Wind power systems for commercial seaweed drying

Roy S. Bartle, Alasdair Macleod*

Department of Engineering
Lews Castle College, University of the Highlands and Islands, UK.

2020 Arctic Frontiers
Tromsø, Norway
26-30 January 2020

Outline

1. Why dry seaweed with wind power in the Northern Periphery and Arctic region?
   Food security and wind in the Northern Periphery and Arctic region.
2. What does a basic wind power drying system look like?
   Wind power system for seaweed drying
3. What design considerations exist when selecting a system?
   Case study

Food security and wind in the Northern Periphery and Arctic region

Why dry seaweed with wind power in the Northern Periphery and Arctic region?

SWGROW

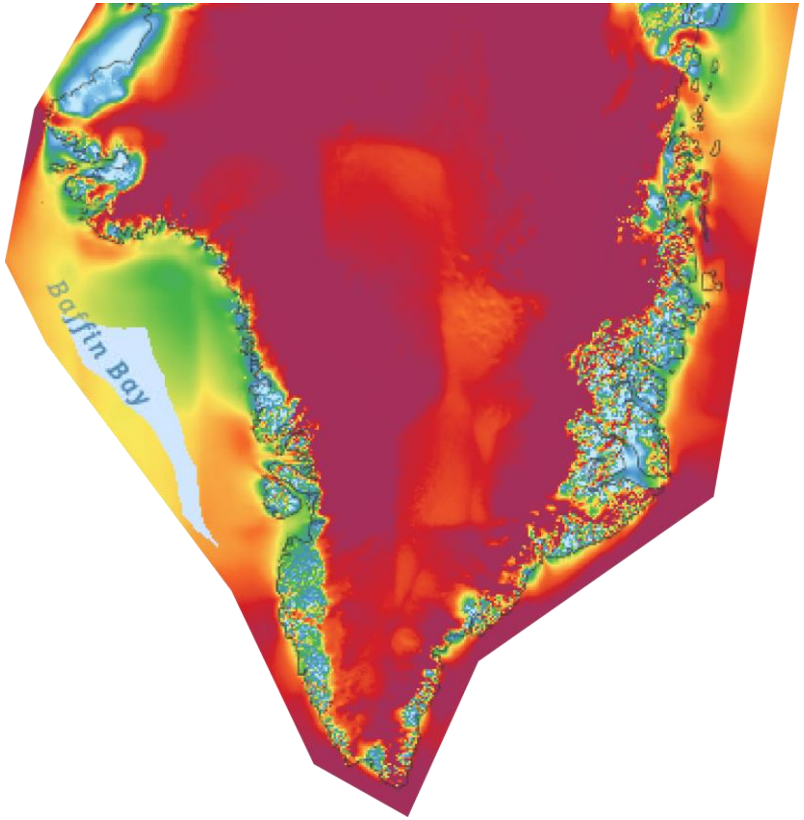
Northern Periphery and Arctic Programme 2014–2020

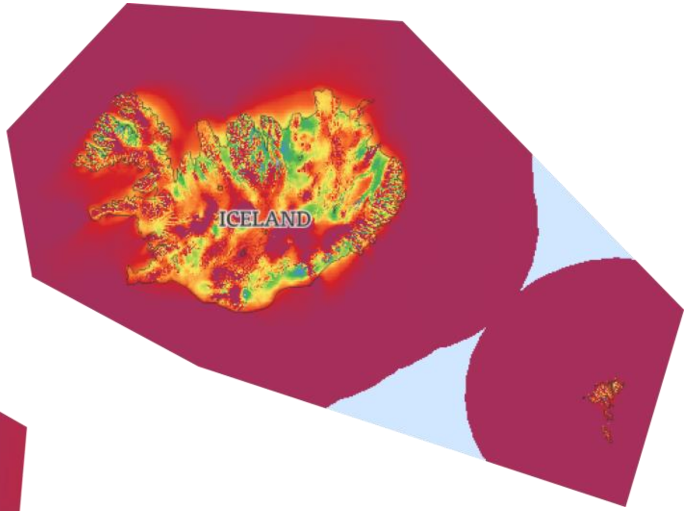
Seaweed for food security in the Arctic region

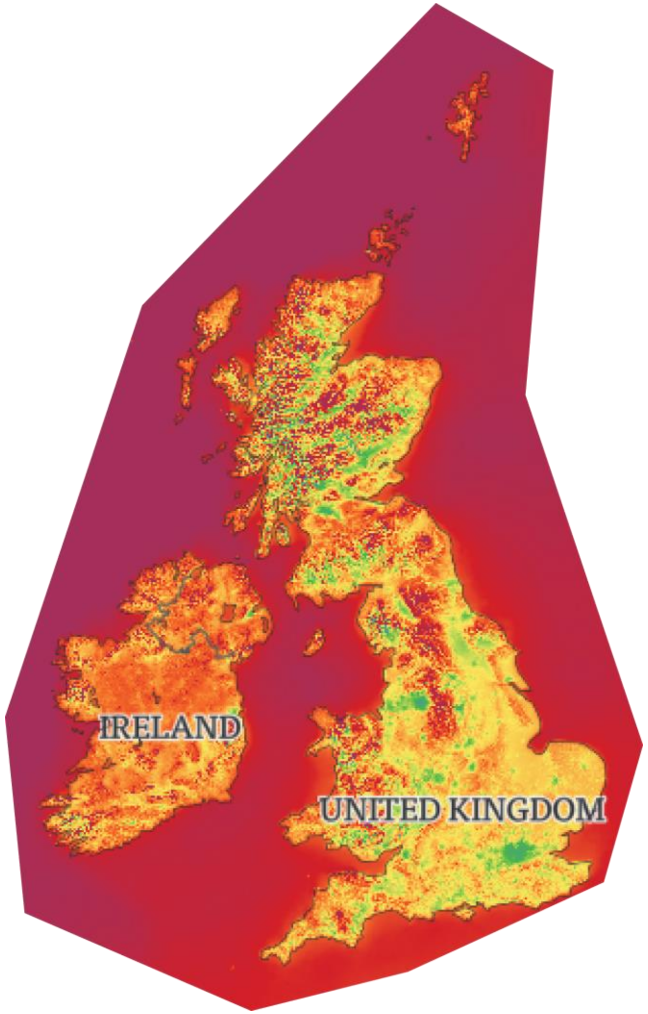
- The higher latitude limit to seaweed growth is c. 80° N (Lüning, 1990).
- High water clarity allows deep penetration of insolation for 2-3 months per year (Gomez et al., 1997).
  - Climate change induced early ice melting expands seaweed growing season (Barnes 2015).
- Alternative naturally occurring food sources are limited.
- Potential alternative locally farmed foods are limited.

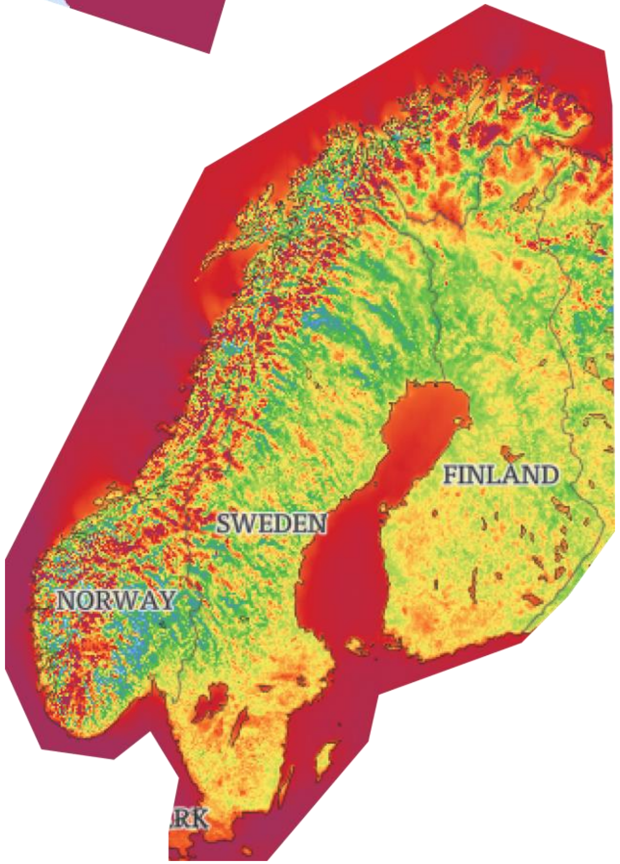
SWGROW

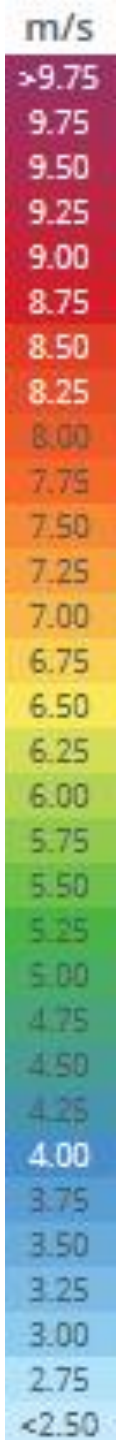
Northern Periphery and Arctic Programme 2014–2020









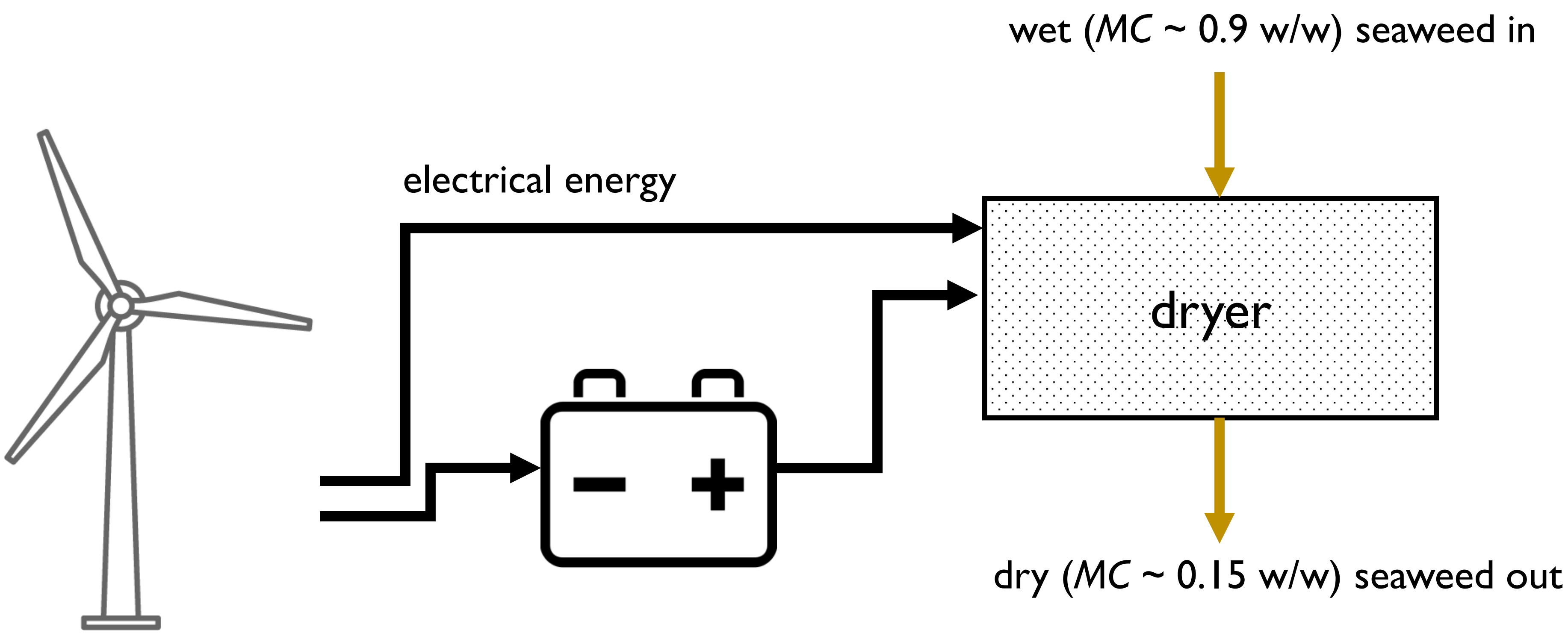


Mean wind speeds at 50 m ASL
(Global Wind Atlas 3.0)
Not to scale or relative position

Wind power system for seaweed drying

What does a basic wind power drying system look like?

Wind power system for seaweed drying



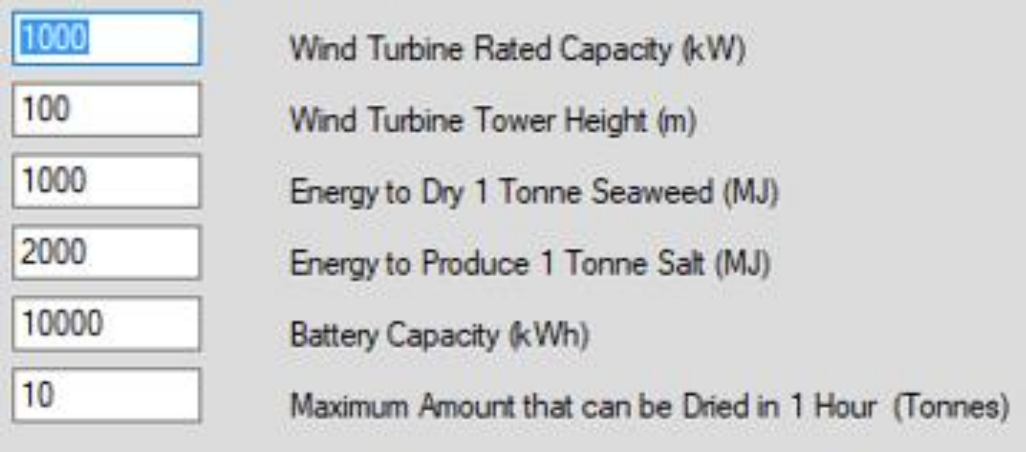
Main user inputs to model

Data inputs:

- Hourly windspeed for year;
- Hourly seaweed production for year;

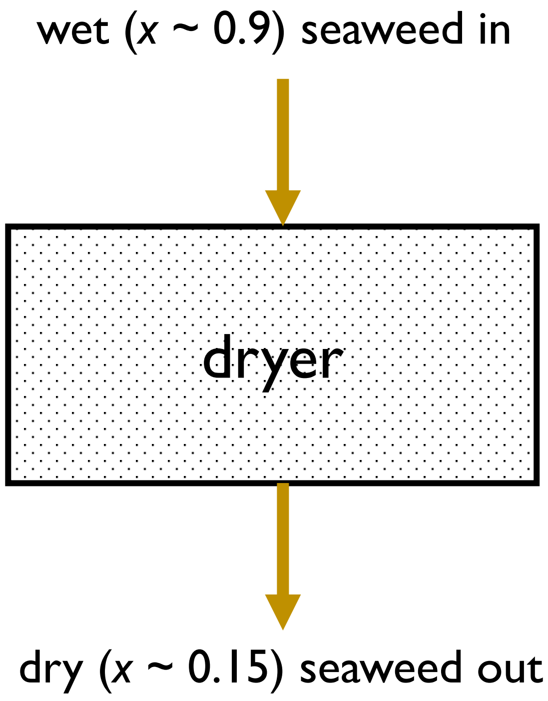
Frontend variables:

- Wind turbine rated capacity and hub height;
- Battery capacity;
- Energy required to dry tonne of seaweed.



Food drying model

- Actual energy requirements are slightly dependent on seaweed species and heavily dependent on process design.
- Typical values:
  - Basic blown air dryer= 1400 MJ tonne^{-1}(Suherman et al 2018) to 2250 MJ tonne^{-1} (Aziz et al. 2013).
  - Blown air dryer with energy recovery = 237 MJ tonne^{-1} (Aziz et al. 2013).



SWGROW

Northern Periphery and Arctic Programme
2014–2020

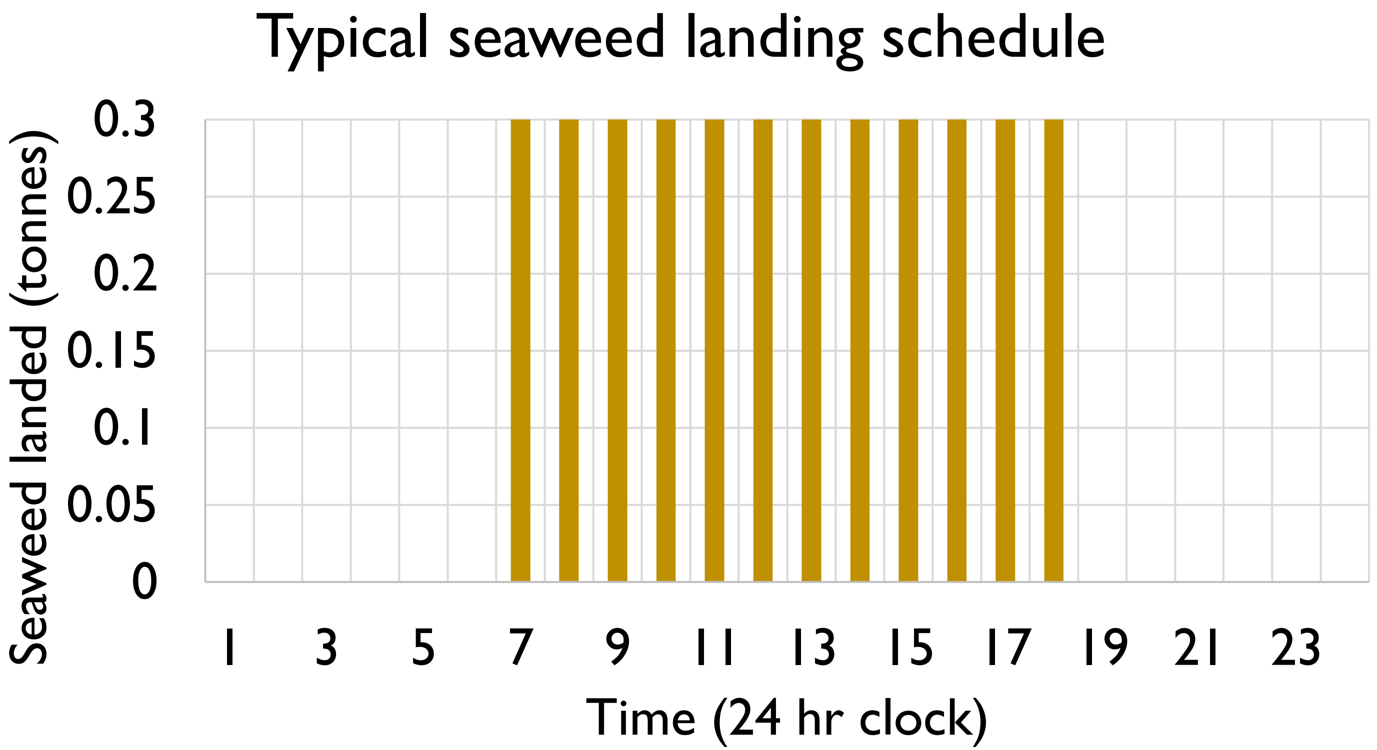
Model frontend

Case study

What design considerations exist when selecting a system?

Case study parameters

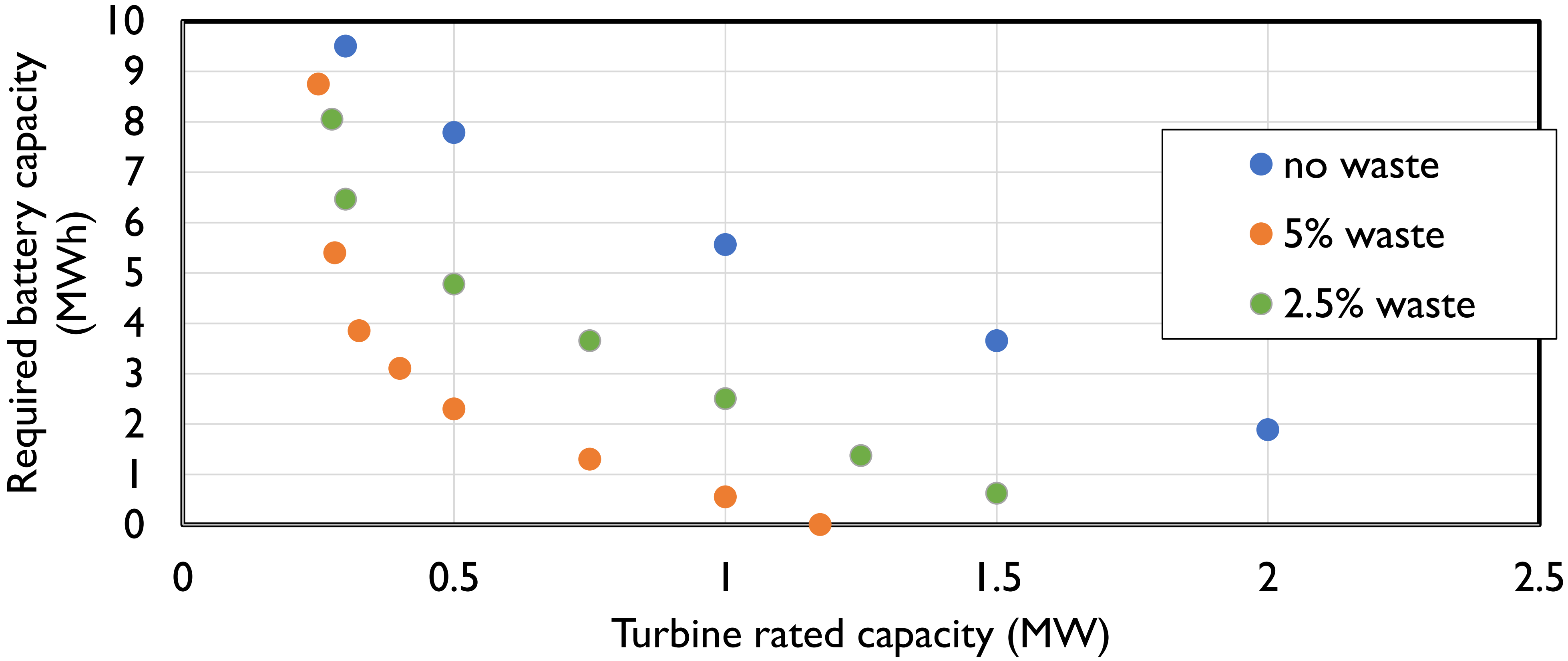
- Wind data location: Stornoway, UK.
- Production: 0.3 tonne/h, 12 h/day, all April and May.
- Drying method: Basic blown air (2000 MJ $tonne^{-1}$)
- Turbine hub height: 100 m



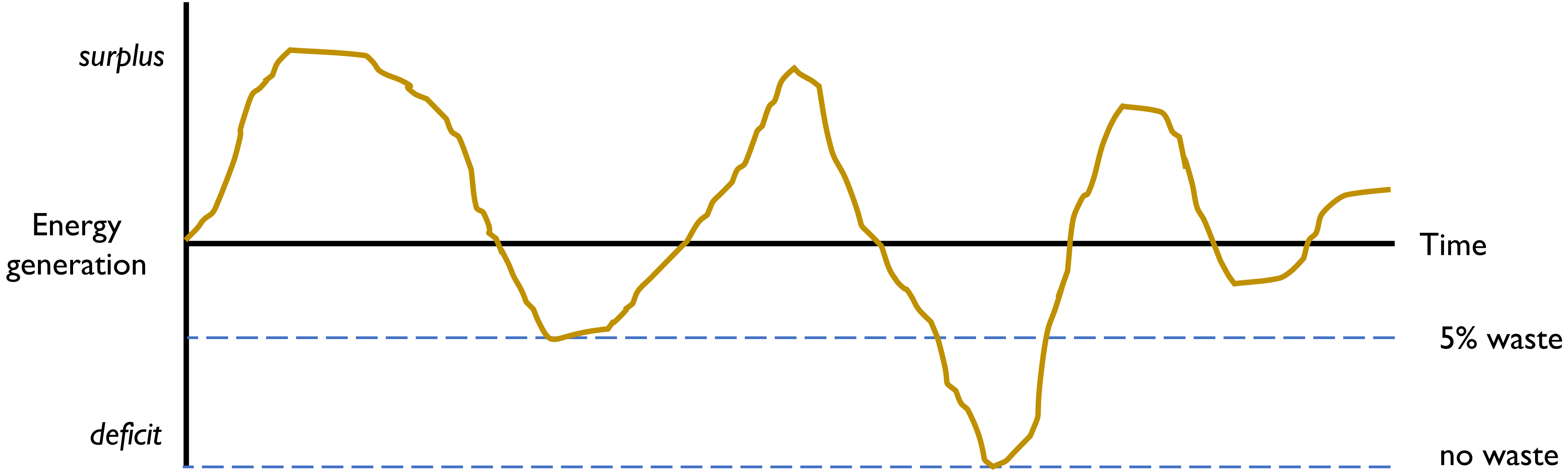
SWGROW

Northern Periphery and Arctic Programme
2014–2020

Case study: turbine-battery-“waste” tradeoff



Case study: turbine-battery- “waste” tradeoff



Conclusions

Conclusions

- Seaweed drying using wind as the primary energy source is very plausible in the NPA region due to:
  - Good water characteristics;
  - Excellent mean windspeeds.
- Order-of-magnitude reduction in power requirement if energy capture drying processes are introduced.
- For an off-grid system, tradeoffs exist between turbine size, battery capacity, and acceptable level of "waste".

Future additions to the model

- Alternative primary energy sources (e.g. solar, wave, hydro)
- Alternative energy storage (e.g. hydrogen)
- Alternative drying processes (e.g. energy recovery)
- Uses for "waste" seaweed (e.g. fertiliser, biofuel).
- Effects of on-grid installation
- Alternative uses of drying facility when seaweed is not harvested (e.g. salt production)
- Installation and lifecycle economic analysis
- Transient seaweed drying

SWGROW

Roy Bartle, *Postdoctoral Research Associate*
roy.bartle@uhi.ac.uk

Alasdair Macleod, *Senior Lecturer*
alasdair.macleod@uhi.ac.uk

Department of Engineering
Lews Castle College UHI

References (1)

Aziz, M., Oda, T., Kashiwagi, T. "Enhanced high energy efficient steam drying of algae," in *Applied Energy*, 109, 163-170, 2013.

Barnes, D. K. A. "Antarctic sea ice losses drive gains in benthic carbon drawdown," in *Curr. Biol.* 25, 789–790, 2015.

Fellows, P. J. Chapter 14, "Dehydration," in *Food Processing Technology: Principles and Practice*, Woodhead, Duxford, UK. 2016.

Gomez, I; Weykam, G; Kloser, H; Wiencke, C. "Photosynthetic light requirements, daily carbon balance and zonation of sublittoral macroalgae from King George Island (Antarctica)," *Mar. Ecol. Progr. Ser.* 148:281–293, 1997.

Global Wind Atlas 3.0, Technical University of Denmark.

References (2)

Lüning, K. *Seaweeds: their environments, biogeography and ecophysiology*. Wiley, New York, 1990.

Rienecker, M. M., Suarez, M. J., Gelaro, R., Todling, R., Bacmeister, J., Liu, E., Bosilovich, M.G., Schuberg, S. D., Tacaks, L., Kim, G. K., Bloom, S., Chen, J., Collins, D., Conaty, A., Da Silva, A., Gu, W., Joiner, J., Koster, R. D., Lucchesi, R., Molod, A., Owens, T., Pawson, S., Pegion, P., Redder, C. R., Reichler, R., Robertson, F. R., Ruddick, A. G., Sienkiewicz, M., Woolen, J. "MERRA: NASA's modern-era retrospective analysis for research and applications", in *J. Clim.*, pp. 3624—3648, 2011.

Suherman, S., Djaeni, M., Kumoro, A. C., Prabowo, R. A., Rahayu, S., Khasanah, S. "Comparison drying behavior of seaweed in solar, sun and oven tray dryers," in *MATEC Web of Conferences, Special Issue for RSCE2017*, 156, 05007. 2018.

References (3)

Wiencke, C. and Bischof, K. (eds). *Seaweed biology: novel insights into ecophysiology, ecology and utilization*. Springer, Heidelberg, 2013.