

# "River Hydrokinetic Energy Overview"

ESMAP Training Program, IFC, 17<sup>th</sup> June 2014  
John McGlynn

## The Energy Innovation Center @ Energy Division

Inter American Development Bank



# Presentation Objectives

- ❖ Provide a brief overview of the emerging **River Hydrokinetic Energy Sector**

*Industry origins, benefits of RHK technology, potential energy matrix contribution*

- ❖ Cross-section of the **Leading RHK Technologies\*** -

*Technology overview & development to date*

- ❖ Overview of **Primary Applications** for RHK technology

*Downstream of dams & standalone application*

- ❖ **Comments & Discussion!**



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\* Not possible to include every technology – others do exist!

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# What is 'Hydrokinetic' Energy?



**Waves**



**Tides or Ocean  
Currents**



**River Currents**

**Technologies that generate clean, renewable electricity from the movement of water – in the ocean or in river systems**



# Marine Energy Overview

Past 5 years has seen considerable advancement towards commercialisation of the Marine Energy sector in the UK, France, Canada & other countries...

...Orkney, Scotland is a world leader with the first and largest test centre (EMEC) and 12 commercial seabed leases in place for projects up to 1.23GW in capacity



# Tidal Techs Demonstrated in Real Ocean Conditions

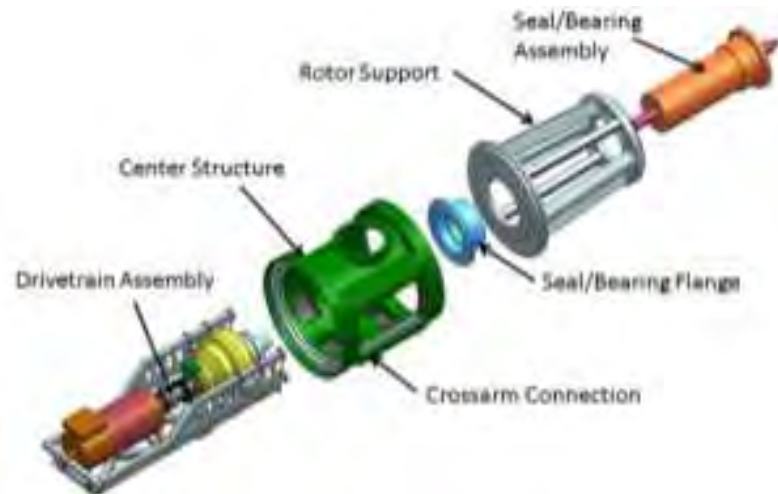
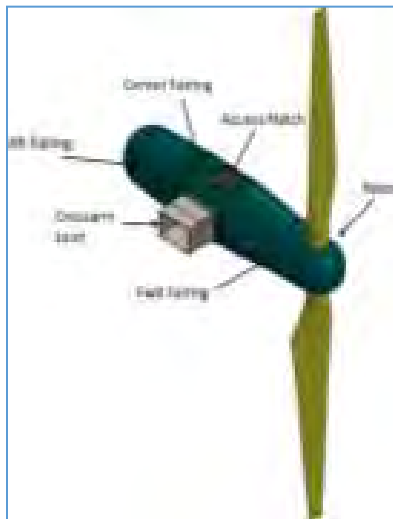


Courtesy of the European Marine Energy Centre  
([www.emec.org.uk](http://www.emec.org.uk))

# Generic RHK Overview

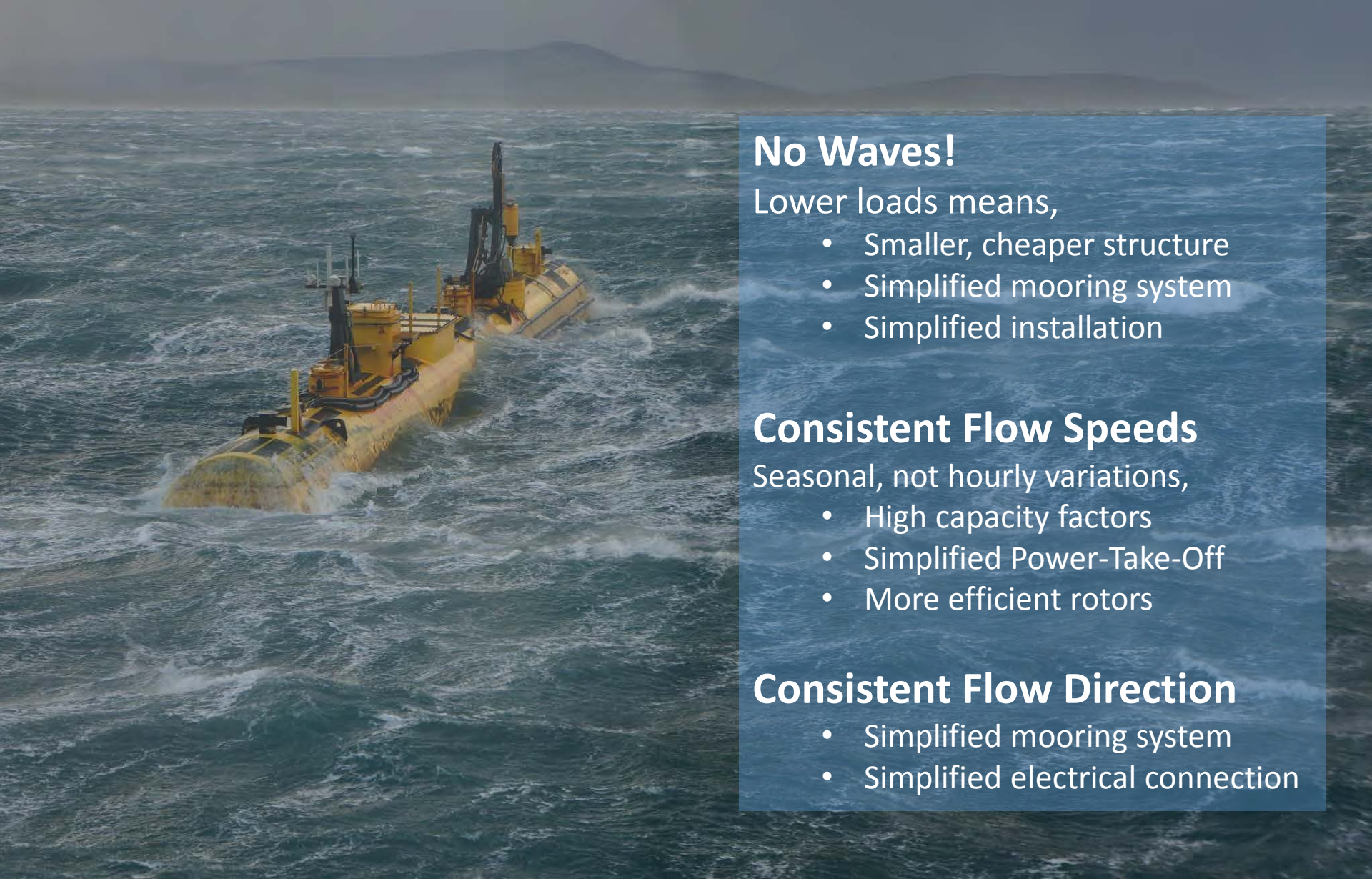
- ❖ All concepts; kinetic energy of moving water converted to rotational motion used to drive a generator – draw upon mature wind energy technology
- ❖ Subsystem converting rotational motion to electricity is Power Takeoff (PTO)

Moving water ➤ Rotors ➤ Rotor Shaft ➤ Gearbox ➤ Generator ➤ Power Export



Images from US DOE Marine & Hydrokinetic Overview, June 2013





## No Waves!

Lower loads means,

- Smaller, cheaper structure
- Simplified mooring system
- Simplified installation

## Consistent Flow Speeds

Seasonal, not hourly variations,

- High capacity factors
- Simplified Power-Take-Off
- More efficient rotors

## Consistent Flow Direction

- Simplified mooring system
- Simplified electrical connection



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# Ocean Tested Tidal Concepts Suited for River Application

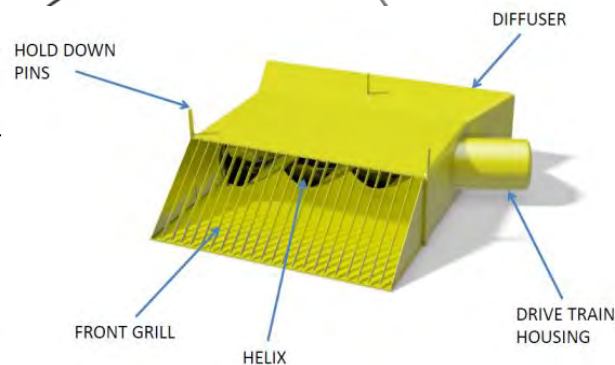
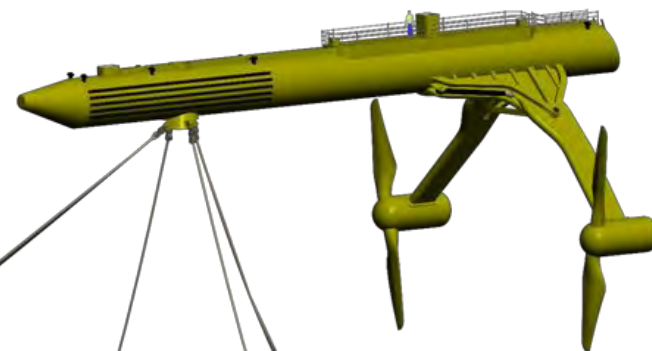


**ORPC**  
—  
**River unit**  
**25kW+**

**Scotrenewables –**  
**River unit 250kW**  
**to 1500kW**

**Flumill**  
—  
**Micro to**  
**200kW+**

**Nautricity**  
—  
**Micro to**  
**500kW+**





## There are also 'River Specific' Concepts



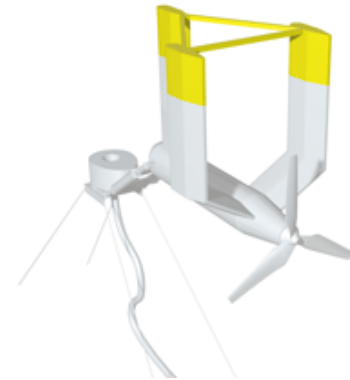
**Tocardo**  
–  
**100kW+**

**RER Hydro**  
–  
**550kW @  
4.5m/s**



**Oceanflow Energy**  
–  
**20kW up to  
100kW**

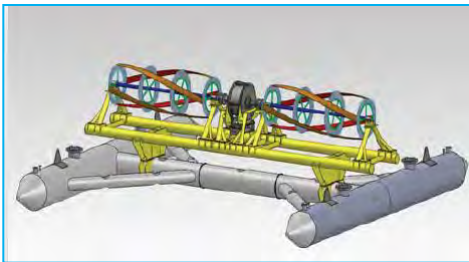
**Smart Hydropower**  
–  
**5kW (now) – up to  
50kW (future)**



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# Technology Links:



[www.scotrenewables.com](http://www.scotrenewables.com)

[www.orpc.co](http://www.orpc.co)

[www.flumill.com](http://www.flumill.com)

[www.nautricity.com](http://www.nautricity.com)

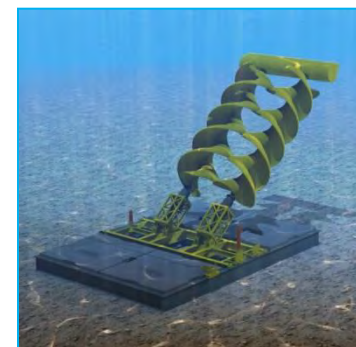
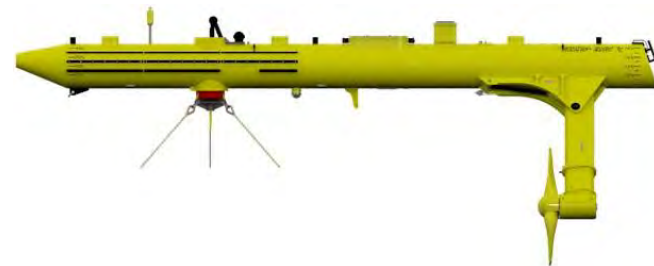
[www.rerhydro.com](http://www.rerhydro.com)

[www.smart-hydro.de](http://www.smart-hydro.de)

<http://www.oceanflowenergy.com/>

<http://www.tocardo.com/>

[www.theriteproject.com](http://www.theriteproject.com)



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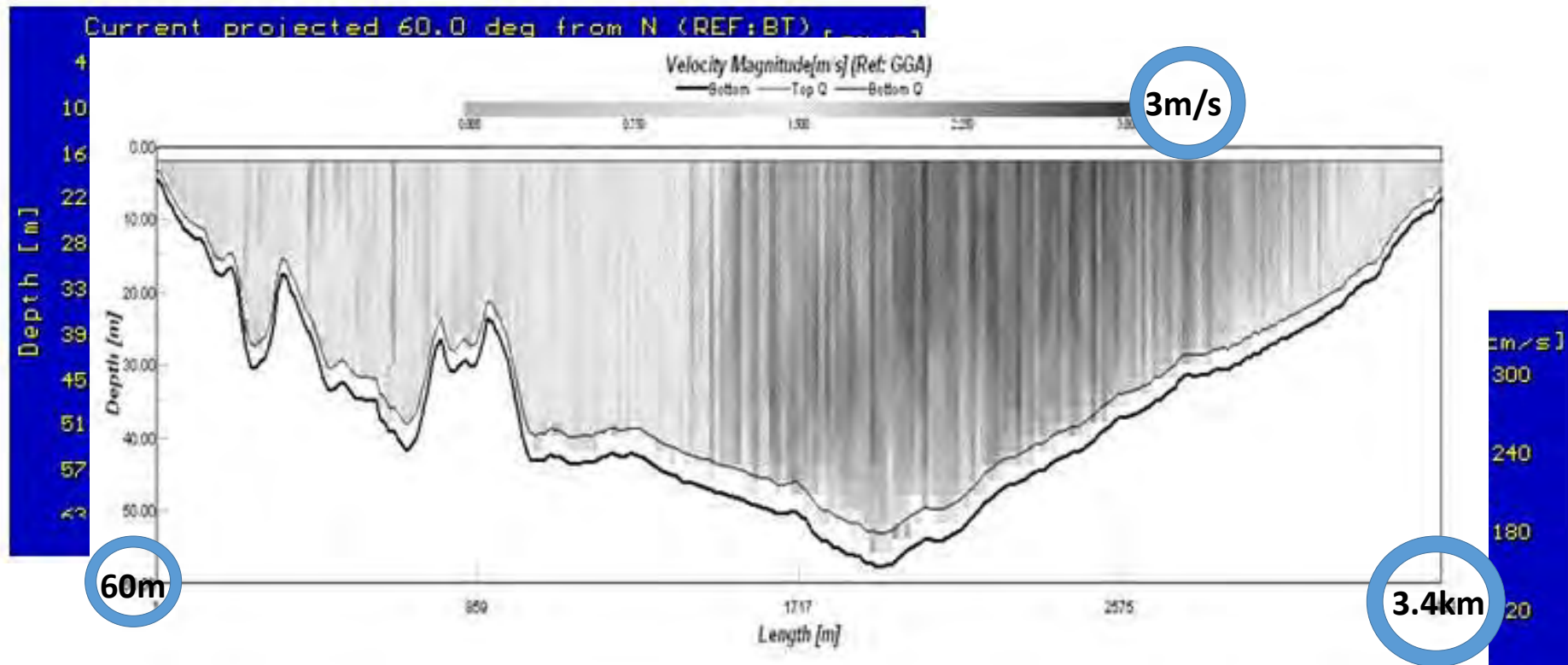
# River Hydrokinetic Energy – A Global Resource



World Rivers >10km<sup>3</sup> / year discharge



# Amazon Basin – Sample Resource Data



1. Upper Rio Solimões  
(approx. 500km from  
Colombia / Peru)

Est. Gross Available Power = **85MW / km**



# RHK Advantages

Technology	Median Capacity Factor	Low GHG Emissions?	Baseload Power?	Modular Distributed Option?
Natural Gas	80%	✗	✓	✗
CCGT	84.6%	✗	✓	✗
Coal	84.6%	✗	✓	✗
Nuclear	90%	✓	✓	✗
Hydropower	50%	✓	✓	(Possible)
Adv. Geothermal	90%	✓	✓	✗
Solar PV	21%	✓	✗	✓
Offshore Wind	43%	✓	✗	✗
Onshore Wind	40.4%	✓	✗	(Possible)
Diesel	90%	✗	(not desirable)	✓
River Hydrokinetic	Est. 65% - 95%	✓	✓	✓

Source (excl. RHK) : US EIA

# What Does River Hydrokinetic Energy Offer?

- ❖ Very consistent resource close to demand centres – many using expensive FF's
- ❖ Potential for extremely high capacity factors – 65% - 95% = competitive LCOE
- ❖ Leading technologies large scale prototypes already technically proven
- ❖ Add-on / Alternative to conventional dammed hydropower
- ❖ Clean reliable power for remote communities while maintaining vital transport links – creation & development of local supply chain



***As with any emerging sector support is required in early stages – particularly, in the case of RHK, in financing of resource assessment & project enabling studies***



**Thanks for your attention!**

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# **Supplementary Appendix:**

## **RHK Technology Information**



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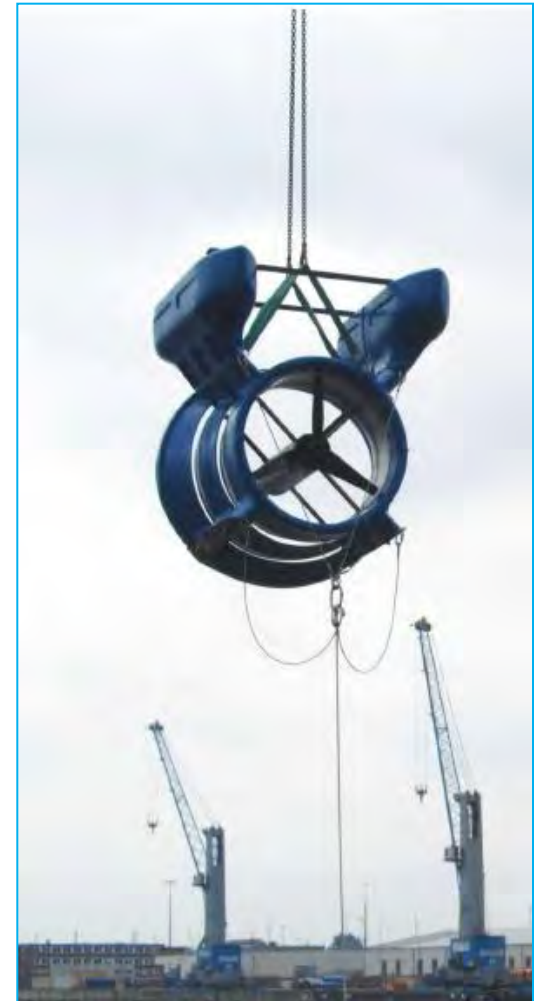
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# Smart Hydro Power (Germany)

## Technology Summary:

- Pico scale 'ducted' turbine - 5kW per unit
- Synchronous PM generator, gearbox-less
- Power conditioning on-shore
- Floating unit – can submerge in flood events
- Debris protection system

Parameter		Unit
Rated Power	5	kW
Rated Current Speed	2.7	m/s
Cut-in Current Speed	0.7	m/s
Shut-down Current Speed	3.5	m/s
Rotor Diameter	1	m
Maximum Rotor Speed	280	Rpm
Turbine Weight	0.38	Tonnes
Rotor Diameter	1	m
Turbine Dimensions (i.e. length, width)	2.5/ 1.8	m
Minimum Depth Requirement	2 / 1.6	m





# Smart Hydro Power

## *Commercial Aspects:*

- 5kW models installed / tested in Germany, Austria, Colombia, Brazil, Indonesia & Nigeria
- Upcoming projects in :
  - Nigeria array project (14 turbines)
  - Rio Madera, Brazil
  - Kalimantan, Indonesia
  - Huayabamba, Peru
- Concept is suitable for array application & scalable with potential for larger units in future

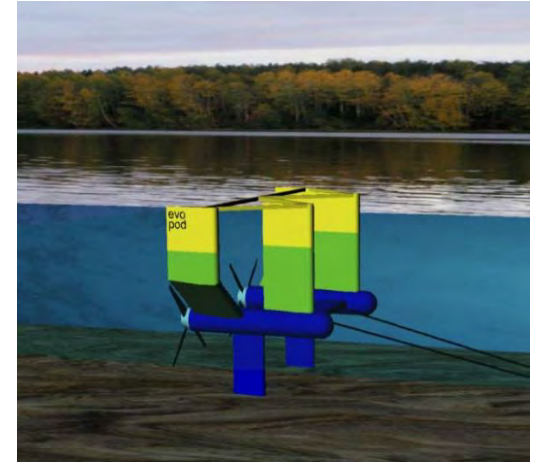


# Ocean Flow Energy (Scotland)

## Technology Summary:

- Generic hydrokinetic concept – rivers, estuaries, open ocean
- Floating w/ submerged nacelle. Streamlined ‘struts’
- Generator w/ gearbox
- Power conditioning done on-shore
- River unit initially potentially up to 100kW (twin rotor)
- Potential for array type unit with higher capacity

Parameter		Unit
Rated Power	100	kW
Rated Current Speed	2.8	m/s
Cut-in Current Speed	0.7	m/s
Maximum Rotor Speed	60	Rpm
Minimum Depth Requirement	5	m



# Ocean Flow Energy

## *Commercial Aspects:*

- 2 x 1kW models installed commercially
- 1 x 37kW model trialled in ocean in Scotland

## *Other Points:*

- Floating turbine copes passively with changes in river level
- Slow rotational speed at larger scale = reduced potential for harm to riverine life





# Verdant Power (USA)

## Technology Summary:

- 3-bladed bottom-mounted concept
- 35kW units installed array demonstrator, East River NYC
- Ongoing technology refinement process through 2015 – testing of main components and proving of system longevity
- Future units up to 470kW

Parameter		Unit
Rated Power	56 – 470	kW
Rated Current Speed	2.0 - 3.0	m/s
Cut-in Current Speed	0.8 – 1.0	m/s
Shut-down Current Speed	3.0 – 4.0	m/s
Rotor Diameter	5 – 11	m
Maximum Rotor Speed	40 - 18	Rpm
Minimum Depth Requirement	10 - 22	m



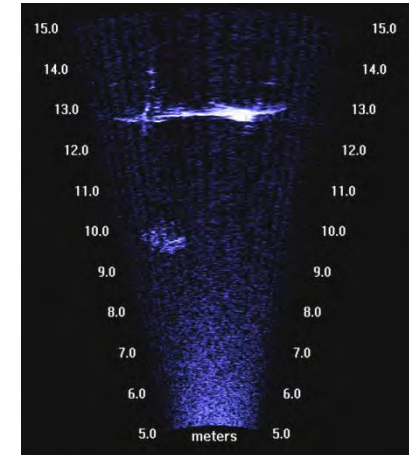
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# Verdant Power

## *Commercial Aspects:*

- License awarded to develop up to 1MW commercial project
- US FERC pilot license awarded & compliance achieved
- Demonstrated lack of fish impacts during monitoring program – see radar image right showing school of fish avoiding system
- \$700k USTDA funding to explore Turkey project feasibility



# Tocado (Netherlands)

## Technology Summary:

- 'Flexible foundation' turbine – can be mounted on variety of support structures – fixed, floating, existing
- Direct-drive PM , fixed pitch rotors
- Current offering 80kW – potentially larger in future

Parameter	T100		Unit
Rated Power	42	98	kW
Rated Current Speed	2	4,5	m/s
Cut-in Current Speed	0,4	0,9	m/s
Shut-down Current Speed	2,6	6,8	m/s
Rotor Diameter	6,3	3,1	m
Maximum Rotor Speed	32	64	rpm
Turbine Weight	6,4 - 6,6		tonnes
Min. Depth Requirement	4		m





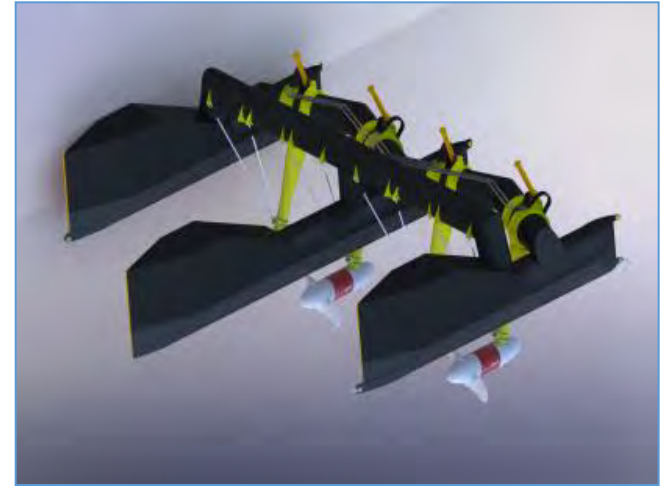
# Tocado

## *Commercial Aspects:*

- Netherlands 80kW canal pilot project operational since 2008 – 20,000 hours
- Demonstrator river project in Nepal – turbines to be installed Q2 2014

## *Other Points:*

- Adaptable, scalable concept
- Low rotation speed. Fish passage tests carried out previously with positive results

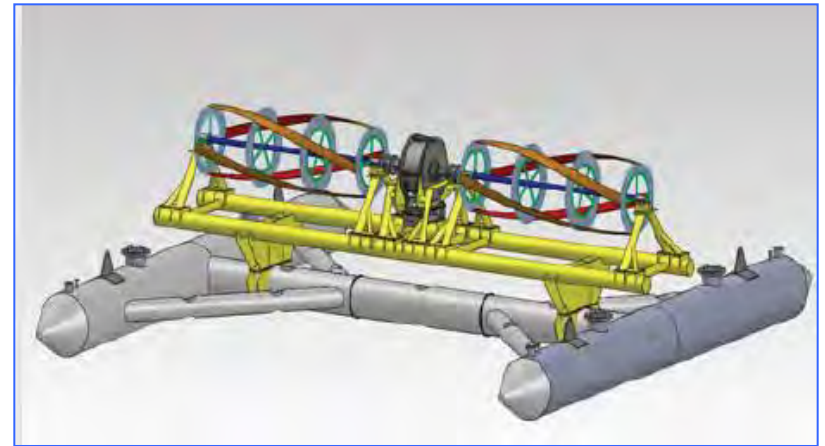


# Ocean Renewable Power Company (USA)

## Technology Summary:

- 25kW River unit - 2 x cross flow rotors
- On board direct drive generator, no gearbox
- Horizontal axis = suitable for shallow sites
- Submersible support structure – designed for ease of deployment & retrieval

Parameter		Unit
Rated Power	25	kW
Rated Current Speed	2.25	m/s
Rotor Diameter	1.3	m
Maximum Rotor Speed (free Wheel)	90	rpm
Turbine Weight	10.5	Tonnes
Rotor Diameter	1.3	m
Minimum Depth Requirement	4	m



# Ocean Renewable Power Company

## ***Commercial Aspects:***

- 150kW tidal version (very similar components to 'Rivgen') installed and tested in Maine
- 25kW 'Rivgen' will be installed in Alaska summer 2014

## ***Other Points:***

- Environmental monitoring survey carried out 2012 / 2013 – acoustic monitoring, marine life interaction, mammals, birds & other receptors..... “No observed negative effect”

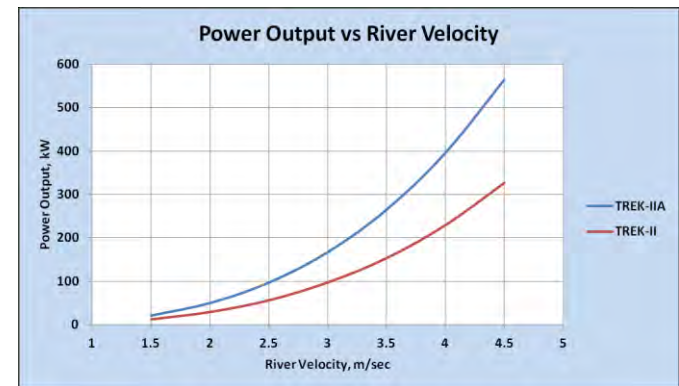




# RER Hydro (Canada)

## Technology Summary:

- River-specific concept— 2 versions –nameplate capacity of 340kW & 550kW @ 4.5m/s
- Submerged, unidirectional, ducted turbine – onshore power conditioning
- Installed / retrieved using crane barge
- Min depth 5.5m – 6.5m, min speed 1.5m/s
- 2.5 year prototype test in St. Lawrence River, Montreal – good success. 31,000 hours operation & 95% availability





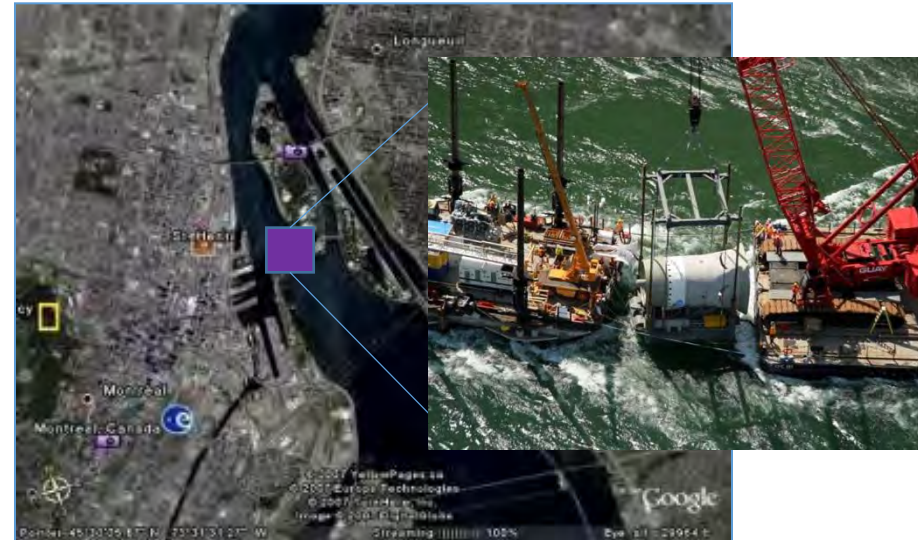
# RER Hydro

## **Commercial Aspects:**

- 6 turbine demo project upcoming in Montreal
- Agreement in place with Boeing for global mkting & sales + technical input
- Currently investigating intl. project opportunities

## **Other Points:**

- Rotational speed 60 – 90RPM. 3<sup>rd</sup> party Fish behavioral tests carried out during prototype testing with positive results.



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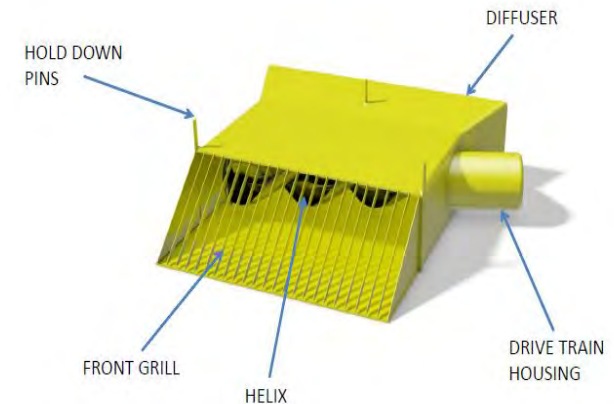
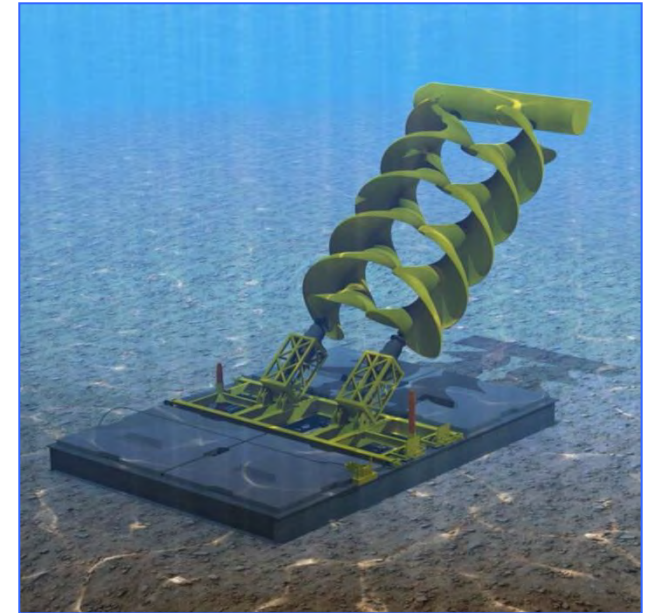
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# Flumill (Scotland / Norway)

## Technology Summary:

- Rotorless Helical concept - high torque & slow rotation
- Bottom mounted, horizontally orientated
- Scalable, adaptable river concept - 3kW to 200kW+

Parameter		Unit
Rated Power	200	kW
Rated Current Speed	2.5	m/s
Cut-in Current Speed	0.5	m/s
Rotor Diameter	2	m
Maximum Rotor Speed	50	Rpm
Minimum Depth Requirement	2.4	m



# Flumill

## *Commercial Aspects:*

- Previous offshore test at EMEC
- River unit has undergone 2 tests in Scotland
- Currently investigating intl. project opportunities for tidal and river units

## *Other Points:*

- Low rotational speed & absence of exposed moving parts = low wildlife impact



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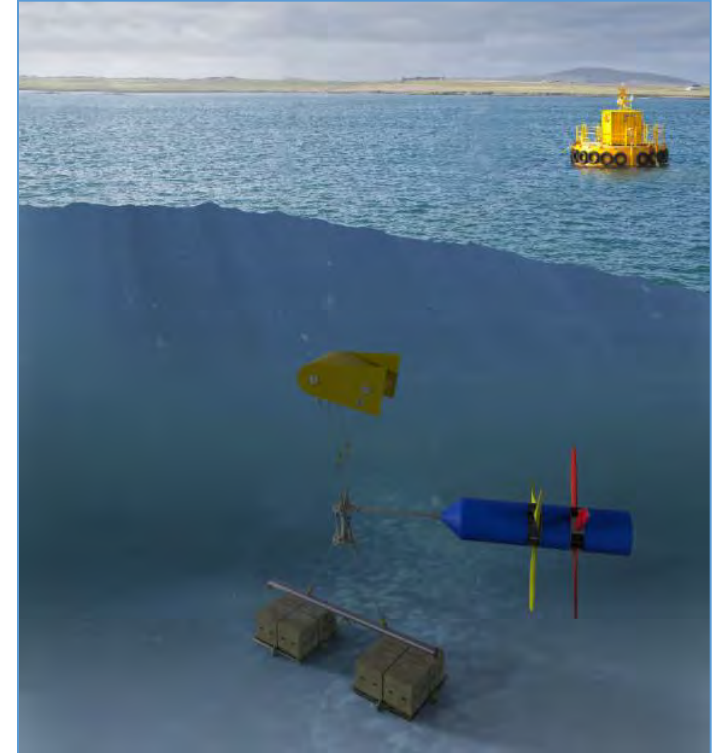
# Nautricity (Scotland)

## Technology Summary:

- 7-bladed, rotor & stator contra-rotating, direct-drive, passively cooled
- Semi-buoyant – suited for offshore or river application
- Contra-rotation = suitability for lower current velocity

Parameter			Unit
Rated Power	25	500	kW
Rated Current Speed	2.3	2.3	m/s
Cut-in Current Speed	0.8	0.8	m/s
Rotor Diameter	3	14	m
Maximum Rotor Speed	204*	44*	Rpm
Minimum Depth Requirement	5	20	m

\* Combined rotor speed, each rotor rotates at half this speed



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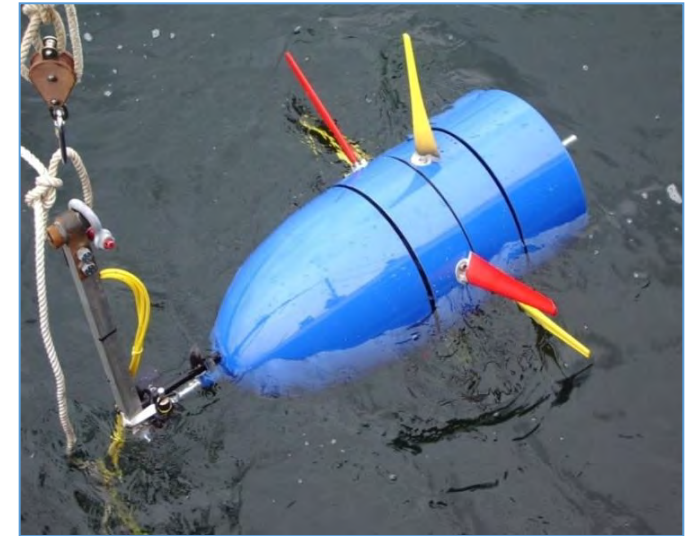
# Nautricity

## *Commercial Aspects:*

- Tested offshore in 4 Scottish locations incl. EMEC & also in Thames River
- Concept is scalable 1.5kW – 500kW = wide range of application

## *Other Points:*

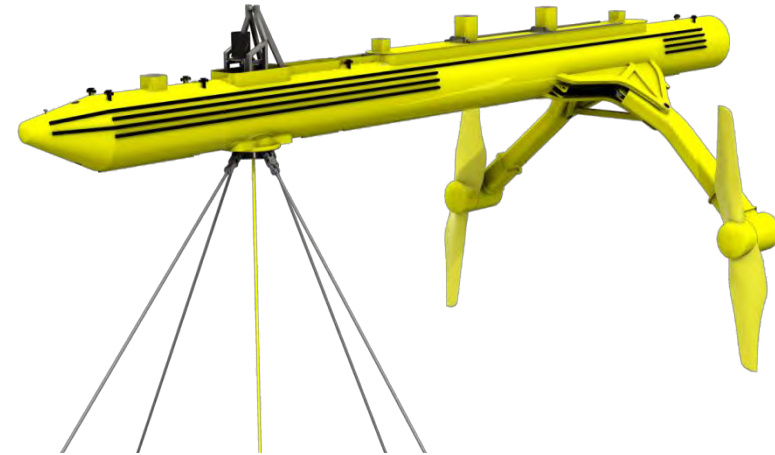
- Mid water-column – away from surface debris
- Experiences from consenting deployment in wide variety of UK sites



# Scotrenewables (Scotland)

## Technology Summary:

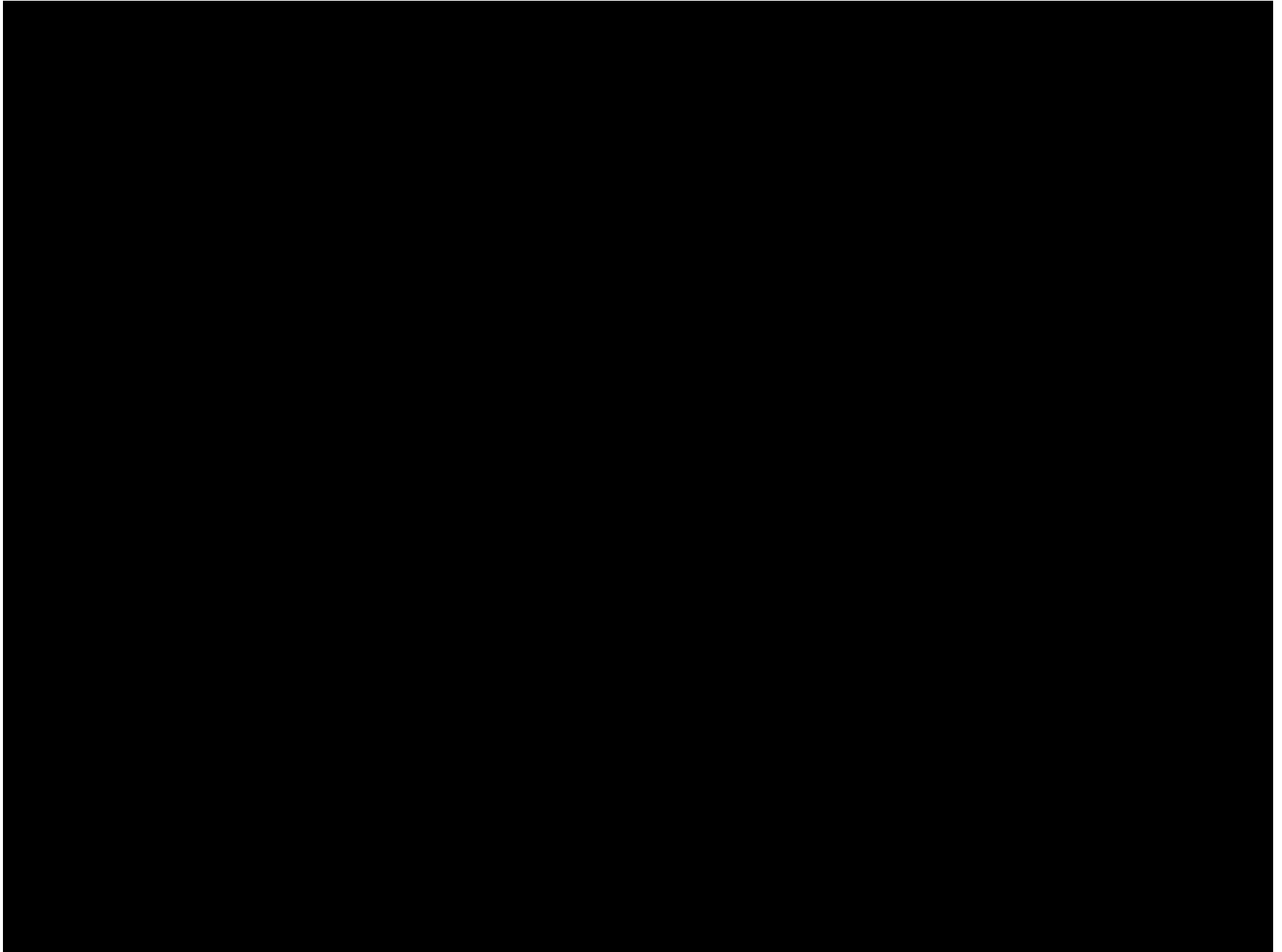
- Floating turbine, dual rotor w/ retractable legs – operational & transport / survival modes
- Designed for survivability but also ease of installation
- Highly accessible for ongoing O&M
- No problem with change in water level - rotors maintained in most energetic part of column



Parameter (River Turbine)		Unit
Rated Power	1000	kW
Rated Current Speed	2.2	m/s
Cut-in Current Speed	1	m/s
Rotor Diameter	18	m
Maximum Rotor Speed	15	rpm
Turbine Weight	300	Tonnes
Turbine Dimensions (i.e. length)	Hull length = 50m	m
Minimum Depth Requirement	26	m



# Scotrenewables Concept Overview



# Scotrenewables

## ***Commercial Aspects:***

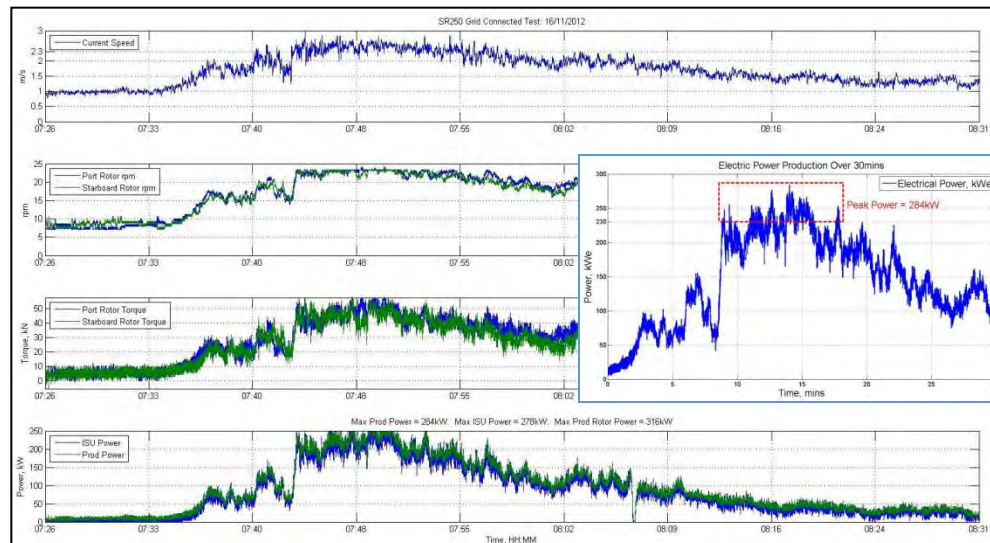
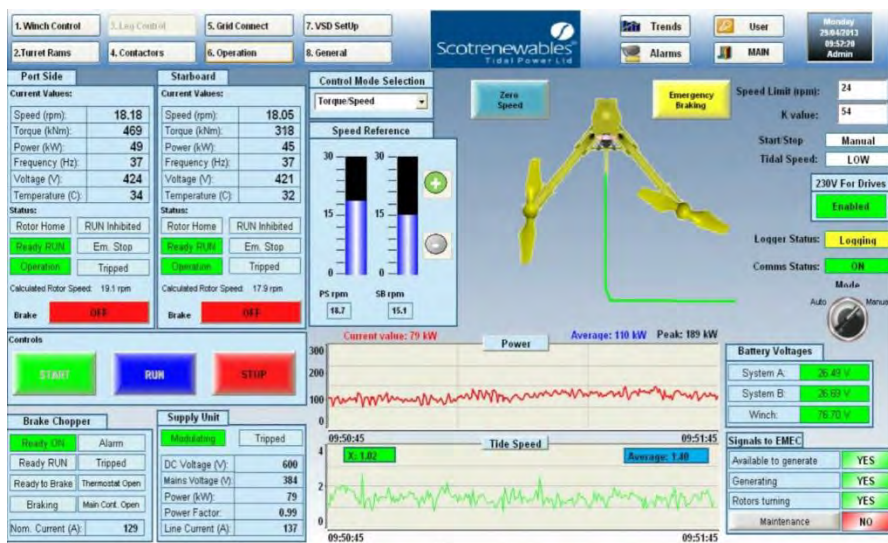
- Tested extensively & successfully at 'full' 250kW scale at EMEC during 2.5 year period & since 2002 at smaller scale - 2MW tidal turbine (world's largest!) to be constructed during 2014
- High applicability for rivers at large scale - commercial units up to 1.5MW
- Tidal demo projects in UK
- Advanced plans to develop high-profile river demo project in Brazil

## ***Other Points:***

- Environmental monitoring program as part of EMEC testing & commercial project development – positive results with zero negative impact shown on bird and mammal populations



# Scotrenewables 250kW Testing



<http://www.youtube.com/watch?v=oYuCH42atCY&feature=youtu.be>



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