, 11092006

[3] *Detailed plans for Ljøsåa power plant*.
Multiconsult (consultant), 04252007

The listed references are all in Norwegian. This is also the case for a number of other documents.

NO02

Name of Power Plant: Jorda Hydropower Plant

Country(State/Prefecture) : Norway

Owner

Name of Owner: Jorda Kraft AS
Type of ownership: Independent Power Producer
Type of Market: Electricity sales / International power exchange

Commissioning Year: July 2012 (New)

Project Evaluation:

Financial Viability: Recovering initial investment, Securing the cost of maintenance and management, Securing an appropriate level of profit
Economic Benefits: Tax revenue
Social Aspects: Local Environment: River environment conservation
Local Community: Vitalization of local community

Keywords: Development of a small hydropower by private water resource proprietary, Business model by professional developer, Cooperation between local landowners and professional developer, Power generation income to local owners in addition to income from traditional farming in remote areas, Effective planning and construction

Abstract

Jorda power plant is a run-of-river type hydropower plant of 2.4MW capacity (commissioned in July 2012) located in a side valley to the main valley Gudbrandsdalen in the northern part of South-East Norway (Nord-Fron Municipality in Oppland County), some 280 kilometers north of the capital Oslo. In recent years, the economic development of agriculture and forestry has been difficult, and rural depopulation has been a threat many places. The development of small hydropower was one possibility to contribute greatly to the family income of local owners and allow them to continue working as farmers and thus secure economic development of Nord-Fron district. As the results of considering an

effective harnessing of hydro power potential in river Jorda, 10-12 landowners decided to enter into an agreement with Norsk Grønnkraft (NGK), giving NGK the privilege to lease the fall rights for 40 years. NGK planned and constructed the power plant. Jorda Kraft AS, a private limited company whose 51% shares are owned by NGK and 49% by 12 landowners and rights holders, is now a formal plant owner and performing operation and maintenance.

Unique points in the case of Jorda project are that the 12 landowners jointly hold all necessary rights to utilize the river fall for power production and the property in which all plant facilities are located, the project was developed in cooperation (joint venture) with a professional engineering and investment company NGK, and that it is a compact high pressure power plant situated in a rural agricultural region. Small-scale hydropower development may be beneficial for regional development, but investments may also be risky, and uncertainties are likely to occur. In this project, cooperation with a professional developer who can guarantee all phases of a project from planning, construction to operation and maintenance reduces the landowners' risk.

1. Outline of the Project

(1) Background

The Energy Act from 1991 opened access to the grid and the electricity market, and there was a general understanding that a small hydro plant could be a sustainable contribution to the economy and progress in rural areas by promoting settlement. From about year 2000 a new era for small-scale hydro was initiated in Norway. In 2002 the government expressed an aspiration for an increase in the number of small-scale hydropower plants in Norway. The aim was to make the process from planning to operation more systematic and efficient, and also minimizing environmental impacts. The Norwegian Water Resource and Energy Directorate (NVE) received from the Ministry of Petroleum and Energy the task of implementing a national programme to enhance small-scale hydropower development and thus launched a country wide GIS based study program for small hydro plants.

The idea for developing the river fall in river Jorda for electricity production was conceived by landowners and rights holders, who started to give serious considerations. Jorda SHP is one of many projects identified during this program work mentioned above.

(2) Project features

Jorda power plant utilizes a gross head of 335 meters (between intake 778 m.a.s.l. and outlet 443 m.a.s.l.) in river Jorda, which flows into river Veikleåa just downstream the power station. The catchment area is 34.2 km^2. There were no direct flow measurements in the river Jorda or in the river Veikleåa, to which river Jorda is a tributary. Flow figures were collected from other catchment areas. Trustable flow figures are essential for production estimates, and computations were thoroughly carried out by experienced hydrologists.

Norsk Grønnkraft applied for exemption from ordinary license application in April 2008, which NVE approved in November 2008. The plant was commissioned in July 2012, after construction works for 20 months. The implementation of the project was delayed due to civil contractor bankruptcy and tough terrain but was nevertheless built on budget. The power plant delivers a mean annual production of approximately 7.7 GWh.

Photo-1 Intake Dam

The intake dam is about 3.5 m high (see Photo-1) to secure enough water depth to keep the intake ice-free. The intake is equipped with proper equipment for release of required environmental flow to the river downstream the dam.

The penstock is approximately 2.4 km long and is entirely buried. The upper part (627 m) is GPR-pipeline (fiberglass reinforced plastic) with diameter 700 mm and the lower part (1,772 m) is of cast iron type, with diameter 600 mm (see Photos 2 and 3).

Photo-2 Before the penstock in place

Photo-3 Construction of GPR pipeline

The turbine is a 6-jet vertical shaft Pelton with 2.4MW installed capacity and 0.9 m^3/sec maximum design discharge. The generator capacity is approximately 3 MVA. The generated power (0.7 kV) is stepped up to 22 kV and connected to existing transmission line, 1.1 km from the power station.

The power house is built in concrete. There is a short concrete culvert from the power house to the river.

Photo-4 Turbine casing (under construction)

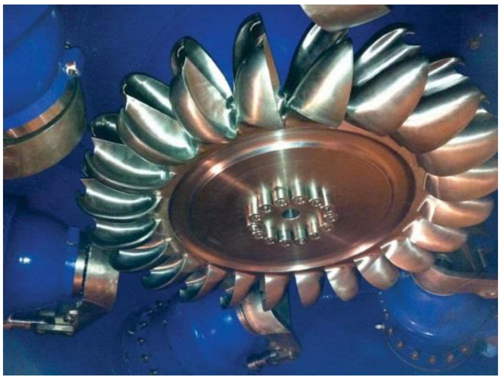

Photo-5 Turbine runner

Photo-6 Generator (back) and
hydraulic system (front)

Photo-7 Power house

Table 1 – Project Specifications

<table>
<tr><th colspan="2">Items</th><th>Specifications</th></tr>
<tr><td colspan="2">Name of river/river system</td><td>Jorda, tributary to river Veikleåa</td></tr>
<tr><td colspan="2">Catchment area (km^2)</td><td>34.2</td></tr>
<tr><td colspan="2">Mean annual runoff (m^3/s)</td><td>0.46</td></tr>
<tr><td colspan="2">Specific runoff ($l/s/km^2$)</td><td>13.4</td></tr>
<tr><td colspan="2">Installed capacity (MW)</td><td>2.4</td></tr>
<tr><td colspan="2">Generator capacity (MVA)</td><td>3.0</td></tr>
<tr><td colspan="2">Maximum discharge (m^3/s)</td><td>0.9</td></tr>
<tr><td colspan="2">Minimum discharge (m^3/s)</td><td>0.05</td></tr>
<tr><td colspan="2">Environmental flow (all year) (m^3/s)</td><td>0.03</td></tr>
<tr><td colspan="2">Gross head (m)</td><td>335</td></tr>
<tr><td colspan="2">Mean annual production (GWh)</td><td>7.7</td></tr>
<tr><td rowspan="2">Type of power plant</td><td>Type of power plant</td><td>Run-of-river</td></tr>
<tr><td>Design</td><td>Dam
Intake
Headrace
Penstock
Surface power station
Electro-mechanical equipment
Tailrace
Connection to existing transmission line</td></tr>
<tr><td colspan="2">Connection type</td><td>On-grid</td></tr>
<tr><td colspan="2">Water use</td><td>Power production, Environmental flow</td></tr>
</table>

2. Financial Viability of the Project

Financial viability was assured after comprehensive evaluation and optimization of construction costs, power production and maintenance costs.

The Norwegian-Swedish Electricity Certificate Market was established from 1^{th} of January 2012. NGK applied for Jorda power plant to be approved for the certificate market in September 2012, and Norwegian Water Resources and Energy Directorate (NVE) gave approval in October 2012. A project's access to the certificate market is approved for 15 years. Last date for access to the certificate market for Jorda power plant is then October 2027.

Because the electricity certificates can be sold to electricity suppliers and certain electricity users, the access to the certificate market gives a valuable addition to the income. The establishment of the certificate market was an essential premise for the investment decision for Jorda power plant.

3. Economic Benefits of the Project

There are a number of positive effects beyond the company's (NGK) income in each of the planning, construction and operation phases. Tax revenue in the operation phase is essential, and the property tax to the municipality is rather large. This is an important contribution to the municipality's economy, and increases the ability to carry out public services. The landowner's income during renting of fall rights is also taxable. The renting of rights is important as an annual income for the landowners. The construction phase had possibility for some local employment, and in the operation phase there is a need for local inspection and supervision.

4. Social Aspects of the Project

4.1 Local Environment.

It is important that preservation of local landscape and regional historic and cultural features are taken into account. This is ensured during the permission application with appurtenant documentation, and the succeeding permission process, which is carried out by NVE. However, some projects with limited capacities have such negligible impact that they do not need a license pursuant to the Water Resources Act. This was the case for Jorda power plant. NGK applied for exemption in April 2008. In such cases the municipally takes over the processing of the project pursuant to the Planning and Building Act and NVE asks for environmental assessment and comments by the county governor and municipally authorities. Exemption from license application was recommended and it was approved by NVE in November 2008.

NVE thus ensures that Jorda hydropower plant is a sustainable hydropower project preserving the local environment by exempting it from licensing procedures.

4.2 Local Community

Jorda power plant is valuable for the landowners. The power plant ensures a secure income for future generations, and increases the possibility for continued settlement and conservation and maintenance of agriculture.

Rural depopulation is a challenge in many districts in Norway, and development of small-scale hydropower has been considered to be a subsidiary income that can reduce this trend. In addition, the power plant provides added tax revenue for the hosting Nord-Fron municipality to use it for stabilizing and improving public services.

5. Reasons for the Success

(1) Cooperation with a professional company

This case shows that a landowners or a small local community desiring to harness the potential value of the local river can establish a joint investment with a hydropower developer who has professional knowledge on project planning, design, construction and operation. This reduces the landowners' financial risk. The power plant can also be a source of tax revenue for the municipality and ensures income for future generations to increase the possibility for continued settlement, contributing to the solution of the depopulation issue.

(2) Local politicians and steering bodies

Local politicians and autonomous bodies were positive to the project.

6. Outside Comments

Comments through the public hearing are mentioned earlier, and in general comments were positive.

7. Reference

[1] Application. Exemption. Norsk Grønnkraft, 04142008

[2] Permission granted. NVE, 11242008

The references are in Norwegian. This is also the case for a number of other documents.

NO03

Name of Power Plant: Storfallet and Veslefallet Kraftverk

Country: Norway

Owner of the Power Plant:

- Name of Owner: Kiær Mykleby Company
- Type of Owner: Independent Power Producer / Landowner
- Type of Market: Power Production and Sales / Open Market

Commissioning Year: Storfallet: 1990 (Renewed)
Veslefallet: 2010 (New)

Project Evaluation:

- Financial Viability: Capital investment cost recovered, O&M cost covered
  Expected production and income
- Economic Benefits: Tax revenue, employment opportunities
- Social Aspects: Local Environment: River environment conservation
  Local Community: Vitalization of local community

Keywords:

Development of small-scale hydropower by local landowner, Family-managed private company,
Additional income to traditional farming in remote area by electricity business

Abstract

Storfallet and Veslefallet power plants are located in a tributary of Søkkunda River in the valley Østerdalen in the northern part of South-East Norway, about 200 km north of the capital Oslo. The Storfallet power plant was originally constructed in 1916 and renewed in 1990. It takes water from the upstream reservoir with a maximum capacity of 2.7MW. The Veslefallet power plant is located just downstream of Storfallet outlet with a maximum capacity of 5.0MW. These two power plants were developed by a family-managed company (Kiær Mykleby[1]) established by a local landowner. Generated

[1] Kiær Mykleby owns and manages forest land (Area:225km^2) in Norway. The Company cultivates forests and agriculture products, as well as operates a machinery company and a power station. Kiaer Mykleby also rents out cabins which includes hunting and/or fishing privileges.

electricity is sold in Nord Pool Market. The access to the Norwegian-Swedish Electricity Certificate Market contributes to improve financial viability of the project. In this district main industries are agriculture and forestry, being declined in recent years and causing a rural depopulation problem same as most of remote areas in Norway. Thus the development of small-scale hydropower using abundant hydro potential in this district has been contributing greatly to the local economy and employment by regional money flow based on the stable income to the landowner by selling electricity adding to traditional farming. Furthermore, a new hydropower project is planned by the landowner in the upstream of Storfallet power plant and received license for development in 2014. Inauguration of this plant is scheduled to be autumn 2017.

1. Outline of the Project

Storfallet and Veslefallet power plants are located in the Østerdalen district in North-East Norway (Stor-Elvdal Municipality in Hedmark County). The area of Stor-Elvdal municipality is 2,166 km^2, of which about 1000 km^2 is forest and area of highlands is of same size. Population is decreasing from some 4,000 in 1965 to approximately 2,600 in 2015.

In recent years, the economic development of traditional farming and forestry has been difficult, and rural depopulation has been a threat many places, and not only in the Østerdalen district. The development of small hydropower is one possibility to contribute to the economic development in the Østerdalen district (like other rural districts in Norway). The company Kiær Mykleby renewed and enlarged Storfallet hydropower plant (originally constructed in 1916) in the river Søkkunda in 1990. Søkkunda is a tributary from west to the river Glomma, which is the longest river in Norway.

The installed capacity of original Storfallet Power Plant was 700kW, equipped with two Francis turbine generators. The capacity of new Storfallet Power Plant was enlarged to 2,700kW by increasing the maximum discharge from 1.5 m^3/s to 4.5m^3/s.

The existing intake tunnel (Length :84m) to surge chamber was rehabilitated, and the penstock was replaced with new steel pipeline (1,400mm dia. x 135m length). The power plant

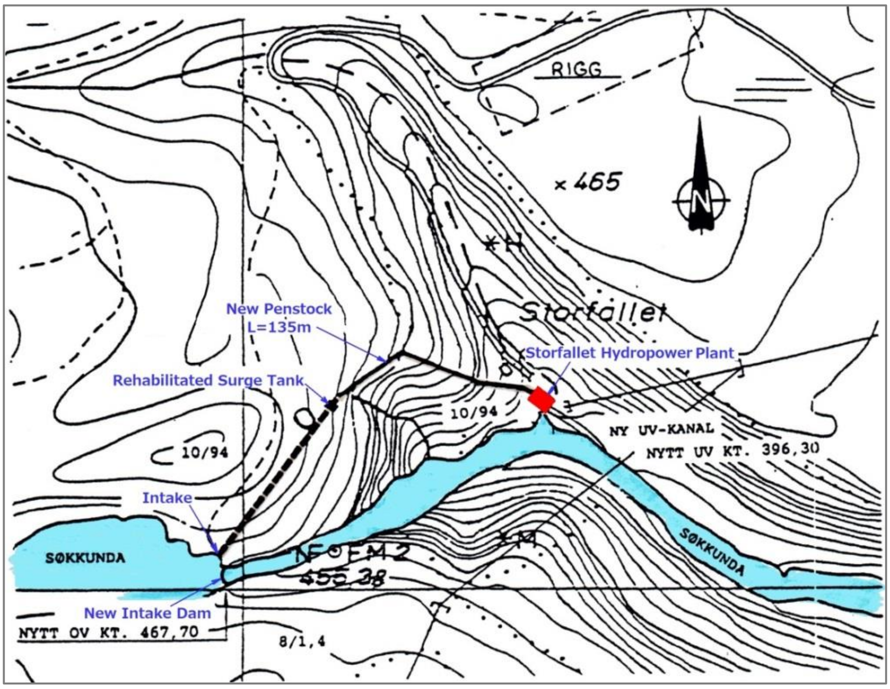

Fig.1 Outline of Storfallet Hydropower Plant[5]

is connected to existing 22kV transmission line. Mean annual production is approximately 9 GWh.

Table-1 Specifications of Storfallet Hydropower Plant

Items	Description
Installed capacity (MW)	2.7
Maximum discharge (m^3/s)	4.5
Gross head (m)	71.4
Type of power plant	Run-of-river
Turbines	2 Francis
Waterway	Tunnel：Cross section $4m^2$ x 84m Length Penstock： Φ1,400mm x 135m Length


Intake Dam


Power Building


Turbine Generators


Tailrace

Photo-1 Storfallet Hydropower Plant

The potential for a new hydropower plant in river Søkkunda was well known from previous studies carried out by NVE as resource mapping. Initial considerations were done by Kiær Mykleby. The Energy Act from 1991 opened for access to the grid and the electricity market, and it was a general understanding that small hydro could be a sustainable contribution to economy, progress and optimism in rural areas. From about year 2000 a new era for small-scale hydro was initiated in Norway. In 2002 the government expressed an aspiration for an increase in the number of small-scale hydropower plants in Norway. The aim was to make the process from planning to operation more systematic and efficient, and also minimizing environmental impacts.

As the results of studying a more effective harnessing of hydro potential in the Søkkunda river, Kiær Mykleby applied for an additional small-scale hydropower plant, Veslefallet power plant, with intake in the outlet from Storfallet hydropower plant. Veslefallet power plant utilizes a head of 133 meters (between 396 m.a.s.l. and 263 m.a.s.l.) in river Søkkunda, which flows into river Glomma. License application was sent to NVE in August 2007, and license was granted in August 2008. Construction works started in April 2009, and the plant was commissioned in April 2010. The implementation of the project has been rapid and the plant was built on budget. Mean annual production is approximately 16.5 GWh. The total capacity of both plants (Storfallet and Veslefallet) increases from 2.7MW to 7.7MW, and the total mean annual production from 9GWh to 25GWh by developing the Veslefallet power plant.

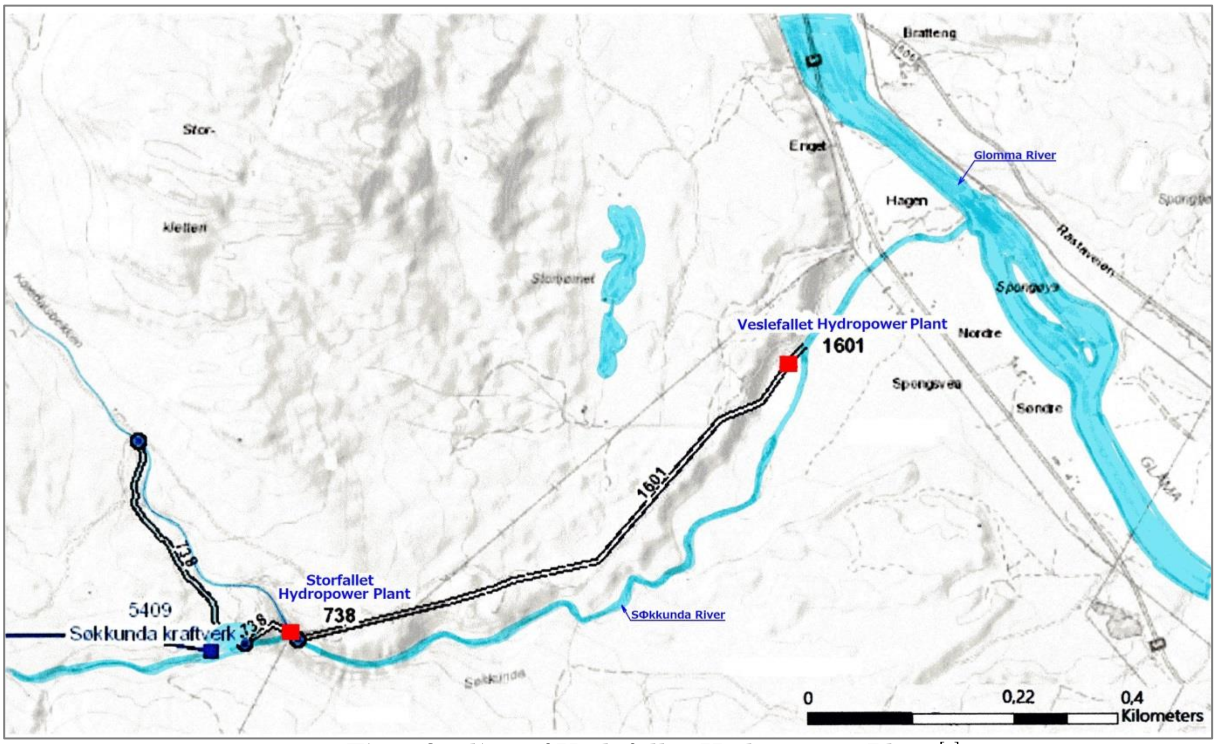

Fig.2 Outline of Veslefallet Hydropower Plant[6]

Søkkunda is a typical tributary to river Glomma, and not that different from other watercourses in the district. Mean runoff (l/s/km^2) were found in NVE-Atlas. NVE-Atlas is a many-sided GIS-based map worked out by NVE and is available on NVE's web page (www.nve.no). Flow variation was estimated by using gauged flows in a nearby catchment area and a scaling factor. In addition, catchment area and runoff of Veslefallet power plant are very close (98%) to those for Storfallet power plant. Since Storfallet power plant has been operated for many years, discharge and production data could also be useful for estimation of runoff and flow variation in Veslefallet power plant.

The intake dam is a concrete gravity dam, with length 25 meters and largest height between 4 and 5 meters. Top of the dam is at same level as lowest tail water for Storfallet power plant, 396.0 m.a.s.l. The dam crest is shaped for flood runoff. The intake pond is regulated between 396 m.a.s.l and 394 m.a.s.l, which gives a regulated volume of 8,000 m^3. In addition, the regulated volume in the intake pond for Storfallet power plant can be added when co-ordinating operation of the plants.

Photo-2 Intake Weir
(Storfallet P/S Tailrace)

The intake combined with the tunnel intake, and is integrated in the dam construction. The intake is equipped with coarse trashrack and stop log for closing. There is a discharge gate (slide gate type) in the bottom of the dam. There is a cast-in tube with integral valve for release of required minimum (environmental) flow.

The headrace consists of tunnel and penstock. From the intake there is a tunnel with length 655 meters and cross-section area 16 m^2. In the lower end of the tunnel there is established a surge chamber. The chamber is equipped with fine track rash and a roller gate for closing the penstock. From the tunnel and down to the power station there is a buried penstock with length 1,810 meters and diameter 1.4-1.6 meter.

The power station is located on the river plain at level 263 m.a.s.l., and is combined with a store in one building with total area of approximately 460 m^2. The building is made of tree (timber), and raised in local barn style. There are installed two Francis turbines, each of them with maximum discharge 2.2 m^3/s and maximum capacity 2.5 MW. Generator capacity is 2 x 2.7 MVA. The power station contains also transformer room, high voltage room, control room and workshop. The transformer with capacity 5.4 MWA has a voltage ratio of 0.69/22 kV. The power plant is connected to existing 22 kV transmission line through an open wire line with length 500 meters.

Power Building

Turbine Generators

Tailrace

Photo-3 Veslefallet Hydropower Plant

Table-2 Specifications of Veslefallet Hydropower Plant

<table>
<tr><th colspan="2">Items</th><th>Specifications</th></tr>
<tr><td colspan="2">Name of river/river system</td><td>Søkkunda, tributary to river Glomma</td></tr>
<tr><td colspan="2">Catchment area (km^2)</td><td>102</td></tr>
<tr><td colspan="2">Mean annual runoff (m^3/s)</td><td>2.9</td></tr>
<tr><td colspan="2">Specific runoff ($l/s/km^2$)</td><td>28</td></tr>
<tr><td colspan="2">Installed capacity (MW)</td><td>5.0 (2.5 x 2)</td></tr>
<tr><td colspan="2">Generator capacity (MVA)</td><td>5.4</td></tr>
<tr><td colspan="2">Maximum discharge (m^3/s)</td><td>4.4 (2.2 x 2)</td></tr>
<tr><td colspan="2">Minimum discharge (m^3/s)</td><td>0.2</td></tr>
<tr><td colspan="2">Environmental flow (May 1-Sept. 30) (m^3/s)</td><td>0.55</td></tr>
<tr><td colspan="2">Environmental flow (Oct. 1-April 30) (m^3/s)</td><td>0</td></tr>
<tr><td colspan="2">Gross head (m)</td><td>133</td></tr>
<tr><td colspan="2">Construction costs (MNOK/MUSD)</td><td>50/6</td></tr>
<tr><td colspan="2">Estimated mean annual production (GWh)</td><td>16.5</td></tr>
<tr><td rowspan="2"></td><td>Type of power plant</td><td>Run-of-river</td></tr>
<tr><td>Design</td><td>Dam
Intake
Headrace
Tunnel
Penstock
Surface power station
Electro-mechanical equipment
Outlet
Connection to existing transmission line</td></tr>
<tr><td colspan="2">Connection type</td><td>On-grid</td></tr>
<tr><td colspan="2">Water use and loss</td><td>Power production
Environmental flow
Flood (loss)</td></tr>
</table>

2. Financial Viability of the Project

When initiating, planning and constructing Veslefallet power plant, there was no actual subsidy. The Norwegian-Swedish Electricity Certificate Market was established from 1th of January 2012, it will say after commission of Veslefallet power plant. In June 2015 the Parliament passed that power plants that were commissioned earlier than January 2012 (back to January 2004) also can be approved for the certificate market. Kiær Mykleby applied for Veslefallet power plant in September 2015. Norwegian Water Resources and Energy Directorate (NVE) gave approval in January 2016. Normally a project is approved for 15 years. For Veslefallet HPP the operation time before January 2012 is deducted, and last date for access to the certificate market is then 21th of May 2029.

The Electricity Certificate Market is a support system for renewable energy. The power producers receive electricity certificates from the authorities according to data on generated energy. It is compulsory for electricity suppliers to purchase electricity certificates according to the electric energy they have delivered to customers. The expence will finally be included in the bill to the customers. The producer of the electricity certificates can also sell them directly to certain electricity users or to brookers.

Veslefallet hydropower plant was planned and constructed independent of the certificate market, and proved profitable also without access to this market. The access to the electricity certificate market, however, has proved important since the price in the electricity spot market over a long period has been very low. The owner of the plant will receive an income, which is the sum of the price per kWh in the electricity spot market and the electricity certificate market. The prices for the kWh in the two markets depend on the overall generation capacity in the Nordic and Nord European market (Electricity Spot Marked) and the capacity in the Swedish/Norwegian electricity certificate market. Roughly, 2/3 of the income have been originated from the electricity spot market, but the prices vary dramatically and make it difficult to forecast long term income.

3. Economic Benefits of the Project

Rural depopulation is a challenge in many districts in Norway, and development of small-scale hydropower has shown up to be a subsidiary income that can reduce this trend. There are also a number of positive effects beyond the company's income, both in planning, construction and operation phases.

Tax revenue in the operation phase is essential, and the property tax to the municipality is large. This is an important contribution to the municipality's economy, and increases its ability to carry out public services.

The construction phase included local, regional and national suppliers, with possibility for some local employment, which further gave cumulative effects.

With only 9 GWh in mean annual production, Kiær Mykleby is too small for employed personnel on a permanent basis for the power plant only. The company is also small in the electricity market. The realization of Veslefallet hydropower plant is an improvement of the company's strength as a hydropower producer when regarding plant operation as well as market conditions.

In addition to Veslefallet power plant, the new hydropower plant, Søkkunda hydropower plant, is planned in the upstream of the Storfallet power plant. The head is 242 meters, between 710 m.a.s.l and 468 m.a.s.l. The capacity is 10 MW, with two Pelton turbines of same size, 5 MW. Estimated mean annual production is approximately 25 GWh. The license was granted in July 2014 and the plant is now in the construction phase. Scheduled commissioning is November 2017.

4. Social Aspects of the Project

4.1 Local Environment

It is important that preservation of local landscape and regional historic and cultural features are taken into account. This is ensured during the license application with appurtenant documentation, and the succeeding licensing process, which is carried out by NVE. NVE is a directorate under the Ministry of Petroleum and Energy (OED), and has been delegated the licensing authority pursuant to the Water Resources Act for hydropower plants up to 10 MW.

NVE's decision is based on the license application, public hearing and received comments, and also a public meeting with site inspection. License can be granted, or refused. The license terms can imply changes (stronger obligations, required mitigation measures, reduced project) compared with the application. In the application, Kiær Mykleby proposed a project without requirements for environmental flow. However, NVE considered environmental flow to be necessary for sufficient conserving of the river environment in the period May 1 to September 30, and this was included as a license obligation.

4.2 Local Community

Veslefallet power plant is valuable for the company Kiær Mykleby. The power plant means income that is an important addition to income from other sources. The power plant ensures safe income for future generations, and increases the possibility for continued settlement and then conservation of the established occupation.

Depopulation is a challenge in many rural districts in Norway, and development of small-scale hydropower has been considered to be a subsidiary income that can reduce this trend.

5. Reasons for the Success

(1) Aggressive regional energy development by landowner

The family managed company established by a local landowner cultivates forests and agriculture products, as well as operated small hydropower plant utilizing the potential value of the local river from a long time ago. Since this small hydropower plant operation can obtain a stable income for family-managed company, the upgrading and expansion of new hydropower plants are developed by applying the experiences for planning and management of small hydropower plant in the area. As the results, these plants can be a source of tax revenue for the municipality and ensures income for future generations to increase the possibility for continued settlement, contributing to the solution of the depopulation issue.

(2) Local politicians and steering bodies

Local steering bodies and politicians were positive to the project.

6. Outside Comments

There are some newspaper reportages, in particular from the construction period and the period just after commissioning. The reportages are mainly subjective, with facts, but emphasizes also the project as a promising and positive enterprice for the district.

7. Reference

[1] License application. Kiær Mykleby, 08212007

[2] License granted. NVE, 08122008

[3] Detail Plan. Ulvig Kiær Kraft AS, 12152008

[4] Approval of Detail Plan. NVE, 01192009

[5]Upgrading and Expansion of Hydropower. NVE Publication No.16, 1991

[6]NVE Map services, https://www.nve.no/map-services/

The listed references are all in Norwegian.

PH01

Name of Power Plant: Ambangal Hydropower Station

Country(State/Prefecture): Philippines / Ifugao Province

Owner

Name of owner: Ifugao Province

Type of Ownership: Power Producer / Local Municipality

Type of market: Power Purchase Agreement

Commissioning Year: 2010

Project Evaluation

Financial Viability: Securing the cost of maintenance and management, Ensuring an appropriate level of income

Economic Benefits: Creating employment, Promoting local industries

Social Aspects: Maintaining local landscape and culture: protecting nature parks (world heritage)
Revitalizing local communities, Promoting community development, Providing environmental and energy education, Capacity building

Keywords: e8 (GSEP), world heritage, rice terraces of the Philippine Cordilleras, Rice Terraces Conservation Fund, consensus development, briefings for residents

Abstract

Tokyo Electric Power Company, a member of the international NPO 'e8' consisting of electric utilities of major countries including G8, initiated a micro hydro project aimed at conserving the rice terraces of the Philippine Cordilleras, listed as 'World Heritage site in danger', improving the standard of living for local residents and revitalizing the local communities as part of the sustainable energy development program in developing countries.The e8 built a micro hydro power station with the output of 200kW in the Ifugao Province in 2010, and donated it to the Provincial Government. Generated power is sold to a local power distribution utility with revenues allocated to the maintenance and management of the power station's operation and the conservation fund set up for the rice terraces. This means the Provincial Government has no burden of initial investment, ensuring the economic viability of the project, which carries out plant

operation and rice terrace conservation for revitalizing local communities. In building the power station, the local government took an approach of involving local residents, conducting briefing sessions for local residents to form consensus, designing facilities in full considerations for the natural environment (e.g. layout that does not affect rice terraces and the use of buried waterway), using traditional local techniques and mobilizing local residents for construction. After completion, e8 members facilitated operator trainings and developed a structure for managing rice terrace conservation activities so that the Provincial Government can smoothly maintain / manage the plant operation, conserve rice terraces and manage the conservation fund.

1. Outline of the Project

The rice terraces of the Philippine Cordilleras[1] (Photo 1) in the Province of Ifugao in the Philippine island of Luzon, have 2,000 years of history, spreading across mountainous land at the altitude of over 1,000m. UNESCO listed it as World Heritage site in 1995. However, the outflow of local population to urban areas led to abandonment, and the lack of funds made it impossible to implement sufficient conservation activities, making the site inscribed in the list of 'World Heritage in Danger' in 2001. With various forms of assistance from domestic and international sources, the local government began repairing / preserving the rice terraces and implementing a program for handing over traditional knowledge to future generation. In 2012, the site became delisted from the 'In Danger' list.

Photo: 1 Rice terraces of the Philippine Cordilleras

Tokyo Electric Power Company, a member of the not-for-profit organization 'e8' [2] (today's GSEP), planned and proposed this micro hydro project, which promotes the use of renewable energy to repair / conserve the rice terraces, achieve sustainable development of local energy, improve the local residents' standard of living and revitalize the local communities. The project went ahead in 2008 following an agreement with the

[1] The rice terraces, created by locals over the period of 2000 years, are sometimes called the 'stairway to heaven' for their beauty. The culturally-significant landscape, a joint masterpiece of men and nature, became listed as World Heritage site in 1995. However, the abandonment of the rice fields by farmers and insufficient management planning resulted in its becoming registered in the list of World Heritage Site in Danger. UNESCO took the site off the 'In Danger' list in 2012 after recognizing that the government of Ifugao Province has created a long-term and stable mechanism for generating conservation fund for the rice terraces through the operation of the Ambangal Hydro Power Station, is running a campaign to build awareness within local communities about the need for organizational conservation efforts even though individual rice terraces are personally owned, and has improved the level of the site's conservation.

[2] The e8 (today's GSEP: Global Sustainable Electricity Partnership) was established in April 1992 by major electric utilities of the Group of Eight (G8) nations at the time as a not-for-profit organization for becoming involved in international debate on issues concerning the environment and development, including global warming. Today, the organization consists of 14 electric utilities from 12 countries.

governments of the Philippines and Ifugao Province.

(1) Aim of the project

1) Contributing to the preservation of the World Heritage rice terraces
2) Establishing a model case of community-initiated energy development combined with community revitalization
3) Promoting the development of sustainable micro hydro
   - Promoting micro hydro development as a public utility project for local communities by local people
   - Transferring e8's technologies and know-how for building, administrating, maintaining and managing hydro plants

The 200kW micro hydro power station, built by e8 on the Ambangal River in Ifugao Province (Tables-1 and 2, Fig.-1, Photos-2 – 8), was donated to the Philippines' Department of Energy and commenced operation upon completion in January 2010. Its ownership was transferred to the Ifugao Provincial Government in December 2011. Generated electricity is sold to the province's power distribution utility (IFugao ELectric COoperation / IFELCO), with revenues allocated to maintaining / managing the plant facilities and preserving the rice terraces. The power station is operated, maintained and managed by a management cooperative consisting of local residents, formally employed by the Provincial Government. Operators are trained by e8. The Provincial Government and e8 jointly compiled regulations / guidelines for assigning part of the revenues as the rice terrace conservation fund, which is administrated and managed by the Provincial Government's Ifugao Cultural Heritage Office / ICHO). (Fig.-2)

Prior to the plant construction, from the initial stage of planning, over 20 briefing sessions were held for local residents to build consensus on project support. The local government took an approach of involving local residents, designing facilities in full considerations for the natural environment (e.g. layout that does not affect rice terraces and the use of buried waterway), using traditional local techniques and mobilizing local residents for construction.

Table-1: Specifications of the power station

Item	Specifications
Name of the water system / river	Ambangal River
Maximum output	200 kW
Maximum discharge	0.425 m^3/s
Effective head	63.5 m
Power generation type	Run-of-river type / canal type
Grid connection	Yes

Table-2: Specifications of the facilities

Item	Specifications
Intake dam	Floating type H:1.2m×L:20m
Headrace	W:0.6m×H:0.8m×L:1,600m
Head basin	W:2m×L:6.5m
Waterway	PVC pipes (buried) φ0.5m×L:290m
Power plant	W:3.35m×L:7.4m×H:2.5m
Water turbine	Inline Francis turbine
Generator	Synchronous generator
Transmission line	Three phase 13.2kVAL:1.8km

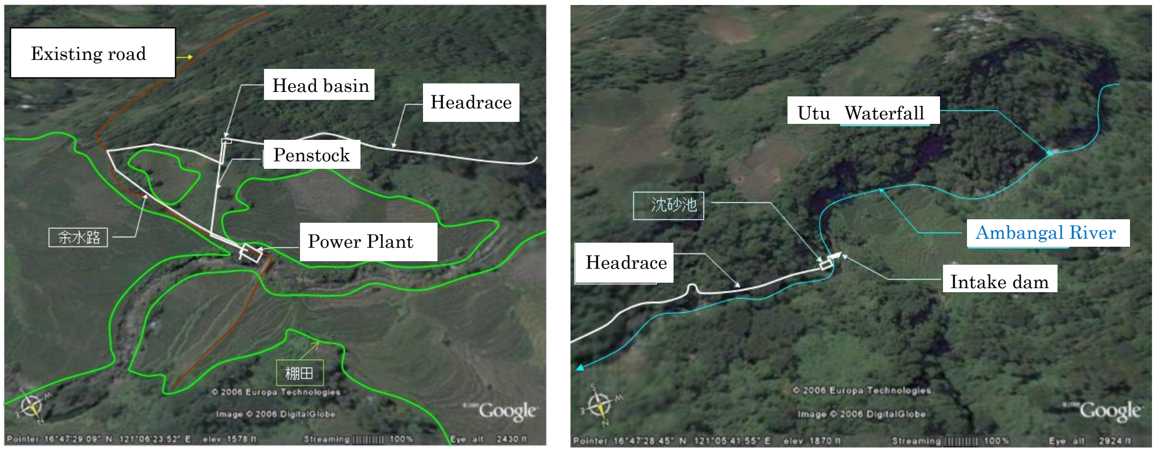

Fig.-2: Facility layout and relative position to rice terraces

Photo-2: Intake dam

Photo-3: Waterway

Photo-4:　Head basin

Photo-5:　Waterway

Photo-6: Plant building

Photo-7: Water turbine and generator

Photo 8: Generator control panel

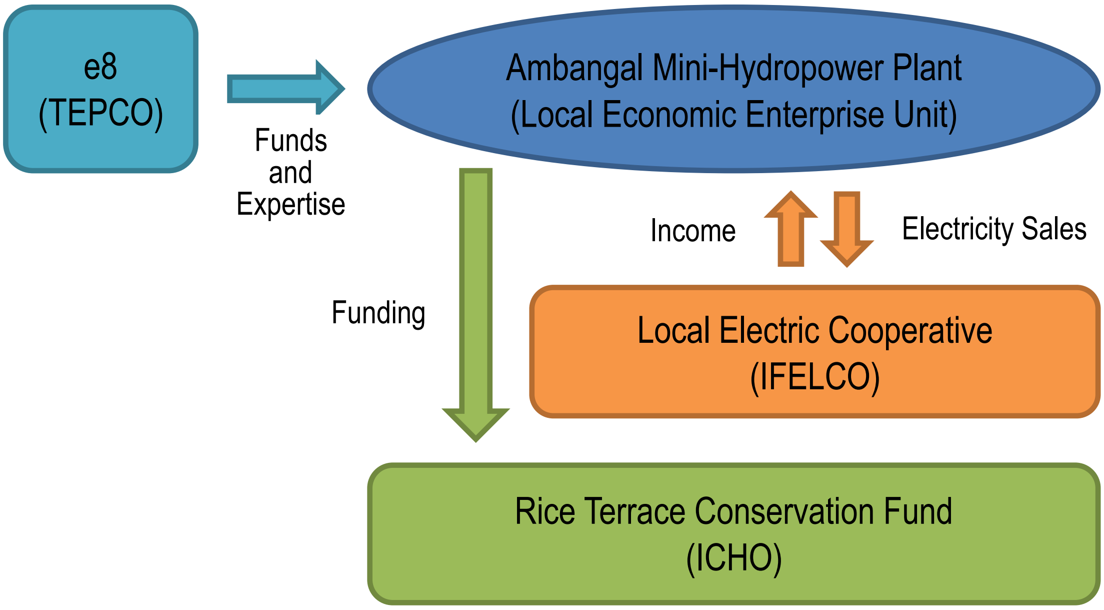

Fig.-2:　Concept of the Ambangal Mini-Hydropower Plant

2. Financial Viability of the Project

(1) Allocating electricity revenues to cover the maintenance / management cost and securing fund for rice terrace preservation

In this project, Tokyo Electric Power Company, which is a member of e8, covered the cost of building the power station and donated the plant to the Ifugao Provincial Government as a form of international cooperation. That meant that the local government, which operates the plant, did not have to bear the cost of initial investment. The project's economic viability is therefore concerning the ability to cover the cost of its operation, maintenance and management and raise fund for conserving the rice terraces. The power station has the average annual power generation of 1,200MWh, which is sold to the local power distribution utility (IFELCO), raising approx. 3 million pesos (USD67,000[3)]) for the cost of plant operation, maintenance and management as well as rice terrace conservation. This enables smooth plant operation. Since its operation launch, 47 rice terrace preservation projects have been carried out. The plant uses the inline Francis water turbine and generator to simplify maintenance and management.

3. Economic Benefits of the Project

(1) Use of local residents for plant construction, operation, maintenance and management to create employment

The power station was built with the participation of (up to 180) local residents, creating short-term jobs and improving their incomes (Photo-9). Plant operation, maintenance and management are carried out by operators, who are selected local residents who have undergone e8's education and training (desktop study & OJT). This has created 6 plant operator jobs and 1 administration job (Photo-10).


Photo-9: Plant construction involving local residents


Photo-10: Operator education and training

3) 1US$ = Php44.03 = ¥118.24

(2) Application to new projects

The revenue of the Ambangal power station allocated to rice terrace preservation represents about 10% of the total amount required for the Ifugao Provincial Government's terrace preservation master plan. Since Ifugao Province has rich underdeveloped water resources, a Japanese ODA organization (JICA) has initiated a micro hydro project (output of 820kW, completed in July 2015) to expand the funding for rice terrace preservation since 2012 as a grand aid project. In effect, this project is becoming Philippines' model case for sustainable community development using micro hydro power.

(3) Positive effects on communities outside Ifugao Province

The fact that the Ambangal power station is being operated smoothly under community initiative, is attracting people wishing to inspect the site from neighboring provinces. Consequently, the Ifugao Provincial Government is becoming increasingly aware of its position as the pioneer of community-led micro hydro power generation. The project has also boosted the enthusiasm of other provinces wanting to take on similar micro hydro development, increasing expectations of economic ripple effects.

4. Social Aspects of the Project

4.1 Local Environment

1) Contributing to the rice terrace preservation project

The revenues from selling electricity secure the fund for terrace preservation. The following activities are funded under the management of the Ifugao Provincial Government. The preservation work has restored the World Heritage landscape, boosting the site's tourism value.

A) Restoring abandoned rice terraces
B) Restoring the area's irrigation systems
C) Assisting the effort to improve the livelihood of rice terrace farmers
D) Tree-planting project
E) Contributing to cultural enhancement
F) Eradicating pests and improving soil

2) Paying considerations to the natural landscape

The project installed waterway underground and designed the plant building and operator rest area in a way sympathetic toward surrounding environment, so as not to undermine the rice terrace landscape recognized as UNESCO World Heritage.

4.2 Local Community

1) Revitalizing local communities

The rice terrace preservation fund is used to support the livelihood of farmers in low season with sideline work (looming, woodworking, forging, etc.). This stabilizes farmers' income and facilitates the development of farming successors, thereby contributing to slowing down population loss and revitalizing local economy.

2) Handing local traditions and cultures to future generation

Replicating traditional farming techniques (masonry, ridge-making in paddies, etc.) and handing them over to younger generation, help preserve rice terraces in a better condition. Rice festival and other rice farming events are also organized to form local communication and bonds.

3) Human resource development

In order to ensure smooth plant operation and sustainable rice terrace preservation, e8 members exchange opinions with engineers / managers of the Philippines government and Ifugao Provincial Government, compiling regulations and guidelines concerning the preservation fund's administration and management and reinforcing the management capacity of provincial government staff. Also, six local residents were selected as plant operators, and received desktop and OJT education and training. Consequently, they are now capable of implementing repairs and enhancements for civil engineering facilities based on their own judgment. The number of preservation activity projects, using the rice terrace preservation fund, is also on the rise year after year.

4) Contribution to local communities

When the level of water in the river drops during the dry season from March to May, water is used primarily for irrigation in agriculture, the area's main industry, while the power plant is shut down. Maintenance and inspection of plant facilities are carried out during this time of outage.

5. Reason of the Success

(1) The project's economic viability

Since the power station was donated as a form of international cooperation, the Ifugao Provincial Government, which operated the plant, had no burden of initial investment. The project's economic viability is therefore secured, covering the cost of its operation, maintenance and management and raising fund for conserving the rice terraces. For smooth operation, maintenance and management of the power station, e8 members have provided education and training to plant operators.

(2) The project's economic benefits

To promote hydroelectric power development as a utility project by local people, one of the goals of this project, local residents participated in the construction work, operation and maintenance of the power station. This has resulted in economic benefits such as raising income of local people and employment creation. Other ripple effects from the success of this project include the implementation of a new similar project by a Japanese ODA organization (JICA) and the improvement of enthusiasm for micro hydro development in other provinces.

(3) Contributing to local environment and society

As for the primary objective of preserving the World Heritage rice terraces, the revenues from selling generated electricity provided for the rice terrace preservation fund. With cooperation from e8 members, the Ifugao Provincial Government has properly administrated and managed the fund and increased the performance of the conservation project, thereby steadily preserving the rice terraces in the area. In order to become a model of region-led energy development and regional revitalization which is one of the goals of this project, the project convened briefing sessions for local residents from the initial stage of planning to build consensus (Photo 11), and designed the plant in full consideration for the natural environment (e.g. layout that does not affect rice terraces and the use of buried waterway). Upon completion, the e8 team extended cooperation in training plant operators, building a plant management structure and improving the administration of the rice terrace fund so that the Ifugao Provincial Government can handle operating / managing the plant and controlling the fund for terrace preservation.


Photo-11: Briefing sessions for local residents

6. Outside Comments

(1) Denki Shimbun newspaper (January 18, 2010 issue): The 'Stairway to Heaven' being Abandoned --- Completion of Micro-Hydro Plant funded by TEPCO --- Power Revenues to Fund Terrace Preservation

(2) Kyodo News (January 22, 2010 issue): Hydro Power Revenues to Fund Rice Terrace Preservation --- TEPCO / World Heritage Site in Philippines' Luzon Island

(3) International Development Journal (No.647): Corporate International Contribution / TEPCO's Philippines Rice Terrace Preservation Project, October 2010

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http://www.globalelectricity.org/upload/File/Project%20Communciations/IFUGAO%20publication%20FINAL.pdf

[2] GSEP website: http://www.globalelectricity.org/en/index.jsp?p=121&f=236

PT01

Name of the Power Plant: Canedo hydropower plant

Country(State/Prefecture): Portugal(Vila Real, Trás-os-Montes)

Owner

Name of owner: HDR.- Hidroeléctrica lda, a subsidiary company of the RPGlobal Group

Type of ownership: Independent power producer

Type of market: Green Tariff Scheme

Commissioning Year: Dec., 2008

Project Evaluation

Financial Viability: Recovering initial investment, Securing the cost of maintenance and management, Securing an appropriate level of profit

Economic Benefits: Tax revenue (Yearly contributions for the community associations and municipalities), Employment opportunities, Local industrial promotion

Social Aspects: Local Environment: Infrastructure improvement
Local Community: Facilitation of regional development (Yearly improvements and repairs of the local irrigation channels)

Keywords Canedo dam, an ancestral winter irrigation method (rega de lima), RPGlobal Portugal (RPG), Best Small Hydro Plant, Trout farming, Optimum reservoir operation, Landscape conservation

Abstract

Canedo hydro power scheme is a small hydro project with 10MW power developed on the Beça River in northern Portugal. The scheme is situated in the Trás-os-Montes region, extending 5.5km through the municipalities of Boticas and Ribeira de Pena. The river Beça is not only used for irrigation purposes, but is also known for its rich trout community, with a trout farm actually located upstream of the Canedo project's intake. The powerhouse is located near a village, upstream of a river beach, and is a very visible part of the landscape. The scheme comprises a dam, low-pressure waterway, surge tank, penstock and powerhouse. The fish pass was designed to operate to a satisfactory level continuously

throughout the year at each reservoir operation level, given the importance of the trout farming community on the Beça River. The region has an ancestral winter irrigation method called "rega de lima" for protection against frost, where the water is transported through long open channels called levadas. The dam automation scheme guarantees the release of the necessary irrigation flows in order to accommodate this concurrent water use. The maximum storage capacity of the dam is optimized during the daytime as the energy tariff is higher, and is minimized in the evening. Major contributions to the community include infrastructure development such as roads and bridges that were constructed with the dam, and the powerhouse designed with special consideration for landscape conservation.

1. Outline of the Project

The Canedo project was launched in the early 1990s with preliminary studies beginning in 1992. The project was, however, halted in 2002 due to concerns about the preservation of aquatic life in the river and the fish farm upstream of the dam. A new or reformulated technical and economic feasibility study and an environmental impact study were executed and delivered in 2003. These studies were issued for public consultation and received several concerns from the local irrigation associations. However, through a process of channel flows measurement, studies, and several explanatory meetings with the associations and public entities, the benefits resulting from the project implementation were shown to them. The negotiations were concluded in August 2006 with the publication of the project's Declaration of Public Interest. A concession contract, which included the construction license, was approved in 2008.

The River Beça is a tributary of the Tâmega River, which itself is a tributary of the Douro River, the most important watercourse in northern Iberia. The

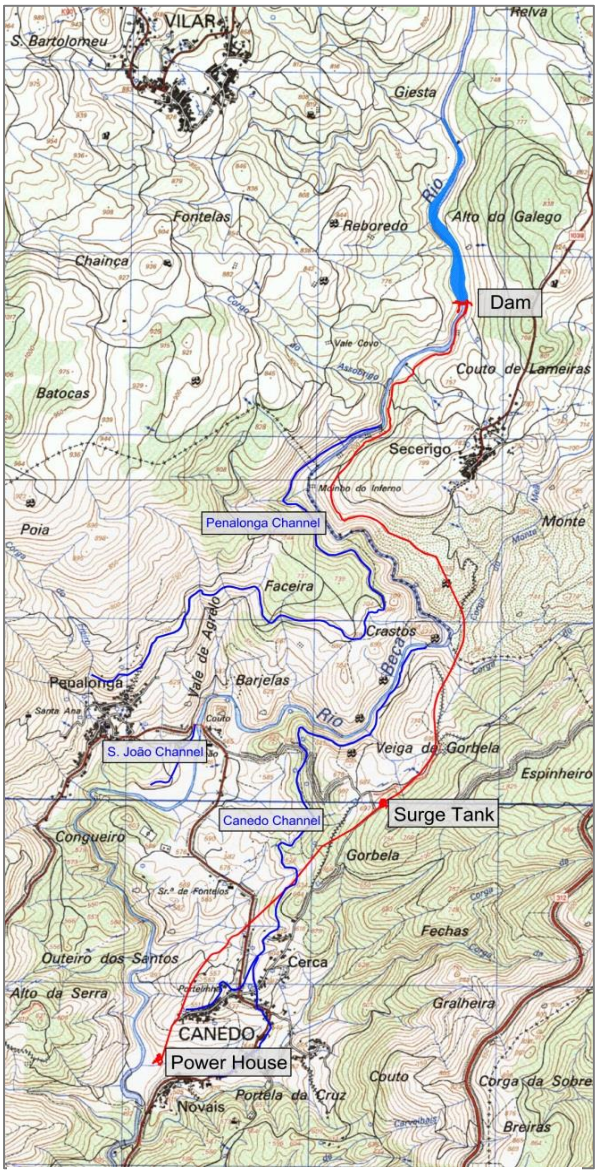

Fig.-1 General view of the scheme

watershed is mostly occupied by forest and pastures and has an area at the intake section of 114.5km^2. The river has an average bed slope of 3% in the area utilised by the scheme. The median average annual rainfall is 1350mm, which creates an estimated 815mm (2.95m^3/sec) average runoff (see Fig.–1 for the general view of the scheme).

The scheme comprises a dam, low-pressure waterway, surge tank, penstock, and powerhouse. The installed power of 10MW is accomplished with a turbine flow of 5.4m^3/s, under an effective head of 226m. Table-1 shows the project specifications. Since start of production, it has supplied, on average, 29GWh of clean electricity for the national grid. Canedo's powerhouse is located close to a river beach. The building was subject to a thorough architectural study, which focused on integration with the striking surrounding landscape and accessibility for visitors. Fig.-2 and -3 show the plan view of the dam and the intake section, respectively, and Fig.-4 and Photo-1 show the longitudinal section of the fish pass and the fish passage in operation, respectively.

The dam's automation scheme guarantees the release of the necessary irrigation flows in order to accommodate the concurrent water use. The fish pass was designed to operate to a satisfactory level continuously throughout the year at every reservoir operation level, given the importance of the trout farming community on the Beça River.

Table-1 Project Specifications

Items	Specifications
Name of river/river system	Beça River
Installed capacity (kW)	10,000
Maximum discharge (m^3/s)	5.38
Effective head (m)	226.44
Generator type	One horizontal Francis unit
Type of power plant	Dam – penstock
Penstock	Φ1,800mm Flowtite plastic pipe: 3.7km length Φ1,400mm Steel: 1.9km length
Connection type	On-grid

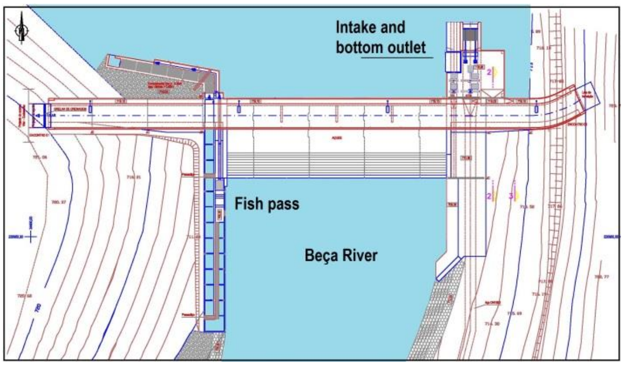

Fig.-2 Plan view of the dam[2]

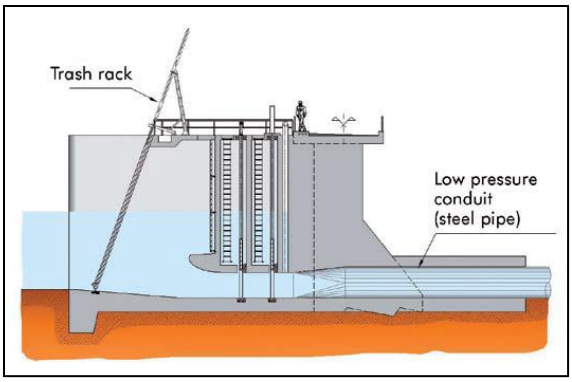

Fig.-3 Intake section[2]

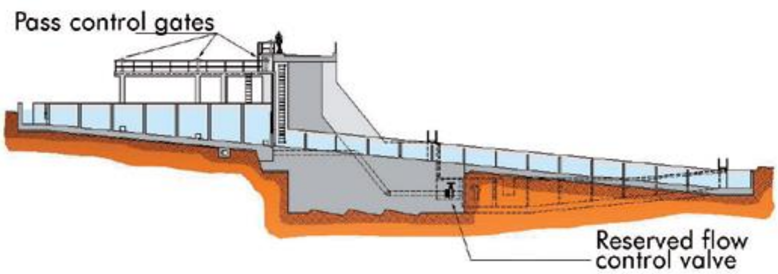

Fig.-4 Longitudinal section of the fish pass[2]

Photo-1. Fish passage in operation[2]

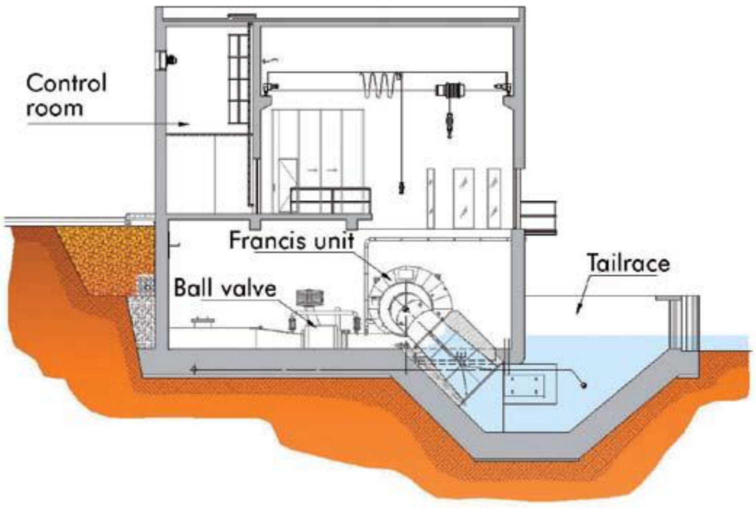

Fig.-5 Powerhouse[2]

Photo-2. Powerhouse interior[2]

2. Financial Viability of the Project

(1) Financial viability improved by dividing the project into a number of contracts

Rather than a single contract with a large enterprise on a turnkey basis, a number of contracts are managed by dividing the project into several lots. This resulted in contracts with smaller businesses locally with more competitive prices, improving financial viability. The initial capital investment cost was €31,090,070 which was funded from a bank with the payback period of 22 years. There were no subsidies applied for this project.

(2) Securing profit by the optimized reservoir operation

The maximum storage capacity of the dam is optimized during the daytime, to be the highest in the morning when the energy tariff is higher, to increase the profit, and it is minimized in the evening so as to store the water.

The data taken over 5 years from 2010 to 2014 show that annual gross revenue was €3,052,260 and operation and maintenance cost was €226,740 per year, yielding the EBITDA[1] of €2,825,520 (see Table-2). Therefore, simple payback period for capital investment cost was calculated for 11 years.

Table-2 Main commercial data using 5 years average (2010～2014)

Capital investment cost (x1,000€)	Production (GWh)	Average energy price in 2014 (€/MWh)	Gross revenues (€/Year)	Operational cost (x1,000€/Year)	EBITA (x1,000€/Year)
31,090.07	31.51	92.17	3,052.26	226.74	2,825.52

3. Economic Benefits of the Project

(1) Tax revenue and contributions for the community

The property tax, water use tax and corporate tax have been paid to the region by the implementation of the project. Further, RPG provided a financial contribution, which was used by the municipalities for new social equipment. Table-3 shows the tax revenue for 5 years(Year:2010-2014).

Table-3 Tax revenue (Unit : €/year)

Year	2010	2011	2012	2013	2014
Tax on property	26.58	126.58	339.68	315.66	276.84
Taxes related to the water use	---	5,436.59	2,470.13	1,938.11	4,904.45
Corporate tax	249,627.00	0.00	0.00	77,022.88	180,594.76
Donations	0.00	1,000.00	0.00	1,000.00	2,000.00
Total	249,653.58	6,563.17	2,809.81	80,276.65	187,776.05

(2) Employment opportunities

The main part of the civil works construction was carried out by local workforce, contributing to the regional economy.

The local companies carry out some of the annual maintenance operations such as access repairs, vegetation removal and irrigation channels repairs. To date, these costs have amounted to not less than **€**17,000 each year.

(3) Economic spin-offs to the community during the construction

The external workforce during construction also contributed to the regional economy, through intensive usage of the local restaurants and hotels available in the region.

4. Social Aspect of the Project

4.1 Local Environment

[1] Profit before deducting interest, tax payment, depreciation of tangible and intangible fixed assets

1) Guaranteed irrigation discharge by dam automatic system

The region has an ancestral winter irrigation method called "rega de lima" for protection against frost, where the water is conveyed through long open channels called "levadas". In 2003 RP Global carried out a very deep and extensive analysis of the complex system of levadas in order to analyse the demand of the irrigation users and optimise the system. The dam automation scheme guarantees the release of the necessary irrigation flows in order to accommodate this concurrent water use.

2) Economic effect on the region during the construction

The local population's mobility has been improved by the new road and the bridge over the dam, which connect the villages of Vilar and Codecoso. Before their construction, the travelling distance between those two villages was 9.3km, and now, it stands at only 3.1km. The bridge over the dam, and the correspondent accesses, were part of the agreements and contributions made with the local populations and Municipalities. The cost of these works was approximately 500T€, which was paid solely by RPG.

3) River environment conservation

The fish pass was designed to operate at a satisfactory level continuously throughout the year at every level of reservoir operation, given the importance of the trout farming community on the Beça River. This conservational approach was combined with an environmental study into the river's flow, which enables the preservation of all species, habitats and ecological characteristics downstream.

The installation of a hydroelectric power plant requires that every three years, upstream and downstream the project, the water quality of the river must be measured and analysed to demonstrate its ongoing sustainability.

4) Landscape conservation

During the design phase, before defining the dimensions and appearance of the power house, and due to its aesthetic visual impact on the village, RP Global decided to organise an architectural competition. With the support of a reputable Austrian architect, RP Global has agreed with the University of Architecture and Arts in the University of Coimbra (Northern Portugal) to organise the competition among the senior students, and to submit design proposals and ideas for the hydroelectric power station, focusing on the landscape and architectural framework.

Photo-3 Powerhouse[2]

After considering the projects submitted, the most interesting ideas were utilised and adopted: namely the cube shape, the large windows, and the exterior pedestrian access which allows people to look inside the building. Photo 3 shows the external view of the powerhouse. The idea behind it was to "open" the power plant to all local people, within the health and safety guidelines, and to bring the local community closer to the plant, so that they might better understand the benefits through this literal transparency.

5) Pipes buried underground / Water utilized for other purposes

The dam's reservoir provides other significant advantages, including acting as a water reserve to fight forest fires; for recreational purposes such as fishing; as well as serving as a water reserve for cattle and wildlife.

All pipes, penstock and pipeline, were placed into a trench and completely covered with soil. This solution allows the maintenance of existing traditional culture, as well as ensuring the preservation of existing flora and fauna. Also, with this solution, the pipes are insusceptible to fires or other physical damage.

4.2 Local Community

1) Regional vitalization by the measure of irrigation system improvement

This region is an interior zone of the country with a depressed economic condition, mostly due to population migration from rural to urban areas. As a consequence, the residents are predominantly the elderly, who rely on agricultural work and cattle breeding. RP Global hopes that the hydropower plant, Canedo, slows down that negative process, due to the measures taken in the irrigation system.

2) Regional vitalization by regional infrastructure development

The construction brought greater prominence to the region which is very rich in scenery, and also – perhaps surprisingly – in gastronomy[2]. In 2009, the prestigious annual event, "Portugal lés a lés" included this region in its motorcycle tour. This meant that hundreds of motorcycling enthusiasts were able to utilise the great improvements in local transportation infrastructure which resulted from the construction of the plant.

During project construction it was possible to improve approximately 8km of the local existing roads, and also build 6km of new ones. Some were constructed because it was necessary for work to progress, others resulted from the needs of the local community, allowing the public to reach difficult places for agriculture or forest firefighting.

As a contribution to the local region, the local communities were offered €600T in compensation to be used for construction projects chosen accordingly by local authorities. Several works of improvement in local infrastructures, such as roads and paths to water supply and sewage were proposed by them and executed during the ten month construction period.

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[2] Although food ingredients from the Atlantic Ocean are easy to gain, Portuguese cuisine uses many Mediterranean Sea products. It is famous for seafood, and due to Portugal's trading activities in the colonial period, it uses various spices including piri piri (meaning "small and fiery pepper"), black pepper, cinnamon, vanilla and saffron. Olive oil is used as the base for most Portuguese cuisine, both for cooking and flavoring. Garlic is very popular as are herbs such as bay leaves and parsley.

5. Reasons for the Success

Contribution to the regional community and environment

It can be said that, since the beginning development up to completion, we have permanently kept a team on site with an open dialogue to the local population and authorities, allowing them to clarify all issues related to the project.

There were several briefings with the population and authorities in order to explain the results from the measurement campaigns in the irrigation channels, in which we were always striving together for the best solutions for any problems that arose. Since the beginning, it was decided to consider the local community as partners and neighbors, with whom we have to cooperate for the next 35 years, which is the time defined in the water use permit issued by the central government.

6. Outside Comments

(1) The power plant in the first year was widely reported in the local press.

(2) The very next year it was mentioned on national television in a story about forest fires. Footage showed a helicopter filling up its water tanks in the center of the dam reservoir, to be used to fight a deadly forest blaze.

(3) IWP&DC's Best Small Hydro Project' award (Oct. 2009): International Water Power & Dam Construction

7. Reference

[1] International Water Power & Dam Construction (July 2009): Best of the best in small hydro

[2] International Water Power & Dam Construction (December 2009): Canedo hydro plant – an award-winning design

[3] RP Global: http://www.rp-global.com/

UK01

Name of the Power Plant: Eigg Hydropower Stations

Country (State/Prefecture)： United Kingdom (The isle of Eigg, Scotland)

Owner

Name of owner： Eigg Electric Ltd. (Subsidiary of the Isle of Eigg Heritage Trust)

Type of ownership： Community-owned power utility / Community-owned private company

Type of market: Community-owned power utility

Commissioning Year： Feb., 2008

Project Evaluation

Financial Viability: Recovering initial investment, Securing the cost of maintenance and management, Securing an appropriate level of profit

Economic Benefits: Tourism resource, Local industrial improvement

Social Aspects: Local Environment: Infrastructure improvement, Preservation of a natural park
Local Community: Vitalization of local community, Facilitation of regional development, Education for environment/energy, Improvement to public appeal of the local region

Keywords: Renewable Energy Hybrid System, Self-Supply System, The Isle of Eigg Heritage Trust, The United Kingdom's National Endowment for Science, Technology and the Arts (NESTA), Power source of remote island, Micro grid, Demand side management

Abstract

The Isle of Eigg is situated approximately 25km off the west coast of Scotland and has a permanent population of less than 100. Since it was not connected to the national grid, residents depended on individual diesel generators or a micro hydropower plant. The Isle of Eigg Heritage Trust (EHT)[1], a charitable organization with members of Eigg Island residents, the Scottish government, environmental NGOs, acquired land ownership of the island in 1997. Since the buyout, the Isle of Eigg Heritage Trust has established its own independent energy grid to be entirely self-sufficient in

[1] The Isle of Eigg Heritage Trust is a company limited by guarantee, and a registered Scottish charity. The Trust has three members, namely, Eigg Residents' Association, The Highland Council and The Scottish Wildlife Trust.

terms of energy, as a part of infrastructure development and started its operation in 2008. The hybrid power generation system consists of small-scale hydro, wind and solar power generation, stand-by diesel generation, batteries, a load management system and a network of underground high voltage distribution grid. The Eigg Electric Ltd., a subsidiary of the Isle of Eigg Heritage Trust, operates the system. Hydro power generation system has one run-of-river (100kW) and 2 Pico generators (6kW each) which supply over 70% of energy demand of the island, making hydropower the most important energy source. To prevent overloading, household electricity use is capped, to which the residents are agreeable so that enough energy is constantly secured for all users. Financial viability of this project is secured by utilization of funding at the time of construction, application of FIT and ROC (Renewable Obligation Certificates) and pre-payment system to cover maintenance and operation costs.

1. Outline of the Project

The Isle of Eigg is part in the Inner Hebrides group of islands. It is situated off the west coast of Scotland, south of the Isle of Skye, approximately 25km from the mainland coast. The nearest mainland port is Mallaig. It is approximately 45km² in area and has a permanent population of less than 100. Its permanent residences number less than 50 and it has approximately 20 commercial buildings and half a dozen community buildings. Fig.-1 shows the plant locations and the island grid.

Before the electrification project came to life in 2008 the island did not have electricity supply. Most residents used individual diesel generators but a few relied on a micro hydropower plant. Batteries/inverters were commonly used to ensure electricity access. The cost to users varied depending on the size of generators used, their running time and cost of fuel but on average most

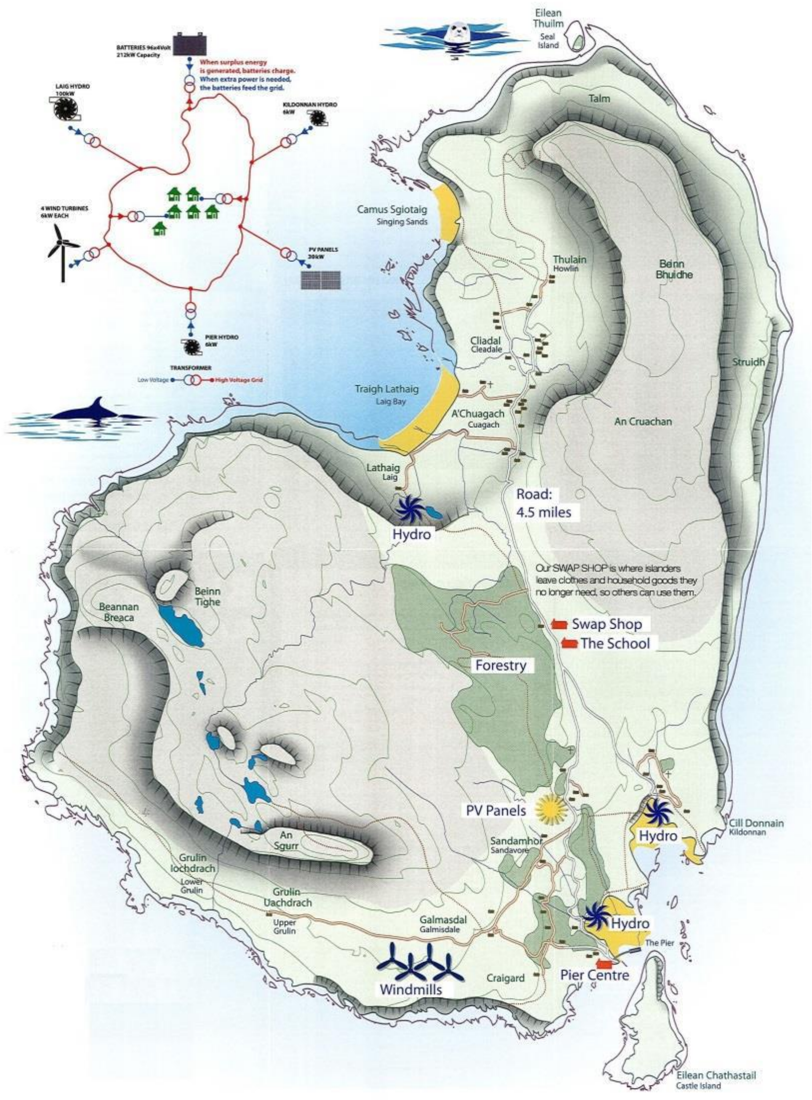


Fig. 1 Plant Location & Island Grid

users used to spend £500 per year of diesel generator running cost in 2003. Isle of Eigg's remoteness from the Scotland mainland has proven to be uneconomical to connect to the national grid. The cost of connecting the island to the main grid system in the mainland was estimated between £2 million and £4-5 million but funding for the investment was hard to find and the plan was abandoned.

Now the Isle of Eigg is a model of energy sufficient island, because all electricity generate locally. The new system incorporates a 50kWp PV system, three hydro generation systems (totaling 112 kW) and a 24 kW wind farm supported by stand-by diesel generation and batteries to guarantee continuous availability of power (see Photo–1 which shows all the generation systems and see Table–1 for their specifications). A load management system has been installed in the same management building for PV, batteries and stand-by diesel generators to provide optimal use of the renewables. This combination of solar, wind and hydro power should provide a network, in which 45 houses, 6 buildings and 20 shops along 16km long underground high voltage distribution system are connected, that is self-sufficient and powered 98% from renewable sources. To prevent overloading, household electricity use is capped at 5kW and that for commercial properties is capped at 10kW each (see Fig.–2, Photo–2 and –3). This gives the simultaneous total maximum load of 225kW, but the system demand remains much lower due to load diversity and demand management practices.

The system was turned on 1 February 2008. The Eigg Electric Ltd., a subsidiary of the Isle of Eigg Heritage Trust, manages the electricity supply and distribution activity on the island. The system generates a finite amount of energy and so Eigg residents agreed from the outset to cap electricity use at 5 kW at any one time for households, and 10 kW for businesses. If renewable resources are low, for example when there is less rain or wind, a "traffic light" system asks residents to keep their usage to a minimum. The traffic light reduces demand by up to 20% and ensures there's always enough energy for everyone.

Photo-1 System components

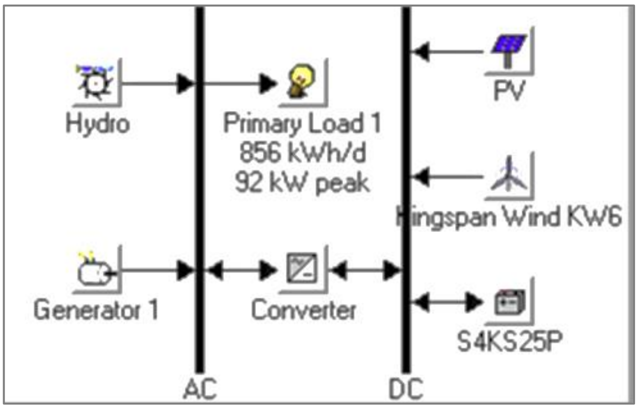
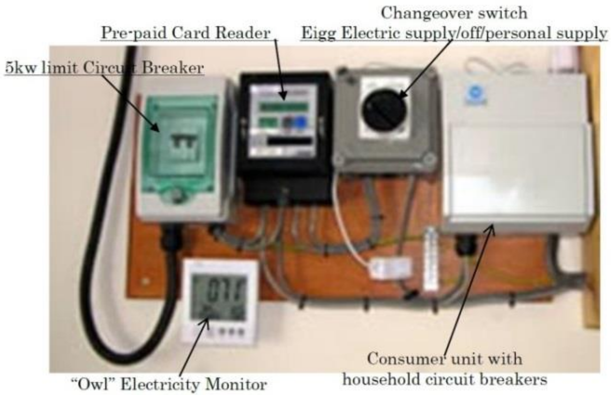


Fig.–2　System configuration diagram



Photo–2 Meters at home[7]

Photo-3 Outdoor switchboard

Table-1 Project Specifications[3]

System	Items	Specification
PV array	Power	50kWp
	Modules	60 x BP Solar BP31655PV
	Inverters	(2 x SMA Sunny Boy SB-3000) 21kWp
		126 x BP Solar BP4180 180Wp PV (3 x SMC-7000HV) 22.5kWp
		90 x REC Solar REC 250PE 250Wp PV (3 x SMC-7000HV)
Wind turbines	Model	kW6 Kingspan
	Power	4 x 6kW
	Inverter	6 x SMA Windy Boy WB-6000A
Hydro turbine	Model	Gilkes Single Jet Turgo
	Power	100kW, 6kW, 6kW
Diesel generator	Power	2 x 80kW Thistle Generator P80P1
Battery bank	Model	Rolls Surrette 4KS25 PS
	Quantity	4 clusters 24 batteries each
	Inverter	12 x Sunny Island SI-5048 5 kW
Controller		Multicluster Box

Photo-4 Laig farm hydropower plant

Photo-5 Pico hydropower generator

2. Financial Viability of the Project

(1) Funding secured from a number of sources

The project cost was £1.66 million in 2008. Funding the investment was a significant challenge for the Isle and was secured from a number of sources as grant as indicated in Table–2, such as European Regional Development Fund (ERDF) aimed at regional development within

European Union, Scottish Community and Householder Renewables Initiative (SCHRI) which is a Scottish government-funded programme to develop community- and household-based renewable energy schemes and Highlands and Islands Enterprise (HIE) which is the Scottish Government's economic and community development agency having the role to develop sustainable economic growth across northern and western regions of Scotland.

Table-2 Source of project funding[5]

Source	Share (%)
European Regional Development Fund	46%
Scottish Community and Householder Renewables Initiative	12%
Highlands and Islands Enterprise, Lochaber	18.9%
Big Lottery Fund	15%
Island Trust and residents	6%
Energy Savings Trust	2%
Highland Council	0.1%
Total (￡1,664,828)	100%

(2) Off-grid FIT and ROC

The electricity company covers the running costs by using revenue generated through the off-grid Feed-in Tariff (FIT) [2]and the income from Renewable Obligation Certificates (ROCs) [3]and local tax paid by enterprises and residents.

(3) Pre-payment system with respect to operation and maintenance cost

Electricity charges are collected via pre-payment card operated meters, and are set at a level necessary to allow Eigg Electric Ltd. to fulfill its duties to the community. The tariff in the island is higher than the tariff charged for electricity on the mainland. These have been set to cover the costs of operation and maintenance of the system, with an amount accumulating over time to form a sinking fund for replacement components.

(4) Electricity consumption restriction for construction cost reduction ("Capping" system)

To reduce facility investment costs, household electricity use is capped at 5kW and that for commercial properties is capped at 10kW each.

(5) Effective use of renewable power in the hybrid system

Figs.-3 and -4 present the monthly electricity production from the system between 2009 and 2015. They show that 70 to 90% of the island's total power demand is supplied by renewables,

[2] Like the Feed-in Tariff, the off-grid FIT pays households or businesses a fixed payment per unit of energy generated to promote the use of renewable technology. All power produced by renewable generation systems approved by the Office of Gas and Electricity Markets (Ofgem) is purchased for generation tariff.

[3] Renewables Obligation Certificates (ROCs) are green certificates issued to operators of accredited renewable generating stations for the renewable electricity they generate. ROCs can then trade with other parties. They are used by suppliers to demonstrate that they have met their obligation. ROC is now applied to all generation facilities of 50kW or greater capacity. Although the project has received grant funding, it also benefits from feed-in tariff and ROC payments as the project came into operation prior to the rule change in the United Kingdom that disallows state aids in the form of feed-in tariff or ROC for grant-funded renewable energy projects

and periods of the year during which diesel generation is heavily depended on are limited.

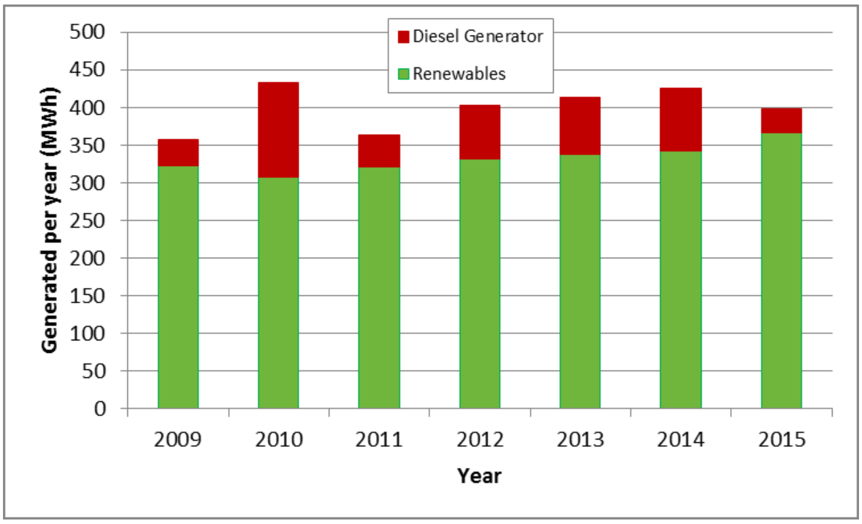


Fig.-3 Electricity production between 2009 and 2015[6]

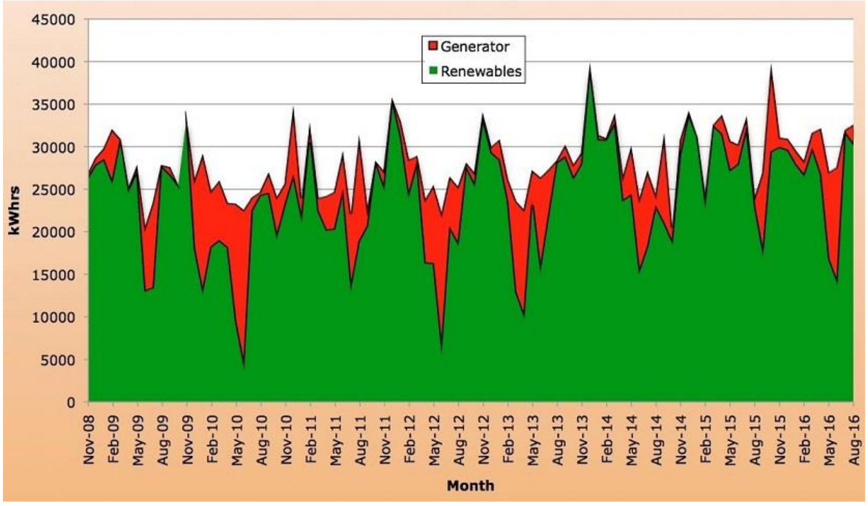


Fig.-4 Electricity consumption/production for each month

(November 2008 through August 2016)[6]

Fig.–5 shows monthly energy consumption and the breakdown of energy production for each month during fiscal 2015. It shows hydropower generation covers 50-90% of all power generation.

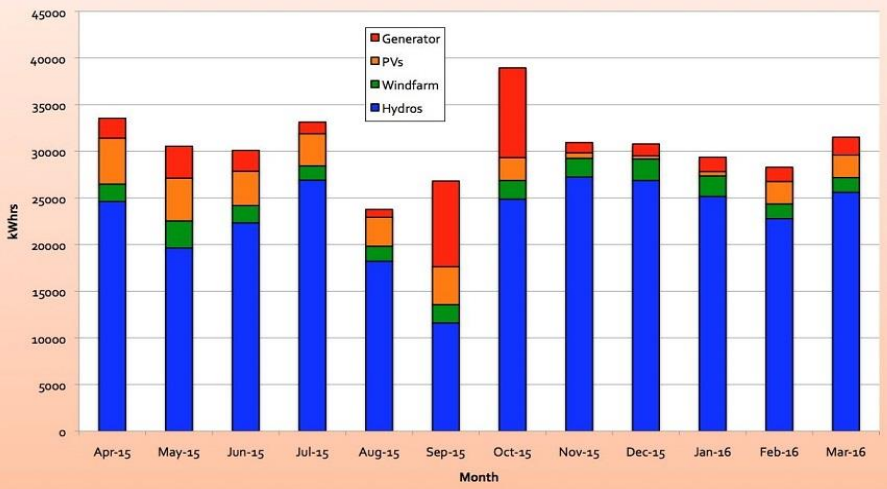


Fig.-5 Breakdown of energy production for each month during fiscal 2015[6]

3. Economic Benefits of the Project

(1) Regional infrastructure improvement

After acquiring the ownership of Eigg Island in June 1997, the islanders built a new jetty, restored their own house, refurbished village hall and school, refurbished coffee shops and visitor's accommodations. Further, they are constructing Laig farm hydropower station, solar power generation, wind power generation and so on by building an electric power self-sufficiency system of the island.

(2) Increase of visitors

Eigg with its nature and heritage and its renewable grid is attracting interest and having an impact across the world. An increasing number of visitors from academic institutions and development organizations are taking the ferry to the island. Recent visitors have come from Alaska, Pitcairn Island, Nigeria and Jamaica.

Tourists and group training teams attracted to the beautiful nature on the island are also on the increase (about 10,000 people visit during the months between April and September).

4. Social Aspects of the Project

4.1 Local Environment

1) Reduction of CO_2 emission by renewable energy utilization

Their carbon footprint has fallen considerably as about 90% of their electricity comes from renewable sources of energy. It is reported that the CO_2 emission per household in the island is 20% lower than the rest of the UK.

2) Conservation of natural and social environment

An underground transmission grid was built with respect to landscape conservation of Eigg and its nature and heritage.

4.2 Local Community

1) Modern life style supported by renewable energy electrification system

The Isle of Eigg off-grid electrification system clearly shows that an off-grid system can support the electrical energy needs of a modern life style. The islanders receive 24 hr supply and have no complains about the supply. It also helps tourism by furnishing accommodation facilities with an uninterrupted power supply.

2) Power system operated by islanders

This system is jointly operated as equipment of the islanders, and strengthens the unity of residents in the island.

3) Counteracting depopulation

The population has grown significantly over the past few years partly due to a young generation who once left the island coming back to live and do business. The new energy grid and 24 hour power has given house building a boost.

5. Reasons for the Success

(1) Financial Viability of the Project

The Scottish government has several schemes to fund renewable energy projects and development of remote areas, which EHT, a registered Scottish charity, was able to use for the construction. Another factor that helped reduce the initial investment cost was that application of ERDP was granted. In addition, the residents taking active parts in the operation of the system by cooperating with a restriction of power usage when necessary and the pre-payment system helped reduce the facility costs to secure maintenance and operation cost.

(2) Establishment of self-sufficient power system by renewable energy sources

Very few off-grid communities in remote areas, including remote islands, have been successful in completely establishing a self-sufficient energy supply system in which almost all power sources are renewables with the exceptions of demonstrative projects. This project on Eigg Island therefore attracts attention both domestically and from abroad. It has won the Big Green Challenge of the United Kingdom's National Endowment for Science, Technology and the Arts (NESTA)[4] and the prestigious UK Gold Award (Ashden Award[5]). As an economic spin-off to the island community, visitors from academic institutions and development organizations, as well as tourists, are on the increase.

6. Outside Comments

(1) In September 2008, Eigg began a year-long series of projects as part of their success as one of ten finalists in NESTA's Big Green Challenge. While the challenge finished in September 2009, the work to make the island "green" is continuing with solar water panels, alternative fuels, mass domestic insulation, transport and local food all being tackled. In May 2009, the island hosted the "Giant's Footstep Family Festival", which included talks, workshops, music, theatre and advice about what individuals and communities can do to tackle climate change.

(2) In January 2010, Eigg was announced as one of three joint winners in NESTA's Big Green Challenge, winning a prize of £300,000. Eigg also won the prestigious UK Gold Award(Ashden Award) in July 2010.

7. Reference

[1] Island Power Eigg Electric

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4) The United Kingdom's National Endowment for Science, Technology and the Arts (NESTA) was established in 1998 as a grant organization dedicated to supporting advanced, innovative projects by individuals and organizations and human resource development in the three areas of science, technology and the arts.
The key word in grant decisions is "Innovation." Choosing the term "investments" instead of "grants", NESTA "invests" in projects in the areas of pioneering businesses, unique inventions, national health and projects that promote understanding of scientific technology, all with the aim of nurturing innovative talent that will lead to clear returns for British society in the future.

5) Ashden rewards and promotes local sustainable energy solutions in parts of Europe and the developing world through its annual Ashden Awards. Awards are given to organisations and businesses that deliver local, sustainable energy schemes with social, economic and environmental benefits. Awards are provided across several different categories, including UK and international awards.

[2] "Best Practice Case Study : Islands going green, Isle of Eigg, Scotland,UK"
www.rets-project.eu
[3] Analysis of off-grid electricity system at Isle of Eigg (Scotland): Lessons for developing countries/Renewable Energy (journal homepage: www.elsevier.com/locate/renene)
[4] BBC NEWS/Eigg powers on with energy scheme
[5] The Scottish Government/Community Renewable Energy Toolkit
Case study 17 : Electrification of Eigg, Isle of Eigg – PV, Hydro & Wind turbines
http://www.gov.scot/Publications/2009/03/20155542/37
[6] Eigg Electric Ltd.: http://isleofeigg.net/green_eigg.html
[7] Isle of Eigg, Inner Hebrides, Scotland/Wind & Sun Ltd.
(http://www.windandsun.co.uk/case-studies/islands-mini-grids/isle-of-eigg,-inner-hebrides,-scotland.aspx#.WGtdQLm7rIU)

UK02

Name of the Power Plant: Torrs Hydro

Country(State/Country): United Kingdom(Derbyshire, High Peak)

Owner

Name of owner: Torrs Hydro New Mills Ltd. (A community-owned company)

Type of ownership: Power producer / Industrial and Provident Societies (IPS)

Type of market: Power purchase agreement with users

Commissioning Year: Sep. 2008

Project Evaluation:

Financial Viability: Recovering initial investment, Securing the cost of maintenance and management

Economic Benefits: Tourism resources, Usage of profit for the benefit of the community

Social Aspects: Local Environment: River environment conservation, Preservation of landscape and/or culture, Preservation of a natural park

Local Community: Vitalization of local community, Education for environment/energy, Improvement to public appeal of the local region

Keywords: Industrial and Provident Societies (IPS), Reverse Archimedean Screw Turbine, Renewable Energy Resources Cooperative, Fish pass

Abstract

Torrs Hydro is located in the Torrs, Riverside Park in New Mills, Derbyshire. Torrs Hydro (New Mills) Ltd is a small Renewable Energy Sources Cooperative (REScoop) that was founded in 2007 and is incorporated as an Industrial and Provident Society (IPS[1]) for the benefit of the community. This plant is the first community- owned hydro scheme in the United Kingdom. The corporate objectives of Torrs Hydro New Mills Ltd. as well as the investors who are local community members, include promoting environmental sustainability in the New Mills area, educating on enterprises which benefit the local environment and providing an opportunity for people to contribute financially to the community. With

[1] An IPS is 'an organization that conducts industry, business or trade either as a co-operative or for the benefit of the community' As such, it does not distribute to its members any profit made through its activities. The IPS has been renamed as Community Benefit Societies by the Co-operative and Community Benefit Societies Act 2014.

these goals in mind, they have developed a grant system out of revenues from the hydro project for other community projects and an educational program on environmental issues. The system is rated at 63kW and is designed to produce around 240,000kWh of electricity per year. The electricity produced by the weir is used to power a nearby supermarket. On average the system produces 60-70 per cent of the local Co-op supermarket's electricity consumptions over a 24-hour period, and also sell the excess to the grid during the night when the Co-op is shut. Torrs Hydro is open to the public and offer open days for visitors to come and see the scheme as well as offering school visits and private visits to others considering a scheme.

1. Outline of the Project

Torrs Hydro is located where the River Goyt and the River Sett join in New Mills. The scheme is installed on an existing weir on the site of Torr Mill, a textile mill built in 1790 which was destroyed in a fire in 1912. Photo-1 shows the layout of power plant components and Table-1 shows the project specifications.

Photo-1 Components of Torrs Hydro[2]

1-River Goyt; 2-River Sett; 3-Torr Weir; 4-Headrace; 5-Powerhouse; 6-Fish Pass; 7-Turbine Generator; 8-Tailrace; 10-Ruins of Torr Mill; 11-Torr Bridge

The turbine actually sits in the same location as the original mill pit, where the water wheel would have been. Some of the original stones from the mill pit now line the surrounding of the turbine.

A 63kW Reverse Archimedes screw turbine aims to generate over 240,000 kWh/year. Torrs Hydro worked closely with the developer and the Environment Agency to ensure that the scheme was environmentally sustainable. This included installing a fish pass to allow the movement and migration of fish up and down the river.

Table-1 Project Specifications

Items	Specifications
Name of river/river system	River Goyt and River Sett
Maximum output (kW)	63
Maximum discharge (m^3/s)	3.0
Effective head (m)	3.0
Water turbine type	ϕ 2.6m Reverse Archimedes Screw Turbine
Generator type	3-phase Synchronous generator
Power generation type	Run-of-river
Grid connection	On-Grid

The scheme uses a 9m long reverse Archimedes screw turbine weighting 10 tonnes (see Photo-2). The placement in the gorge was the main obstacle. The gorge is a historical site near the old Torrs mill with a history of business activity. Therefore, archaeologists had to be involved in the construction. The constructer did a month of archeological excavation before they could start to remove 3 meters of Gristone bedrock. After building the structure to hold the turbine, including a fish pass, the turbine was lowered from historical Union Bridge into place (see Photo-3).

Photo-2 Lowering the turbine from historical Union Bridge[2]

Photo-3 Turbine and Fish Pass[2]

Torrs Hydro objectives include promoting environmental sustainability in the New Mills area, educating on enterprises which benefit the local environment and providing an opportunity for people to contribute financially to the community. With these goals in mind, the members have developed a grant system out of revenues from the hydro project for other community projects and an educational program on environmental issues.

2. Financial Viability of the Project

(1) Project cost and funding

Torrs Hydro New Mills Ltd. is an Industrial and Provident Society. Since Torrs Hydro has been able to identify itself with the resolve to use the profit made by this mini hydro plant in regeneration of the community and promotion of environmental sustainability in the New Mills area, it has been able to raise funds using the nationwide financing scheme. IPS is an organization that conducts industry, business or trade as a co-operative financed by shareholders, but it is operated in a democratic way by giving the right of one vote to each shareholder regardless of the amount of shares held. There are 231 shareholders for Torrs Hydro, two thirds being local people and businesses who have one third of the shares and the rest from further afield who hold two thirds of the shares. Table 2 shows the project cost and funding composition.

Table-2 Source of project funding

Funding source	Share (%)
Torrs Hydro Community share (231 members)	37.9
Grant funding from; - The East Midlands Development Agency - The Co-operative Fund - The Sustainable Development Fund of the Peak District National Park	40.9
10-year loan from the Co-operative Bank	21.2
Total (£330,000)	100

(2) Electricity generation and Profit/Loss

Fig.-1 shows annual electricity generation for each calendar year from 2008, the year of commissioning, to 2014. In 2011 electricity generation dropped off because of flooding in this area. Fig.-2 shows the average, best and worst record of monthly generation during the 7 years since commissioning. During the months from June to August, it is the dry season in this area and less power was generated as a result of less precipitation.

Gross generated output since the start of operation reached 1,000,000kWh on April 8th, 2015.

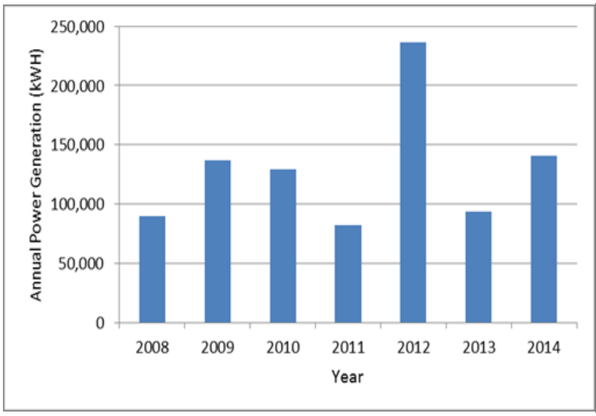

Fig.-1 Electricity Generation for each year from 2008 to 2014[5]

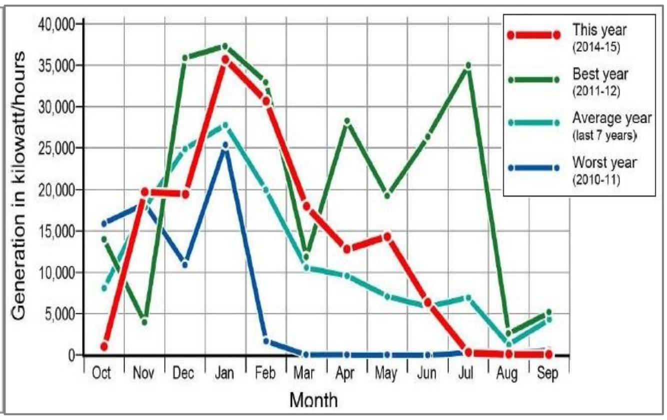

Fig.-2 Output Power Chart by month[3]

Fig.-3 shows annual profit/loss from fiscal 2008 (October to September the following year) to 2014. No profit was returned in the first 3 years after commissioning until 2012 when the profit was made because of increased power generation.

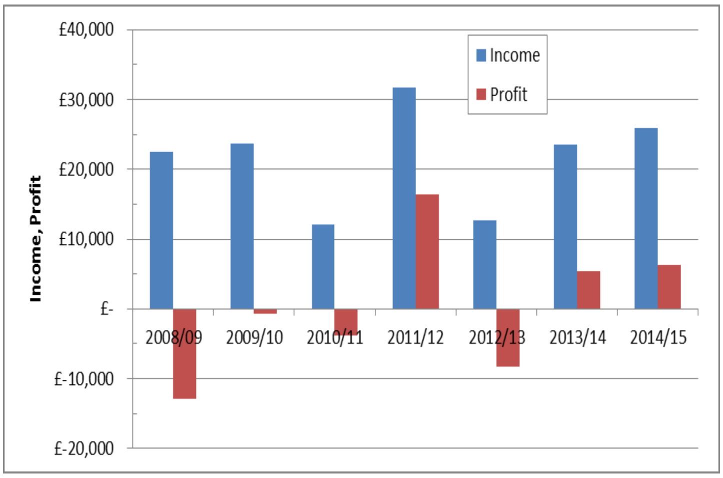

Fig.-3 Income and Profit/Loss for each fiscal year from 2008 to 2014[7]

(3) Securing the economical efficiency by purchasing the electricity with local supermarket

The Coop Bank helped by providing a loan, making a capital grant, and by agreeing to purchase the electricity to power their local supermarket, thereby putting in place a secure income stream for Torrs Hydro.

Photo-4 Local supermarket

(4) Operation and maintenance cost

Profit gained through the sale of electricity is used for the payment of local tax, charges for water use and operation / maintenance cost.

Torrs Hydro is run entirely by volunteers. The maintenance costs are kept very low as the plant continues to be checked daily and maintained by a group of talented and committed volunteers. The volunteer members continue to build on their experience of managing the plant and this helps the plant to maximize the running time of the equipment.

(5) Renewable Obligation Certificate (ROC)

Because this project was developed before the implementation of the Feed-in-Tariff, ROC can be traded.

(6) Dividend to Torrs Hydro Community shareholders

Loan repayment is prioritized as the usage of the profit, and the remaining small sum is used as dividend to the Community shareholders. The amount of grants to other community projects and an educational program on environmental issues is determined at the annual meeting of the cooperative.

The loan was scheduled to be paid off in late 2018, however, full repayment has already finished in late 2016, 2 years earlier. The equipment and civil structures maintenance will have to be considered as a new expenditure.

3. Economic Benefits of the Project

(1) An increase of visitors in the power plant

People who have ideas of developing their own hydro schemes are visiting the town of New Mills and the site of Torrs Hydro scheme. The regular events such as fairs and festivals at the site gives added motivation.

(2) Construction procurement at a local

Around 60 per cent of the construction costs were spent in the area. For example, a local company built the sluice gate.

(3) Micro hydro generation is gaining popularity

The scheme implemented in this micro hydropower generation is helping to establish similar projects in other areas.

On the same Goyt River, 8km downstream of Torrs Hydro Scheme, this first community-owned mini hydro plant in Manchester was built at Otterspool weir and commissioned in 2012.

Photo-5 Stockport Hydropower plant [6]

4. Social Aspect of the Project

4.1 Local Environment

1) Migratory fish protection

Torrs Hydro works very closely with the Environment Agency, the guardian of the nation's rivers. They funded the fish pass incorporated into the scheme to allow upstream access for migratory fish.

2) Local development and landscape conservation

The New Mill area became rather desolate after the textile mill was destroyed. When the Torrs Hydro scheme was started, pedestrian's sidewalks, cycling courses alongside the river and a square in the park were built at the same time, developing an attractive local environment for the area.

3) Preservation of local environment

The turbine actually sits in location of the original mill pit, where the water wheel would have been sited. Some of the original stones from the mill pit now line the surroundings of the turbine. The Environment Agency contributed to the landscaping of the area by turning a felled tree into a sculpture of leaping fish.

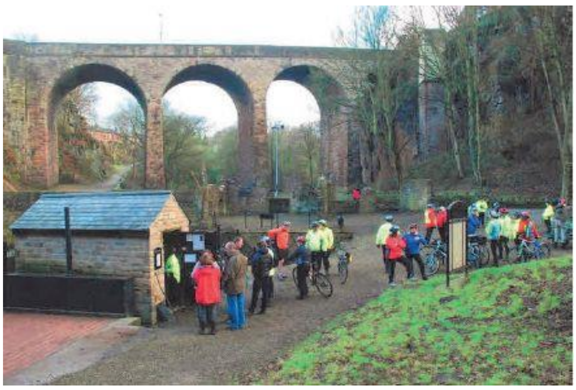

Photo-6 Park Square in front of the power

4) Consideration for other water users

Water flow is controlled to ensure the weir does not run dry and to keep the water level constant.

4.2 Local Community

1) Sustaining local culture

- The local Town Council were involved from the beginning of the scheme, and the council-run Heritage Centre provided information and hosted events for Torrs Hydro.
- Local businesses and groups have supported the project, echoing the enthusiasm of local people for the project.
- Community Benefits

The majority of the profits from the scheme will fund a community grants program:

- New Mills Solar Schools Project
- New Mills Heritage Centre
- New Mills One World Festival
- New Mills Festival
- Sticky Exhibits (environmental education)
- Provided refreshments for the New Mills Walkers are welcome kick-off event
- Sponsored a tree at St George's Parade of Trees
- Hosted a number of art projects carried out by students at New Mills School

2) Education on environmental and energy issues

The machine also acts as an educational facility for students from primary school age through to university, and a training facility for the Environment Agency. The weir, alongside Archie, is also used by Derbyshire Fire and Rescue Service for training.

5. Reasons for the Success

In the United Kingdom, the main objective of social corporates is to reinvest the profits for the benefit of the community and environment. The objectives of Torrs Hydro New Mills Ltd. as well as the investors include promoting environmental sustainability in the New Mills area, educating on enterprises which benefit the local environment and providing an opportunity for people to contribute financially to the community. With these goals in mind, Torrs Hydro has been able to gain the understanding and cooperation of the investors to raise funds to construct this project and develop a grant system out of revenues for the benefit of the community. Another factor that made a considerable contribution to a secure income stream is the support for this scheme from the local co-op and its agreement to purchase the electricity at the same rate as power supplied through the main grid.

6. Outside Comments

A great deal of media coverage in newspapers and TV programs made Torrs Hydro known as the first community-owned hydro scheme in the United Kingdom.

7. Reference

[1]Best practices Report, REScoop 20-20-20

[2] toorshydro NEW MILLS, homepage (http://torrshydro.org/TorrsHydro/)

[3] Torrs Hydro Annual Report 2014/15(http://torrshydro.org/)

[4]Case Study: Torrs Hydro, Sustainable Funding Project, National Council for Voluntary Organisations

[5] Torrs Hydro New Mills Ltd. (URL: http://torrshydro.org/)

[6] New Mills Torrs Hydro Electric Scheme (http://www.shawfarmholidays.co.uk/new-mills-hydro.htm)

[7]Income and Profit/Loss for each fiscal year from 2008 to 2014 (http://www.torrshydro.org/TheProject/Community-Ownership.html)

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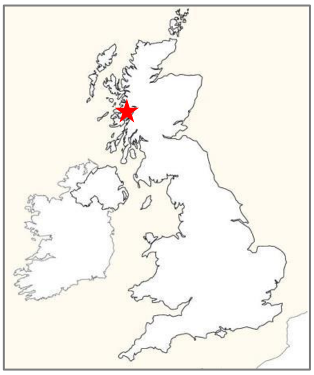

Name of the Power Plant: Abernethy Trust Hydropower Station

Country (State/Prefecture): United Kingdom (Ardgour, Scotland)

Owner

Name of owner: Abernethy Trust Outdoor Adventure Centre

Type of ownership: On-site Power Generator/Non-Profit Organization

Type of market: Surplus power sold under the FIT scheme

Commissioning Year: June 2010

Project Evaluation:

Financial Viability: Recovering initial investment, Securing the cost of maintenance and management, Securing an appropriate level of profit

Economic Benefits: Employment opportunities

Social Aspect: Local Environment : Infrastructure improvement
Local Community: Facilitation of regional development, Local activation by promoting inter-regional human exchange

Keywords Financial partnership with key supplier, Long-term equipment lease, Value engineering, Feed in Tariff, Outdoor activity programs for youths, Charity activities

Abstract

The Abernethy Trust Hydro Scheme is an 89kW conventional 'run-of-river' scheme (commissioned in June 2010) situated at Ardgour on the shores of Loch Linnhe on the West Coast of Scotland, developed by the Abernethy Trust Outdoor Adventure Centre of Abernethy Trust - a non-profit making charity organization specialising in outdoor activities of youths - to provide electricity to all the Abernethy Trust buildings, the facilities in its training center and also to the staff houses on the site. Taking advantage of the FIT regime, the surplus power is sold through the nearby transmission line and also used for water heating by an electric boiler to enhance the amenity value of the facility, reduce CO2 emission for environmental conservation and improve the quality of the charity activity. The scheme was part financed using a Manufacturer's long-term equipment lease. This

"financial partnership" involving the package of financing and equipment lease provides a reassuring incentive for the manufacturer to keep the equipment running as efficiently as possible and is helpful in developing a very close partnership between the manufacturer and the plant owner.

1. Outline of the Project

The Abernethy Trust Hydro Scheme is located at Ardgour on the shores of Loch Linnhe on the West Coast of Scotland. The catchment area feeding the Abernethy Trust scheme is approx 1.6 square kilometres and is subject to, on average, 2,376 mm rainfall per annum. The water is abstracted at a 1.3m high weir using a 'Coanda' style self- cleaning screen. This screen also allows no more than the design flow of 96 l/s (litres per second) to enter the intake. The water is then conducted via a 850m long penstock pipeline to a powerhouse, giving 126.4m of gross head. A secondary intake was utilised on a tributary to the main watercourse, in order to increase the size of the catchment captured by the scheme. From the intake channel beneath the Coanda screen, water is conducted through a header tank, and then into the main penstock. Throughout its length, the main pipeline is provided with concrete thrust blocks at all significant changes in direction (See Photos 1 & 2).

Photo-1 Main Intake

Photo-2 Secondary Intake

The powerhouse is constructed 200m from the main Trust building. Built on a concrete foundation, it covers an area of approximately 25 square meters (5 by 5 meters). The powerhouse contains the turbine, generator, hydraulics, main inlet valve and the protection and control panels. A 415V/11kV transformer and switching device are pole-mounted and located approximately 50m from the powerhouse. The turbine installed is a Gilkes 265mm (10.5") Single-Jet Turgo Impulse Turbine running with an in line 4-pole induction (asynchronous) generator and producing 89kW peak power.

The turbine has recently been redeveloped and optimised to suit the 100kW market defined by the UK Feed-in Tariff. The optimization process included reducing the manufacturing cost by standardization of components and Value Engineering[1]. New features include: a reduced 'footprint' and a self-contained electro-hydraulic actuator unit (that is installed directly on the turbine casing) rather than the traditional, separate hydraulic unit. A deflector mechanism is used to control the speed of the turbine during start up and as a shutdown to stop the generator when required. The actuator has an integrated, electro-hydraulic system that allows precise control in normal operation but will 'fail-safe' to the closed position in the event of loss of oil pressure (See Photo-3).


Photo-3 Internal View of the Power House

Table-1 shows the project specifications for Abernethy Trust Hydropower Station

Table-1 Project Specifications

Items	Specifications
Name of river/river system	Local Burn
Installed capacity (kW)	89
Maximum discharge (m^3/s)	0.096
Effective head (m)	120.0
Turbine type	Horizontal single-jet turgo impulse turbine
Generator type	3 phase induction generator
Type of power plant	Run-of-river, diversion weir – headrace – penstock
Penstock	Φ280mm x 850m
Connection type	On-grid

2. Financial Viability of the Project

The project was originally planned to have a capacity of 49kW. However, taking advantage of the FIT scheme would enable surplus power sales through the utility grid.

1) Value engineering is a systematic method to improve the "value" of goods or products and services by examining the "value" in relation to the "cost" at which due "function" is performed by them.

Since the project had already attracted significant public grant, a financial partnership through a long-term equipment lease with the turbine manufacturer (Gilkes) was considered in order to resize the project to 89kW capacity which eventually materialized.

The breakdown of power plant construction cost is shown in Table-2.

Table-2 Cost and Grant Funding [2]

Source	Amount (£)	Remark
CARES grant[1)]	100,000	(CARES grant percentage against total project cost: 33.6%)
Other grants and funding	119,000	Highlands and Islands Enterprise[2)]： £37,000 Leader[3)]： £25,000 Abernethy Trust： £50,000 Local community gifts in-kind： £7,000
Self-financing	101,000	Financial partnership with Gilkes
Total construction cost	320,000	

Note 1) The project was approved during the period of the Scottish and Community and Householder Renewables Initiative – however, due to the scale and timeline of the project, it was completed during the period of the Community and Renewable Energy Scheme (CARES) programme.

- Scottish Community and Householder Renewables Initiative (SCHRI):

  Scottish government-funded programme to develop community- and household-based renewable energy schemes, to heighten awareness for and promote technologies and industries related to the field. This programme was originally planned to last 3 years when it commenced in March 2003, but it was extended to March 2008 with the added budget granted in 2004.

- Scottish Government Community And Renewable Energy Scheme (CARES):

  CARES provides loan to renewable energy projects designed to benefit the community that is deeply interested in renewable energy utilization when such projects seem to have some risk of failure and may have difficulty in gaining approval. The Scottish Government released this new Scheme on February 15th, 2011. The Scheme is administered and managed by Local Energy Scotland in behalf of the Government.

Note 2) Highlands and Islands Enterprise (HIE) is the Scottish Government's economic and community development agency for northern and western regions of Scotland. Its role is to develop sustainable economic growth across the regions, which is unique because HIE aims to integrate economy and social growth. Its activities cover more than half of Scotland including Shetland, Argyll, Outer Hebrides and Moray. To achieve the role, it creates the infrastructure for future investment, assists large and small businesses with growth aspirations and has a unique role in strengthening communities, particularly in fragile areas.

Note 3) LEADER - Links Between Activities Developing the Rural Economy

LEADER serves as links between activities developing the rural economy and is a bottom-up method of delivering support for rural development through implementing Local Development Strategies.

(1) Scale of power production and equipment development suited to FIT

Considering potential energy at the site of the scheme, power production scale was determined in the course of discussion with Gilkes so that there would be a surplus of power that could generate profit. Facility investment cost was cut down by reducing the footprint and weight of the turbine, making the area that the plant occupied smaller.

(2) Equipment lease

The lease is linked to an agreed % of revenue – if the scheme is not generating no lease payments are due (unlike bank debt). This reduces the overall financial risk for the owner as in dryer than average years the lease cost reduces. This financing package and 'partnership approach' provides a reassuring incentive for Gilkes to keep the equipment running as efficiently as possible and develops a very close partnership between Gilkes and the plant owner who share a mutual interest.

(3) Generated output and O & M costs

Annually, about 344,000kWh is estimated to be saved at the Abernethy Trust Outdoor Adventure Centre which helps financing charity activities at the center. Approximately 5% of the annual revenue is highlighted for operational and maintenance costs.

3. Economic Benefits of the Project

(1) Utilization of heavy equipment owned by local farmers

The local farmers labored using their heavy equipment (for digging and hoisting) for the foundation work and delivery of heavy materials, which resulted in economic benefits to the region.

(2) New hydropower schemes

The success of this project opened the way to further adjacent scheme with a capacity of 50kW. This scheme is called "Abernethy Trust #2 Hydropower Station" and it was commissioned in 2013. Resizing of this #2 Hydropower Station to 100kW is now being planned.

(3) Opening of the service center

Abernethy Trust concluded an O & M agreement with the manufacturer (Gilkes). Many other neighboring schemes have similar agreements with Gilkes which promoted Gilkes to open a Service Centre close to the Abernethy Hydropower Station.

4. Social Aspects of the Project

4.1 Local Environment

1) Harmonized hydropower station with the landscape

The exterior of the intake and power house is designed to merge with the surrounding landscape. The Scottish Environment Protection Agency (SEPA) approved all stages of the plans inclusive of water abstraction license etc. (see Photo-4).

2) Water heating system by the surplus power

Instead of fossil fuel, the surplus power produced by this scheme is used by an electric boiler to provide the training center buildings with water heating, reducing both heating expenses and CO_2 emission (see Photo-5).

Photo-4 Abernethy Trust Hydropower Plant

Photo-5 Water heating boiler

4.2 Local Community

1) Help to charity activities

Since charity activities of Abernethy Trust Outdoor Adventure Centre include giving outdoor training to young people from economically less favored backgrounds, this scheme is very helpful in improving the Trust's service quality because it covers the power utility charge and generates profit through surplus power. Charity activities in the local community can stimulate interactions among residents and those involved in the Trust activities, which in turn hopefully vitalizes the entire community.

Photo 6 Outdoor sport activities [3]

2) Model micro hydropower generator

The plant owner has opened this scheme to other potential hydro scheme developers and local residents who can come and visit, thereby contributing to their understanding of the sustainable hydropower generation.

3) Stabilization of the local distribution grid

The scheme which is located far from the main grid may have stabilized the local grid by surplus power sales through the connection to the main grid.

5. Reasons for the Success

(1) Financial Viability of the Project

The project provides income to the Trust and secures its financial security for the long-term future. Although the project was faced with a number of unforeseen technical issues arising midway through the project, with Gilkes' help, on both the technical side and with the equipment lease financing package, the project has come to a success.

(2) Local community's understanding for hydropower construction

Charity activities of Abernethy Trust which include giving outdoor training to young people have proved to be a meaningful welfare programme for the local community. Furthermore, they can lead to more stimulative interactions among local residents and the trainers/trainees of the Trust. These facts must have promoted understanding for this scheme among local residents, because it would give financial security to the Trust that operates important activities for the community.

(3) Effects on development of new schemes

Many from other areas visit the site and are motivated to start their own schemes because the Trust makes this scheme open to public as a model. Therefore, it has a very positive effect on hydropower development at other sites. The Trust itself has started Abernethy Trust #2 Hydropower Station which is planned to be resized.

(4) Support from local residents

The project had local support and cooperation. Construction cost was reduced because the local farmers worked for the Trust using their heavy equipment. It created job opportunities for them too.

6. Outside Comments

There has been a great deal of media coverage in newspapers and TV programs of Abernethy Trust and its micro hydropower plant.

7. Reference

[1] GILKES Homepage (http://www.gilkes.com/case-studies/Abernethy-UK))

[2] Abernethy Trust Hydro and Electrification Scheme (The Scottish Government's Community and Renewable Energy Scheme (CARES).

[3] Abernethy Trust Home Page: http://www.abernethy.org.uk/

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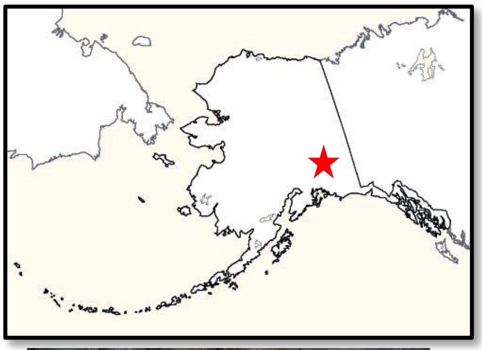


Name of the Power Plant: Humpback Creek and Power Creek Hydropower Plants

Country (State/Prefecture): USA(Alaska, Cordova)

Owner

Name of owner: Cordova Electric Cooperative Inc.

Type of ownership: Community-owned power utility / Electric Cooperative

Type of market: Community-owned power utility

Commissioning Year: Power Creek: 2002
Humpback Creek: July 2011 (rebuilt)

Project Evaluation:

Financial Viability: Recovering initial investment, Securing the cost of maintenance and management, Securing an appropriate level of profit

Economic Benefits: Tax revenue, Employment opportunities, Local industrial promotion, Economic activity during project construction

Social Aspects: Local Environment: Infrastructure improvement, River environment conservation, Preservation of landscape and/or culture
Local Community: Vitalization of local community, Facilitation of regional development, Education for environment/energy, Creation of leisure opportunities, Improvement to public appeal of the local region, Electrification for non-electrified area

Keywords: Remote off-grid community, Eyak Native Village, Electric cooperative, Low-impact projects, Sediment flushing, Micro grid, Enterprise attraction

Abstract

Because the Cordova region is isolated from the Alaska Railbelt (bulk) power grid and the road system, Cordova Electric Cooperative (CEC) supplies power through the local grid from two run-of-the-river hydropower stations (6MW Power Creek and 1.25MW Humpback Hydroelectric Projects) and several diesel generators to the region. This includes the community of Cordova and the surrounding area. The two hydropower stations have supplied up to as much as 77% of Cordova's total electricity

demands. These power stations are operated by CEC. Financial viability of the Hydroelectric Projects has been secured by government grants and a construction loan from CoBank (Cooperative Bank of America). Primary economic benefits include the promotion of local industries and employment opportunities because the city's energy policy of having less dependency on diesel has attracted fish processing plants. Primary contributions to the local community include heightened awareness on the part of the native community for energy conservation and their cooperation to renewable energy sources development.

1. Outline of the Project

Cordova is a small city located near the mouth of the Copper River on the southeast edge of the Prince William Sound. There is no road system connecting it to any other Alaska city, and the community relies on power generated from two run-of-the-river hydropower stations and several diesel generators. The Cordova Electric Cooperative (CEC) provides electricity to the City of Cordova and to several fish processing plants.

The Humpback Creek hydroelectric plant is located 11km north of Cordova in part of Eyak Corporation Lands and has a total installed generating capacity of 1.25MW. The first hydroelectric facility at Humpback Creek started power generation in 1909, but was later abandoned in favor of coal and diesel fired boilers and eventually diesel electric generators. In 1991, the co-op completed construction of the newer 1.25 megawatt plant on the creek at a cost of $11.5 million. That facility was operated without major problems until 2006 when the project was heavily damaged by two storms which delivered 46" (1.5meters) of rain in 72 hours. The Federal Emergency Management Agency provided $5.3 million and the State of Alaska provided $8 million for rebuilding the project through the renewable energy grant program, and the co-op financed the balance of $8.6 million. The power conduit from the intake structure enters 34.4m of 1,370mm diameter HDPE pipe, reducing to 9.5mm thick 1,070mm diameter steel pipe for the remaining 457m including a deep canyon bridge crossing to a trifurcation (three pipes) entering the power house. The Powerhouse contains two 500kW Francis turbines and one 250kW Turgo turbine rated for 53.4m of head (see Photos-1 and -2). A concrete tailrace returns water to Humpback Creek upstream of the pink salmon spawning beds.

Photo-1 250kW Turgo impulse turbine and generator

Photo-2 500kW Francis turbine generator

The Power Creek hydroelectric plant is located 11km east of Cordova on Eyak Corporation Lands and has a total installed generating capacity of 6.0MW. Construction began in 1998 and commercial operation began in January 2002. The project diversion dam consists of an inflatable bladder that can impound a forebay of about 0.07 hectares. The surface water level and forebay depth are controlled by the inflation or deflation of the bladder as power demand and streamflow fluctuate. Streamflow that is greater than project capacity or power generation needs spills over the diversion dam. The power conduit has four distinct sections of pipeline; a 180m long upstream buried pipeline, a 2.7m diameter horseshoe shaped power tunnel approximately 900m long housing the pipeline, a penstock bridge totaling 55m and a buried pipeline extending approximately 670m from the bridge to the powerhouse. At the powerhouse a steel manifold distributes the water flow to two turbines rated 3,124kW each at 85.3m net head. Maximum water flow is 9.06m^3/s total for both turbines. The turbines are twin-jet Turgo turbines by Gilkes. The generators are 400 min^{-1} 3,500kVA 0.8pf units. The water is returned to Power Creek via an open channel tailrace approximately 18m long, 9m wide, and 1.5m deep. 11.2km of transmission line carries the electricity from the powerhouse to the Eyak Substation and on to Cordova Electric's power grid, without any connections to the State bulk grid. 3.7km of the transmission – from the powerhouse to Eyak Lake – are buried under Power Creek Road. Another 7.5km are submarine under the lake. A submarine cable was used because high winds and the steepness of the surrounding slopes and the cost trenching in existing roadways would have made construction of overhead lines difficult and more costly.

Access roads to both intake structure locations dramatically decreased the total cost of construction and remain as recreational walking and hiking paths for the community.

Fig.-1 shows the photos and locations of Humback Creek and Power Creek Hydropower Projects related facilities and Table-1 shows the project specifications.

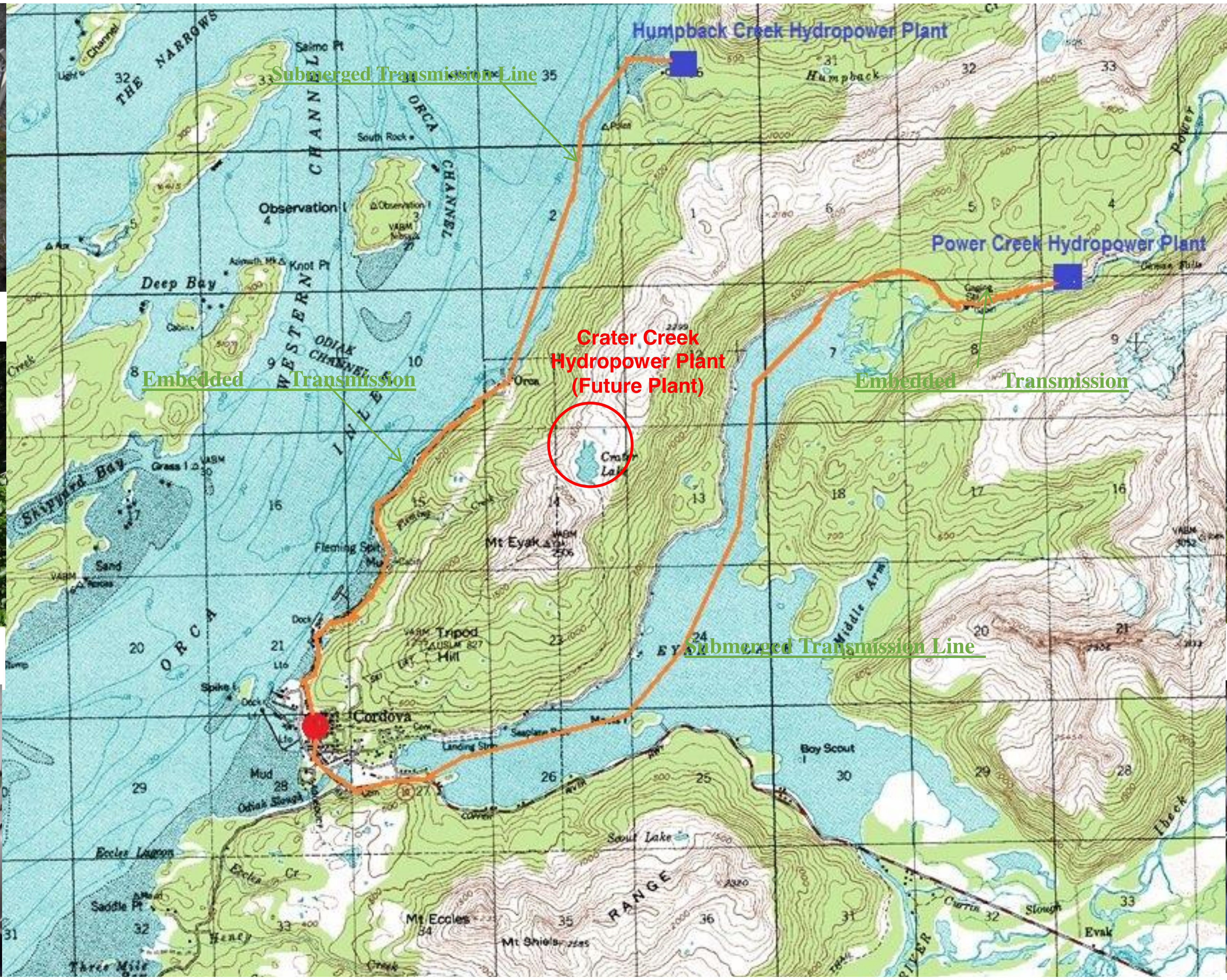
Table-1 Project specifications

Items	Description	
Name of Project	Humpback Creek	Power Creek
Catchment area	About 8km^2	About 40km^2
Installed capacity (kW)	1,250	6,000
Maximum discharge (m^3/s)	3.54	9.06
Effective head (m)	53.4	85.3
Type of power plant	Run-of-river, conduit type	
Connection type	On-grid	
Water used for power plant	Power production only	
Turbine	500kW Francis x 2 250kW Turgo x 1	Turgo x 2
Generator	500KVA Synchronous x 2 250KVA Synchronous x 1	3,000KVA 3-phase Synchronous x 2
Intake Structure	Manual type screen	
Penstock	Φ1,370mm x Φ1,068mm x 1,430m	Φ2,130mm x 914m Φ1,930mm x 914m
Transmission	12.47kV x 10.3km (5.9km buried, 4.4km submarine cable)	24.9kV x 11.4km (3.7km buried, 7.5km submarine cable)

Humpback Creek Intake Structure

Humpback Creek Hydropower House

Turbine in
Humpback Hydropower House



Power Creek Intake Structure

Power Creek Hydropower House

Turbine Generator
in Power Creek Hydropower House

Embedded Transmission line in the trench

Submerged Transmission line

Fig.-1 Location Map of Humpback Creek and Power Creek Plants

2. Financial Viability of the Project

(1) Project cost and grants

Table-2 shows the breakdown of fund sources to cover the Humpback Creek rebuilding project cost, and Table-3 shows that of Power Creek project.

The Humpback Creek rebuilding project was funded by the grants from US Federal Emergency Management Agency (FEMA) and the State of Alaska renewable energy grant fund(REF[1]). CEC also had a construction loan from CoBank, Cooperative Bank of America.

Table-2 Breakdown of fund sources to cover Humpback Creek rebuilding project cost(2011)

Funded by	Amount of grants
Grants from -US Federal Emergency Management Agency (FEMA) -The State of Alaska renewable energy grant fund(REF)	 $5.3 million $8 million
Loan from CoBank	$8.6 million
Total	$21.9 million

Power Creek project was funded by grants from the Bureau of Indian Affairs (BIA)[2] which was founded by the tribal entity of Eyak and Eyak Native Village and the State of Alaska. CEC had a construction loan from CoBank, Cooperative Bank of America, which CEC repaid in five years with the State of Alaska grants of $12 million. The State of Alaska also granted CEC a loan of $1,000,000 for design and licensing for the project.

Table-3 Breakdown of fund sources to cover Power Creek project cost

Funded by	Amount of grants
Grant from Bureau of Indian Affairs	$12 million
Loan from CoBank (see Note 1)	$12 million
Loan for design and licensing (0% interest)	$1 million
Total	$25 million

(Note 1)Repaid with $12 million state grant

[1] Renewable Energy Fund:
The Alaska Renewable Energy Fund (REF) provides benefits to Alaskans by assisting communities across the state to reduce and stabilize the cost of energy. The program is designed to produce cost-effective renewable energy for heat and power to benefit Alaskans statewide. The program also creates jobs, uses local energy resources, and keeps money in local economies.
The REF was established by the Alaska State Legislature in 2008, and extended 10 years in 2012. The REF is managed by the Alaska Energy Authority (AEA) and provides public funding for the development of qualifying and competitively selected renewable energy projects in Alaska.

[2] The Bureau of Indian Affairs (BIA) is an agency of the federal government of the United States within the U.S. Department of the Interior. IA provides services directly or through contracts, grants, or compacts to approximately 1.9 million American Indians and Alaska Natives.

(2) Annual Energy Production

Fig.-2 shows power production ratio from diesel and hydro along with the capacity factors of Power Creek and Humpback Creek plants. When capacity factors of the hydropower plants increase, diesel generation ratio decreases.

Figure 3 shows monthly power production during the year 2012. In the months from June to August (during the dry season) water from melted snow contributes to power generation increase. However, in winter power generation from hydro plants drastically decreases resulting in more dependency on diesel.

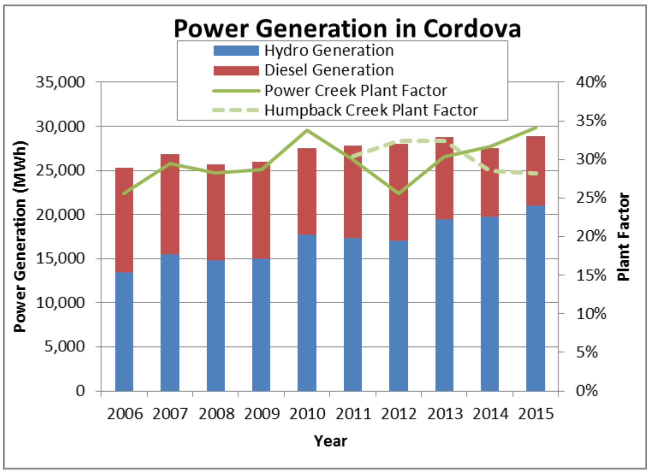


Fig.-2 Annual power production using different energy sources and Capacity factors of hydropower plants[1]

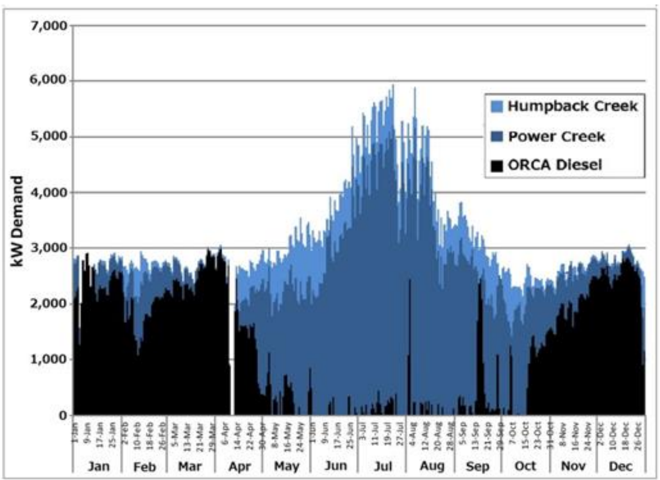


Fig.-3 Monthly power production using different power source (2012)[1]

(3) Trends in energy demand

Fig.-4 shows energy consumption as required by different sectors in Cordova City. As more fish processing plants move to the City, the peak demand tends to increase.

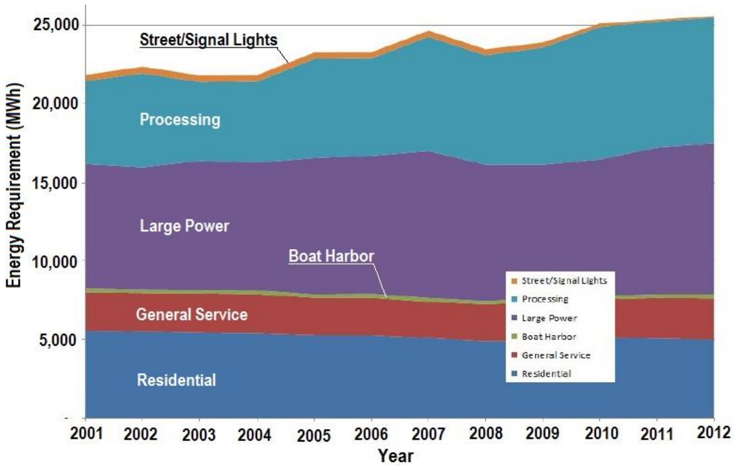


Fig.4 Energy requirement of different sectors in Cordova City[1]

(4) Alternative power for Diesel engine generator

In its first 13 years of operation, the Power Creek Project has saved over $30,000,000 in diesel fuel cost, completely recovering the capital cost.

Since the refurbished Humpback Creek project went into service in 2012, it has saved nearly $3,000,000 in diesel fuel, and is expected to recover the capital by 2027 in diesel fuel savings alone. (According to Renewable Energy Fund Status Report 2015 released by Alaska Energy Authority, it produced 10,880MWh from July 2011 to 2014 which would be converted to US$3,050,000 worth of diesel.)

Both projects also provide a significant operations and maintenance cost savings over diesel fuel generation (add O&M costs).

3. Economic Benefits of the Project

(1) Fish Processing Industries Attracted

The Cordova port becomes an attractive port for the fishing industry because the fish processors don't have to rely on offshore equipment powered by diesel fuel. One producer of pharmaceutical-grade fish oil relocated its facility from Mexico to Cordova in order to reap the benefits. Commercial fishing is the main industry in Cordova. Half of all households in Cordova have at least one person involved in commercial fishing or processing. The cooperative's notable efforts have helped turn Cordova into a premier fishing port, one that was named the fifth largest dollar catch port in the country.

Photo-3 Cordova Harbor[1]

(2) The Cooperative strengthens its efforts through strategic partnerships with companies such as Pacific Rim Inc.[3] that make proactive efforts in energy efficiency improvement and energy conservation.

4. Social Aspects of the Project

4.1 Local Environment

1) Fish Protection

Power Creek is a major salmon spawning stream. Pursuant to both Cordova Electric's and Whitewater's commitment to preserve the fish habitat, they devoted approximately $2 million to reduce the potential for any soil or riverbed material to migrate to the lower reaches of the stream where the spawning occurs. Measures included double lining the diversion channel with geotextile fabric during construction and high pressure cleaning of each individual piece of riprap. Upon completion of construction, water flow was restored to the original streambed.

[3] Pacific Rim Inc. is a manufacturer of pipes for ships with highly anti-corrosive and heat insulating materials.

2) Accumulated Sand Flushing by periodical operation of bladder weir

The dam bladder for Power Creek diversion dam is periodically deflated to allow stream flows to flush any sediment accumulation immediately upstream of the dam and maintain downstream sediment transport. (See Photo-4)

Damming by inflatable weir   Under shrinking   Flashing the sands

Photo-4 Sand sedimentation flushing by inflatable weir

4.2 Local Community

1) Promoting the effective use of local energy

The area around Cordova is the Native Village of Eyak[4], historically home to the Eyak, and the village must rely on local resources and imported diesel to produce their electricity and heat. They seek to develop local energy resources to stabilize future energy prices and save tribal members, and community money.

2) Symbiosis with the local Native Village

Cordova Electric Cooperative has made many efforts in helping its community and the surrounding environment, establishing an agreement with the local Native Village of Eyak to develop mutually beneficial renewable-energy projects.

For instance;

- CEC's past projects include a town-wide retrofit of street lights to high-efficiency LED bulbs, the distribution of thousands of compact fluorescent light bulbs to members, as well as establishing an agreement with the local Native Village of Eyak to develop mutually beneficial renewable-energy projects.
- CEC also distributed wind anemometers to the village as a preliminary step toward establishing the feasibility of wind-power projects, as well as the purchase of waste-oil boiler controls for the local high school.

3) Maximizing Hydropower Use in the Cordova Electric Cooperative Grid

CEC commissioned ACEP (Alaska Center for Energy and Power) in 2014 to perform a feasibility study for optimizing the different means of power generation, in collaboration with Sandia National Laboratory. At that time a part of the hydropower turbine was used for frequency regulation which resulted in a reduction of available

[4] The Native Village of Eyak
· Federally Recognized Tribe in Cordova, AK
· Governed by a five-member tribal council
· Provides health and social services, economic development, job training and environmental and resource management
· 525 Tribal members

capacity, making the hydropower plant unable to either meet daytime peak demand or operate at full capacity during off-peak hours. As the plant facilities did not include reservoirs, the water that would normally be diverted for power generation was simply directed down the creeks. Therefore, the technical and economic feasibility of maximizing hydropower use and implementing alternative frequency control via energy storage solution and demand response were assessed. In this study project, energy balance model (EBM) developed in the Department of Energy's Energy Storage Program was employed. Optimal incorporation of energy storage and demand respond solutions with regard to the timing and range of the technology application will be determined in spring 2017 based on the findings.

4) Feasibility Study for New Hydropower Plant and Water Project

CEC and City of Cordova are planning recently to co-develop the Crater Lake Power and Water project. The feasibility study for this project was completed last January in 2016. The Project will utilize the existing Crater Lake as a high head reservoir to generate 825kW hydropower and as the primary water supply source of 5 cfs flow to City of Cordova. The primary components of the Project include a small dam (on the order of 25 feet tall) at the existing Crater Lake outlet, a roughly 3,800-foot-long penstock, and a powerhouse/water treatment plant located near tidewater elevation.

5) Public education and awareness

CEC has many strategic partnerships including the Native Village of Eyak (NVE) in particular with the Cordova Renewable Energy Workgroup (CREW) program. CREW meetings continue to be open to the public and will host additional wind program updates in the community. (See Photo-5 & 6.)

Photo-5 Education of Energy Conservation[5]

Photo-6 Energy Education[5]

5. Reasons for the Success

(1) Energy security in remote areas

Because the Cordova region is isolated from the main power grid and the road system of Alaska, it is dependent on the local grid powered by hydropower and diesel generators. In order for the City to ensure energy security and make it less dependent on imported diesel fuel, the ratio of hydropower generation to diesel must be increased and the dependence on diesel decreased. From 2006 when the Humpback Creek project was heavily damaged by storms to the 2011 rebuilding of the plant, the amount of hydropower generation was between 50 to 60% and dependency on diesel was not greatly reduced. However, by 2016, it was brought up to about 77.2%. The efforts of the City show the community's strong awareness of the importance of hydropower generation.

(2) Leadership taken by Cordova Electric Cooperative (CEC) and symbiosis with the local Native Village

The Cordova city tries to utilize the region's natural potential sources of energy, including wind, tidal and hydroelectric, with the vision that Cordova's energy supplies can be drawn from resources all local to the region. To that end, CEC has made great efforts in establishing an agreement with the local Native Village of Eyak to develop mutually beneficial renewable-energy projects, resulting in sustainability of the local power supply system in this area centering around hydropower use.

6. Outside Comments

There has been a great deal of media coverage in newspapers and TV programs of CEC activities in Cordova.

7. Reference

[1] Home page of Cordova Electric Cooperative, (http://cordovaelectric.com/)

[2] Cordova Electric Cooperative Inc.: Alaska's Renewable Energy Trailblazers/US Business Executive

[3] Technical Report No.12-06, Distribution of Resident Dolly Varden in Power Creek, Cordova, 2005-2007/April 2012 Alaska Department of Fish and Game Division of Habitat

[4] Replacing Diesel Fuel With Hydroelectric Generation, Hydro Review / September 2002

[5] A Case Study in Community Green Power/Renewable Energy Marketing Conference November 16 2011

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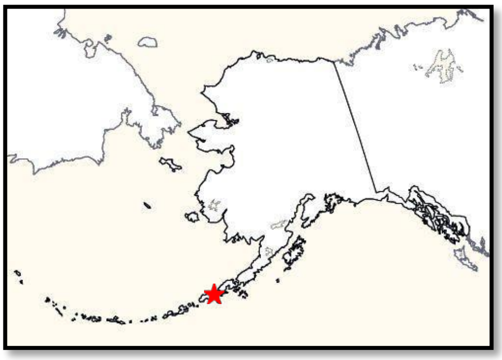


Name of the Power Plant: Delta Creek Hydropower Station

Country (State/Country): USA(Alaska/King Cove city)

Owner

Name of owner: City of King Cove
Type of ownership: Public Utility / Municipality
Type of market: Public Utility

Commissioning Year: Dec., 1994

Project Evaluation:

Financial Viability: Recovering initial investment, Securing the cost of maintenance and management, Securing an appropriate level of profit

Economic Benefits: Employment opportunities, local industrial promotion

Social Aspects: Local Environment: Infrastructure improvement
Local Community: Vitalization of local community, facilitation of regional development

Keywords: Aleutian Islands, King Cove City, Power Cost Equalization (PCE), Title 26 of the Energy Policy Act, Diesel replacement, Off-grid community, Micro grid, Agdaagux tribe, Waste heat utilization

Abstract

Delta Creek hydropower plant is the 800 kW run-of-river plant in King Cove which is situated in the Aleutian Islands in Alaska, USA. Because King Cove is isolated from the bulk power grid and the road system, the local government-owned utility supplies power through the local grid to the City. The City's power sources are diesel generators and the Delta Creek hydropower plant that provides approximately 60% of King Cove's electricity. Financial viability of this hydroelectric project was secured by government grants and other funding. Residential electricity rate is low and stable, not affected so much by diesel fuel prices. The city of King Cove is constructing another hydro power plant with a 375kW capacity to further develop renewable potential in the area. The new plant is planned to start operation in April 2017.

1. Outline of the Project

The city of King Cove, population 900, is in Aleutians East Borough, which stretches from the tip of the Alaska Peninsula to the easternmost Aleutian Islands. This region is bordered on one side by the Pacific Ocean and on the other by the Bering Sea (see Photo-1). Most King Cove are native Aleuts. The village has about 205 households and a cluster of commercial and government facilities, including a large fish processing company. Because of its remote location, the city of King Cove relies heavily on expensive diesel generation. The city has four diesel units with a total generating capacity of almost 2.7MW. To reduce its dependence on diesel, the city of King Cove developed the 800 kW Delta Creek hydro project. This power plant began operating in December 1994, and provides approximately 60% of King Cove's electricity.

Photo-1. Panorama of King Cove City[3]

The Delta Creek hydroelectric power plant draws water from two sources. Both are tributaries to Delta Creek. The primary water source is Glacier Creek, a glacier-fed stream. The second source is Clear Creek, a snow and rain-fed stream that is tapped when additional flow is needed. Intakes erected on the two tributaries generate 90m gross head and 73.8m effective head at full load. Diversion structures measure 3m high by 30m long; the pipe diameter is 0.8m. A check valve prevents water from Glacier Creek from backing up into the lower intake of Clear Creek during high flow conditions.

The power plant is fitted with a Turgo impulse turbine. It is a dual-jet unit equipped with a speed governor and hydraulic deflectors to control flow. To accommodate fluctuations in user loads, the system includes a 4,000kg flywheel that can either store or provide energy to ensure smooth transitions during load changes. The power plant ties into King Cove's existing power substation via a 12.5kV, three-phase, 60Hz transmission line, installed along 9km road. Table-1 shows Delta Creek Project specifications.

Table-1 Project Specifications

Items	Specifications
Name of river/river system	Delta Creek(Glacier Creek and Clear Creek)
Installed capacity (kW)	800 (One Turgo Impulse turbine, a dual-jet unit)
Maximum discharge (m^3/s)	1.41
Effective head (m)	73.8
Turbine type	Turgo impulse, dual-jet, horizontal
Generator type	Synchronous
Type of power plant	Run-of-river, conduit type
Connection type	On-grid (micro grid)
Penstock	Φ800mm x 730m
Water used for power plant	Power production only

The City of King Cove owns and operates the electric utility in King Cove. The City's power is supplied by the 800kW capacity Delta Creek hydroelectric plant, and a diesel power plant with a total capacity of 2,700kW (1,050kW x 1, 650kW x 1, 500kW x 2). Table-2 shows load statistics of King Cove, power production relating to different types of generators, annual diesel consumption etc. Photos-2 and -3 are the diesel units and diesel fuel storage tanks.

Table-2. King Cove Electricity Production by Type[3]

Average Load	486 kW
Peak Load	904 kW
Hydroelectric production	3,019,175 kWh/year
Diesel electric production	2,198,000 kWh/year
Diesel used for generation per year	571,921Liter/year
Diesel efficiency	3.84 kWh/Liter
Liter of diesel offset by hydroelectric	785,389 Liter/year

Photo-2 Diesel Engine Generator Units[3]

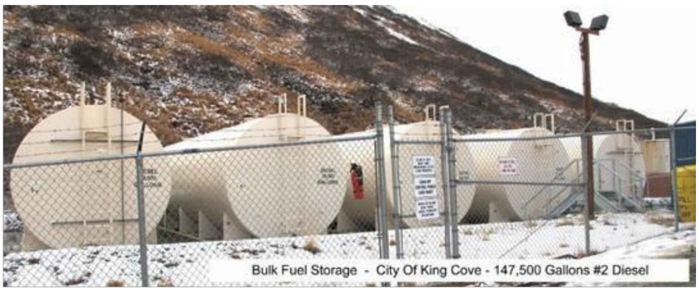
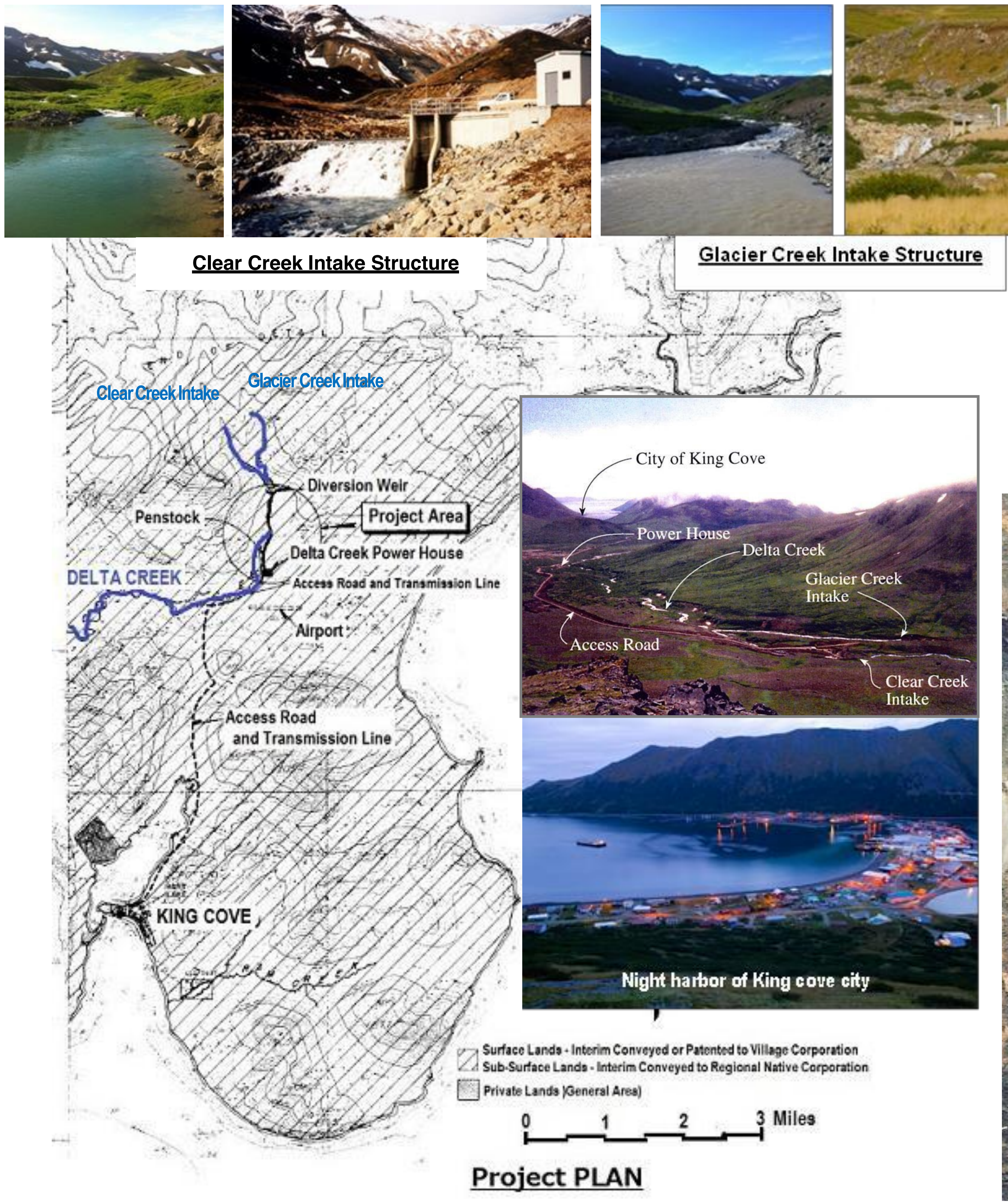
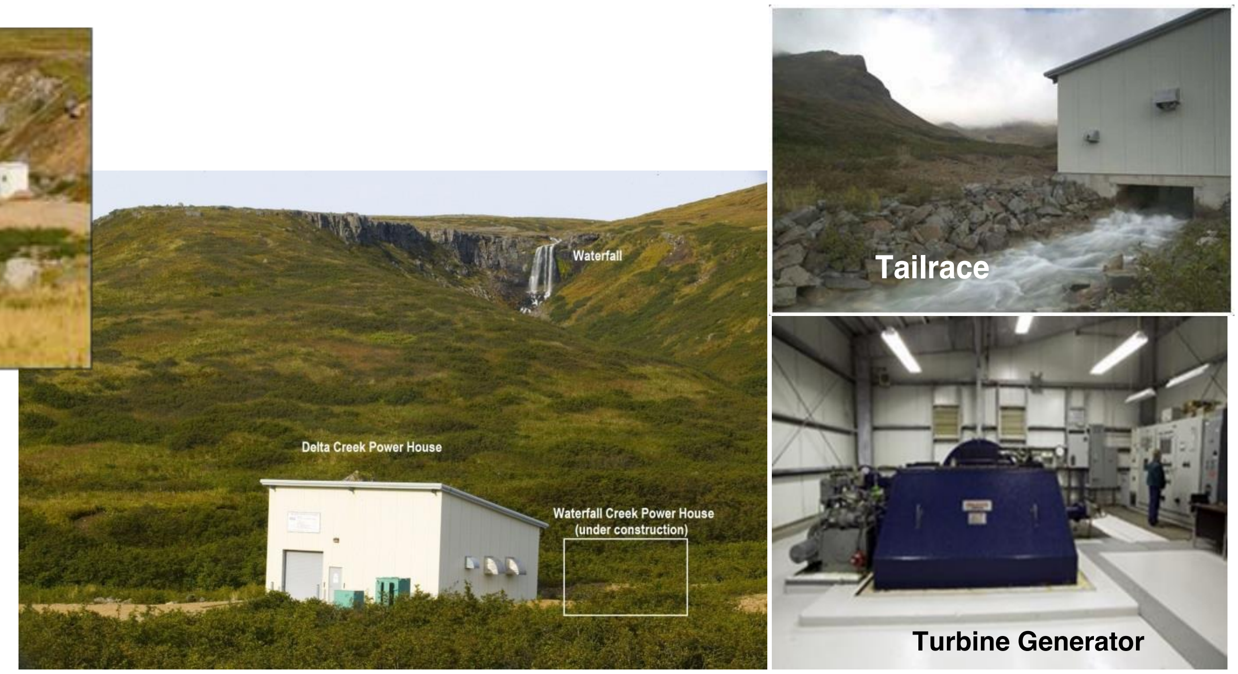


Photo-3 Diesel Fuel Storage Tank[3]





Delta Creek Hydropower Plant

Fig. 1 General Outline of Delta Creek Hydropower Plant

Fig. 2 General Outline of Waterfall Creek Hydropower Plant (Under construction)

The majority of the City of King Cove's electric production comes from the Delta Creek hydroelectric plant. The remaining comes from diesel generation. Fig.-3 shows King Cove's monthly electricity generation by source over the past 5 fiscal years. Fig.-4 shows the percentage of diesel and hydroelectric generation from 2009 to 2013. Fig.-5 shows monthly power generation of Delta Creek hydropower plant during the same years. As can be seen in Fig.-5, the hydroelectric production peaks during the late summer, and reaches a minimum during the winter. As the city's consumption is greatest during the winter, the hydro resource is countercyclical to the community's power needs. Over the past four years, the hydroelectric plant has had an average capacity factor of 35%.

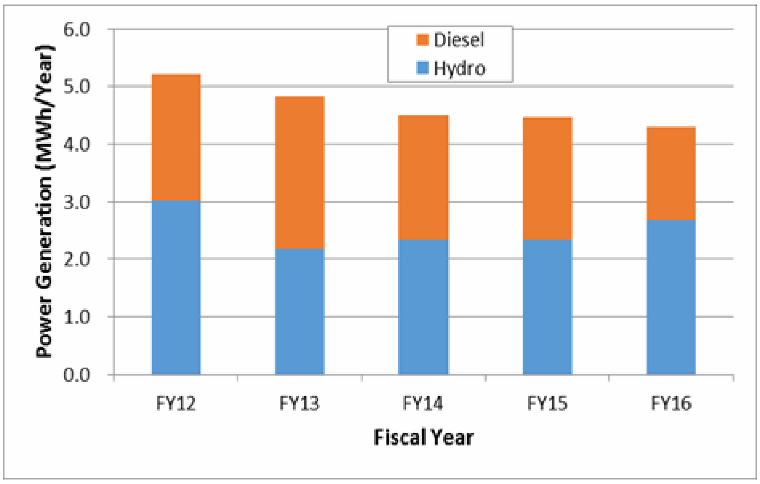


Fig.-3 Power generation using different energy sources (FY 2012-2015)

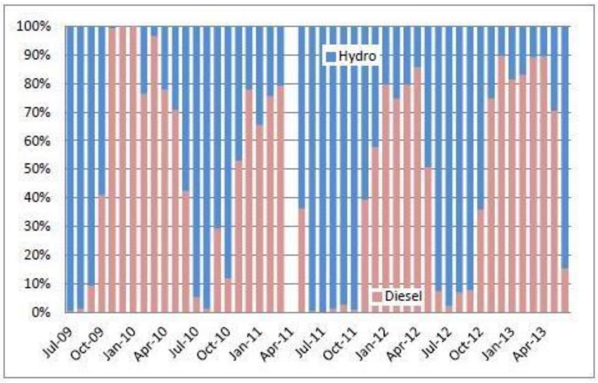


Fig.-4. Diesel and Hydroelectric Generation Production as Percent of Total FY10-FY13[3]

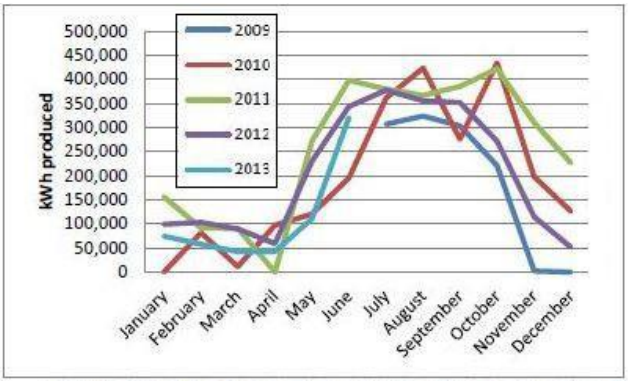


Fig.-5. Delta Creek Hydroelectric FY10-FY13[3]

The City of King Cove has installed an electric boiler to act as a dump load for the hydroelectric plant, which improves control of the diesel/hydro power plant. The produced waste heat is utilized for heating in the local school, medical clinic, and 12 residential units. This allows the City to better integrate the hydroelectric and diesel power sources and tap the full potential of the hydroelectric resource.

2. Financial Viability of the Project

(1) Government grants

Numerous hydrological surveys, geotechnical studies, load inventories and feasibility assessments finally led to a series of grants, including a Title 26 award through the US Department of Energy to the Agdaagux Tribal Council, located in the town of King Cove, and other government grants listed in Table 3. The Agdaagux Tribal Council was the prime grant applicant and the city of King Cove acted as a contributing partner providing advice.

Table-3 Funding Sources

Source	Provided by;	Share(%)	Remarks
Grants	State/Alaska Energy Authority	45	granted to city
	State/Department of Administration	9	Hickel Administration match of Aleutians East Borough/City of King Cove/State of Alaska funds
	U.S. Department of Energy	4.5	through Tribal Council
	Aleutians East Borough	4.5	
	City of King Cove	4.6	Cash from city permanent fund
Loans	Farmers Home Administration	32.5	25years/5.5% interest (1)
	Total US$5.6million	100	

Note (1): This loan was refinanced by the State of Alaska Municipal Bond Bank in 2014 with a new interest rate of 4.3% with a payment duration of 7 years.

(2) Diesel replacement

To date, the savings King Cove has experienced from using hydroelectric power in place of diesel fuel have already been significant. The yearly fuel savings, in fact, more than pays the annual debt service on the remaining $750,000 the city borrowed to construct the Delta Creek hydroelectric facility.

(3) Operation and maintenance cost

The profit made through electricity sales at present is enough to cover operation and maintenance cost and provide funds for a modest repair and replacement fund.

3. Economic Benefits of the Project

(1) The lowest cost of power among the other communities

As can be seen in Fig.-6 below, King Cove is the lowest, single-site cost of power among more than 160 communities in the State of Alaska's Power Cost Equalization (PCE) program[1]. The development of the Delta Creek hydropower resource is credited as the primary reason for the low cost of power.

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[1] The Power Cost Equalization program (PCE) became effective in October 1984.
The PCE program provides economic assistance to communities and residents in rural areas of Alaska where, in many instances, the kilowatt hour charge for electricity can be three to five times higher than the average kWh rate of 12.83¢ (July 2007) in Anchorage, Fairbanks, or Juneau. The PCE program was established to assist rural residents at the same time that state funds were used to construct major energy projects to assist urban areas.

Generally speaking, utility residential rate links with diesel fuel price, but as Fig.-7 shows, it does not apply to King Cove City so much; that is, although diesel price almost doubled during the years shown in the figure, utility rates did not change proportionally. It could be attributed to hydropower development at Delta Creek which was the primary factor that kept the rates low.

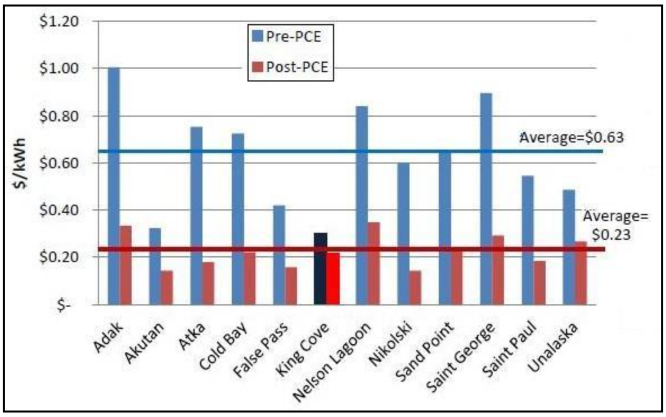

Fig.-6 Regional Tariff of Electricity FY2013[3]

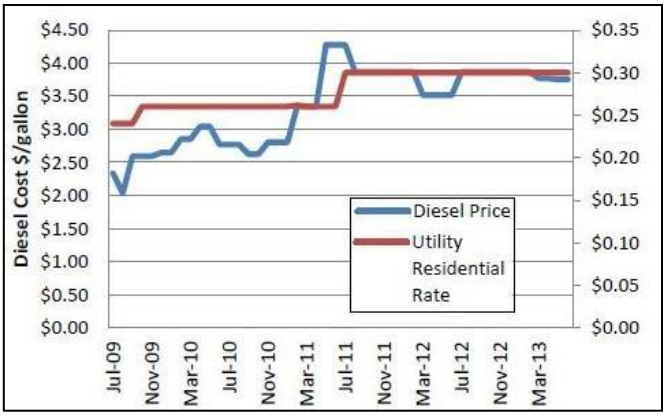

Fig.-7 Correlation between diesel price and utility residential rate (FY10-FY13)[3]

(2) Development of next hydroelectric project

The City of King Cove started construction of another hydropower plant (Waterfall Creek hydro project) that will come online in April 2017. Together, with the Delta Creek hydro plant, Waterfall Creek is expected to provide up to 80% of the City's annual power demand. Earlier Fig.-2 shows the overview of Waterfall Creek's ~~its~~ location and surrounding facilities.

Waterfall Creek Project specifications:

Type of power plant:	Run-of-river
Turbine type:	Pelton (maximum output: 375kW)
Effective head:	152.4m
Estimated generated output:	1,000MWh/year

4. Social Aspect of the Project

4.1 Local Environment

River discharge maintenance for the new project

With the Delta Creek project, the intake weir was sufficient to conserve river environment and fish habitat, whereas maintaining river flow discharge would be necessary for environmental conservation with the Waterfall Creek project.

4.2 Local Community

The recoverable heat system by an electric boiler using surplus hydro energy has been saving about 40,000 gallons of diesel fuel every year. The subsequent waste heat is being used in the local school, medical clinic, and 12 residential housing units.

5 Reasons for the Success

(1) Energy security in remote areas

Because the City of King Cove is isolated from the main power grid and the road system of Alaska, it is dependent on the local grid powered by hydropower and diesel generators. In order for the City to ensure energy security and make it less dependent on imported diesel fuel, the ratio of hydropower generation to diesel must be increased and the dependence on diesel decreased. Due to the efforts toward that direction, King Cove is charged the lowest cost of power among more than 160 communities in the State of Alaska, which can be attributed to the development of the Delta Creek hydropower resource and therefore the city's electricity rate is not affected so much by fluctuations of diesel fuel price. The efforts of the City show its strong awareness of the importance of hydropower generation.

(2) Financial viability of the project

In Alaska where it is difficult to connect all communities to the bulk power grid of the State, the State government encourages and supports the off-grid communities to build an independent, self-sufficient energy supply system. The US federal government has also supported the efforts to create employment opportunities, regional economic development and promotion of self-sufficient energy resources. The public grants for these purposes were utilized to reduce initial investment cost of the Delta Creek hydro project.

6 Outside Comments

(1) There has been a great deal of media coverage in newspapers and TV programs of Delta Creek Plant.

(2) HDR Engineering Inc., the company that designed and planned Delta Creek Plant, won Engineering Excellence Awards in 1995.

7 Reference

[1] Hydro-power for a Remote Alaskan Community, CADDET Technical Brochure No.37

[2] King Cove Hydroelectric Project/1995 Engineering Excellence Awards, HDR Engineering, Inc.

[3] Aleutian & Pribilof Islands Regional Energy Plan Phase 1 Resource Inventory(Draft), 2013

ZA01

Name of the Power Plant: Brandkop Conduit Hydropower Plant

Country(State/Country) : South Africa

Owner

Name of owner : Bloemwater

Type of ownership : On-site power generator / Water utility

Type of market : On-site power generation

Commissioning Year : March 2015

Project Evaluation:

Financial Viability : Investment cost recovery, Securing operation & maintenance cost, Securing proper profit

Economic Benefits: Tax revenue, Local industrial promotion

Social Aspects: Local Environment: Infrastructure improvement

Local Community: Education for environment/energy, Facilitation of regional development

Keywords: Conduit-hydropower, water distribution systems, Utilization of excess energy in pressurized conduit, Low development cost, Low environmental impact project

Abstract

The Caledon-Bloemfontein potable water supply system that supplies tap water to the Bloemfontein area consists of a 105 km-long gravity supply line from the De Hoek Reservoir to the Brandkop Reservoir, where the Bloemwater's head office is located. In this system, excess energy is dissipated through pressure control valves. The Water Research Commission (WRC) together with the University of Pretoria (UP) designed and implemented a conduit hydropower generation unit which converts excess energy in the pressurized conduit to renewable electricity to power Bloemwater's head office. Since this project utilized already existing water conduit, it required minimal civil works, had only positive environmental and social impact, needed a relatively small capital investment and had a short implementation period with a positive return on investment. This project has given Bloemwater motivation to develop other potential conduit hydropower sites. It has had other effects such as greenhouse gas emission reduction from its head office, promotion

of small hydropower development with little impact on the environment and free sharing (though still under discussion) of excess power with the surrounding areas where electricity is in short supply.

1. Outline of the Project

The Caledon–Bloemfontein potable water supply system was commissioned in the late 1960's, operated and owned by the Department of Water Affairs and Forestry (DWAF). The supply system has a design capacity of 141,000m³/day (1.632m³/s). With the exception of the Welbedacht Dam the assets were transferred to Bloemwater in 1991. Bloemwater had operated the infrastructure ever since.

Fig.-1 shows the Caledon–Bloemfontein system that supplies potable water from Welbedacht Dam in the Caledon River to Bloemfontein. The water treated at Welbedacht Dam is then pumped with a high lift pump station, 6.7 km to the De Hoek reservoir (22,700m³). From here it gravitates through a Ø 1168mm pre-stressed concrete pipe, 47 km to the Uitkijk break water reservoir (9,100m³) and a further 58.8 km to the Brandkop Reservoir (136,000m³). Excess energy is dissipated through pressure control valves upstream of the Uitkijk and Brandkop reservoirs, before being discharged into the reservoir.

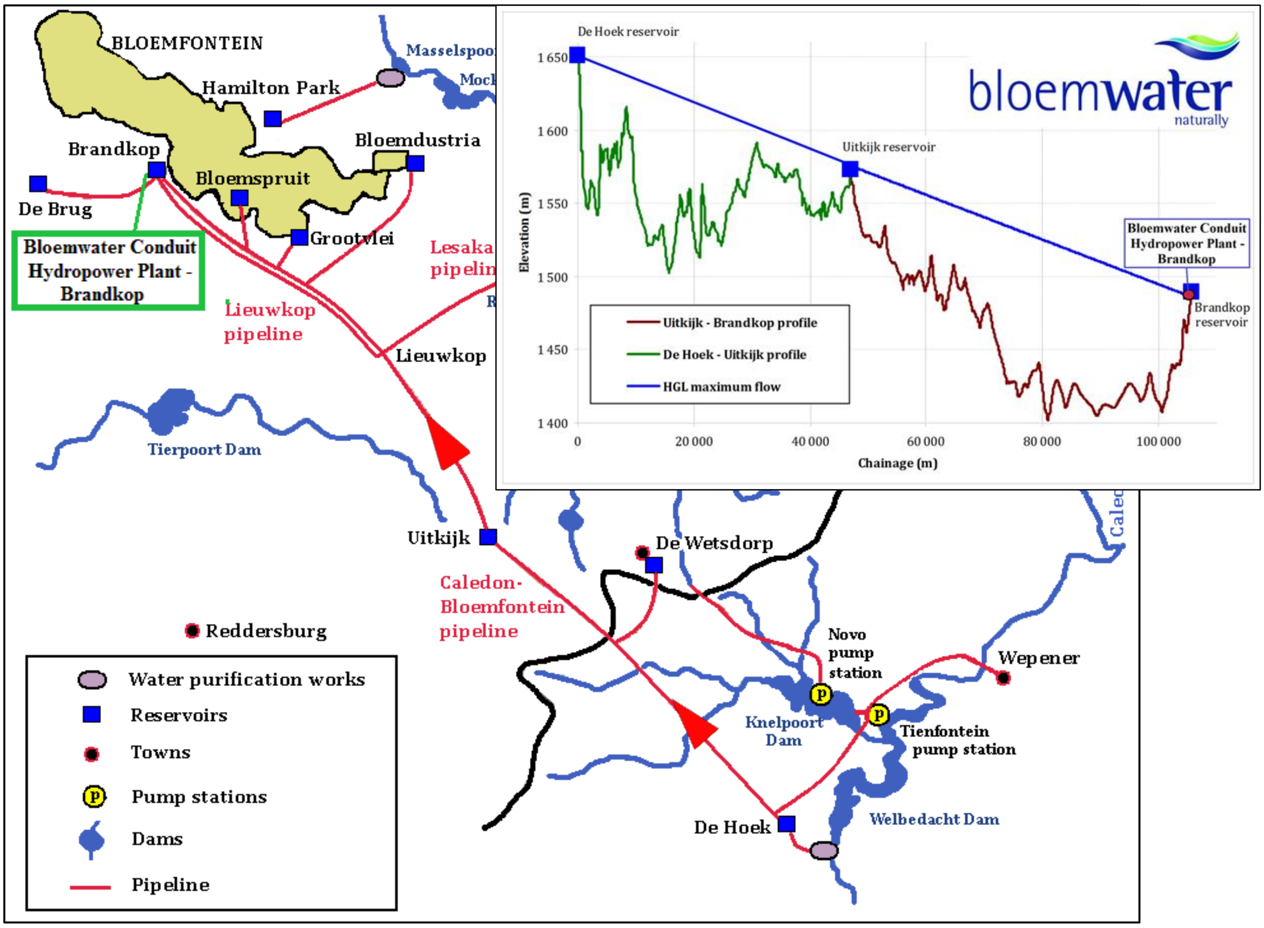

Fig.-1 Caledon-Bloemfontein Bulk Water Supply System Layout

Table-1 Project Specifications

Items	Specifications
Name of river/river system	Caledon River
Installed capacity (kW)	96
Maximum discharge (m^3/s)	0.35
Effective head (m)	40
Generator type	Crossflow turbine
Type of power plant	Conduit hydropower plant which converts excess energy in the pressurized conduit to renewable electricity
Connection type	Off-grid (Stand alone)

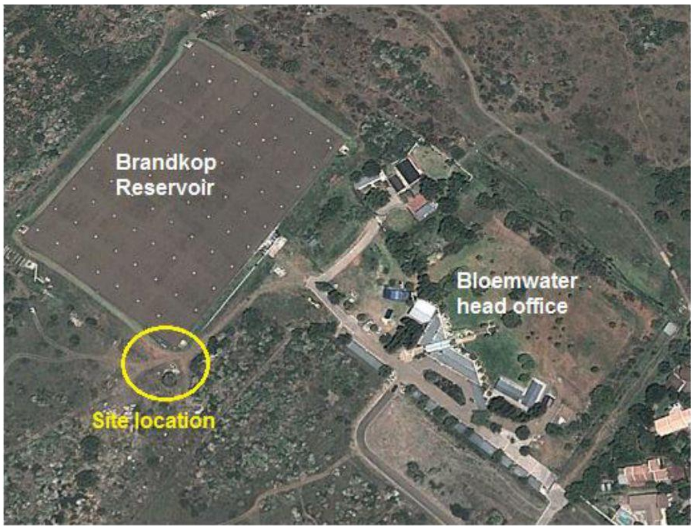

Fig.-2 Hydropower plant location

Bloemwater decided to develop a hydropower plant with sufficient capacity to meet the electricity demand of their head office which is situated at the Brandkop Reservoir. In order to determine the energy potential in the conduit, it was hydraulically assessed by measuring pressure head and flow, and electricity consumption of the office was recorded to determine the correct turbine to meet the demand. The obtained peak demand of Bloemwater's head office and demand for power from other facilities at the Brandkop Reservoir led to the construction of a hydropower plant at which the flow through the plant is restricted to a maximum of $0.35m^3/s$ with 40m head with 96 kW installed generating capacity. The theoretical annual energy that can be generated with this plant is 837,500 kWh (see Fig.- 2).

Based on the available pressure head range and fixed flow rate of $0.35m^3/s$ it was decided to select a 96 kW cross flow (Banki) turbine. The type of turbine selected was the IREM ECOWATT Micro hydroelectric power plant type TBS 4-0.5 with synchronous generator. The flow in the bulk pipeline could vary from 0 to $1.5m^3/s$. This results in a varying available pressure head at the end of the pipeline as indicated in Fig.-3. At the conduit hydropower plant the flow is designed to reach a maximum of 0.35m³/s at 40m head.

If the flow in the pipeline is only 0.2m³/s then the available pressure head of 78m is reduced to 40m at which the maximum power is generated and this is kept constant until approximately a flow of 1.1m³/s. If the flow is further increased in the pipeline the pressure drops and subsequently the generated power, although flow through generator is kept at 0.35m³/s. Electronic Regulators (Dummy load governors) (9 x RMP 12000/B with total capacity of 108 kW) keep the voltage and frequency stable.

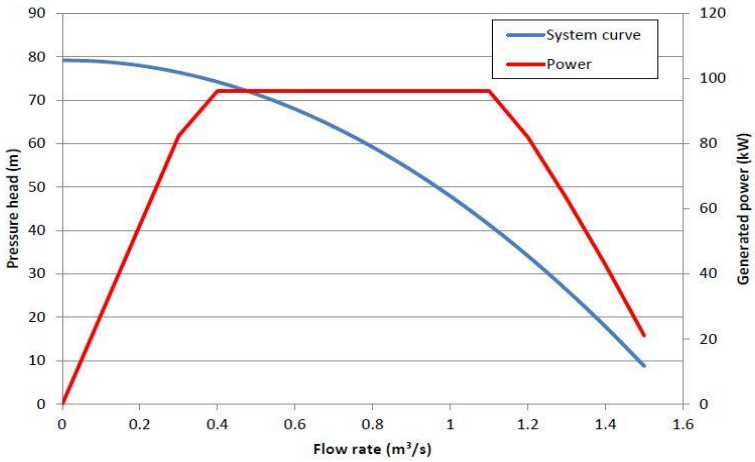

Fig.-3 System Characteristic Curve

The turbine and generator is housed in a turbine room, located next to the Brandkop Reservoir. Approximately 30% on average of the water supplied via the Caledon-Bloemfontein pipeline is diverted through the turbine. After passing through the turbine generator, the water is discharged into the Brandkop reservoir.

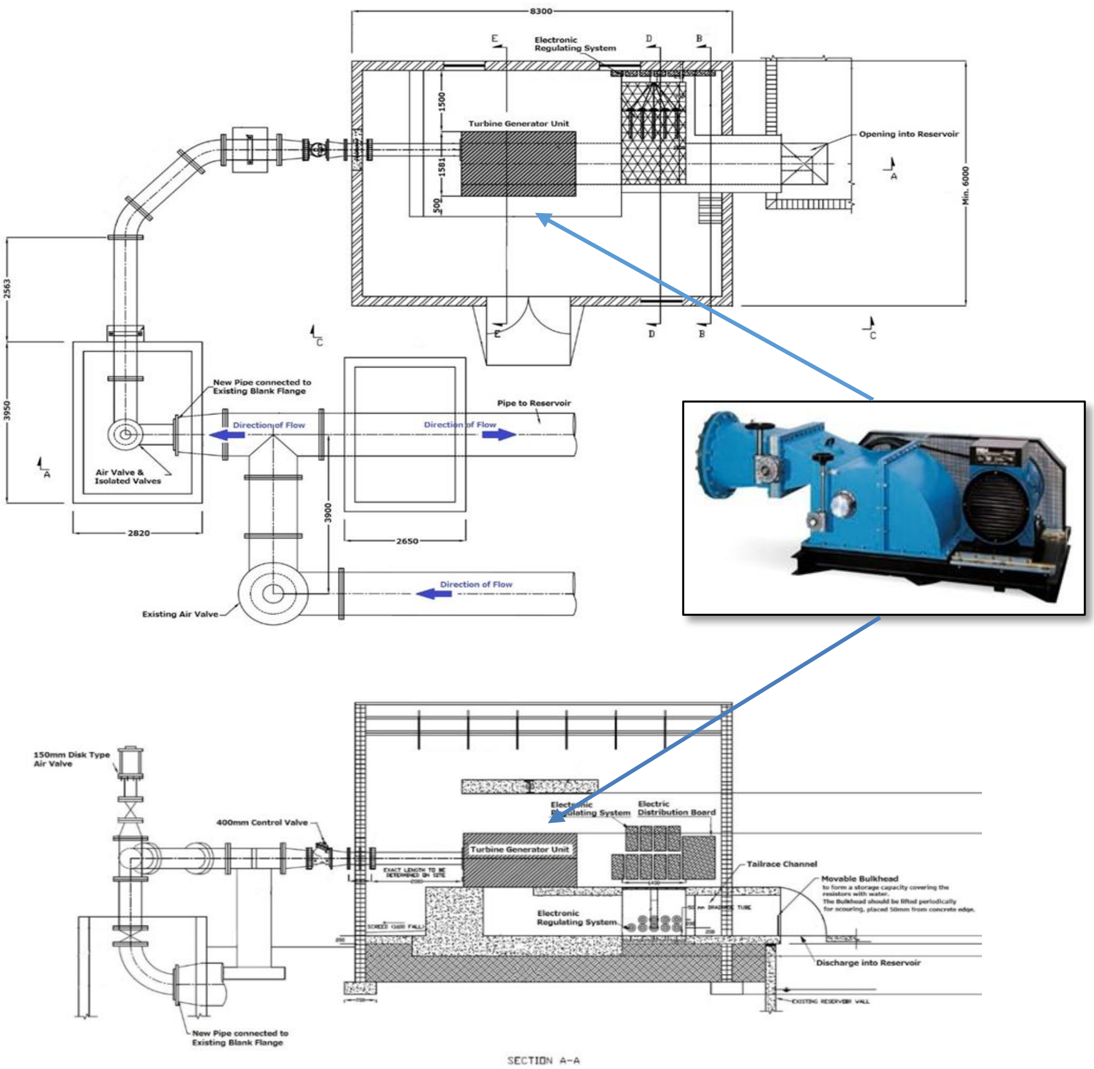

Fig.-4 Turbine and generator installation layout

Photo-1 Penstock and powerhouse

Photo-2 Turbine, generator

Photo-3 Generator control panel

Photo-4 Dummy load resistors

2. Financial Viability of the Project

To make this system viable without receiving special subsidies or tariffs, the feasibility study was conducted for this installation based on some assumptions regarding the design life (40 years), anticipated electricity escalation (8%) and the discount rate (7%) on the investment made by Bloemwater. It also looked at the current monthly spending of the Bloemwater head office on electricity in the past 72 months (approximately 6 years). The resulting estimate was that the total cost for this project was ZAR 3,800,000 or ZAR39,600/kW (i.e. €281,500 or €2,930/kW) and about 7 years for investment recovery period.

The success and short payback period has given Bloemwater the confidence to start planning the next phase and conducting feasibility studies for other potential conduit hydropower sites.

3. Economic Benefits of the Project

This project is an empirical case for the introduction of small hydropower using surplus pressure of the water conduit in South Africa. Already, several potential conduit hydropower sites have been identified, investigated, constructed or are operational at Rand Water, Mossel Bay, Lepelle Water, Amatola Water, Bloemwater, eThekwini Municipality, City of Tshwane, Johannesburg Water, City of Cape Town, Eskom, and Midvaal Local Municipality amounting to 38.6 MW (mega-watts). This has a monetary generating value of R220 million/annum.

Further, an estimated 59.8 MW of power generation facilities can be added in all metropolitan areas excluding all the mines, which provides direct employment opportunities for operational maintenance as well as temporary employment at construction.

There are various initiatives aimed at optimizing energy use and balancing electricity supply and demand which the energy supplier (ESKOM) promotes. This project in a small way assists with these initiatives.

4. Social Aspects of the Project

4.1 Local Environment

The benefit of this hydropower-generating application is that minimal civil works are required. There are virtually no negative environmental or social effects requiring mitigation, and the anticipated lead times are short. Conduit hydropower uses the available water supply and distribution infrastructure and thus as long as there is a demand, hydroelectric energy can be generated. As conduit hydropower "piggy backs" onto existing water infrastructure (by harnessing excess energy in the conduit) it results in minimal environmental impact.

During the generation of energy there is no pollution - no heat or noxious gases released to the environment thus decreasing Bloemwater's carbon footprint.

4.2 Local Community

1) Education for environment/energy

Since this hydropower plant displays proven hydro-technology and the possibilities thereof, it functions as an educational model to allow the public a greater understanding of hydropower, and the role it plays in mitigating of climate change (e.g., zero CO_2 generation, forestation, energy saving, etc.). The system also contributes towards energy savings initiatives.

2) Facilitation of regional development

The plant is not utilized to its full potential as the peak 96 kW is only required during the peak demand hours of the day. After hours and during weekends the plant operates at 30% of its capacity for the limited use of power at the head office. Further plans are being made to provide excess electricity generated at off-peak hours to a nearby disadvantaged community as free basic electricity resulting in a direct impact in the community's lives.

5. Reasons for the Success

(1) Understanding of conduit system characteristics

While this system is in operation, power generation must not hinder the prime objective of the water utility. The capabilities and characteristics of the pipeline system, the demand for both water and power must be coordinated effectively to integrate the system operation. Bloemwater took the bold step by investing in conduit hydropower to apply new technology in cooperation with the University of Pretora to make the power plant a reality, and also assisted in knowledge dissemination, thus making a contribution to similar conduit hydropower projects. If similar schemes are realized in other projects, it will create new employment opportunities in construction, operation and maintenance of the power plants.

(2) Contribution to local environment and community

This conduit hydropower plant has virtually no negative environmental or social impact. It functions as an educational model to enhance public understanding for hydropower generation.

6. Outside Comments

(1) OFM - the Sound of your Life

Bloemwater Conduit Hydropower Plant to be launched

The Minister of Water and Sanitation Nomvula Mokonyane said in a statement water can be a major player in alleviating the energy shortage South Africa is currently facing through the implementation of conduit hydropower.

(http://www.ofm.co.za/article/Local-News/162487/Bloemwater-Conduit-Hydropower-Plant-to-be-launched?utm_source=dlvr.it&utm_medium=twitter)

(2) The Weekly Free State

Generate your own electricity

Water and Sanitation Minister Nomvula Mokonyane has suggested that smaller municipalities in the Free State which have been struggling to pay their electricity bills to national power utility Eskom due to limited revenue should consider using conduit hydroelectricity in order to cut costs and sustain service delivery to their communities.(http://theweekly.co.za/?p=12985)

(3) Water Research Commission

The launch of Bloemwater Conduit Hydropower Plant in Bloemfontein

On Tuesday, 31 March 2015 Minister of Water and Sanitation, Nomvula Mokonyane unveiled the Bloemwater's conduit hydropower facility at Brandkop Reservoir and celebrated the major scientific and engineering achievement made by the team of researchers.

(www.wrc.org.za/News/Pages/ThelaunchofBloemwaterConduitHydropowerPlantinBloemfontein.aspx)

(4) Awards

Community Renewable Energy Award (2014)

(http://mg.co.za/article/2014-06-27-00-a-conduit-to-hydroelectric-energy)

7. Reference

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[5] Bloemwater : www.bloemwater.co.za