

A Wind/Diesel System for the Antarctic Base Eduardo Frei - Conceptual Approach

Benjamin Jargstorf
Factor 4 Energy Projects GmbH



Comisión
Nacional de Energía

W/D System – Conceptual Approach
Antarctic Base Eduardo Frei Montalva

Factor 4 Energy
Projects GmbH



Slide 1/40

Contents

- ◆ Current Situation
- ◆ Recommendations (independently of wind power)

- ◆ Wind Regime
- ◆ Wind Park Site
- ◆ Wind Diesel System
- ◆ Proposals (including the wind energy option)
- ◆ Summary



Comisión
Nacional de Energía

W/D System – Conceptual Approach
Antarctic Base Eduardo Frei Montalva

Factor 4 Energy
Projects GmbH



Slide 2/40

Disclaimer

The following presentation reflects the opinion of the consultant only – it is not the official view of the Comisión Nacional de Energía or any other government body of Chile



Comisión
Nacional de Energía

W/D System – Conceptual Approach
Antarctic Base Eduardo Frei Montalva

Factor 4 Energy
Projects GmbH

Slide 3/40



Current Situation



Comisión
Nacional de Energía

W/D System – Conceptual Approach
Antarctic Base Eduardo Frei Montalva

Factor 4 Energy
Projects GmbH

Slide 4/40



Current Energy Supply Situation

- ◆ two unconnected diesel power plants (380 V)
- ◆ installed diesel power
 - ▶ 2 x 200 kW at the airport (Buffalo)
 - ▶ 2 x 473 kW at Villa Las Estrellas
- ◆ peak demand ~ 90 kW at the airport and ~ 400 kW at Villa Las Estrellas
- ◆ annual fuel consumption 1 ... 1.2 million litres diesel or ~ 1.8 million US\$ fuel costs
- ◆ assuming an typical occupancy rate of ~ 100 persons in winter and ~ 140 in summer: annual fuel consumption 10.000 litres per person or 27 litres per day

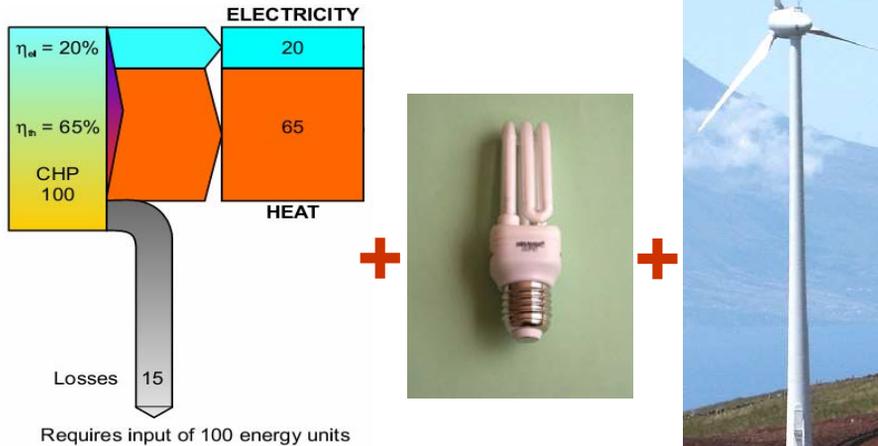


Current Energy Efficiency

- ◆ low efficiency because the diesel sets are over-dimensioned to cover the peak load
- ◆ operate most of the time with less than 30 % load
- ◆ in addition: consumers, such as lamps and heaters, are not disconnected when not needed (to avoid the diesel running with low load)
- ◆ low load operation of diesel leads to short life time, high maintenance costs of diesel gensets
- ◆ no incentives to save energy



Recommendations



Comisión
Nacional de Energía

W/D System – Conceptual Approach
Antarctic Base Eduardo Frei Montalva

Factor 4 Energy
Projects GmbH

Slide 7/40



Recommendations

- ◆ independently from implementing a wind energy project, the following measures are proposed:
- ◆ connect the two diesel power stations (underground cable) with the advantages:
 - ▶ better safety in case of power plant fire;
 - ▶ only one diesel power plant operates at a time;
 - ▶ prerequisite for a wind power plant at Eduardo Frei
- ◆ identify energy efficiency potential of the Base
- ◆ introduce co-generation at the diesel power plants
 - ▶ use diesel dissipation for space heating and warm water
 - ▶ considerably reduced power demand
 - ▶ large warm water storage for optimal wind power operation



Comisión
Nacional de Energía

W/D System – Conceptual Approach
Antarctic Base Eduardo Frei Montalva

Factor 4 Energy
Projects GmbH

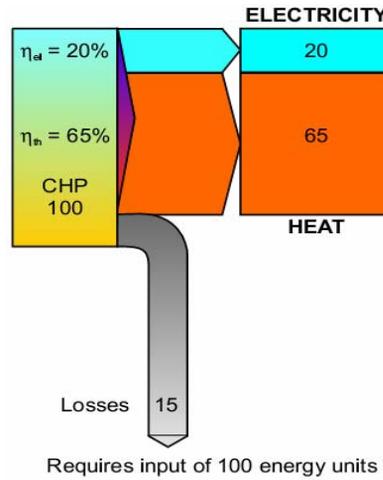
Slide 8/40



Cogeneration of electricity and heat

- ◆ example: an input of 100 energy units can yield 20 units of electricity and, simultaneously, 65 units of heat
- ◆ currently, at least 30 % of the electricity at the Base Eduardo Frei is used for heating
- ◆ energy efficiency:

$$\eta_{\text{cogeneration}} = \frac{85}{100} = 85 \%$$



Comisión Nacional de Energía

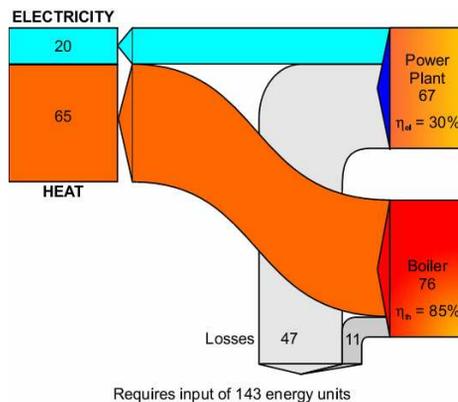
W/D System – Conceptual Approach
Antarctic Base Eduardo Frei Montalva

Factor 4 Energy
Projects GmbH



Slide 9/40

Separate generation of electricity and heat



- ◆ under condition of separate generation of heat and electricity (with a boiler efficiency of 85 %) 143 energy units are needed for the same energy effect
- ◆ energy efficiency:

$$\eta_{\text{separate}} = \frac{85}{143} = 59.4 \%$$



Comisión Nacional de Energía

W/D System – Conceptual Approach
Antarctic Base Eduardo Frei Montalva

Factor 4 Energy
Projects GmbH



Slide 10/40

Using Cogeneration at Base Eduardo Frei

- ◆ is expected to save 50 % of fuel for electricity;
- ◆ have annual savings ~ 0.5 million US\$;
- ◆ could reduce the fuel storage by ~ 30 %; and
- ◆ can replace ~ 80 % of all electric heating load

requires

- ◆ a large warm water storage
- ◆ a district heating system (piped warm water)

note:

figures indicated are first estimates only



Comisión
Nacional de Energía

W/D System – Conceptual Approach
Antarctic Base Eduardo Frei Montalva

Factor 4 Energy
Projects GmbH



Slide 11/40

Modified standard diesel engines

- ◆ transporting the heat from the cooling system to a separate insulated hot water tank
- ◆ enough heat for warm water in kitchen and sanitary installations (example from Great Wall station)



Comisión
Nacional de Energía

W/D System – Conceptual Approach
Antarctic Base Eduardo Frei Montalva

Factor 4 Energy
Projects GmbH



Slide 12/40

Diesel cooling = hot water for the Base



Comisión
Nacional de Energía

W/D System – Conceptual Approach
Antarctic Base Eduardo Frei Montalva

Factor 4 Energy
Projects GmbH



Slide 13/40

Wind Regime



Comisión
Nacional de Energía

W/D System – Conceptual Approach
Antarctic Base Eduardo Frei Montalva

Factor 4 Energy
Projects GmbH



Slide 14/40

Available Wind Data

- ◆ from automatic weather station at the airport available for 1995 – 1999 and 2001 – 2005
- ◆ long-term average of 8.7 m/s in 10m above ground
- ◆ good quality data, reliable
- ◆ a conservative forecast would give ~ 10 m/s at a hub height of 34 m above ground
- ◆ a typical 300 kW turbine would generate ~ 1.500 MWh per year, capacity factor > 50 %

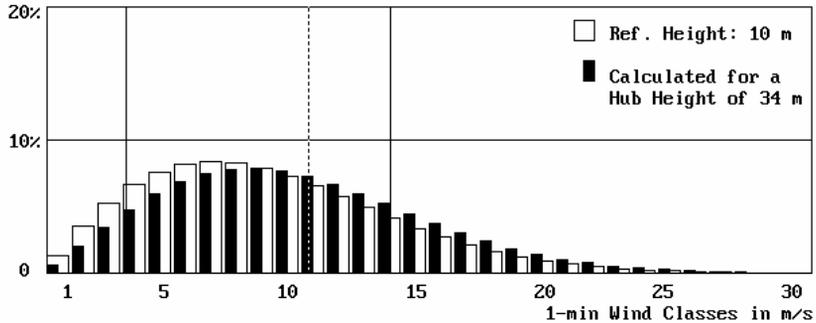
for comparison:

- ▶ best wind sites in Europe and the US ~ 30 ... 35 %

Expected Wind Frequency Distribution

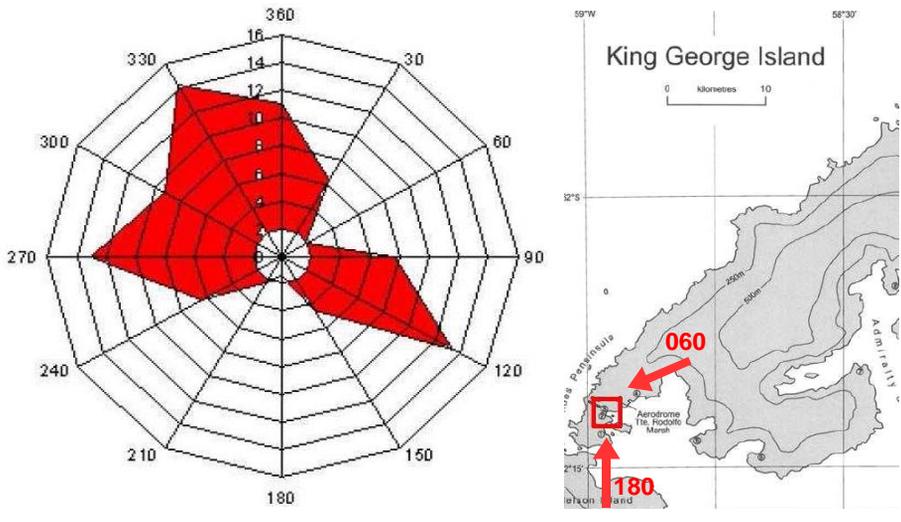
U-month: 9.92 m/s (U-ref: 8.70 m/s)
 E-month: 129,970.8 kWh * E-year, est: 1,559.6 MWh * P-gen, mean: 180.5 kW
 Standstill: 6.1 % * Part load: 62.4 % * Full Load: 31.5 % * CF-gen 51.6 %

FREQUENCY DISTRIBUTION $f(v)$ in % (k = 1.89; c = 9.81 m/s)
 Standstill Part Load Full Load




 WIND PLOT Laguna Las Estrellas R: .002 H: 34 m Enercon E33/330

Wind direction from airport data



Wind Park Site



Proposed wind park site - characteristics

- ◆ out of the way from airport (obstacle-free area)
- ◆ short distance to both power plants (airport and Villa Las Estrellas)
- ◆ easy access road (only ca. 300 m needed)
- ◆ no steep cliffs, not a too complex terrain
- ◆ unobstructed wind flow from the main wind directions
- ◆ a 100 m high hill sits in the South of the site – only small influence due to wind direction distribution
- ◆ no strong visual impact (no mountain top, not on top of or close to a landmark)



Comisión
Nacional de Energía

W/D System – Conceptual Approach
Antarctic Base Eduardo Frei Montalva

Factor 4 Energy
Projects GmbH



Slide 19/40

Proposed wind park site - location



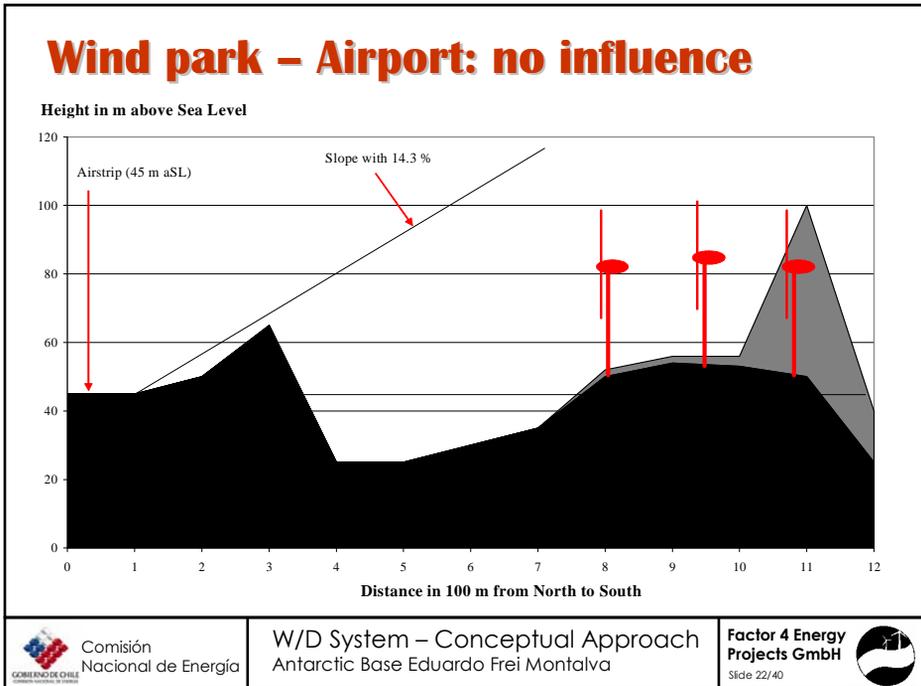
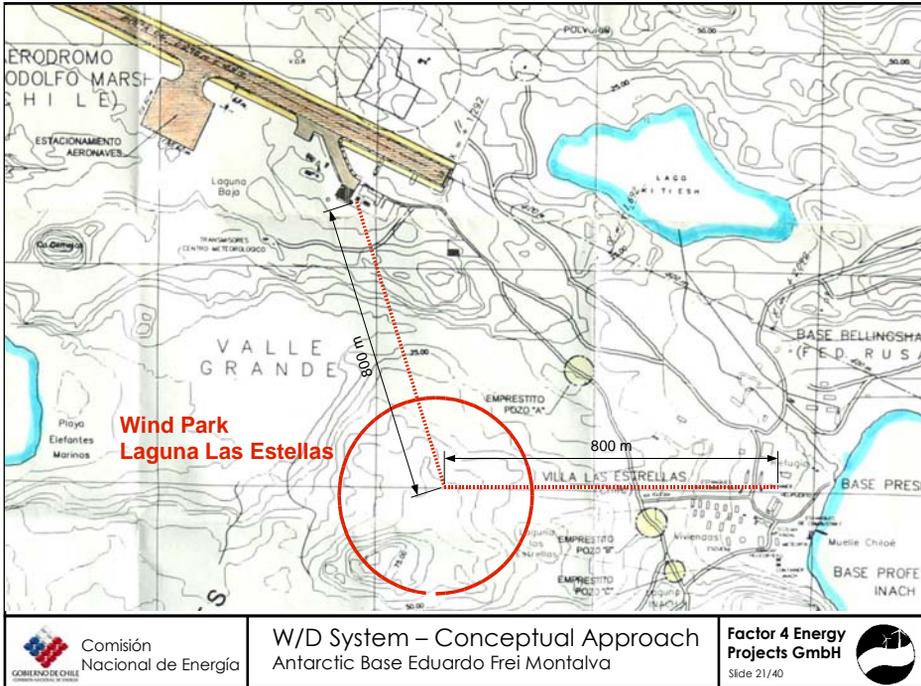
Comisión
Nacional de Energía

W/D System – Conceptual Approach
Antarctic Base Eduardo Frei Montalva

Factor 4 Energy
Projects GmbH



Slide 20/40



Wind park site – seen from Villa



Comisión
Nacional de Energía

W/D System – Conceptual Approach
Antarctic Base Eduardo Frei Montalva

Factor 4 Energy
Projects GmbH

Slide 23/40



Installation of measuring tower



Comisión
Nacional de Energía

W/D System – Conceptual Approach
Antarctic Base Eduardo Frei Montalva

Factor 4 Energy
Projects GmbH

Slide 24/40



First measuring results (48 hrs)

Wind Speed in m/s



Comisión Nacional de Energía

W/D System – Conceptual Approach
Antarctic Base Eduardo Frei Montalva

Factor 4 Energy
Projects GmbH



Slide 25/40



Wind Diesel



Comisión Nacional de Energía

W/D System – Conceptual Approach
Antarctic Base Eduardo Frei Montalva

Factor 4 Energy
Projects GmbH



Slide 26/40

Wind Power Integration with Diesel

- ◆ modern wind turbines designed and built to work in grid-parallel operation with large, interconnected grids
- ◆ parallel with small, isolated electric networks based on diesel generators is quite a different situation
- ◆ wind generators can influence (small) diesel generators (frequency up, reactive power demand ...)
- ◆ best wind turbine for small diesel-driven grids
 - ▶ indirect grid coupling (variable rotor speed)
 - ▶ pitch control (variable pitch angle of the rotor blades)
 - ▶ synchronous generator (no induction generator)
- ◆ additional Antarctic requirement: **no gear box**



Wind Turbine for Antarctica

- ◆ size limitation: max 300 kW (needs a ~ 100 ton crane)
- ◆ cold climate adaptation of series production wind turbines exist (in Norway, Finland, Mongolia)
- ◆ 90 % have gear boxes – would need grid power to be heated up during times of stand-still and low wind
- ◆ for a diesel-powered electric network such electric gear box heaters (up to 10 % of nominal power) prohibitive
- ◆ currently few manufacturers who offer wind turbines without gear box in the below 300 kW range



Transportation of rotor blades (Mawson)



Comisión
Nacional de Energía

W/D System – Conceptual Approach
Antarctic Base Eduardo Frei Montalva

Factor 4 Energy
Projects GmbH
Slide 29/40



Transportation of crane (Mawson)



Comisión
Nacional de Energía

W/D System – Conceptual Approach
Antarctic Base Eduardo Frei Montalva

Factor 4 Energy
Projects GmbH
Slide 30/40



Three modes of wind power integration

1. standard grid parallel operation – installed wind power < 50 % of minimum load in the grid – allows ~ 10 to 15 % wind penetration (= fuel savings)
2. high penetration grid parallel operation – installed wind power < 50 % of maximum load in the grid – allows ~ 15 to 30 % wind penetration
3. wind/diesel system – installed wind power > peak demand in the grid, diesel engine can be switched off completely when there is enough wind (requires additional technology for frequency control, reactive power generation and short circuit power) wind power penetration > 30 % (100 % possible)



Comisión
Nacional de Energía

W/D System – Conceptual Approach
Antarctic Base Eduardo Frei Montalva

Factor 4 Energy
Projects GmbH



Slide 31/40

Three modes of wind power integration

	Typical minimum Load	Technical Complexity	Additional Measures needed	Penetration Rates	Diesel Generator
Standard Grid-Parallel	> 100 kW	low	none	5 to 15 %	always on
High Penetration	50 - 2,000 kW*	medium	dynamic power factor compensation, load management, output reduction	15 to 30 %	always on
Wind/Diesel System	50 - 2,000 kW*	high	modified wind turbine, rotating phase shifter, battery and/or flywheel storage, supervisory control system and more	30 to 80 %, depending on the wind resource	can be switched off

*) larger projects possible



Comisión
Nacional de Energía

W/D System – Conceptual Approach
Antarctic Base Eduardo Frei Montalva

Factor 4 Energy
Projects GmbH



Slide 32/40

Wind power system for Base Eduardo Frei

- ◆ grid-parallel operation not recommended, as diesel generators currently operate always in low load condition (high specific fuel consumption, high wear)
- ◆ additionally, high up-front cost (for transportation and crane) make fuel savings < 30 % uneconomical
- ◆ wind/diesel system with the ability to switch off the diesel completely is the best option for such a small diesel-driven electric grid
- ◆ however, it requires
 - ▶ rotating phase shifter (synchronous condenser, MSM)
 - ▶ short-term energy storage (flywheel)
 - ▶ long-term energy storage and/or non-time critical consumers



Comisión
Nacional de Energía

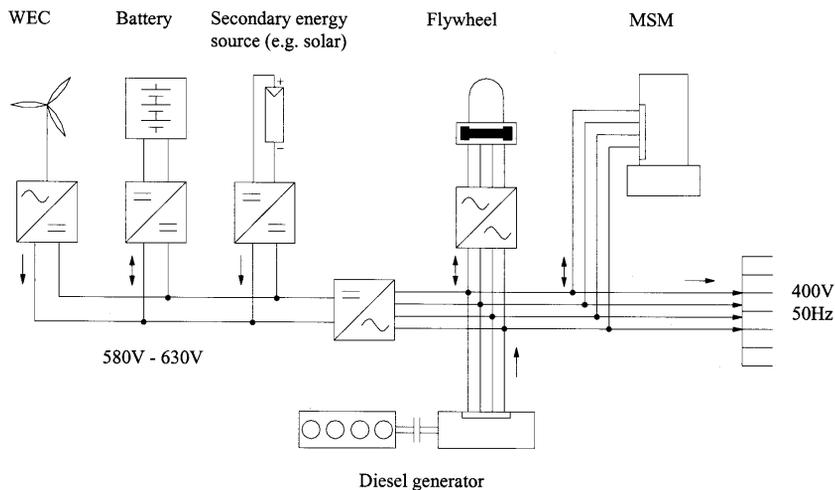
W/D System – Conceptual Approach
Antarctic Base Eduardo Frei Montalva

Factor 4 Energy
Projects GmbH



Slide 33/40

Example for a wind/diesel system



Comisión
Nacional de Energía

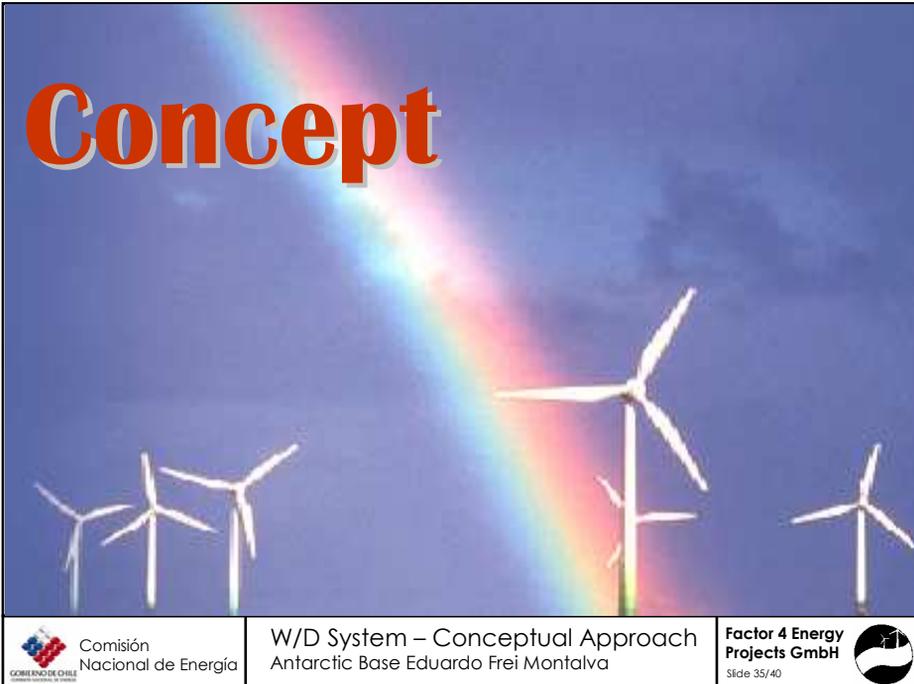
W/D System – Conceptual Approach
Antarctic Base Eduardo Frei Montalva

Factor 4 Energy
Projects GmbH



Slide 34/40

Concept



Comisión
Nacional de Energía

W/D System – Conceptual Approach
Antarctic Base Eduardo Frei Montalva

Factor 4 Energy
Projects GmbH

Slide 35/40



The way forward – Current Proposals

- ◆ connect both diesel power plants with an underground cable via the proposed wind park area
- ◆ contact wind turbine manufacturer of (preferably gearless) wind turbines
- ◆ joint design a wind/diesel system with a target wind energy penetration rate $> 80\%$
- ◆ convert existing power station in Las Estrellas to the main power station of the base (flywheel etc)
- ◆ install switch cabinets for synchronizing of diesel at both power stations
- ◆ install cogeneration of heat and power (= dump load for excess wind power)

note: preliminary proposals only



Comisión
Nacional de Energía

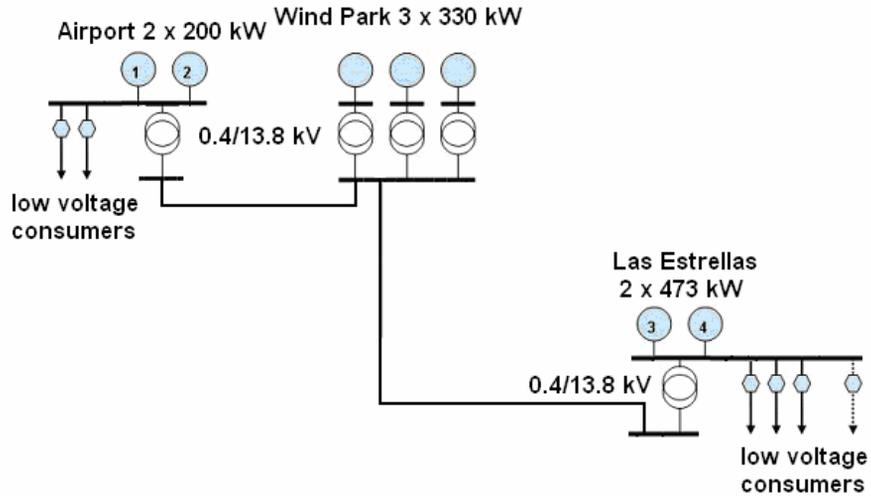
W/D System – Conceptual Approach
Antarctic Base Eduardo Frei Montalva

Factor 4 Energy
Projects GmbH

Slide 36/40



Single line diagram of BEF wind/diesel



Comisión Nacional de Energía

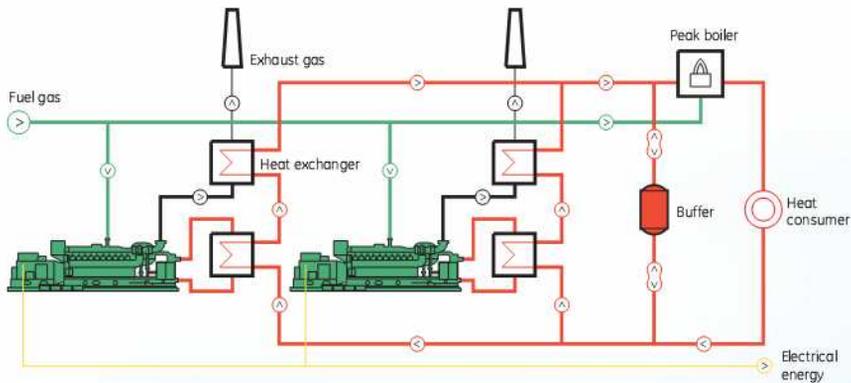
W/D System – Conceptual Approach
Antarctic Base Eduardo Frei Montalva

Factor 4 Energy
Projects GmbH



Slide 37/40

Cogeneration of heat and power



Comisión Nacional de Energía

W/D System – Conceptual Approach
Antarctic Base Eduardo Frei Montalva

Factor 4 Energy
Projects GmbH



Slide 38/40

Summary

- ◆ current two-power station scheme inefficient, lacks security
- ◆ joint power plants better security and efficiency
- ◆ wind power only feasible with a combined electric network
- ◆ plan and design a full wind/diesel system, which allows diesel-off mode
- ◆ avoid low-load operation of the diesels
- ◆ with a wind/diesel system, diesel power always in optimal mode (additional power for battery charging and/or water heating)
- ◆ introduce large hot water storage for catching diesel generator dissipation heat and excess wind power



Comisión
Nacional de Energía

W/D System – Conceptual Approach
Antarctic Base Eduardo Frei Montalva

Factor 4 Energy
Projects GmbH



Slide 39/40

The End.

Contact:

Dipl.-Ing. Benjamin Jargstorf
Factor 4 Energy Projects GmbH
Hinter dem Chor 8
23 966 Wismar GERMANY
+49-3841-40420/21
+49-151-1490 4208 mobile



Office in Chile:

Glamis 3404, Las Condes
Santiago de Chile
++56-2-4927 464

benjamin@factor-4.com



Comisión
Nacional de Energía

W/D System – Conceptual Approach
Antarctic Base Eduardo Frei Montalva

Factor 4 Energy
Projects GmbH



Slide 40/40