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A hybrid wind-diesel stand-alone system for fish farming applications

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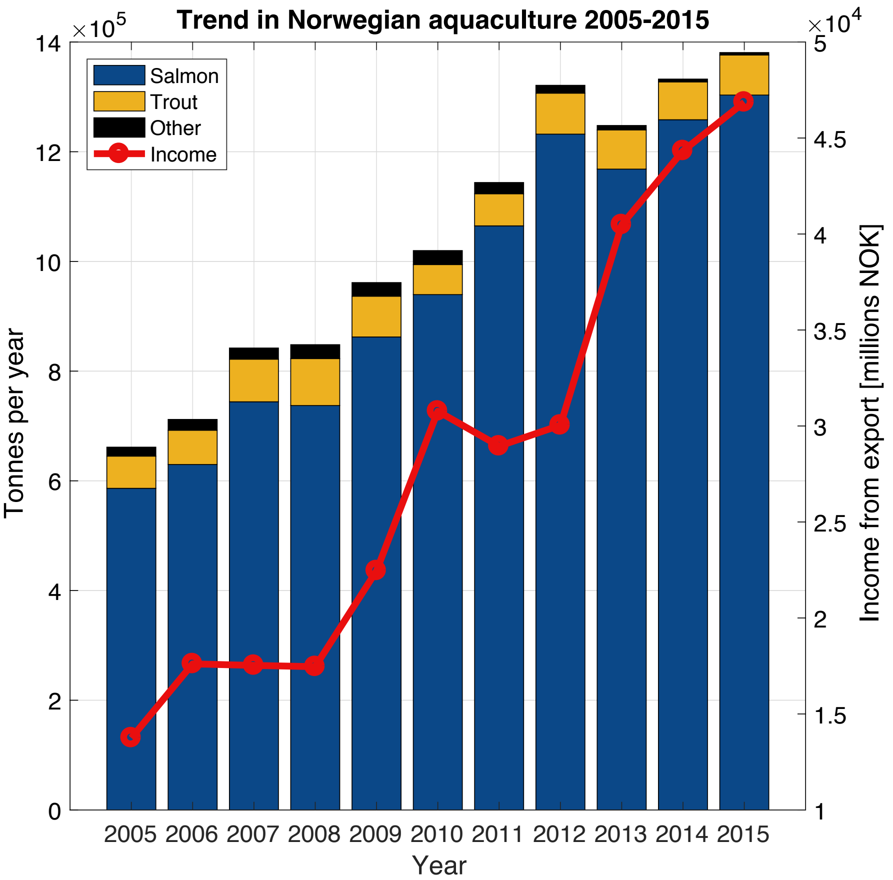
Overview

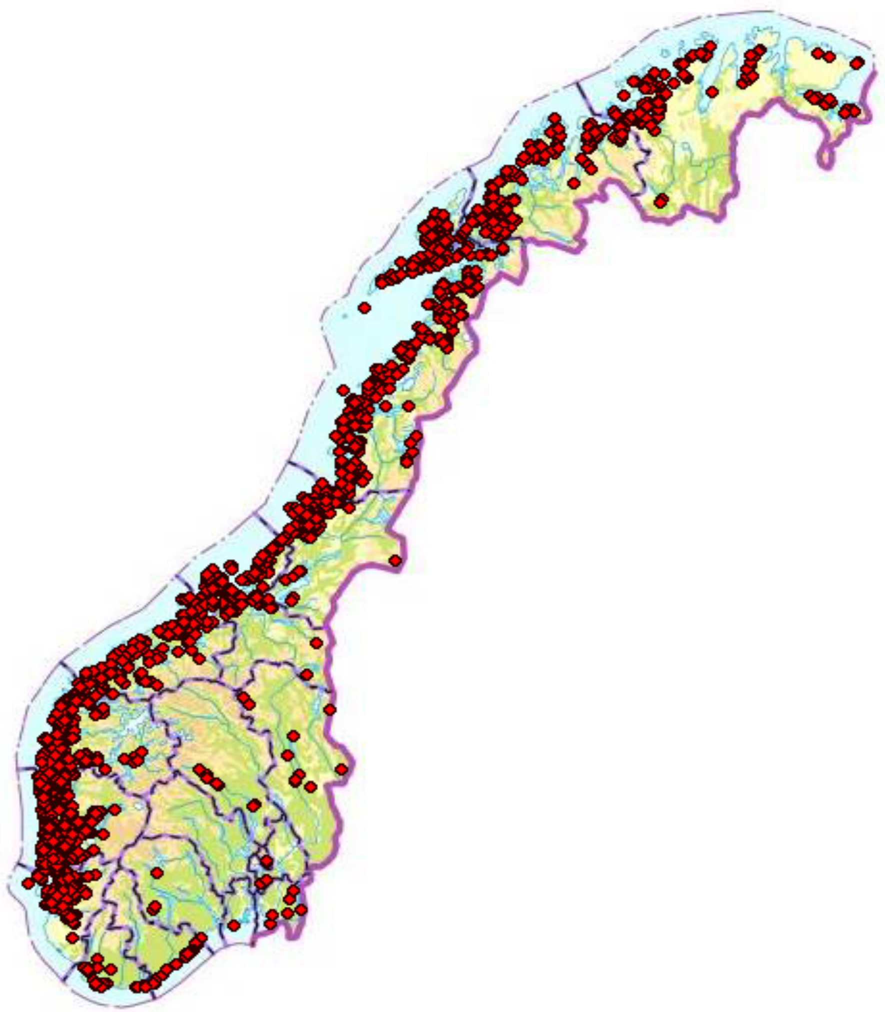
- The Norwegian fish farming industry
- Problem definition
- The proposed fish farm
- The hybrid wind-diesel system
- Setting up a long-term performance model in MATLAB
- Case studies and main results
- Shortcomings and further work

The Norwegian fish farming industry

- Export 2015: ~47 billion NOK
- Salmon dominates
- Direct employment: Nearly 7000 (per 2015)
- Expected to increase further towards 2050
- Challenges
  - Sea lice
  - Escaping fish
  - Available space
  - Environmental impacts



Locations with aquaculture

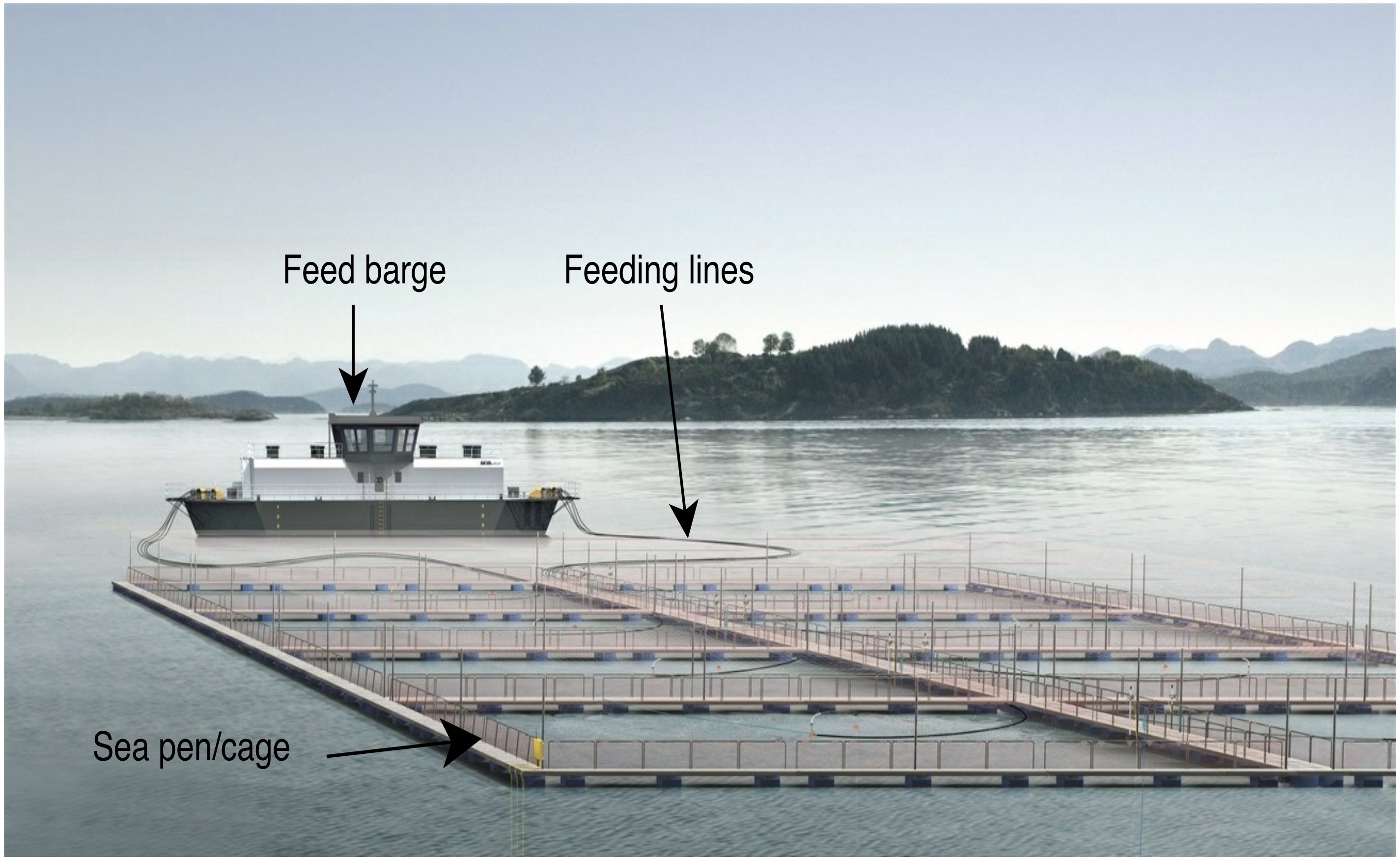


[1] Map from the Norwegian Directorate of Fisheries (2016)

Problem definition

- Used today: Diesel aggregates
- Desirable to replace diesel with local renewable sources
- Excessive energy should be used to run:
  - Production of O_2
  - Production of fresh water
  - High pressure washers
- Initiative by Pure Farming
- Co-op. with The National Wind Energy Center Smøla (NVES)
- Objective: *Design a hybrid wind-diesel system in order to reduce diesel fuel consumption as much as possible*

A conventional offshore fish farm

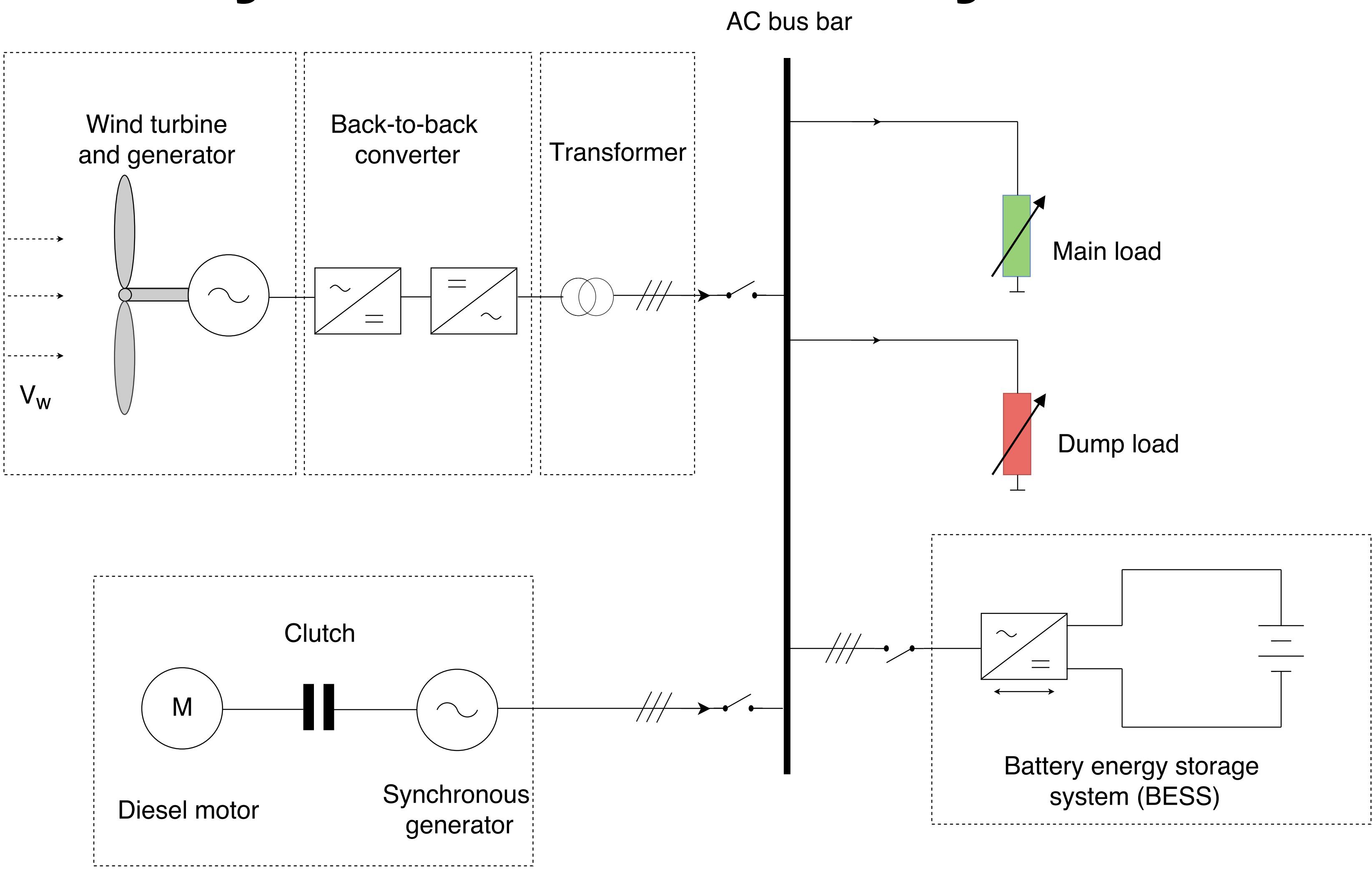


[2] Figure based on AKVA Group's brochure "Cage Farming Aquaculture"

The proposed fish farm

- Location: Gråøya, close to Smøla
- 6 feed blowers (each rated at 22 kW)
- 12 cages
- LED lightning of cages
- Expected yearly energy consumption: ~470 000 kWh
- TN-S electrical system

The hybrid wind-diesel system



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System modelling in MATLAB

- Steady state performance model
  - System state is assessed for every half-hour during one year
  - Wind profile
  - Load profile
  - Modelling of the components
  - Control strategy

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Wind profile

- Based on actual data from Veiholmen (1994-2014)
  - Resolution 1 hour
  - Takes into account seasonal variations
- WAsP used to transform wind speeds to hub height and desired geographical location
- Very good wind conditions
  - Average wind speed: 8.7 m/s (1994-2014)

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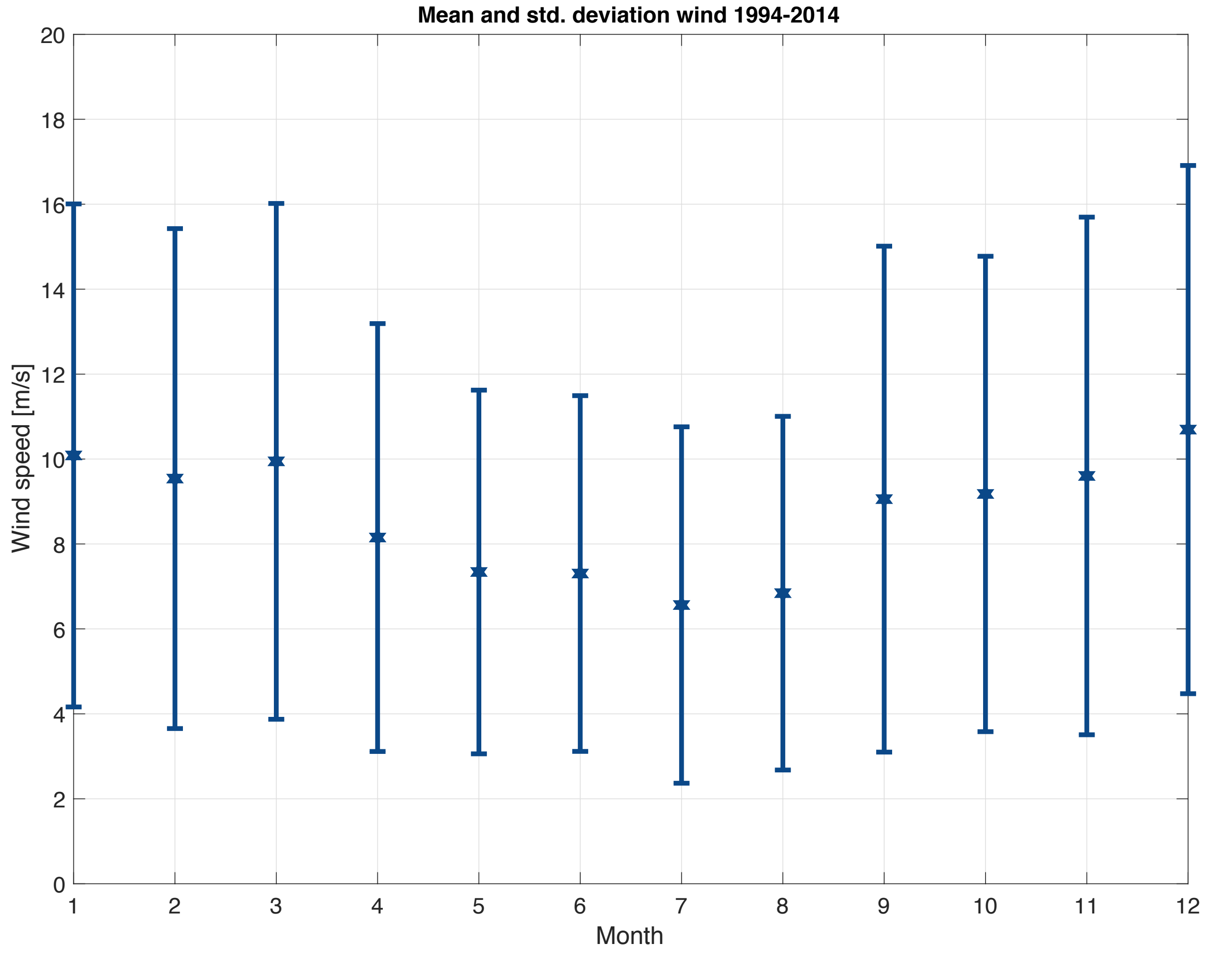
Wind profile



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Consumption profile

- Expected yearly energy consumption ~470 000 kWh

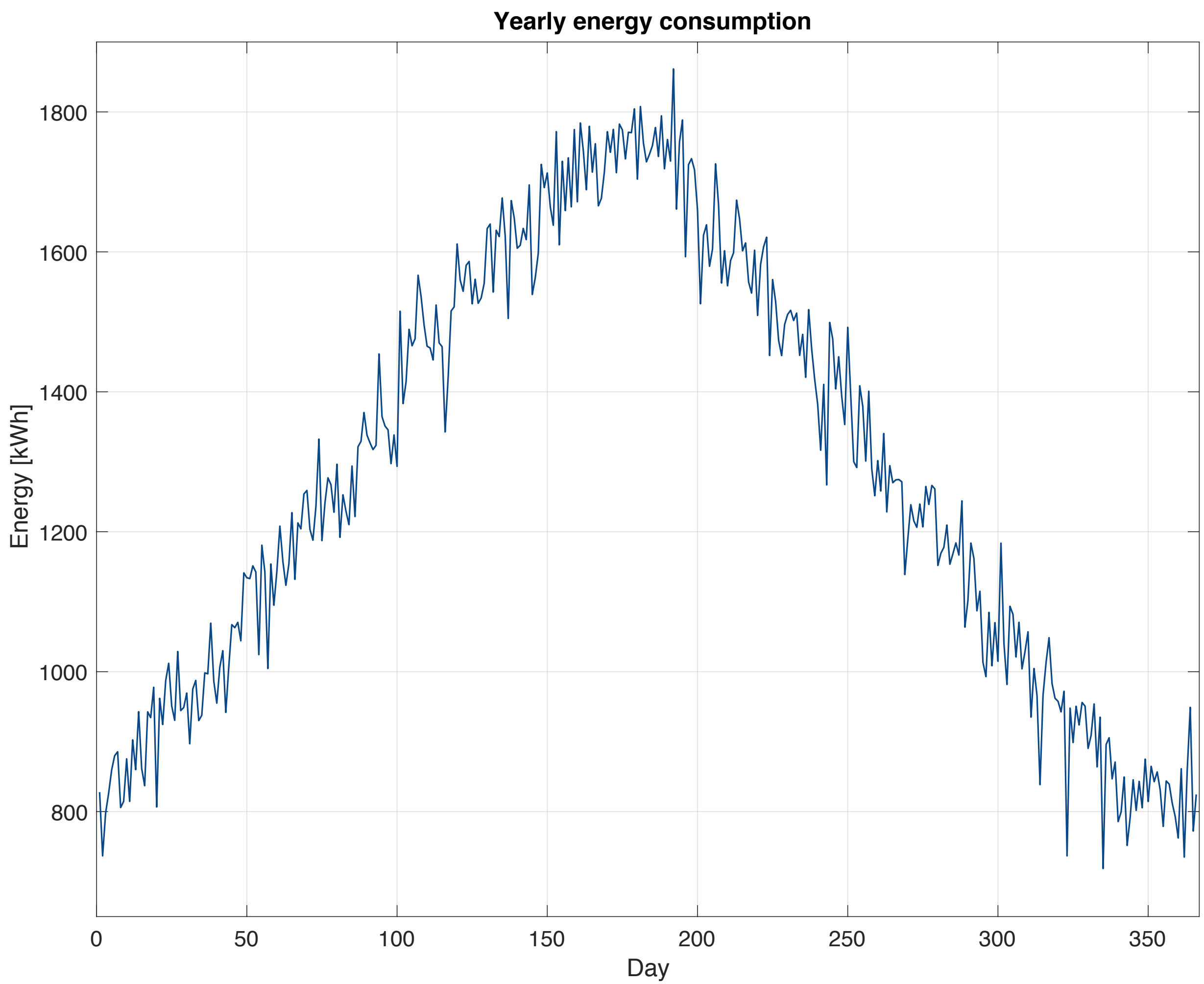
Deterministic load

- Feed blowers and lightning of cages
- Depends on the day length
  - Blowers run at day-time
  - Lightning at night-time
- Blowers: 72.6 kW
- Lightning: 14.4 kW

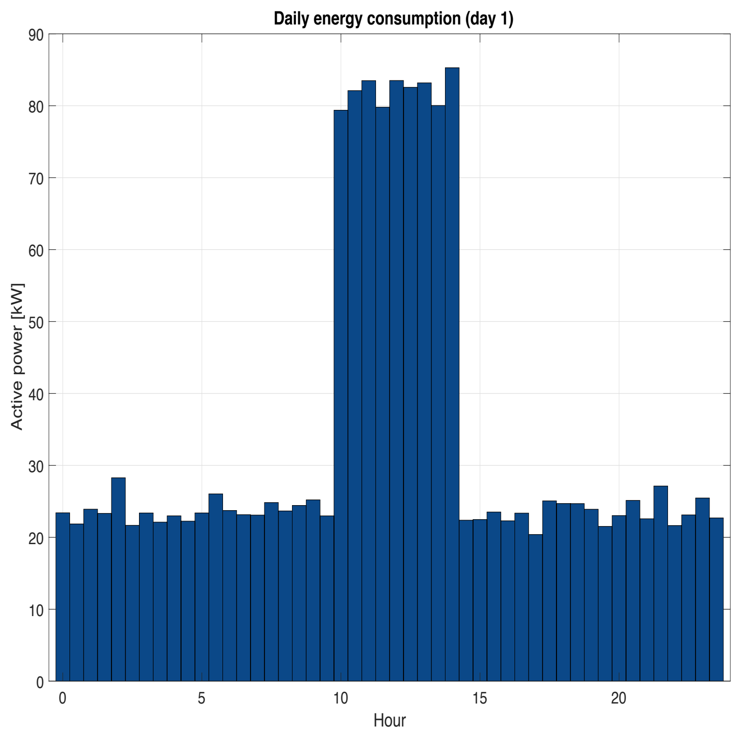
Stochastic load

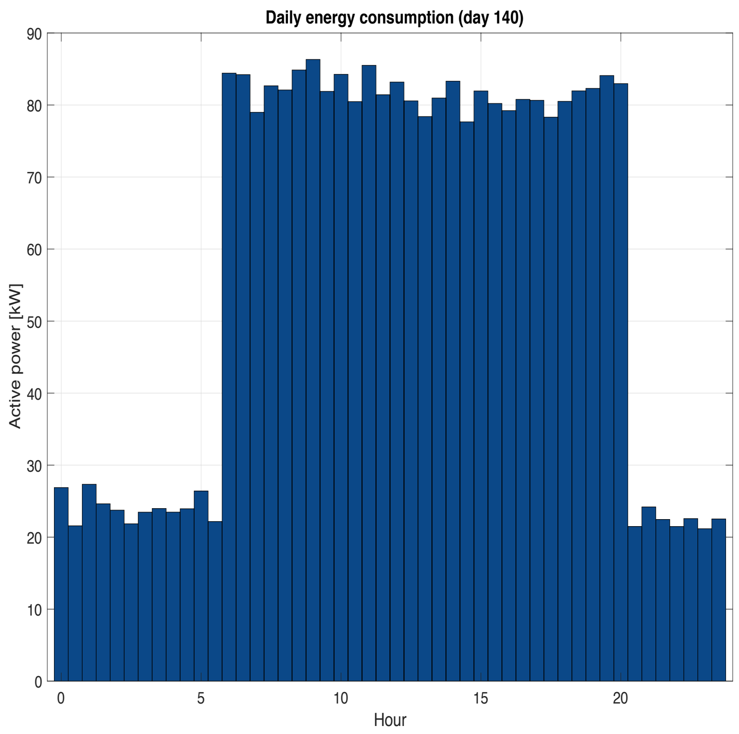
- The feed barge's own consumption
  - Heating
  - Lightning
  - Control system
- Gaussian distribution used
  - Expectation: 9 kW
  - Std. deviation: 2 kW

Consumption profile



Consumption profile

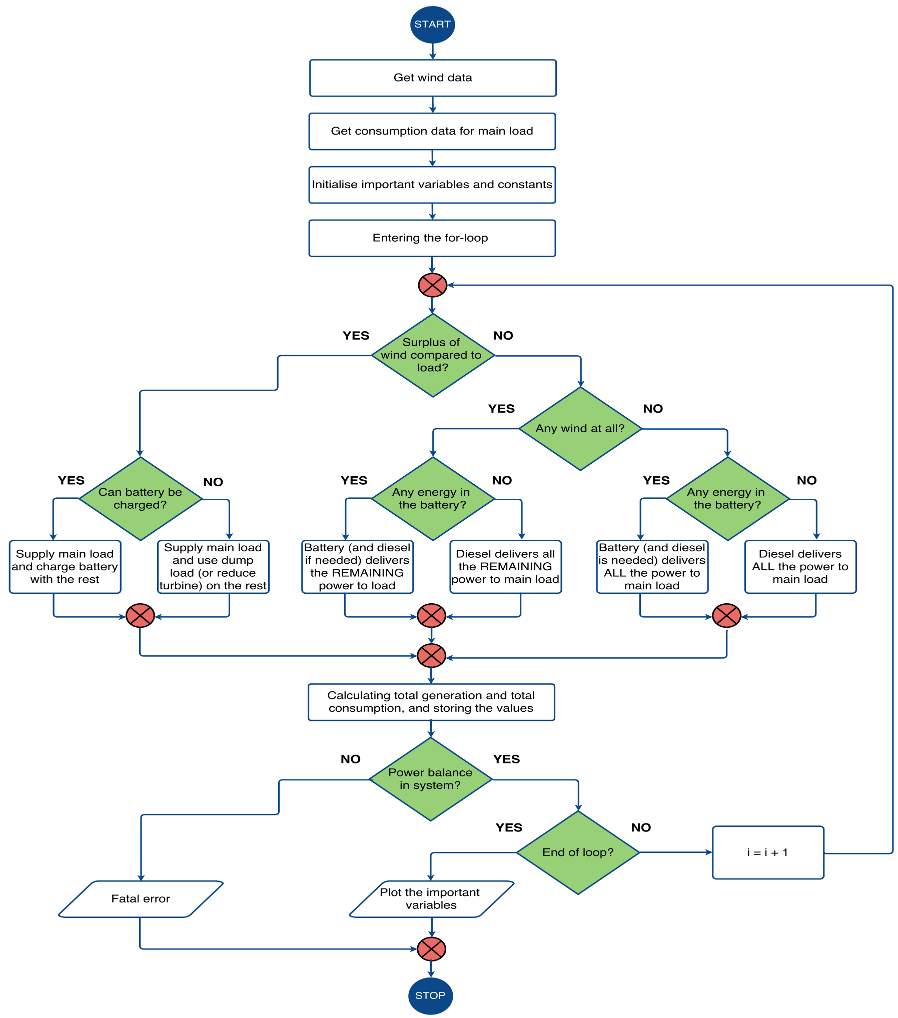




Modelling of the components

- Wind turbine: Power curve of an EWT DW52 250 kW turbine used
- Dump load: Max and min power limits
- Battery Energy Storing System (BESS) :
  - Max power capability
  - Max energy capacity
  - Depth of discharge
- Diesel aggregate: Treated as the resolving post
  - Fuel consumption predicted by a simple linear relationship

The control strategy



Case studies

- Simulated over the year of 2012
- One base case
- Sensitivity cases on
  - Battery size
  - Depth of discharge
  - Max power to/from battery
  - Dump load margins
- Special cases on
  - Wind only
  - Diesel only
  - Wind-diesel

Case studies

Table 5.1: Input data for base case

	Name	Parameter	Value	Unit
Diesel	Diesel fuel constant	A	0.246	l/kWh
	Diesel fuel constant	B	0.08415	l/kWh
	Power rating diesel engine	$P_{D,nom}$	100	kW
BESS	Battery voltage	V_B	520	V
	Battery current capacity	A_B	500	Ah
	Battery depth of discharge	DoD	70	%
	Maximum battery state of charge	$W_{B,max}$	260	kWh
	Minimum battery state of charge	$W_{B,min}$	78	kWh
	Maximum power to/from battery	$P_{B,max}$	100	kW
	Maximum battery through converter	$P_{CONV,max}$	150	kW
Dump	Minimum limit for dump load	$P_{DUMP,min}$	10	kW
	Maximum limit for dump load	$P_{DUMP,max}$	120	kW

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Main results

- Battery size have largest impact on diesel fuel
- Potential of ~1 500 000 kWh from wind turbine only
  - Dump load margins important
- Wind conditions fairly stable
- More than one diesel aggregate may be desirable
- Reduction in fuel from approx. 170 000 litres to 25 000 litres yearly solely by including a wind turbine (~85 % reduction)
  - More than 1 million NOK yearly in purchase cost only
  - Very large battery may not be needed

Shortcomings and further work

- Main goal: form a sound decision basis
- Cost of components and operation not yet surveyed
  - Will be given special focus in the master thesis
- Steady state analyses does not take into account
  - Voltage fluctuations
  - Power quality
  - Other transients
- Detailed component features not included due to the lack of time