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New Zealand's Place in the World

Monday & Tuesday
19–20 April 2010
08:30–18:30
Oceania Room,
Te Papa Tongarewa,
Wellington

Diminishing Returns and Arranging Tidal Turbines in a Channel

Sea Gen 1.2MW at 2.25m/s, Strangford Narrows, Northern Ireland

www.marineturbines.com

www.seageneration.co.uk

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Scaling up Farms

To realize most of an area's potential and to make a significant contribution to electricity demand

→ Need large densely packed Farms

i.e. 10's to 100's of Mega Watt turbines

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Assessing the Potential of Farms is in its infancy

10% Kinetic Energy Flux

- How much energy is flowing along the undisturbed channel?

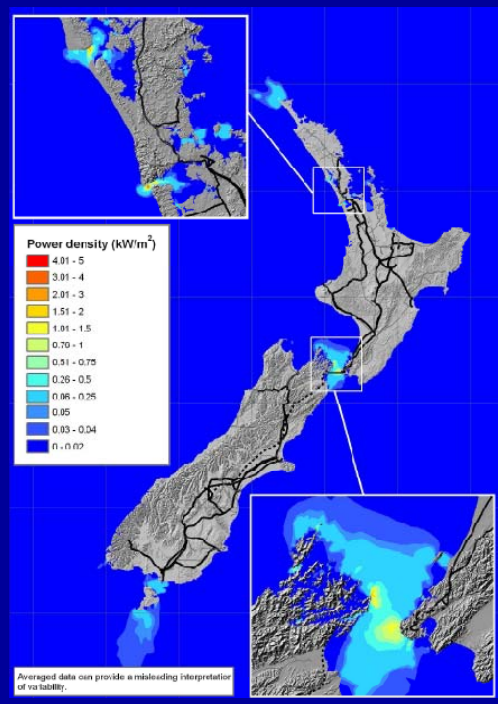
➡ Poor as ignores interaction of the turbines with the flow

Turbine-flow Farm scale interactions

- Drag due to power extraction

1) reduces large scale flows along channels

2) diverts flows around a farm



EnergyScape

Must include effects of turbines on flow in any resource assessment

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Interaction effects and Farm Scalability

- Sea Gen Turbines
  produces 1.2MW at 2.25m/s
- Installing 1 SeaGen in a 2.25m/s current gives 1.2MW
- Installing 100 in the same area will not give 120MW!!!

Power extraction creates drag on the flow which slows the currents in the area to below 2.25m/s

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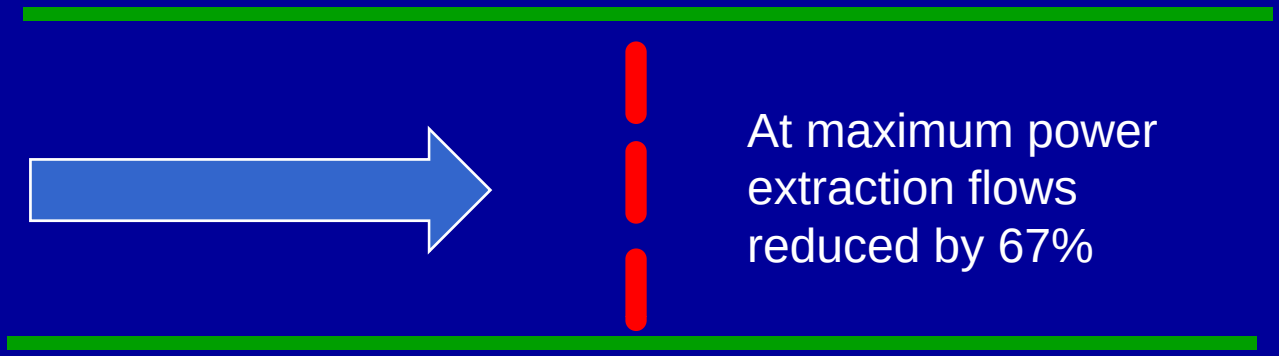
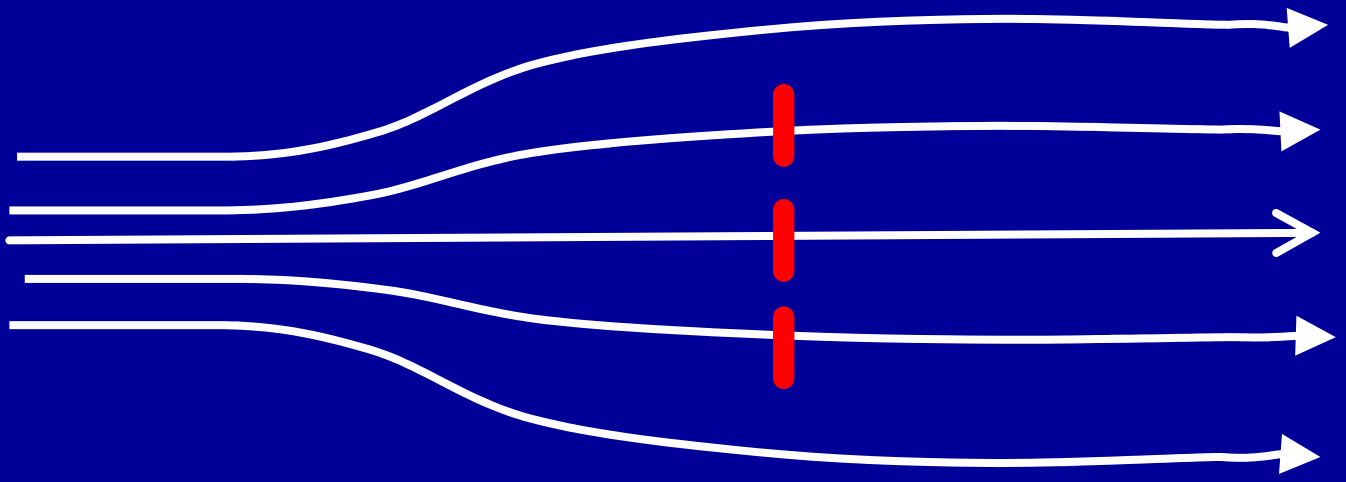
Large Farm Effects

1) Channel Flow Reduction



2) Flow by-passing or diversion



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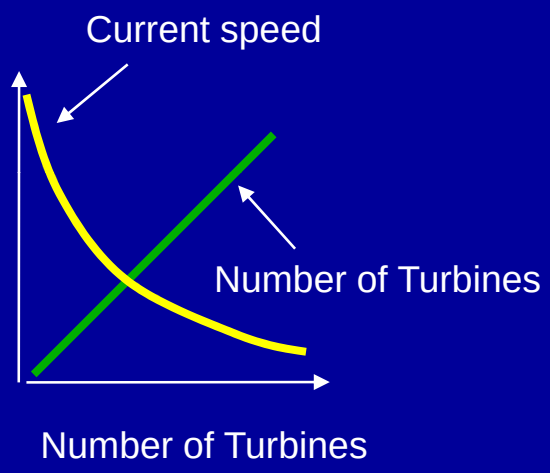
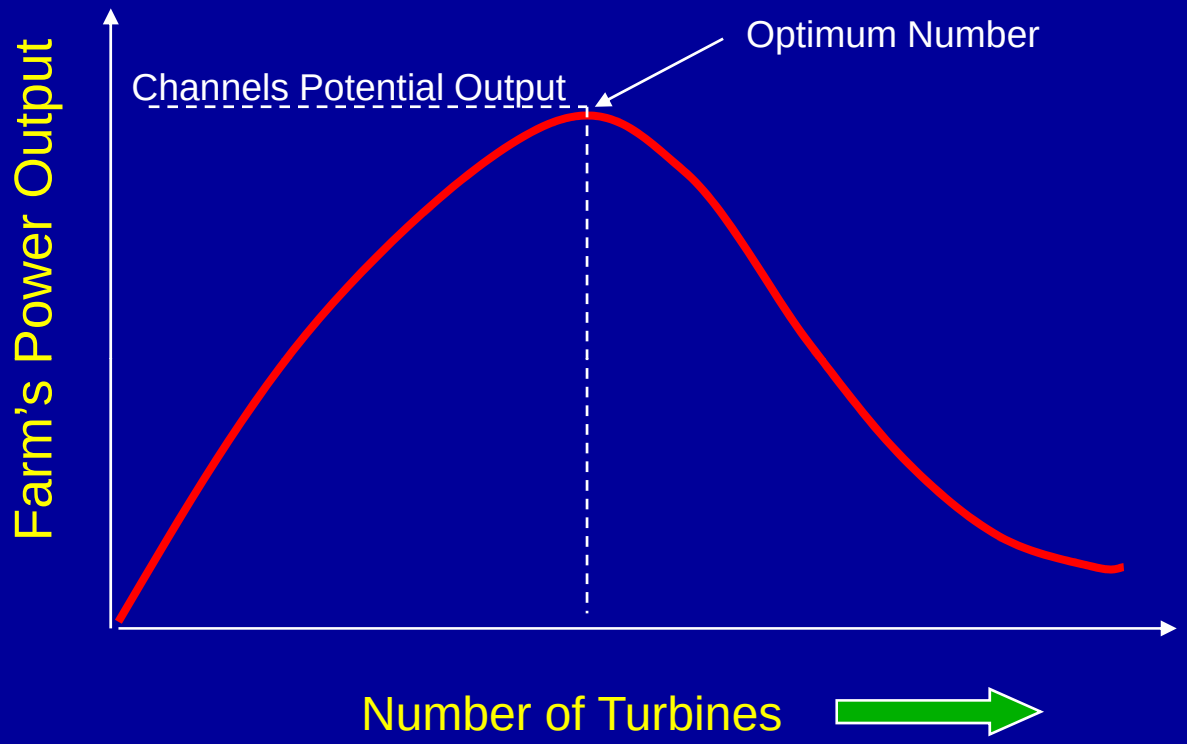
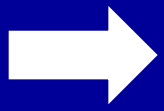
Turbine Farms in Channels and the Law of Diminishing Returns





Farm Power output $\propto$ (number of turbines) $(\text{velocity})^3$



Diminishing returns on Extra Turbines

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Garrett & Cummins 2005

Diminishing Returns

Farm Output Power $\propto$ (number of turbines) $(\text{velocity})^3$

Adding a turbine

- gives extra generation capacity
- slows flow for all turbines, reducing their output

$\rightarrow$ Diminishing returns as the increases in power output from each new turbine is less than the last

$\rightarrow$ At peak all turbines produce only 30% of power first turbine installed

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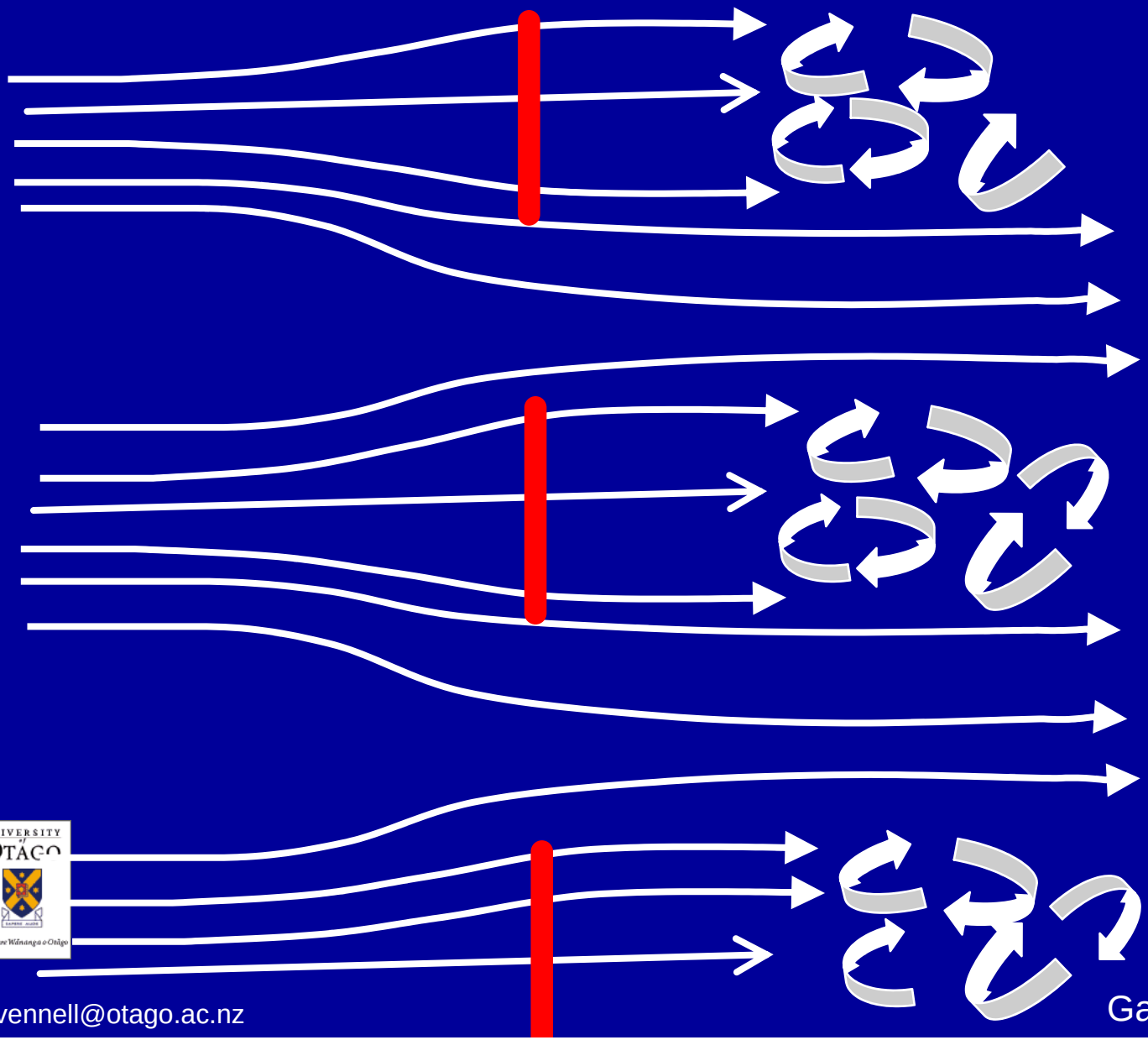
Power Available less than Flow Potential !



Mixing Losses in Turbulent Wake

Losses increase as turbine density increases

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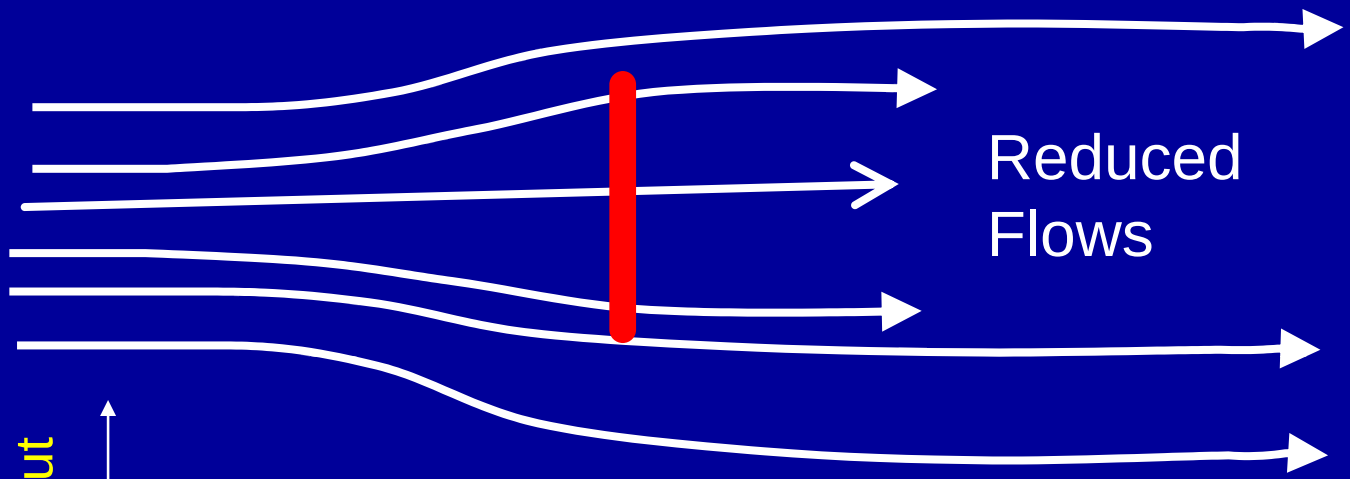
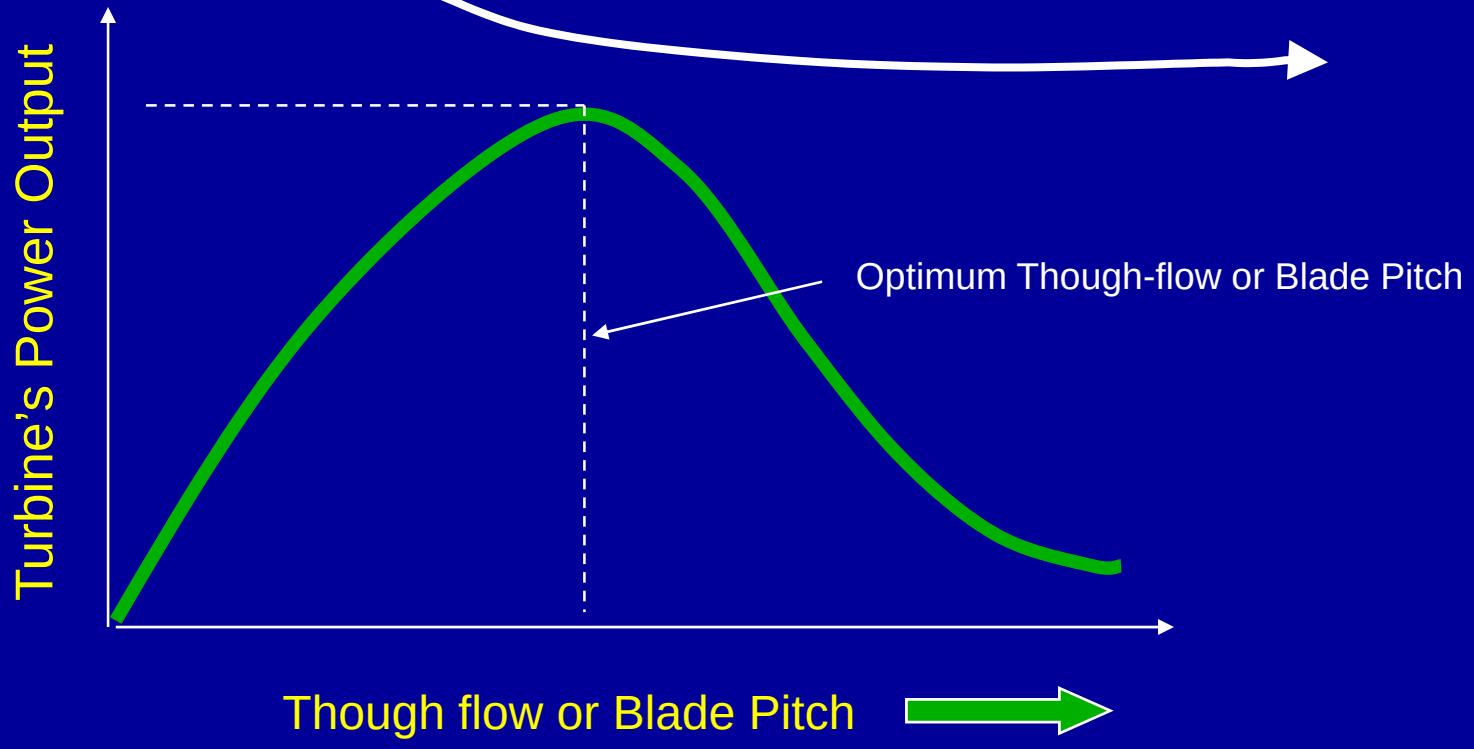
Garrett & Cummins 2007

Tuning Flow Though Turbines





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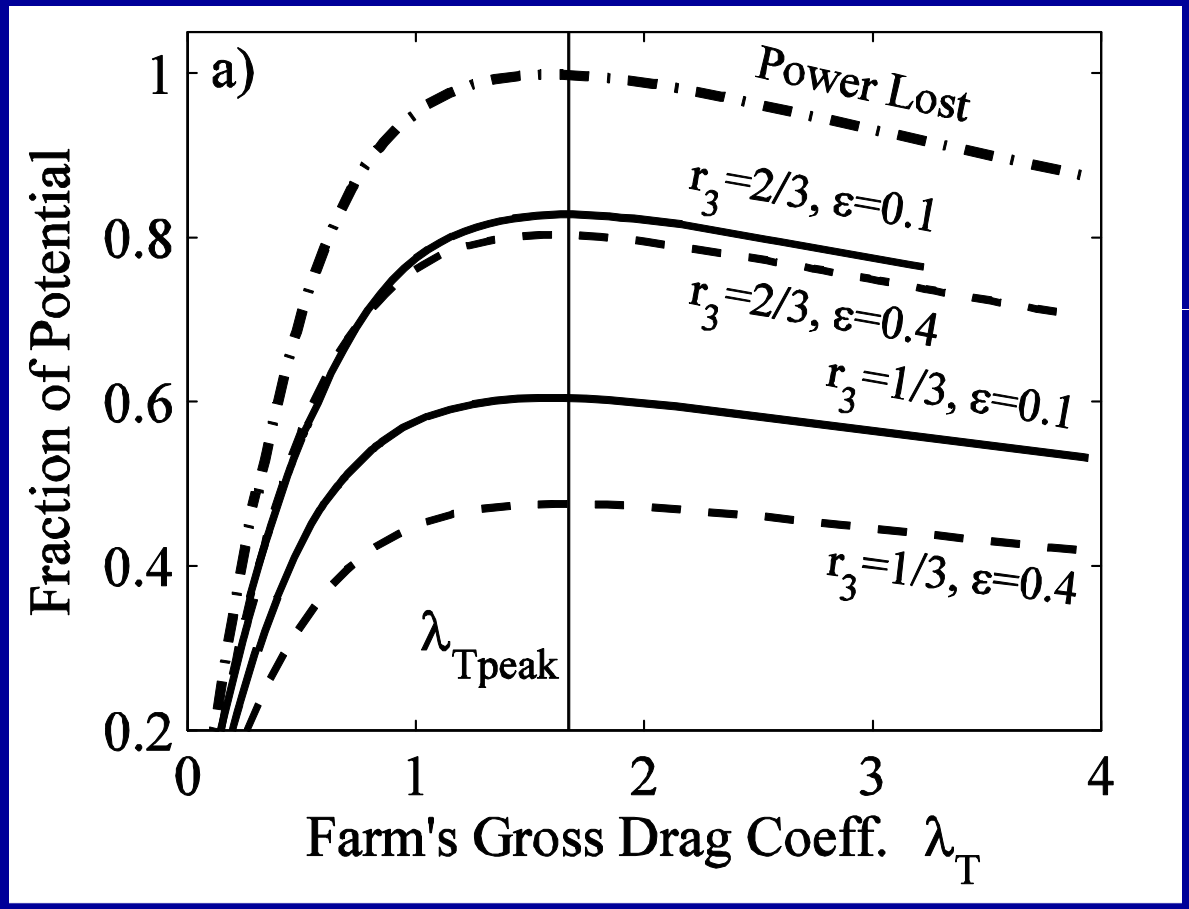
Power Curves, Tuning and Fraction of Cross-Section Occupied



Number of Turbines →

Vennell- Tuning Turbines in a Tidal Channel, *submitted*

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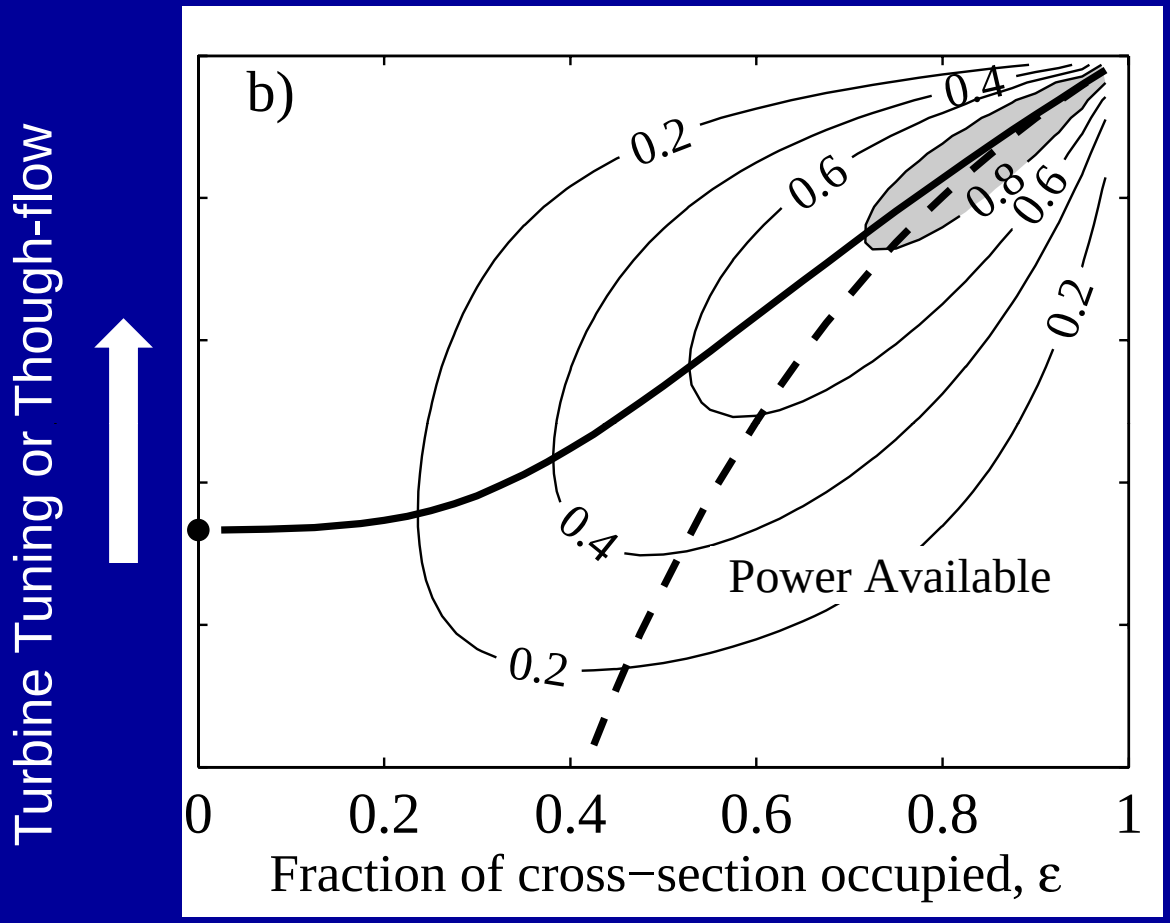
Tuning as Farm Grows to Fill Cross-section



Requirements for navigation and environmental constraints will limit turbines to less than the whole cross-section

→ Must find best tuning for occupied fraction

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Summary

- Turbine flow interaction reduces returns as farm grows

→ Models to assess the potential of a site must include the effects of turbines on the flow

- To maximise the power available turbines must be tuned for a particular channel and density of turbines

→ Using models incorporating turbines to assess potential will be a complex and iterative process requiring finding the best tunings for proposed turbine densities

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