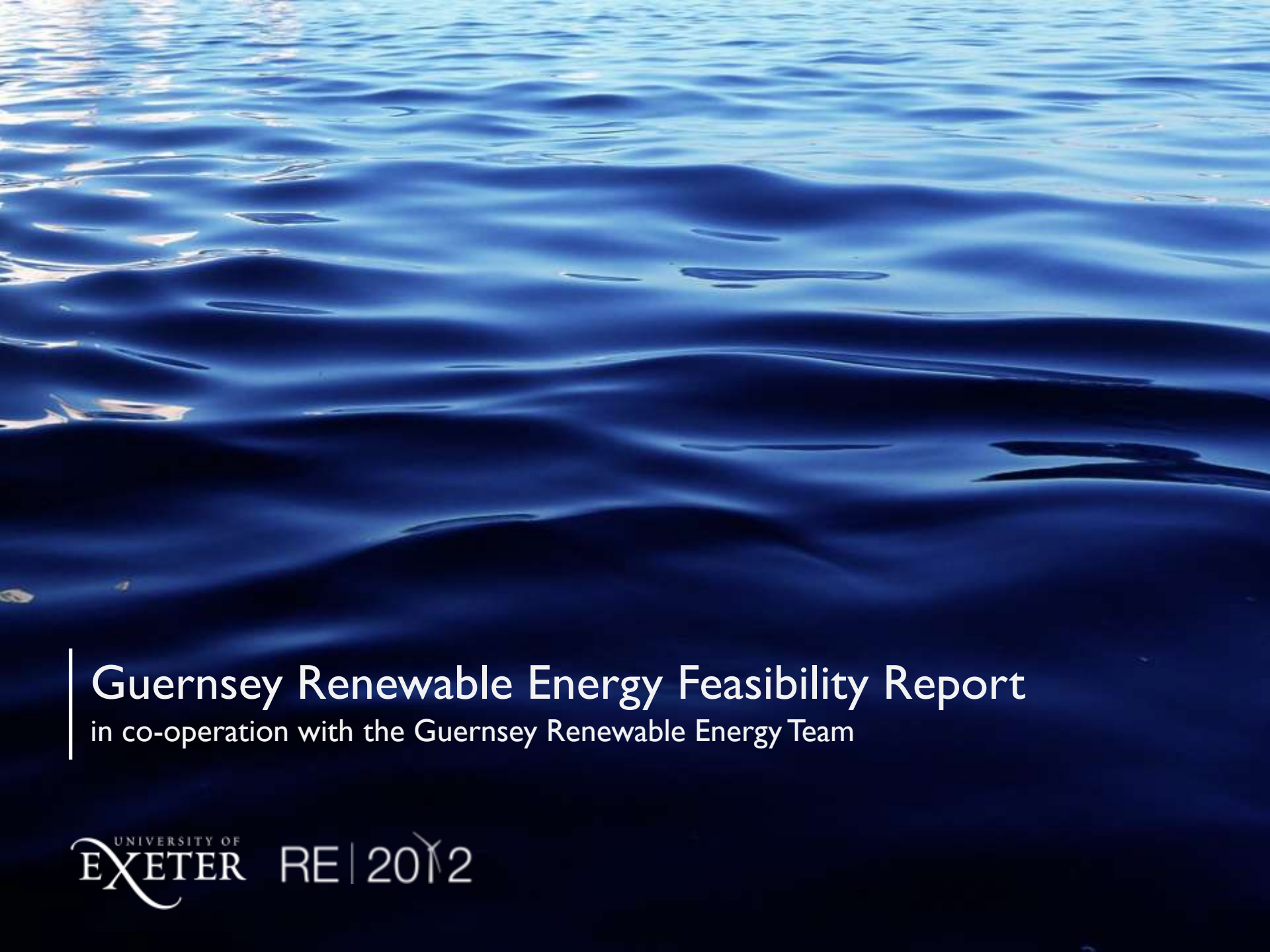


Guernsey Renewable Energy Feasibility Report

in co-operation with the Guernsey Renewable Energy Team

UNIVERSITY OF EXETER RE | 2012

Introduction

The need for renewable energy

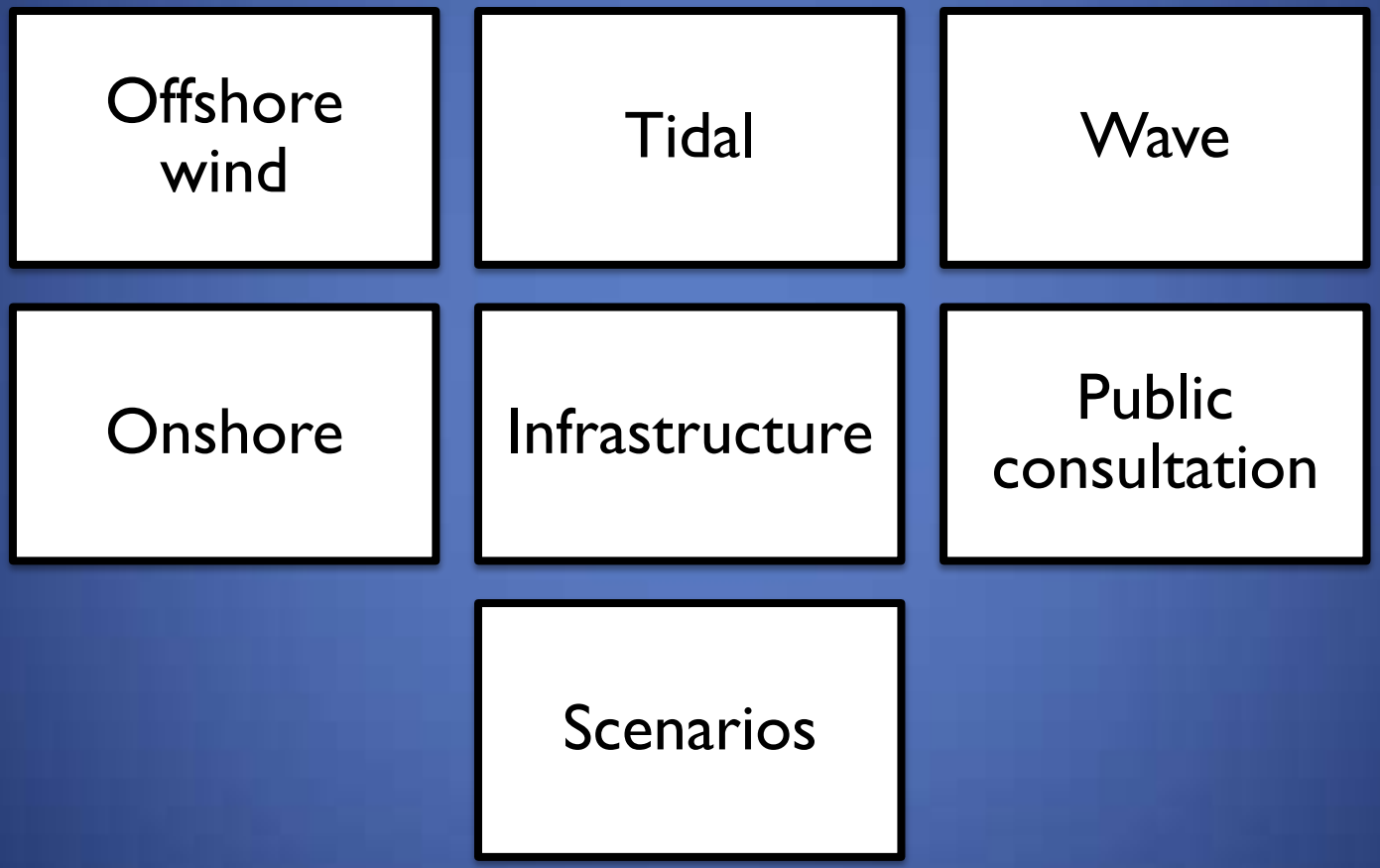
- Energy security
- Human-caused global warming – sustainability
- Financial
  - Rising fossil fuel costs
  - Returns on investment
- A new industry - diversity

Project Scope

- Commerce and Employment
- Renewable Energy Team (RET)

Focus on the strategic implementation of offshore wind, wave and tidal energy; to develop an energy management strategy for Guernsey.

Overview


Offshore wind
Tidal
Wave
Onshore
Infrastructure
Public consultation
Scenarios

RE | 2012 | Overview

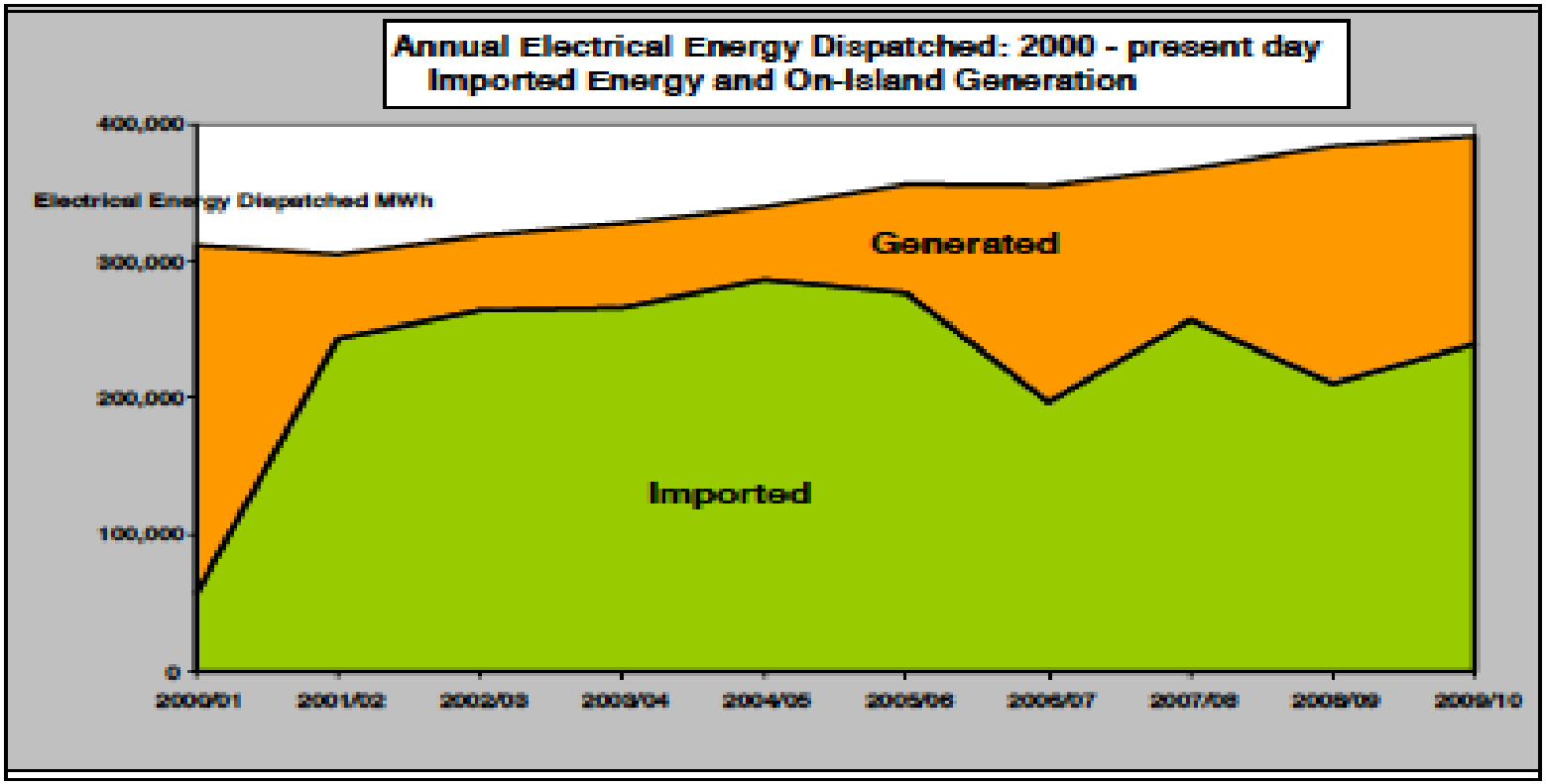
Current Demand

1 of 2

- 85 MW maximum demand
- 35% increase in 10 years
- 23 MW baseload
- 2 MW increase in 5 years
- Met by imported electricity and on island generation

Current Demand

2 of 2



Source: Guernsey Electricity

Imported electricity

- Guaranteed 16 MW
- Can draw up to 55 MW if available – depending on Jersey's demand

On Island Generation

- 115 MW capacity
- Five 2-stroke slow speed diesel generators
- Three gas turbines

Current Cost

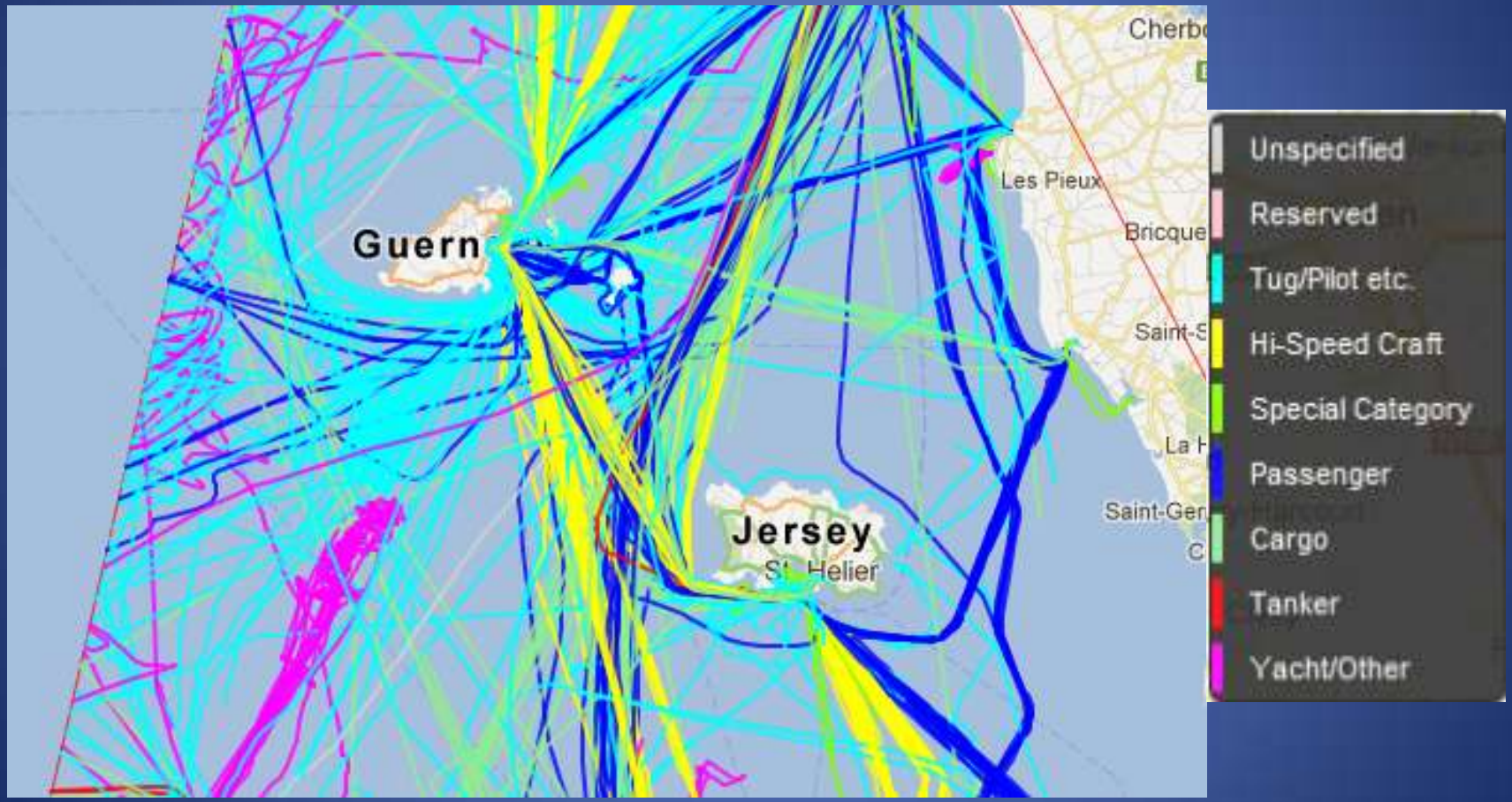
- 400 GWh consumed in 2010/11
- Average cost to consumers of 12.33p/unit (kWh)
- Total annual cost to Guernsey consumers of £48.5m

RE | 2012 | Technologies

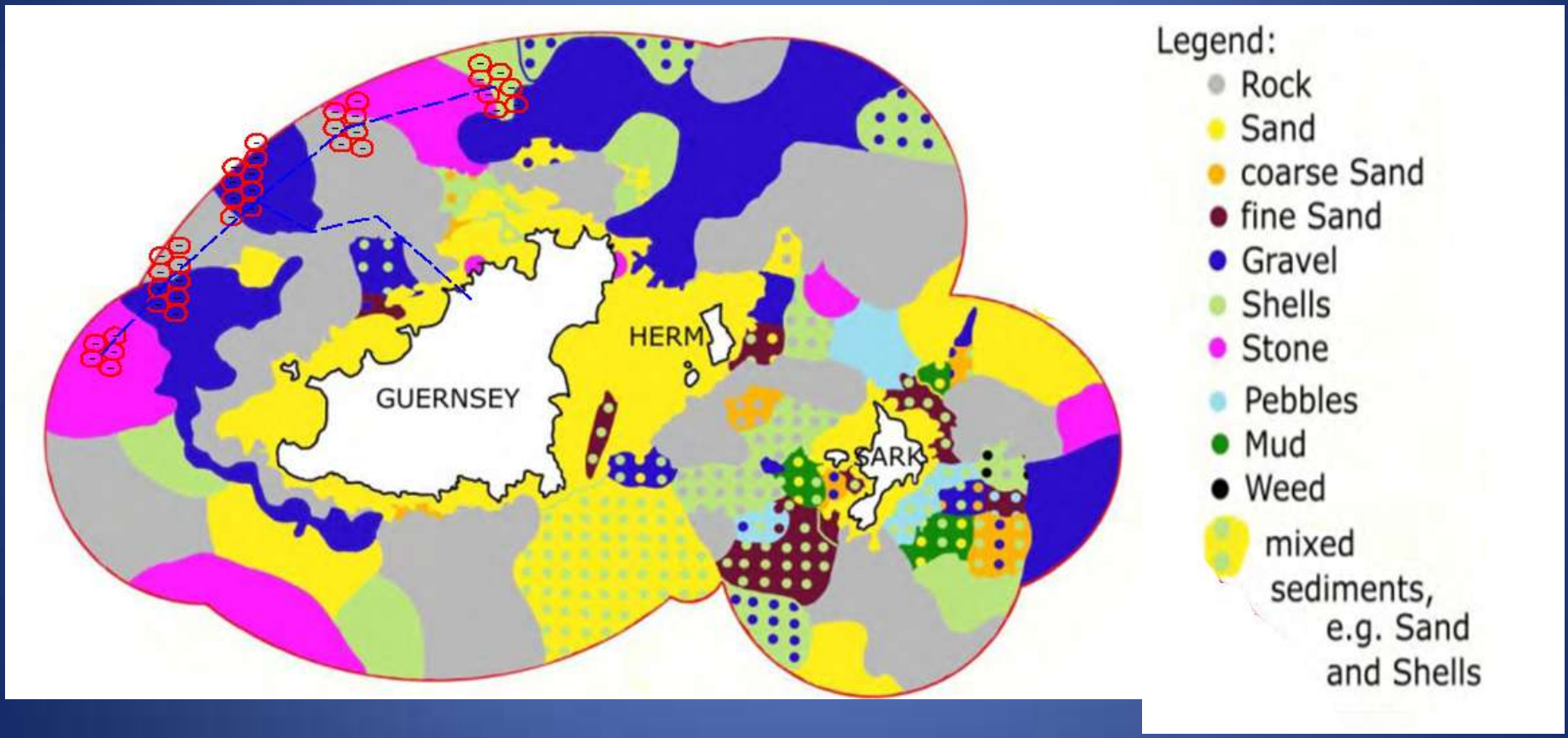
Constraints

- Environmental
  - Sea mammals
  - Fish
  - Flora and fauna
- Fishing
- Seabed/bathymetry
- Visual impacts
- Shipping

Constraints - Shipping



Constraints - Geology



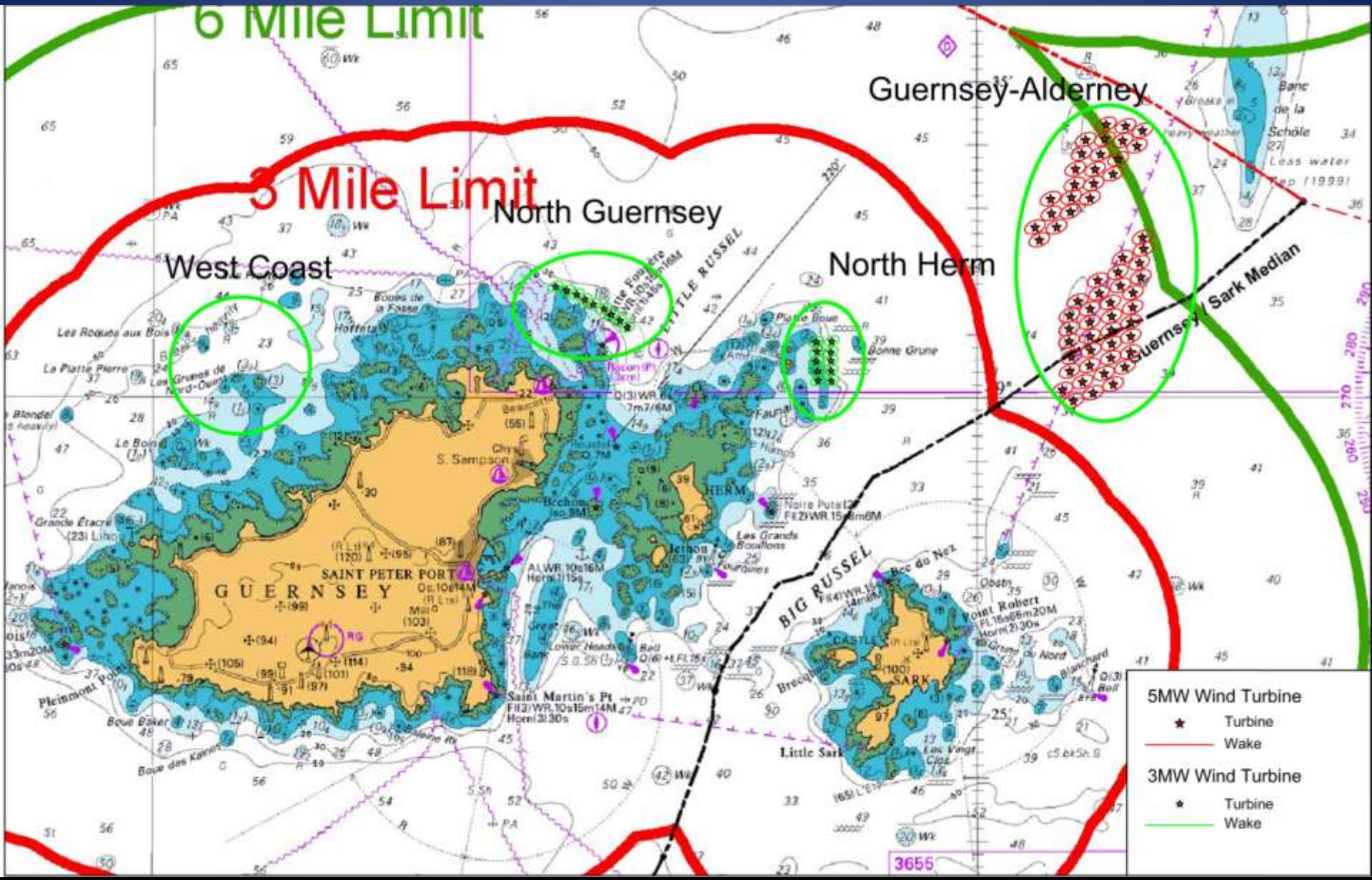
RE | 2012 | Offshore Wind

Introduction

- Feasibility study review
- Further wind farm sites located
  - 30MW capacity
  - 300MW capacity

Feasibility Review

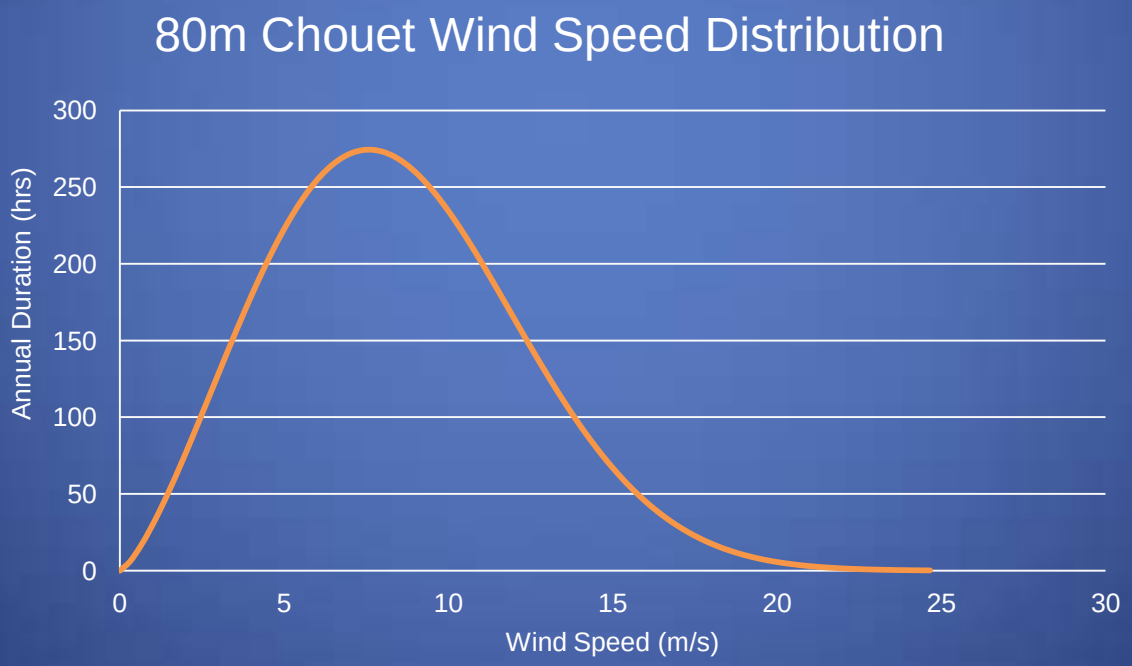
- Identification of two wind farm sites:
  - 12MW, 4 turbines (too small)
  - 30MW, 10 turbines
- 30MW site could be developed in conjunction with a French offshore wind farm
- Visual impact is a key issue
- Recommendations
  - Reliable wind speed estimates using met-mast at Chouet combined with airport wind speed data



Source: Department of Commerce and Employment

Wind Resource

- Wind resource analysis
  - 8.5m/s at 80m (Vestas V90 hub height) at Chouet
  - Weibull distribution applied



Site Selection - Further Sites

- Constraints considered
  - Available resource
  - Distance from the shore
  - Geology
  - Bathymetry
  - Environmental factors
- Potential wind farm sites
  - North Herm 30 MW
  - North Guernsey 30 MW
  - North East Guernsey 300 MW
- Energy yield
  - 30 MW generates 100GWh/year (25%)
  - 300 MW generates 1200GWh/year (300%)

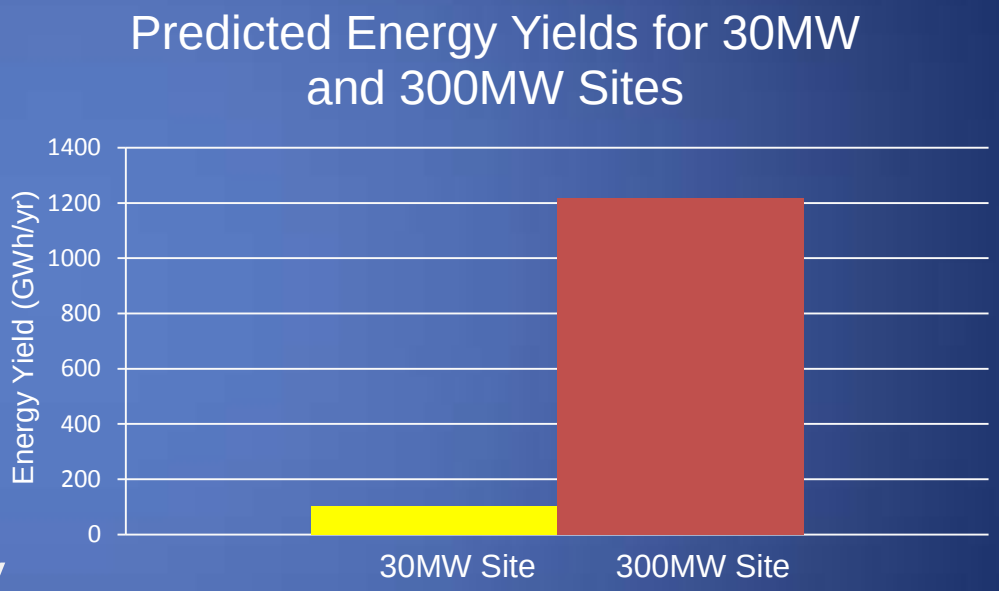


Image for the proposed 30MW array off the west coast by Guernsey Press (15th February 2012)

Realistic image for 10 Vestas V90 turbines from 3km distance

Turbine Selection and Foundation

- Near shore 30MW sites
  - 3MW 'V90' Vestas turbine
- Far from shore 300MW site
  - 5MW '5M' RePower turbine
  - Maximises energy yield
  - Minimises cost per MW installed
- Foundations
  - Geology
  - Water depth
  - Monopile, jacket, tripod or concrete gravity-based
  - Geotechnical and hydrodynamic loading surveys

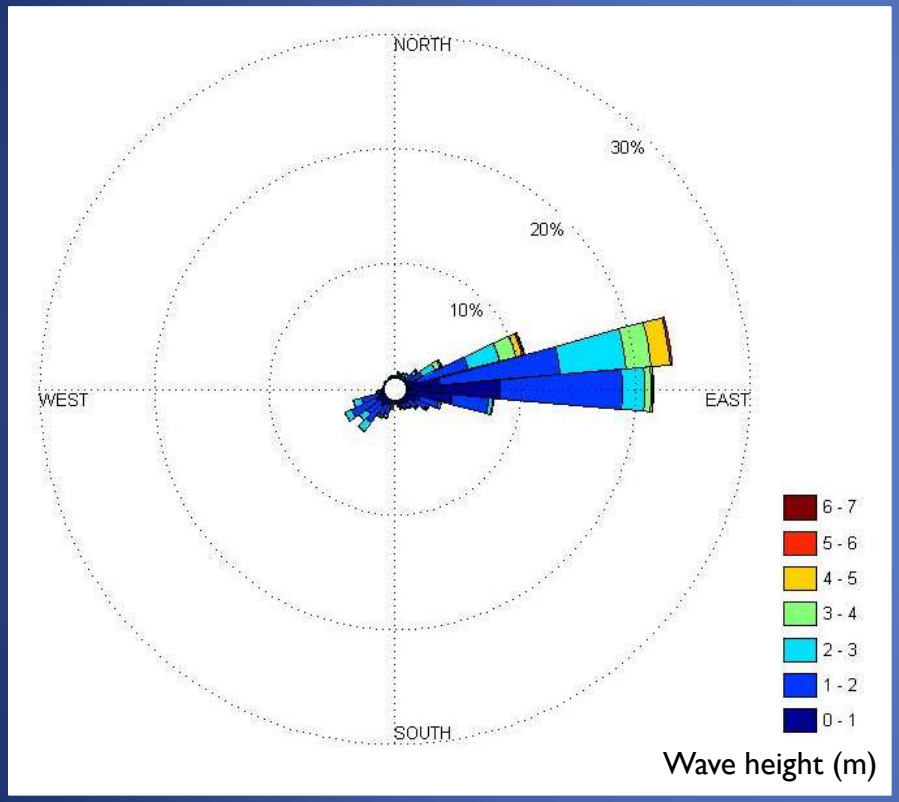
Source: renews.biz 2012

Infrastructure

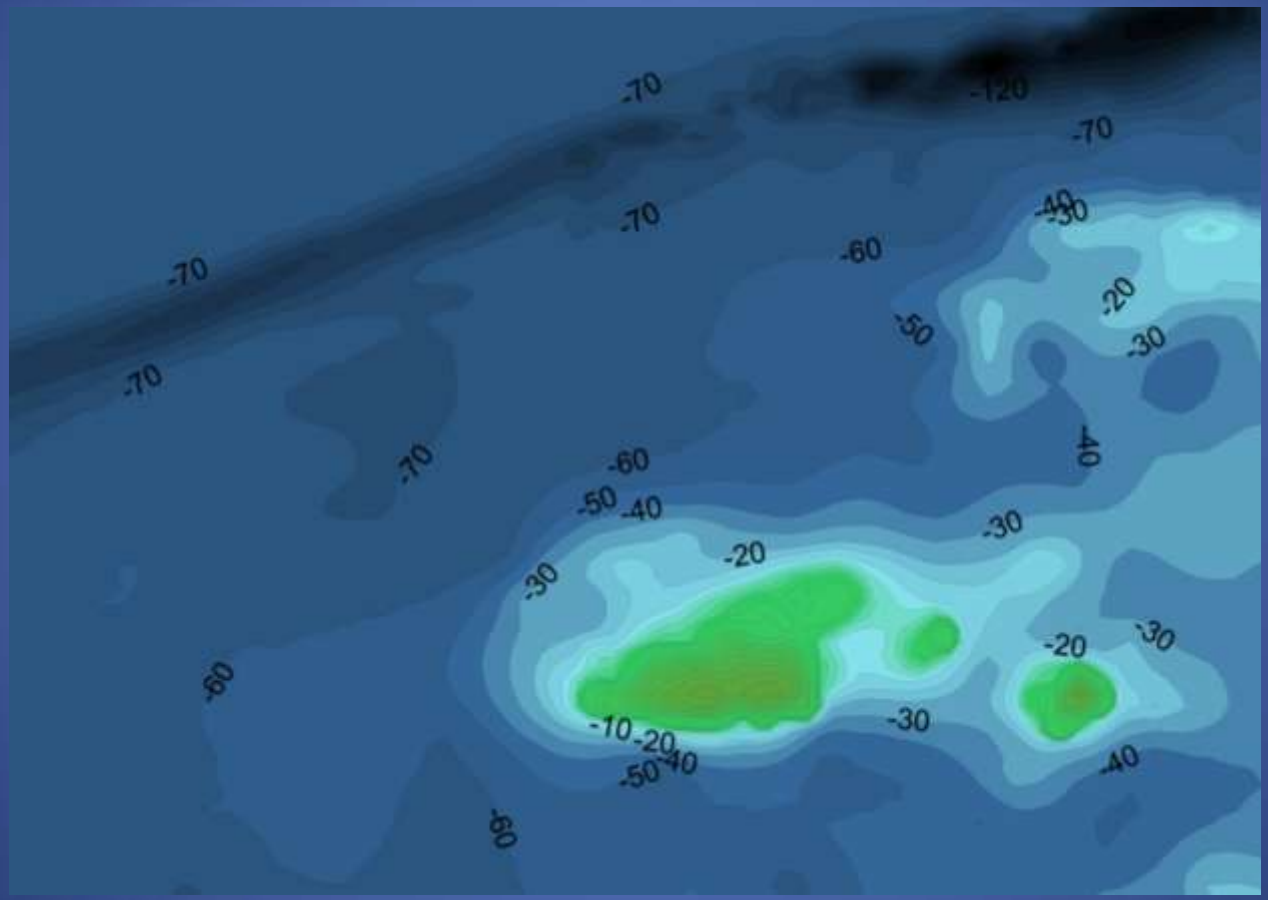
- Offshore substation
  - Not required for the 30MW wind farms
  - Required for 300MW wind farm
  - Costly electrical installation
  - Considerable power conditioning and protection equipment
- Subsea cables
  - Requires detailed seabed study
- Operation and Maintenance
  - Servicing
  - Ports

RE | 2012 | Wave Energy

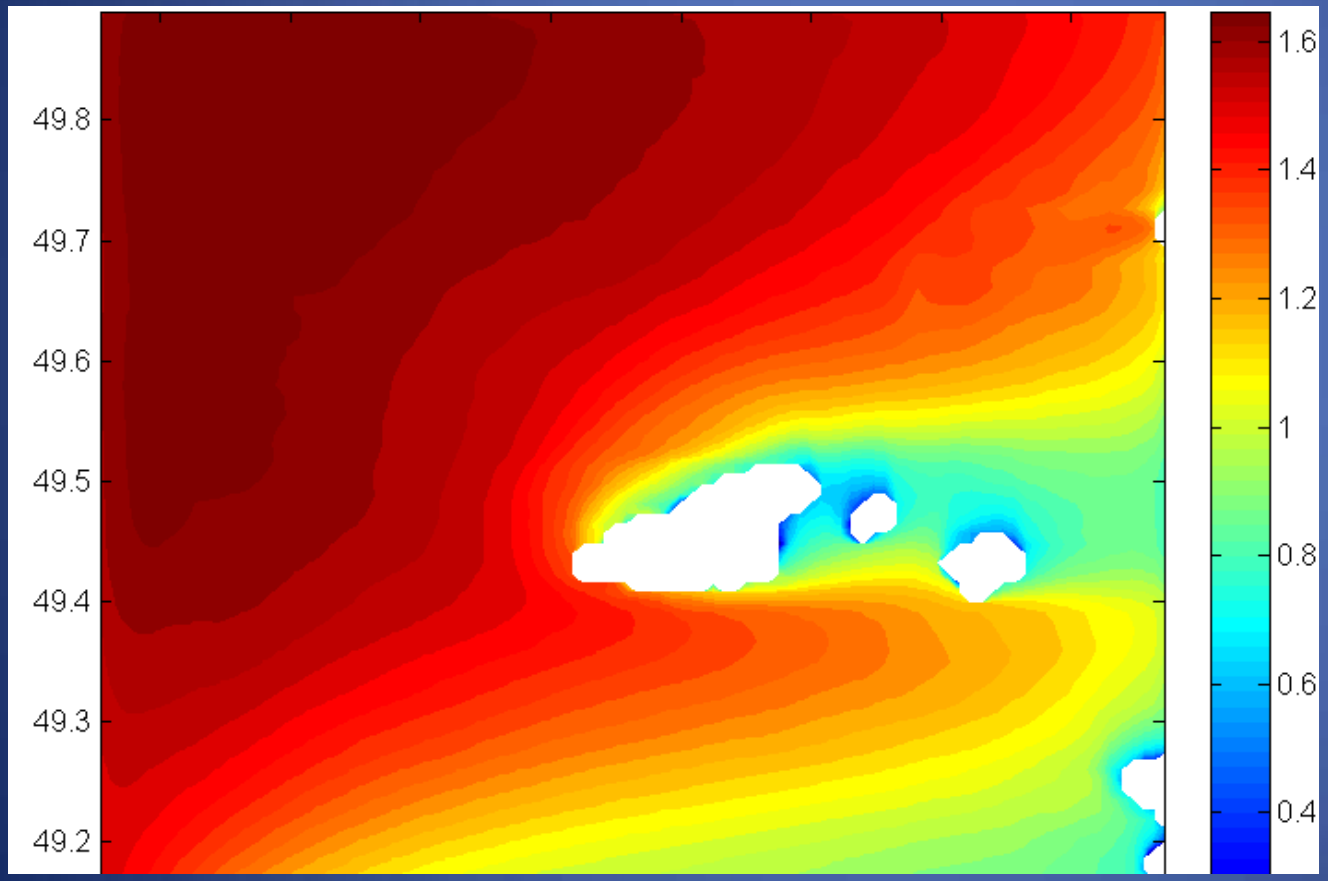
Wave Resource



Constraints - Bathymetry



Near-shore Wave Modelling



Significant Wave Height (m)

Using predominant sea state of 1.5m Hs and 5.5 s Period

Wave Resource

Significant Wave Height(m)	Guernsey Sea State Probability Period (s)							
	3 - 5	4 - 5	5 - 6	6 - 7	7 - 8	8 - 9	9 - 10	10 - 11
0 - 1	1.2	3.4	3.9	4.4	4.9	3.6	1.7	0.8
1 - 2	0.1	5.5	10.8	9.7	8.2	6.1	4.9	2.5
2 - 3			2.3	3.7	4.0	3.1	2.5	2.0
3 - 4				0.2	0.6	1.5	1.0	1.0
4 - 5					0.1	0.9	1.0	0.2
5 - 6						0.1	0.2	0.0
6 - 7								0.1

Significant Wave Height(m)	Wave Power (kW/m) Period (s)							
	3.5	4.5	5.5	6.5	7.5	8.5	9.5	10.5
0.5	0.0	1.1	1.4	1.6	1.9	2.1	2.4	2.6
1.5	7.9	10.1	12.4	14.6	16.9	19.1	21.4	23.6
2.5			34.4	40.6	46.9	53.1	59.4	65.6
1.6				16.6	19.2	21.8	24.3	26.9
3.5					91.9	104.1	116.4	128.6
4.5						172.1	192.4	212.6
5.5								317.6

Pelamis

Wave Resource

Pelamis Power Matrix (kW)									
	Period (s)								
Significant Wave Height(m)		3 - 5	4 - 5	5 - 6	6 - 7	7 - 8	8 - 9	9 - 10	10 - 11
	0 - 1			14.0	18.0	19.0	17.0	14.0	11.0
	1 - 2		44.5	90.0	115.5	119.0	108.0	90.0	73.0
	2 - 3		109.0	220.0	282.0	285.0	254.0	211.0	178.0
	3 - 4			408.0	489.0	477.0	426.0	355.0	300.0
	4 - 5			544.0	684.0	668.0	616.0	515.0	427.0
	5 - 6				750.0	750.0	744.0	685.0	575.0
	6 - 7					750.0	750.0	750.0	743.0

Annual Energy Yield (kWh)									
	Period (s)								
Significant Wave Height(m)		3 - 5	4 - 5	5 - 6	6 - 7	7 - 8	8 - 9	9 - 10	10 - 11
	0 - 1	0	0	4823	6956	8159	5326	2145	730
	1 - 2	0	21584	84760	98292	85128	57865	38559	15887
	2 - 3			44874	92197	99575	68665	46127	31095
	3 - 4				9545	25138	57789	30142	25179
	4 - 5					3260	49898	46742	9168
	5 - 6						5083	13370	2245
	6 - 7								6526
								Annual Yield (GWh)	41

Rated Capacity - 750 kW

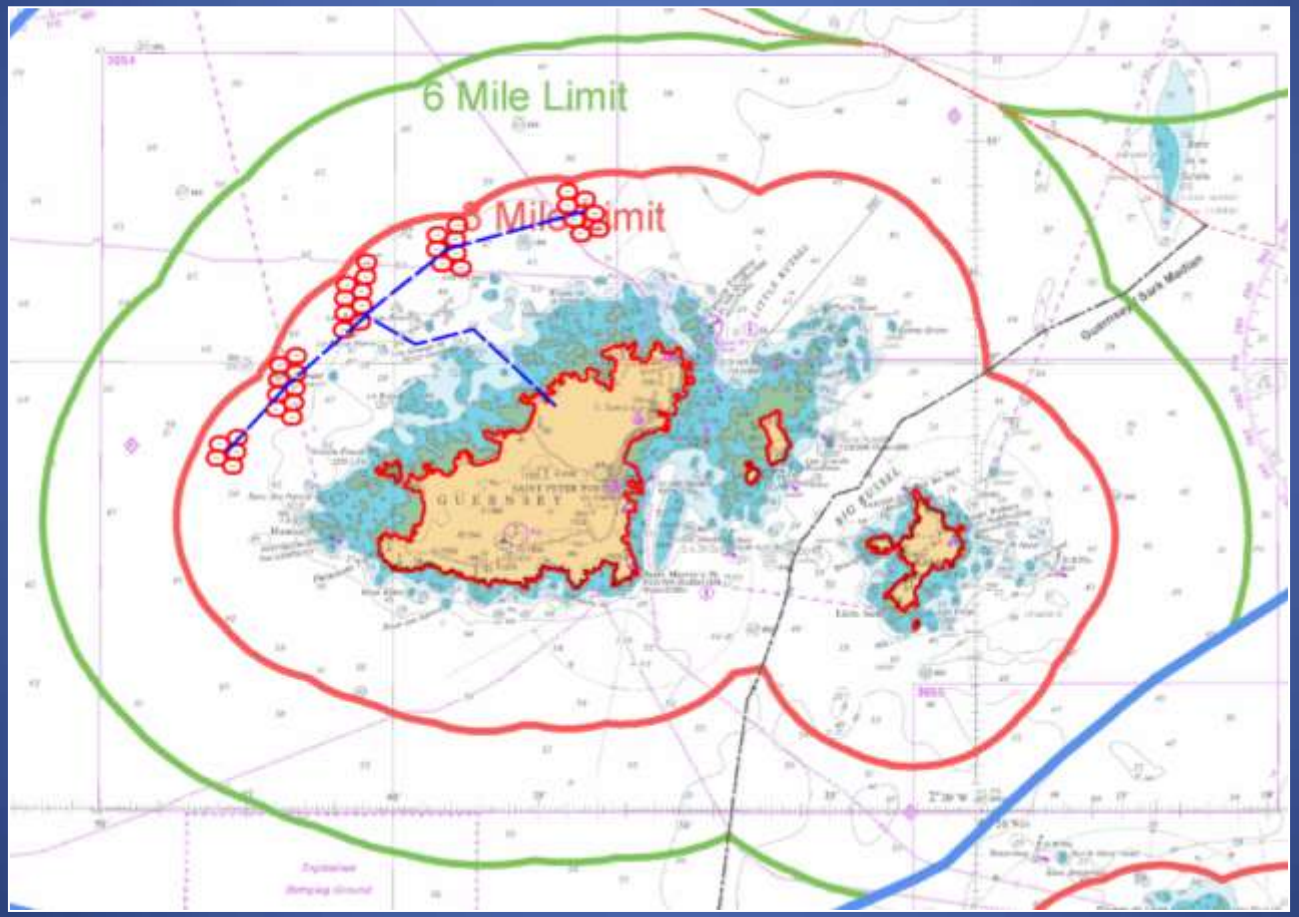
No. of Devices - 37

Installed Capacity ~ 30MW

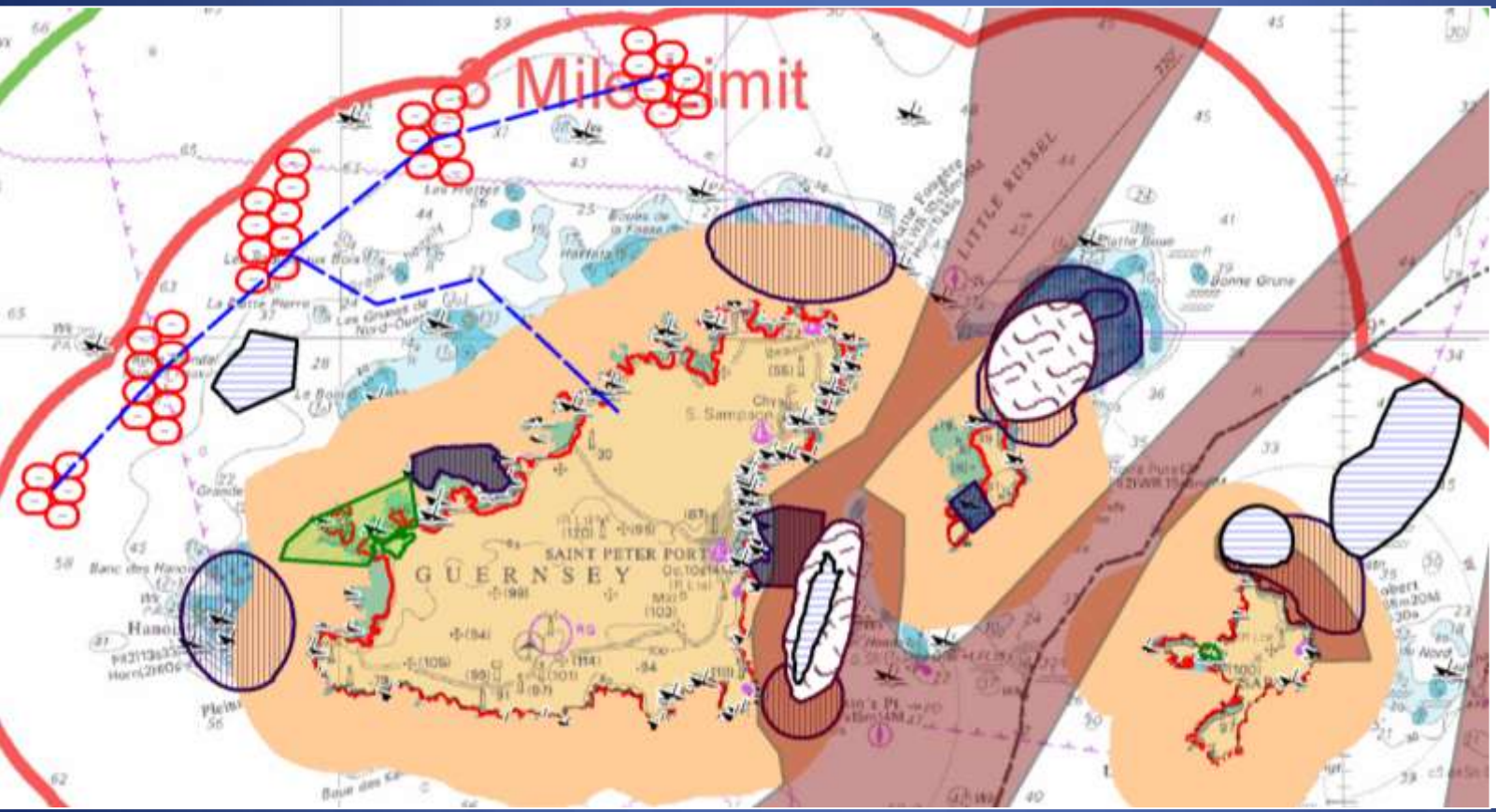
Device Yield – 0.1 GWh p.a

Array Yield – 41 GWh p.a

Site Location



Site Constraints

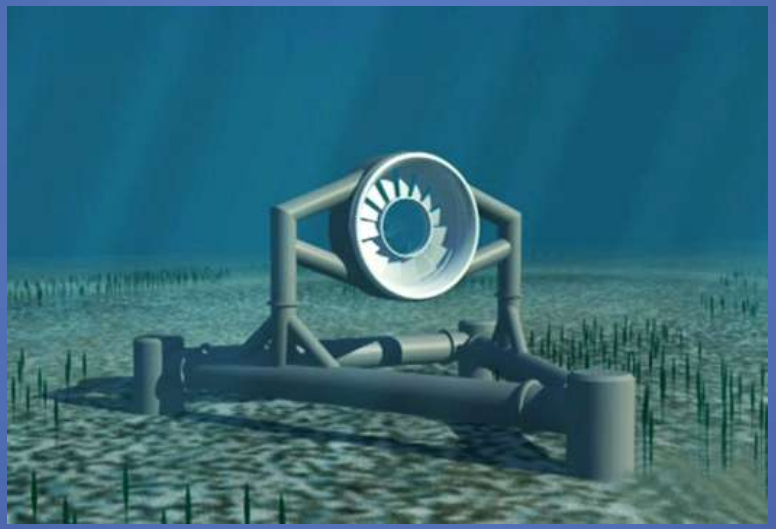


RE | 2012 | Tidal

Tidal Stream Technology

- Technology types and industry front-runners

SeaGen (1.2MW,2MW)



Open Hydro (2.2 MW)

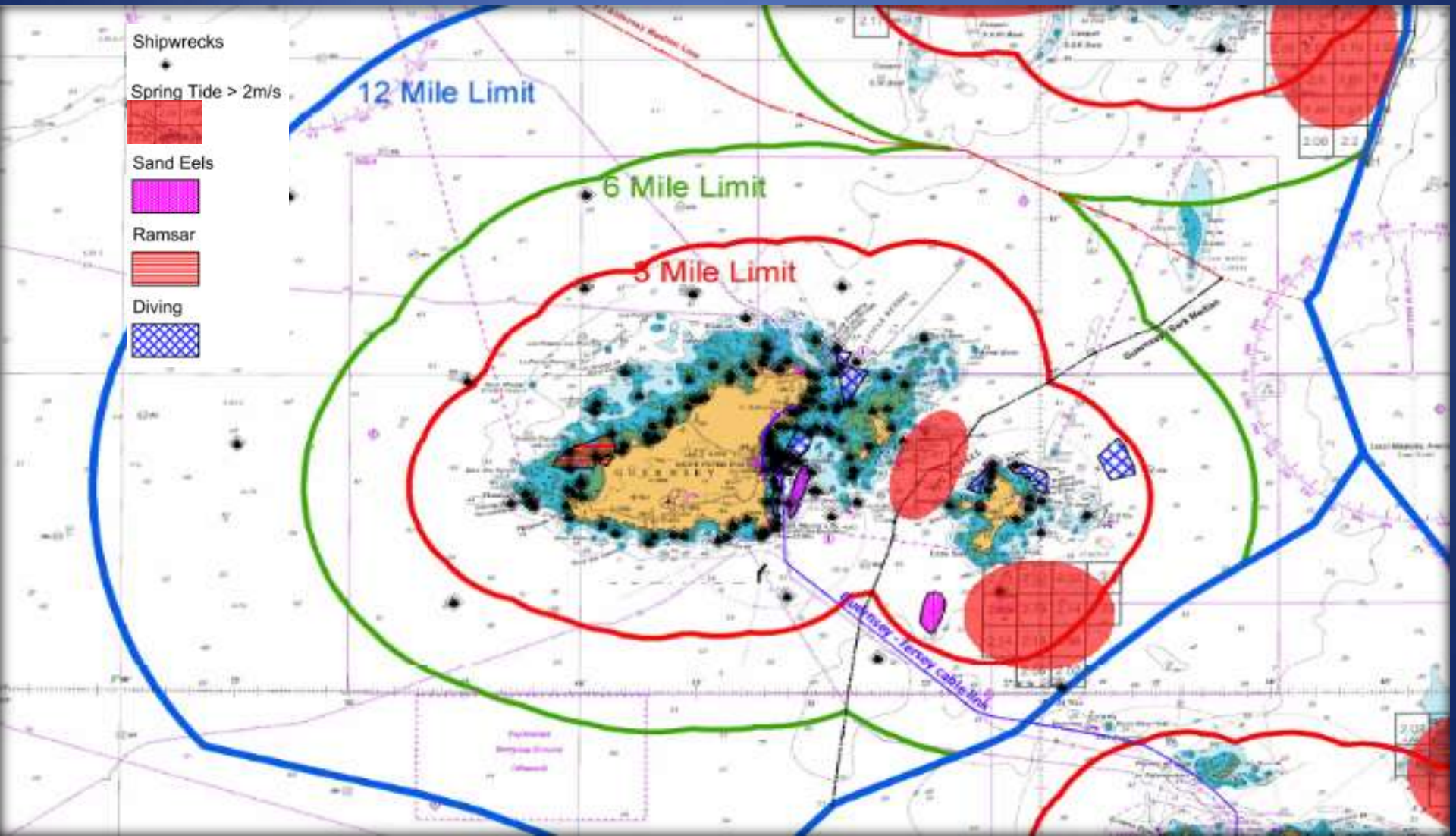
Hammerfest (1MW)

Guernsey - Site Selection Criteria

Considerations and Constraints

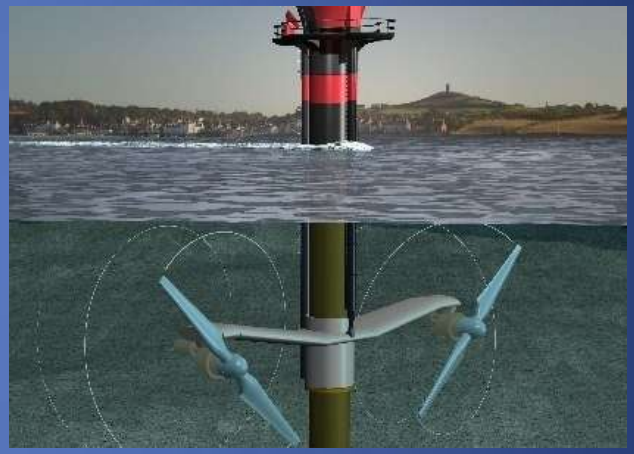
- Tidal resource (at least 2m/s spring tide)
- Water depth (up to 50m)
- Bathymetry (Seabed profile)
- Environmental
- Safety and navigation (shipping routes, etc.)

GIS mapping - Guernsey



Site Assessment - Methodology

- Limited data available
- Tidal profile for local area
- Probability graph derivation
- Application of SeaGen 1.2 MW device power curve



Site Assessment - Findings

3 nautical mile radius

Big Russell (6km sq, < 40m depth)

- Feasible potential 2 x 100 MW arrays (200 MW)
- 83 x SeaGen 1.2 MW devices
- Energy Production: 566 GWh/year (~140% of Guernsey's annual demand)

Site Assessment - Findings

3 nautical mile radius

South East of Sark

- Feasible potential 2 x 200 MW arrays (400 MW)
- 166 x SeaGen 1.2MW devices
- Energy Production: 750 GWh/year (~190% of Guernsey's annual demand)

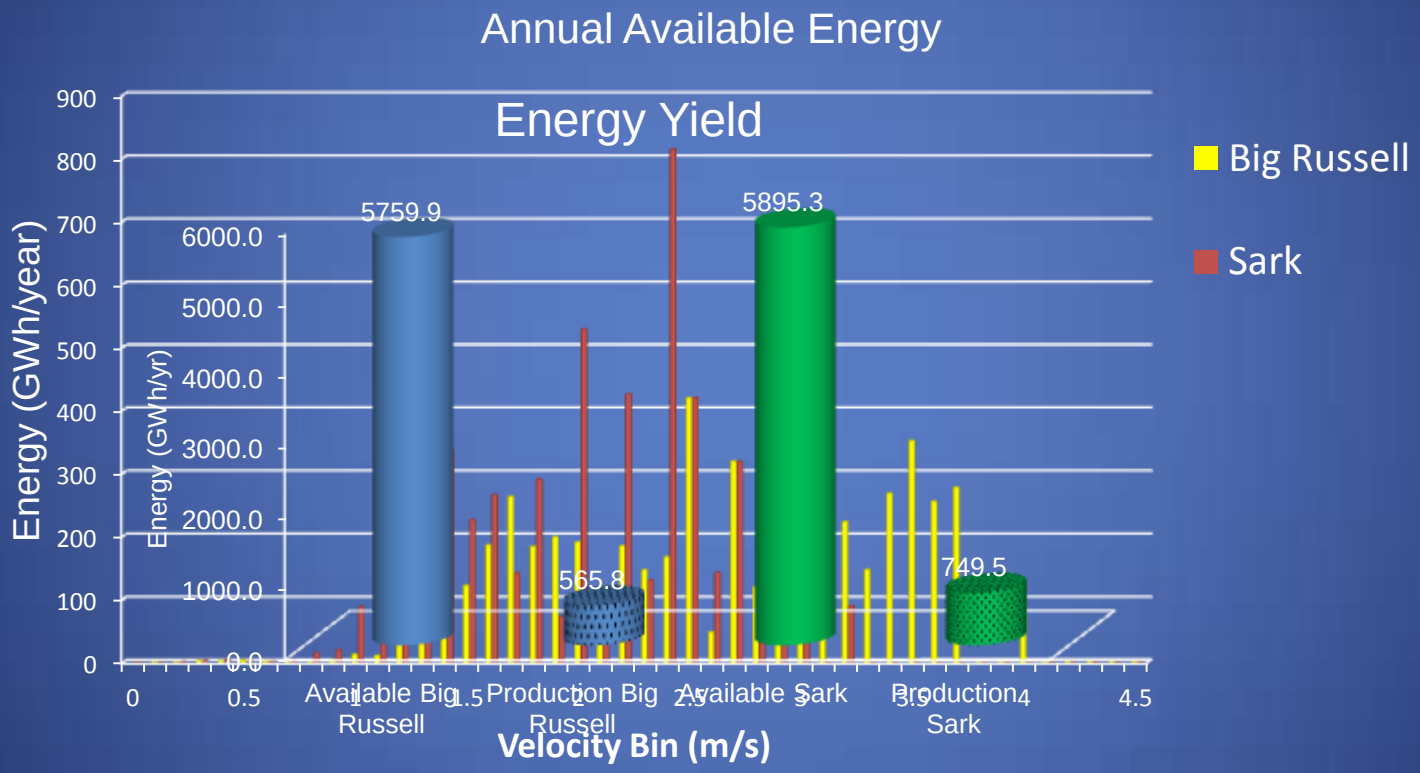
Site Assessment - Findings

12 nautical mile radius

South East of Sark

- Hammerfest tech applicable (up to 70m depth)

Energy (GWh/year)



Tidal Stream Project Costs

- Lack of case studies to give accurate cost indication
- R&D projects (£10m/MW)
- Technology commercially available by 2014
- Cost reductions estimated at 40% by 2040

- CAPEX: ~£3.5m/MW in 2020
- Cost of 30MW installation: £106m
- Cost of 200MW installation: £712m
- O&M costs: 2.1% of CAPEX

R&D and testing opportunity

- R&D site used for commercial purposes in the future
- Joint projects with other islands
- Control over site licensing and leasing – attractive to developers
- Engage with selected developer(s) to speed up the process
- Introduction of the concept to the public
- Key barrier – lack of incentive/subsidy

Conclusions

- Substantial tidal stream resource
- Potential to generate >100% of Guernsey's demand
- Further investigation into cost required
- Early preparation will make process smoother

RE | 2012 | Infrastructure

Infrastructure

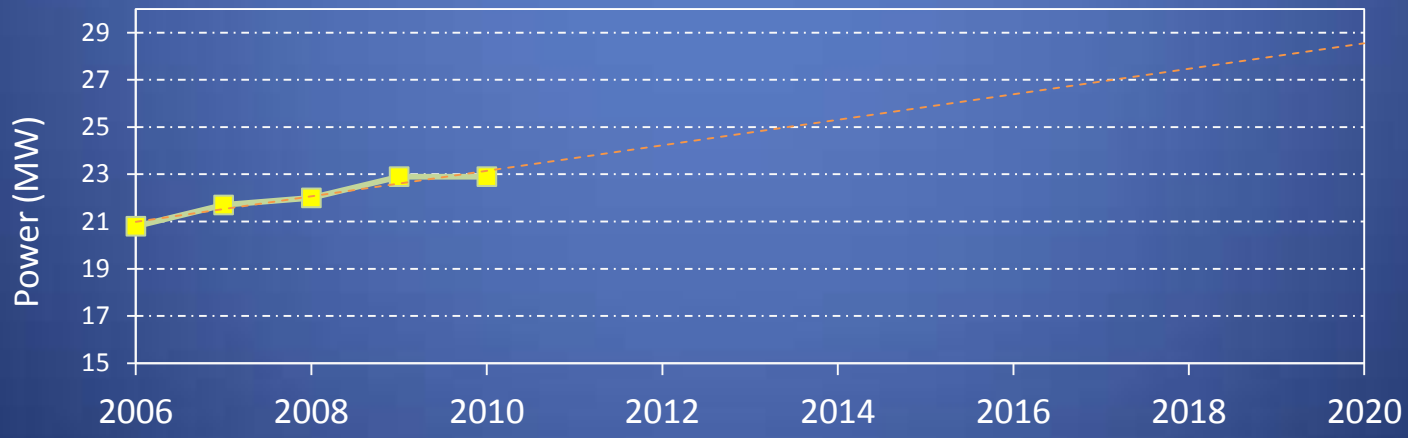
- Electrical Grid Infrastructure
- Port Infrastructure
- Energy Storage
- Transport Infrastructure

Electrical Grid Infrastructure

- Current case
  - Capable and expandable network
  - Plans to improve and increase 33kV grid
  - Second interconnector discussions

Electrical Grid Infrastructure

- Base-load scenario
  - 12.5MW maximum from renewable sources
  - GEL modelling up to 30MW
  - No large infrastructure changes required

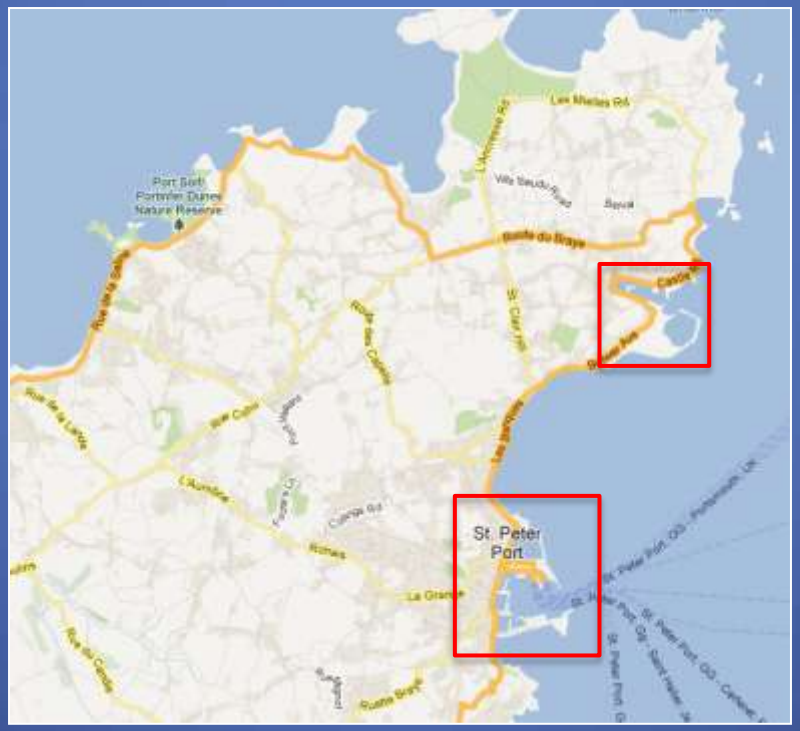


Electrical Grid Infrastructure

- Export scenario
  - Second interconnector required
  - Grid strengthening if power comes onto the island
  - Further modelling and consultation with GEL

Port Infrastructure

- St Peter Port Harbour & St Sampson's Harbour



Port Infrastructure

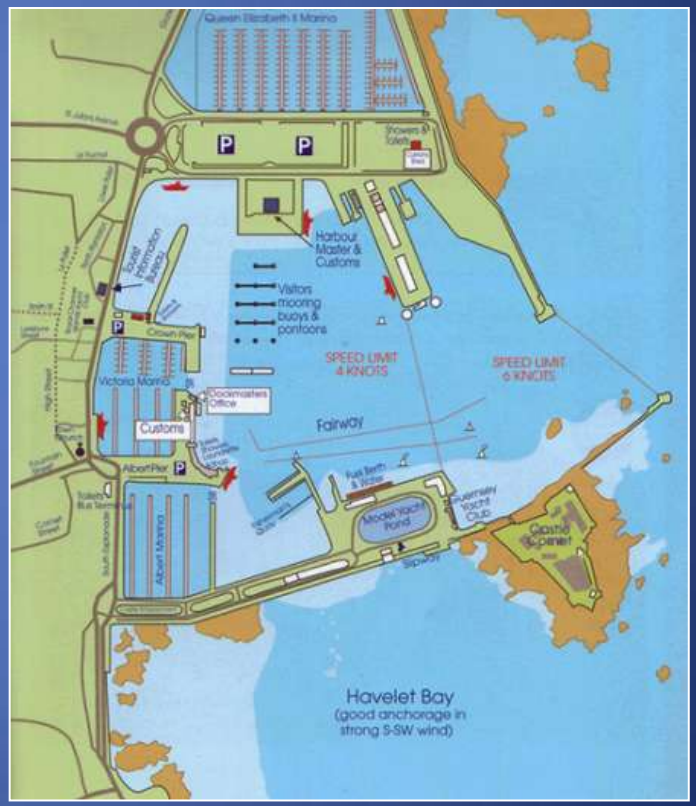
- Harbour requirements
  - Mooring and refuelling for vessels
    - Surveying
    - Foundation Installation
    - Device Installation
    - Operations & Maintenance
  - Storage space for technologies

Port Infrastructure

- Base-load scenario
  - Too costly to expand at this level
  - Large vessels: use French harbours e.g., Cherbourg
  - Smaller vessels: use Guernsey harbours

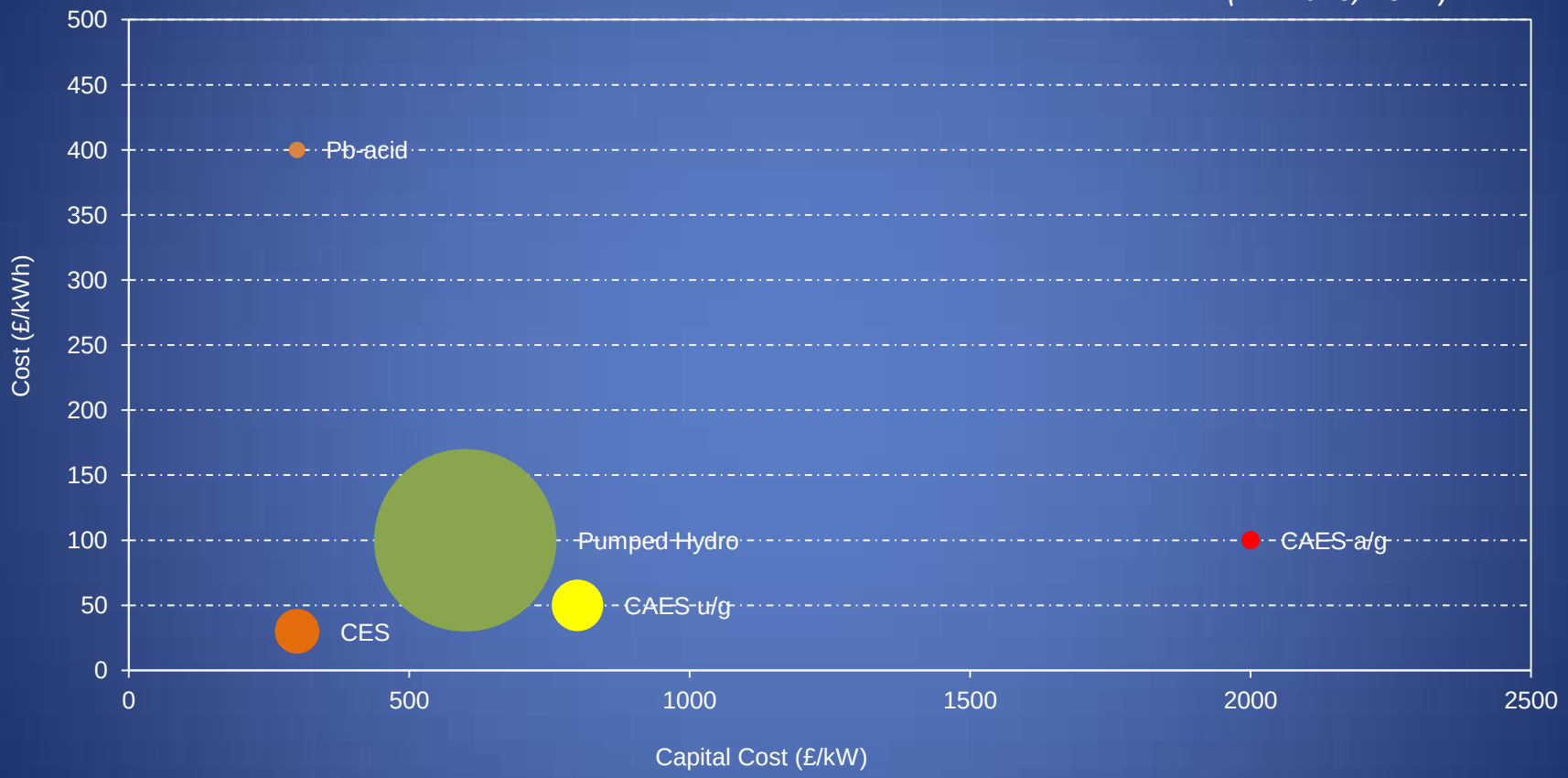
Port Infrastructure

- Export scenario
  - Use French harbours or
  - Include marine renewables in harbour master plan
  - Costly but part of overall master plan



Energy Storage

(A. Evans, 2012)



Note: Size of circle represents the storage capacity of given technology

Transport Infrastructure

- Electrification of Transport
  - Indirect impact
  - Increase demand on network
  - GEL models consider possibility
  - Energy storage provision

Conclusion

- Base-load possible with current plans
- Export requires longer term plans
- Keep open communication between stakeholders

RE | 2012 | Public Consultation

Stakeholders

- Public
- Sustainable Guernsey
- Fishermen
- Local RE companies
- Tourist industry
- Harbourmaster
- Local businesses
- Energy utilities

Education – Schools

- Curriculum – review
- Energy
- Questionnaire
- Teaching aids
- Awareness Program

Source: marcus-povey.co.uk

Raising Awareness

- Government
- Planet Guernsey
  - Towards A Sustainable Future
  - Riding The Storm
- Role of employers – public and private
- Training

Recommendations

- Planned
- Level of engagement
- Target specific groups
- Phased approach
- Questionnaire

Scenarios

Scenarios

- 3 Scenarios:

1. No renewables
2. Baseload
3. Export

Scenario 1- Introduction

- No renewables
- Continuing reliance on imported electricity and on island diesel generation
- Rising demand

Scenario 1 – Assumptions

- Cost to consumer rises 5.5%/year
- Electricity demand rises at 0.4%/year

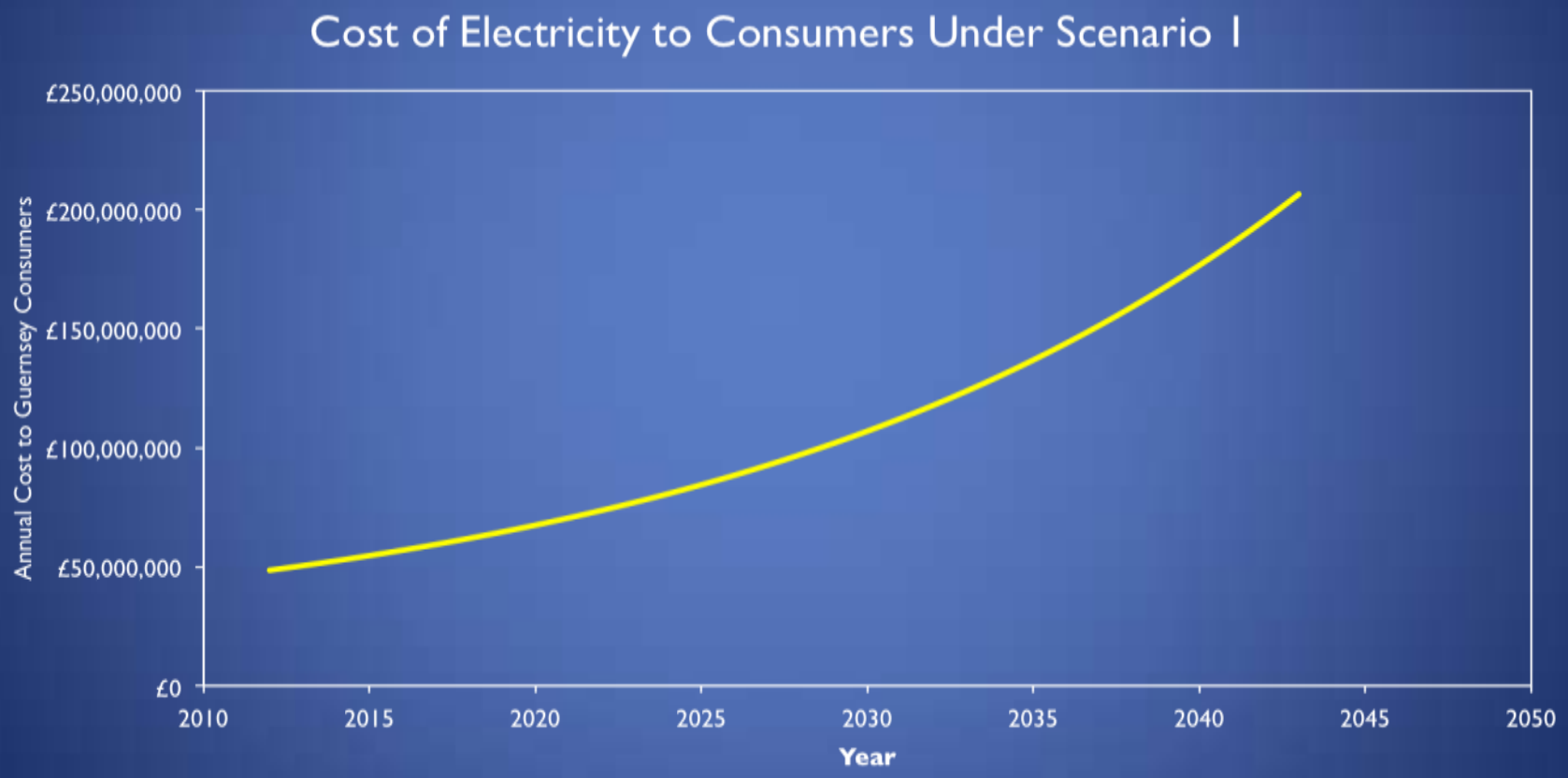
Scenario 1 – Conclusions

1 of 2

- On island generation costs rise as oil prices rise
- Import costs to rise
- Electricity supply therefore likely to become substantially more costly.
- Reliant on France
- Does nothing to tackle emissions

Scenario 1 – Conclusions

2 of 2



Scenario 2 - Introduction

- Meets Guernsey's baseload with marine renewables only
- No access to French or UK subsidy
- Tidal or offshore wind

Scenario 2 - Projections

- Baseload demand increased 4MW over last ten years
- Tidal stream capital cost £3.6m/MW by 2020 and £3.3m/MW by 2030
- Offshore wind capital cost £2.9m/MW currently

Scenario 2 - Recommendations

- Substantial financial undertaking will require initial subsidy.
- Cable contract until 2023 means a planned, phased approach should be considered
- Energy storage and balancing options greatly affect viability and need to be considered.
- Costs still uncertain

Scenario 3 - Introduction

- Based on the assumption that the electricity will be predominantly exported.
- UK and France primary options
- Extensive legal challenges
- Challenging to model and assess

Scenario 3 – Export Options

- UK

Technology	Subsidy	Feasibility
Tidal	5 ROCs (~£200/MWh)	2020-2025
Offshore Wind	2 ROCs (~£80/MWh)	Currently
Wave	5 ROCs (~£200/MWh)	2030-2050

- France

Technology	Subsidy	Feasibility
Tidal	€150/MWh (~£120/MWh)	Not currently
Offshore Wind	€120/MWh (~£100/MWh	Currently
Wave	€150/MWh (~£120/MWh)	Not currently

Can't access either subsidy yet but discussions have been started

Scenario 3 - Capacity

Technology	Capacity	Annual Yield	No. of sites
Tidal	60MW	1130GWh	2
Offshore Wind	390MW	1500GWh	4
Wave	28MW	40GWh	1

- 1GW total, producing ~ 2700GWh/year (almost 7x Guernsey's current annual demand)

Scenario 3 – Conclusions

- Export to the UK most attractive currently, this could change
- Infrastructure considerations
- Legal and commercial research
- Significant barriers restricting feasibility

Conclusions

- The non-financial advantages need to be fully considered.
- 'No renewables' leaves Guernsey vulnerable of significant energy cost rises
- A renewables programme with a mix of self-use and export is most attractive yet needs access to appropriate subsidies
- Just meeting baseload is currently most viable

RE | 2012 | Conclusions

Offshore wind

- Good wind resource
- 12MW too small, 30MW and 300MW potentially feasible
- Visual impact is a key concern for near-shore sites
- Detailed environmental studies at chosen site
- 1-2 year wind speed data collection at Chouet met-mast
- Obtain aviation, radar and communications data
- Detailed cost analysis

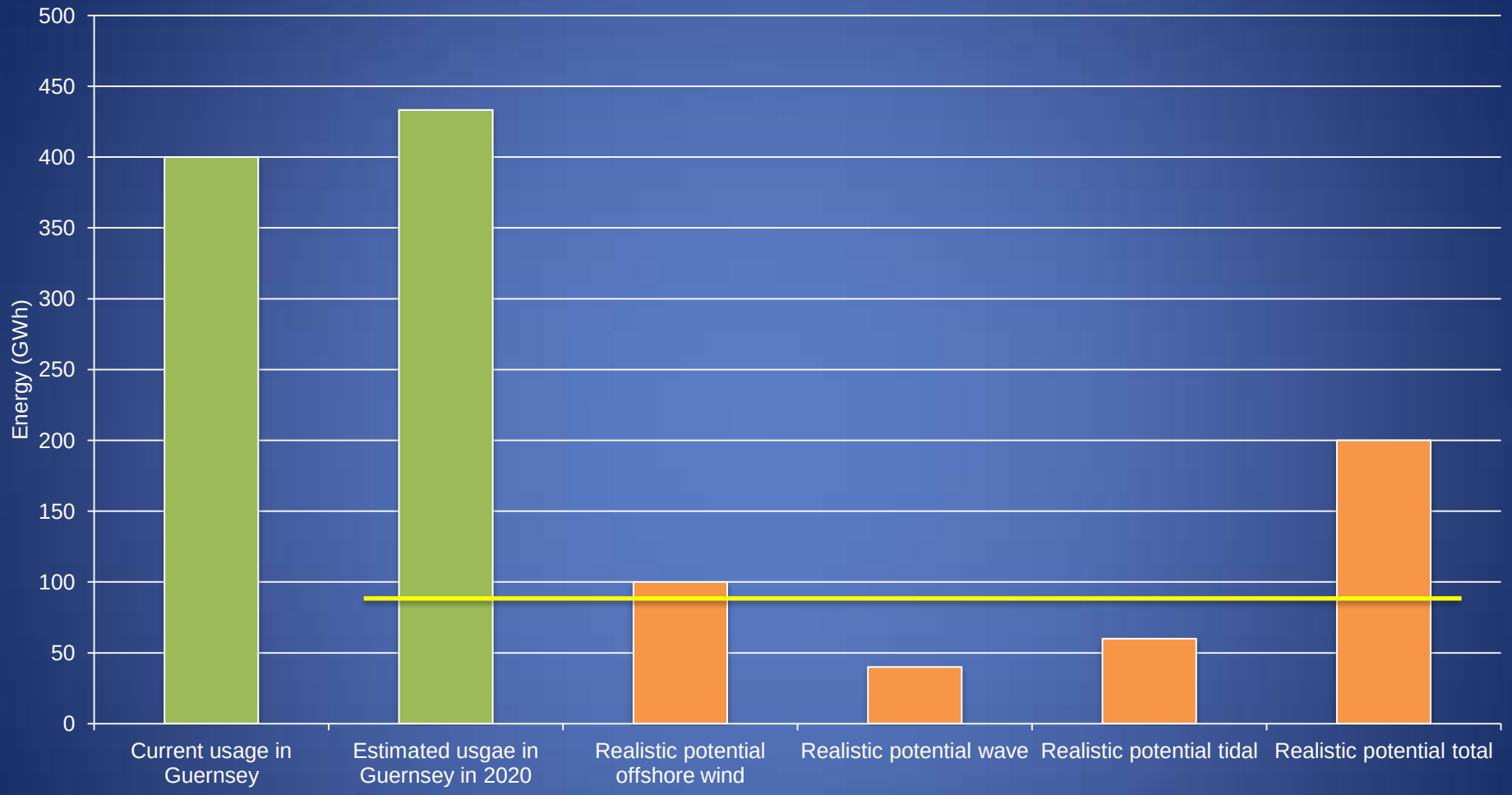
Wave

- Early analysis – significant resource
- Further research required
  - Wave buoys
  - Radar wave monitoring
- No complete wave energy converter solution
- Costs still largely unknown

Tidal

- Very promising tidal stream resource
- Two sites in 3nm radius could generate >100% of Guernsey demand
- Costs still uncertain
- Potential for R&D
- Streamline licensing system
- Prepare groundwork now, ready for the future

Realistic potential for macro-marine renewable energy in Guernsey by 2020-2025



Potential Impacts

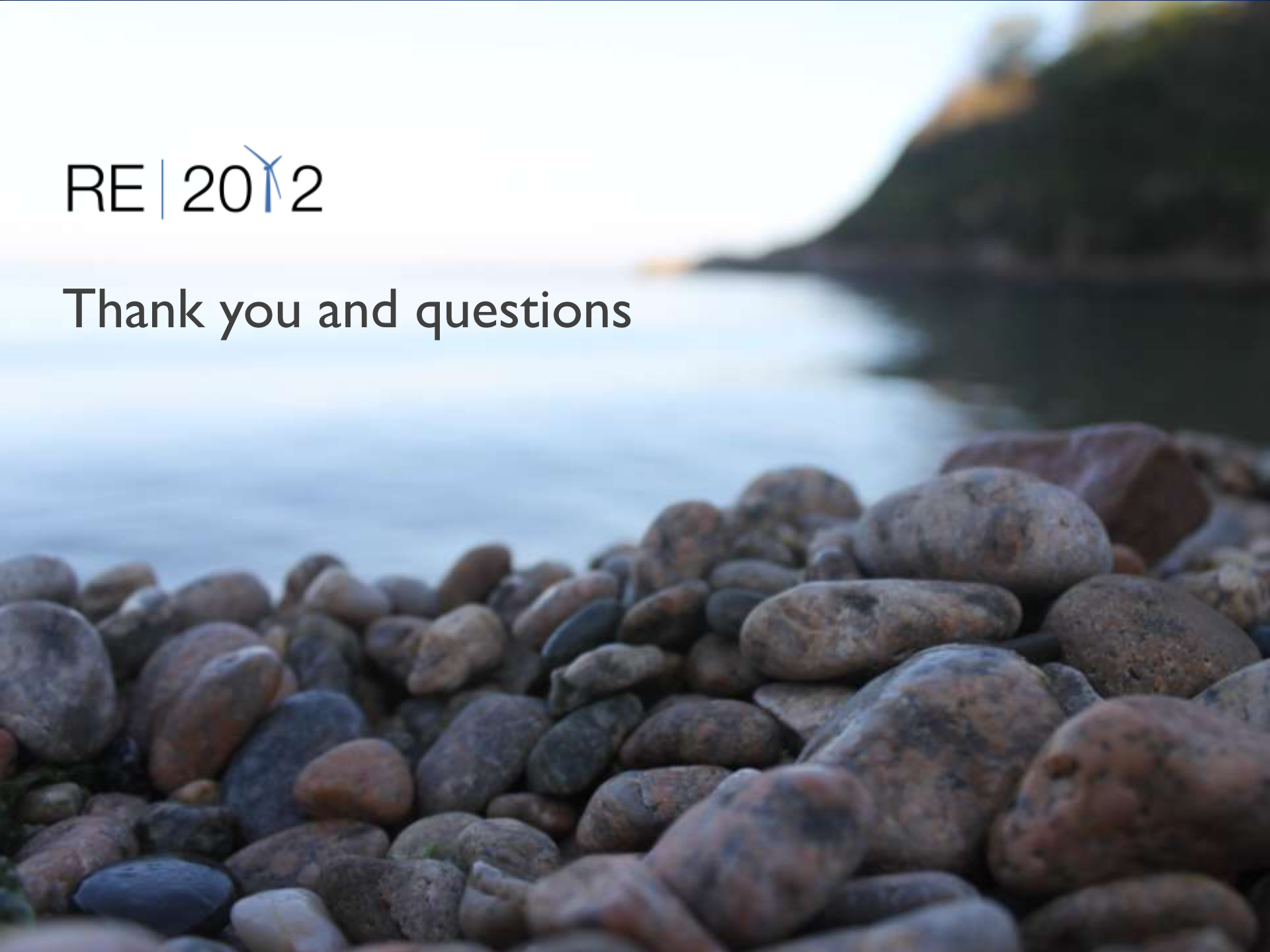
Impacts arising from different phases in the project :

- Energy security
- Environmental
- Visual impacts
- Employment diversity
- Potential export revenue
- Kudos and satisfaction

RE | 2012 | Acknowledgements

Acknowledgements

- Commerce and Employment
- Environment Department
- Guernsey Renewable Energy Team
- Guernsey Electricity Ltd.
- All those who assisted in meetings
- Sea Fisheries – RIB tour
- Digimap
- Harbour Master


RE | 2012
Thank you and questions