Accelerating the development of emerging renewables: research and policy challenges

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The promise of technology acceleration

- most scenarios of UK energy system change see emerging technologies as being too expensive to make much impact on supply, even over longer timescales (ERP, 2010)
- A few scenarios explore the influence of supply-side innovation on energy system evolution over the next four decades
- … seen as a major source of source of uncertainty in identifying preferred pathways for UK energy system decarbonisation from now to 2050
- e.g. UKERC ATD scenarios concluded that there was considerable potential for the accelerated development of emerging technologies…

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Accelerated Development Scenarios, marine energy, solar PV

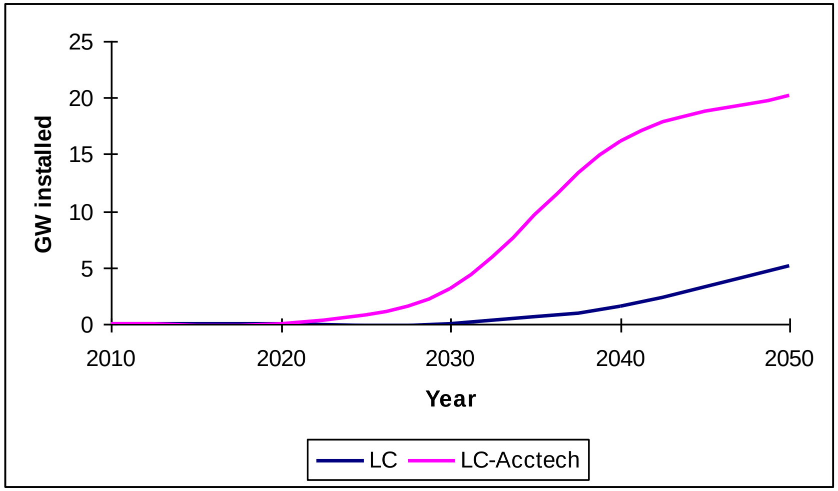
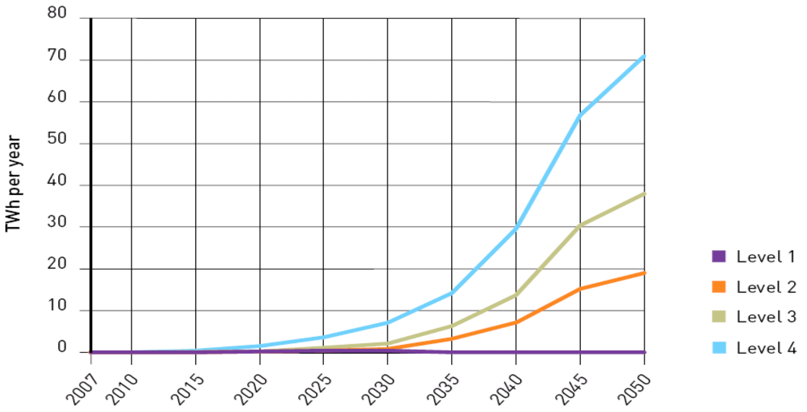


Figure L2: Trajectories for electricity generation from wave power



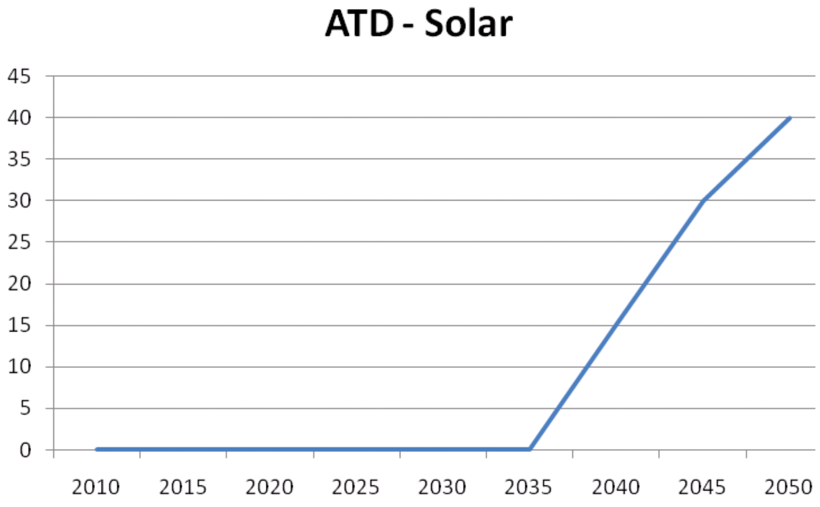
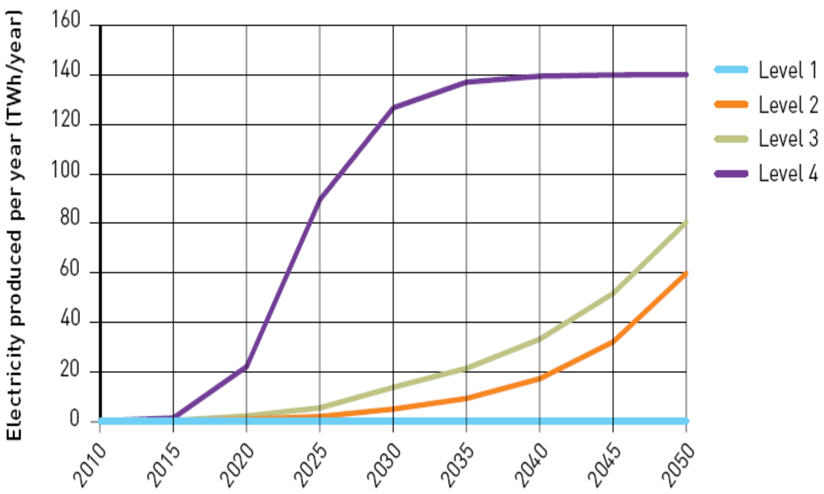


Figure M2: Trajectories for electricity generation from small scale solar PV



System-level advantages of acceleration

- UKERC scenarios suggested that technology acceleration could significantly reduce the overall costs of decarbonisation, especially after 2030
- size of the 'saving' appears to substantially outweigh the added RD&D costs … especially if the costs of accelerated development are assumed to be shared internationally.
- T-acceleration also boosts UK supply portfolio diversity over the longer term, and insures against other technologies (offshore wind, nuclear power and CCS) failing to provide major contributions often suggested.

Policy questions is then, how can technology acceleration be realised?

- what are the financial, organisational and institutional conditions?
- what is the appropriate role in this for the UK, and for different parts of the system?
- requires a more in-depth analyses of the conditions for innovation and learning in specific technology systems, and a significant shift in UK style of energy innovation systems

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UK Renewables Innovation System: NAO, 2010

- UK public sector support for renewable innovation has mostly been short term, generally not guaranteed beyond the 3yr spending review period
- Coordination has historically been limited, with each delivery body developing its own approach in accordance with its own objectives.
- Arrangements often not in place to link support schemes for individual projects to the overarching delivery plan.

without a coherent delivery framework … or a consistent approach to evaluating and reporting performance … the overall value for money of direct support for renewable energy technologies cannot be demonstrated.

- BUT … recent reforms, such as the creation of the *Low Carbon Innovation Group* and action plans, have improved coordination in the system.

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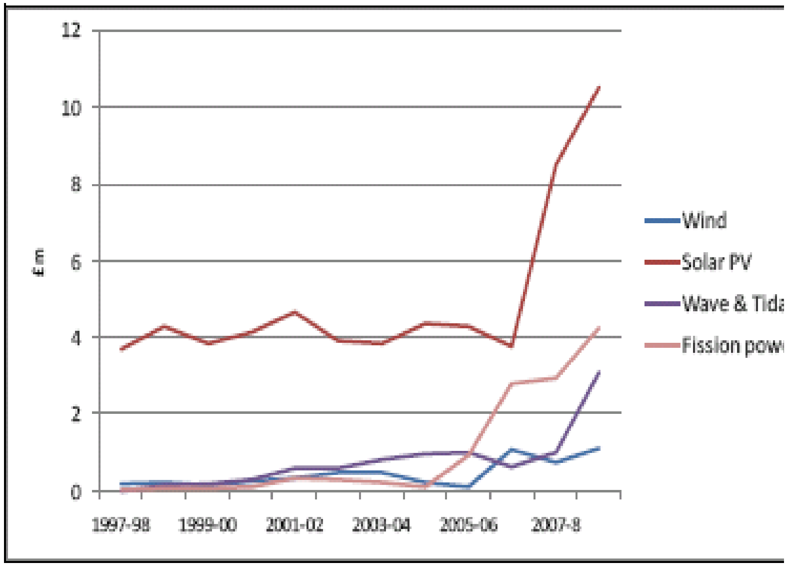
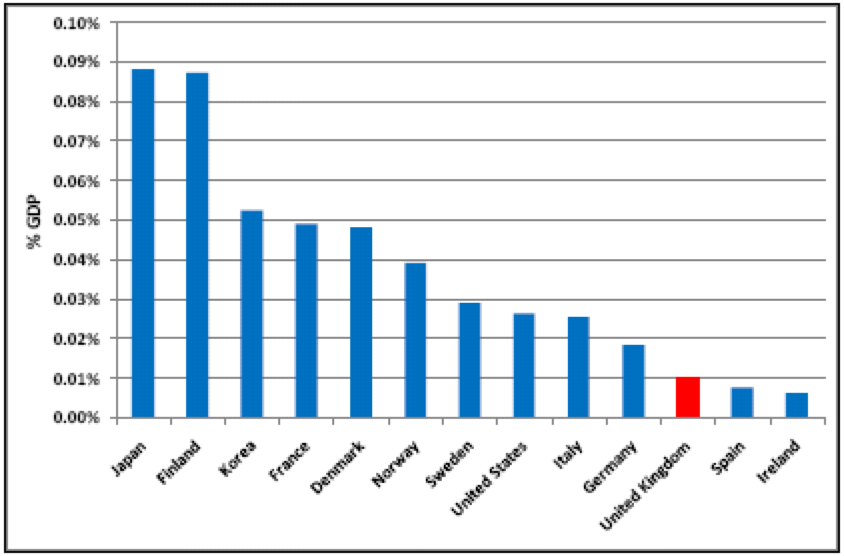
UK Renewables Innovation System: CT, 2009

- Although UK public funding has increased sharply recently, it is still only about half of Germany's and a quarter of the US and Japan.
- need for a more thorough and transparent prioritisation process

UK Research Councils' Energy R&D expenditure, 1997-2008 (£m)



public sector energy RD&D spend (2007)



Innovation System reform

- Carbon Trust: a move away from ‘technology neutrality’ in UK energy and innovation policy, to a system focusing on:
- ‘focused support’ for deployment over the shorter term, and ‘option creation’ through RD&D over the longer term (Carbon Trust, 2009).
- In part, a pragmatic acceptance that the UK can only have a global impact in a small number of low carbon technologies.
- Also, a necessary response to the specifics of innovation enablers and barriers for different technologies:

The most cost effective way to support [innovation] is on a highly technology specific basis because the engineering and commercial barriers, and the solutions that need to be put in place, vary considerably by technology’

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Best practice guidelines (CCC, 2010)

Successful RD&D funding strategy:

- *Material* – nationally and globally. E.g. for onshore wind, the US, Germany and Denmark all spent significant sums on public sector RD&D support
- *Consistent over long-term* – e.g. solar PV in Japan over a period of over 25 years.
- *Comprehensive,* covering enablers such as performance standards, knowledge transfer networks and certification, as well as direct support for developers.

Key features of institutional framework:

- Overarching objective and long-term focus, with objectives linked to resources.
- Clear alignment between overall objective and delivery bodies
- Strong links between all stages of the innovation process
- Monitoring frameworks with feedback to objectives, allowing flexibility to adapt in light of scientific, technological or policy developments.
- Integration with international research programmes and overseas developers

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Test cases: marine and solar PV

- How to respond to the call for greater technology-specifics in energy innovation policy, to realise technology acceleration?

- Consider the context for innovation in each system under the following headings:

  - Technical and social context for innovation
  - Innovation dynamics and learning effects
  - Expectations and roadmapping

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Social context: Marine Energy

- Disrupted / discontinuous development path: initial activity in late-1970s … no significant innovation from the mid-1980s up to around 2000. Recent resurgence since 2000, especially in the UK.
- Immature technology system, with little performance data under real operating conditions UK is a significant part of the overall marine energy innovation system, and so the marine system conforms largely to a ‘UK style’ of innovation system
  - Until very recently, dominant role for private small firms, private capital, IP protection
- Now changing with the involvement of ETI, TSB and the major utilities
- Internationally, a relatively small and low profile system compared to other renewables, but a high profile and important suggested role in the UK
- marine energy is a ‘test case’ in the UK innovation landscape, with DECC’s first pilot action plan being published on marine energy, in 2010

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Technical context: Marine Energy

- Technical diversity: two distinct resources. Large number of prototype designs for both .
- Focus is often on resource potential and capture device technology,
- BUT systems more properly understood as assemblies of capture device components, support infrastructure, O&M, system costs
- support infrastructure for construction and O&M (including vessels, ports, harbours, and subsea grid access) are a significant part of the overall costs of marine energy systems.

Cost Centre	**Component**	***Conventional***	***Novel Specific***	***Novel Widespread***
Device Structure	Ballast mass	X		
	Device structure	X		
Electrical	Generator	X	X	
	Controls			X
Moorings	Anchors	X		
	Mooring lines		X	X
	Fittings/release mechanism		X	
Mechanical	Power storage		X	X
	Hydraulics		X	X
	Turbine		X	
	Seals			X
Control	Control system		X	
	Instrumentation			X
Auxiliary	Assembly		X	
	Insurance		X	
	Project management	X		
	Operation and maintenance		X	

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Technical and social context: Solar PV

- Continuity for over four decades since PV cells were first used in the US space programme.
- sustained technology learning and costs reductions over time during this period
- Solar PV technology systems are assemblies of power cells / modules and balance of system components and costs
- Cell modules typically make up around 50-70% of total system costs, and cell costs are in turn dominated by materials costs, especially as production is scaled-up.
- 3 generations of PV cell technologies:
  - 1. Crystalline silicon (c-Si) (1st generation): mature, dominant in the overall market
  - 2. Thin film (2nd generation), greater potential for module cost reduction than c-Si, increasing share of market 12.5% in 2009
  - 3rd generation emerging technologies, including low cost / low efficiency dye sensitised and organic cells, and high efficiency / high cost devices and other novel concepts. Offer potential step-change breakthroughs

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Technical and social context: Solar PV

- Organisationally mature and specialised along the supply chain, with separate module and inverter component manufacturers, system developers and installers.
- Modular and scalable: off-grid, grid-connected systems. buildings-integrated or ground-mounted) and scales: residential, commercial and utility level
- A wide range of users, financiers and business opportunities
- Innovation system is well-coordinated internationally, in terms of conferences, research networks and international research roadmaps (e.g. within IEA and EU). Influential international industry associations such as the European Photovoltaic Industry Association (EPIA).
- UK PV industry and research communities are comparatively small, with lack of a strong market support programme, until very recently,
- Lack of a UK central research laboratory of the kind that other European countries, the USA and Japan have used to drive forwards their PV research.
- UK R&D activity tends to concentrate on particular areas: particularly dye-sensitised and organic devices, concentrator cell design and materials.

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Innovation and learning, marine energy

- Step-change increases in development costs at each stage of the chain: small tank tests typically cost £10,000s; 1/7th scale prototypes c.£100,000s, and full-scale prototypes deployed at sea c.£1,000,000s. High risks and uncertainties, presenting significant investment barriers.
- Limited opportunities for learning-by-doing at full scale, and an emphasises learning-by-research at model and prototype scales before full scale testing.
- Relatively low level of component innovation in more mature devices
- need to support more radical innovation which may enable step-changes over the longer term. Given the longer timescales involved here, public funding has a leading role to play.
- Opportunities for innovation in 'generic' technologies (foundations, moorings, marine operations and resource assessment) and technology transfer (from offshore engineering and offshore wind), but these face commercial / IP barriers.

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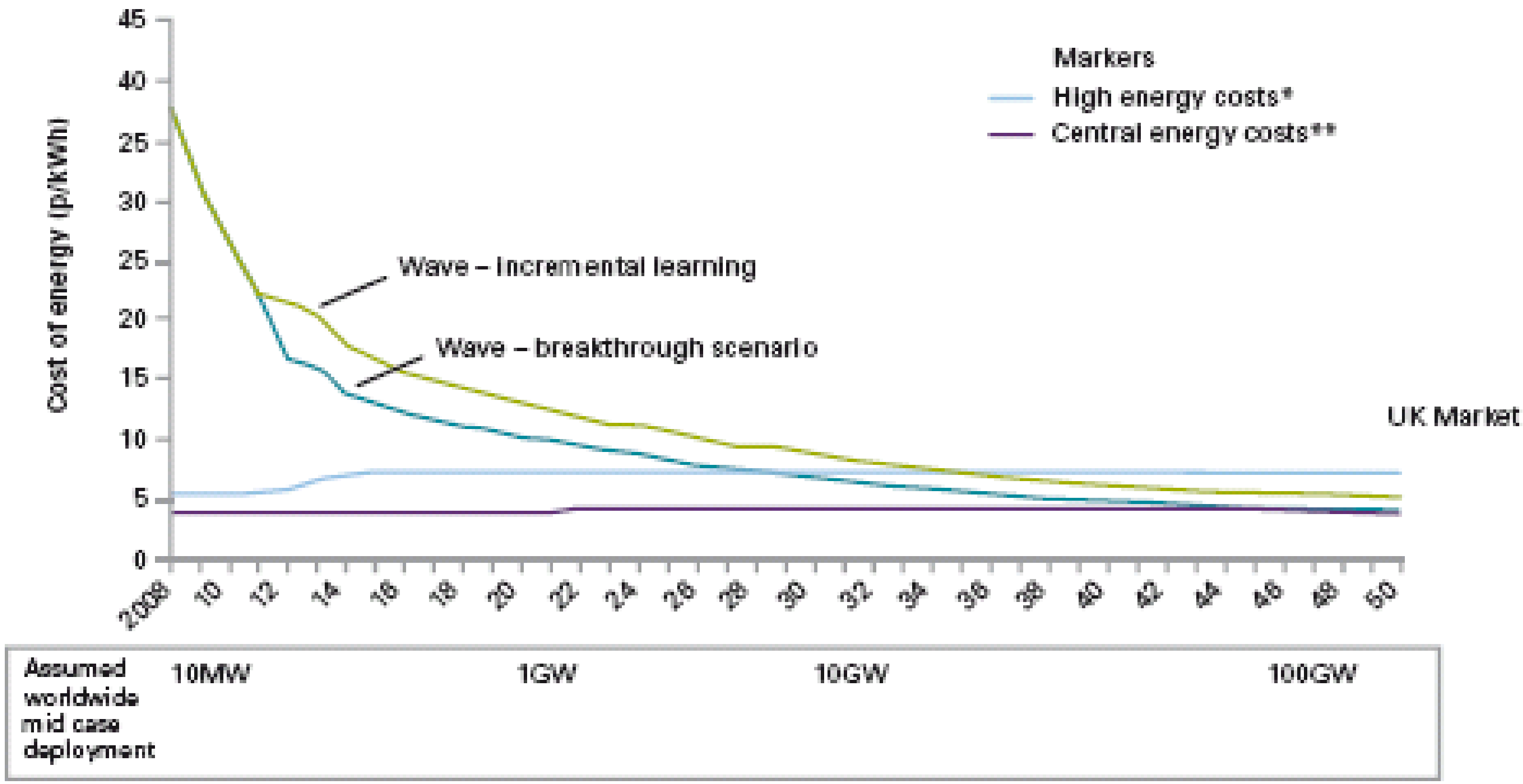
Innovation and learning effects, marine energy

Chart 3.4f Global cost evolution of wave energy – mid deployment case



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Innovation and learning effects, solar PV

- well-established evidence of cost reduction and learning for 1st generation PV, much less for second and third generation technologies. Photovoltaic module costs have decreased in the past with a learning rate of between c20% for four decades
- Important contributions from both *learning by research* (at the device / module level) and *learning by doing* (in module production, balance-of systems and system integration),
- Most PV innovation efforts focus on cells and modules materials innovation
- Private sector industrial innovation important role in economies of scale, improved throughput and production processes.
- Important innovation needs in the wider PV system including for system components and cheaper methods for buildings integration, and grid integration issues
- System innovation is relatively neglected compared to modules. Requires input from a wider engagement of different actors, operating at different stages of the PV supply chain, e.g. system developers and grid operators.
- System-level learning has a more local / national character, varies significantly by location and application.

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Expectations and Policy: Marine

- High level of policy support for marine energy in the UK and Scotland, and increasingly, internationally.
- A recent process of policy experimentation and learning on relative emphasis on RD&D or revenue support.
- UK Government's Marine Renewables Deployment Fund (MRDF) reflected unrealistic expectations of the deployability of marine energy. Led to a rebalancing toward capital support measures, involving the Carbon Trust, Technology Strategy Board and ETI.
- *Renewable Energy Strategy* suggested that marine energy had the potential, over the longer term, to provide up to 20% of UK electricity needs, with wave energy seen as having as much potential exploitable resource as onshore wind.
- *Investing in a Low Carbon Britain* : UK is strongly positioned to lead in the development of the wave and tidal power industry.
- Carbon Trust: wave power is 'likely to play an important part in the radical decarbonisation of UK electricity by 2050'.
- Scottish policymakers perceive an opportunity for industry building analogous to those associated with the fostering of wind energy in Denmark since the 1970s.

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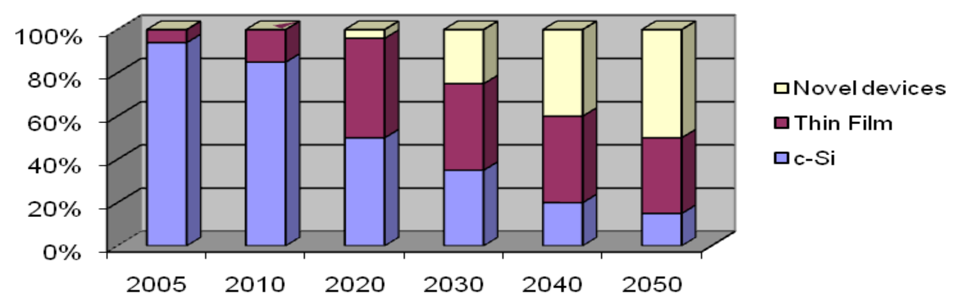
Expectations and Policy: Solar PV

- High level of expectations and legitimacy internationally: IEA's Technology Roadmap for solar PV envisages 11% of global electricity production to be provided by PV in 2050 (see fig?) (IEA, 2010a).
- In the UK, expectations are more muted. For the CCC (2010), high costs are likely to keep the uptake of solar PV in the UK low until at least 2030. Seen as having a more significant role in countries with a better solar resource and fewer alternative low-carbon options.
- DECC noted that the UK has particular research strengths in third generation photovoltaics
- A 'conventional' vision of PV evolution from now to 2050 involves shifts between the three different generations. Up to around 2030) 1st and 2nd generation devices are co
  overall market share.



Summary

- Preliminary survey of innovations systems for marine energy and solar PV highlights significant differences in their technical character, social context, relative role for different learning effects, and the expectations and policy legitimacy in the UK and internationally.
- For both, technology acceleration has significant potential, and promises significant benefits for UK energy system development.
- Step changes in the rate of progress may be essential for both marine and 3rd generation solar to play a significant part in system change
- Marine energy conforms to a UK style of innovation, weakly co-ordinated until recently, dominated by private finance and unable to undertake more radical innovation at a level to bring forwards accelerated development.
- UK policy is now starting to address need for greater co-ordination and risk-taking capacity, but there is a danger that the bulk of innovation will focus on conventional components, restricting possibility of more radical breakthroughs thereafter.
- Globalisation of the innovation system likely to be key for accelerated development. Over short term, UK will have a key role as main driver of the system.
- Solar PV system is much more internationalised, and UK innovation system is unlikely to influence the pace and direction of development
- significant opportunities for UK R&D strengths to be exploited, especially for 2nd and 3rd generation systems.
- Balance of system innovations are also an opportunity for UK advantage as the home market develops, but these are weakly represented at present, with a main focus on R&D in the UK.

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Conclusions

- Verbong et al. (2008) analysed long-term innovation trends for renewable technologies in the Netherlands. Recurrent weaknesses were seen:
  - too much technology-push / R&D. Important challenges in technology transfer were underplayed.
  - narrow and supply-side oriented innovation networks. Learning style focussed on technical learning, and neglected commercial prospects, social acceptability and wider stakeholding.
  - exaggerated expectations which led to ‘hype-disappointment’ cycles. Under urgent policy challenges, policymakers tend to invest faith in certain technical solutions, and promises by technology champions.
  - From the 1990s, a tendency to exclude less radical options – a favouring of more incremental technologies under market pressures
- Both marine and solar PV innovation systems in the UK share some of these weaknesses
- In this context, calls for accelerated innovation – in terms of responding more urgently to policy challenges, and the need for greater ‘technology specificity’ in RD&D – run the risk of repeating some of these failures, possibly amplifying ‘hype-disappointment’ cycles.
- Need for research and policy frameworks which strike a balance between technology specificity and comparability, to enable comparisons of cost-effectiveness across different technology fields.

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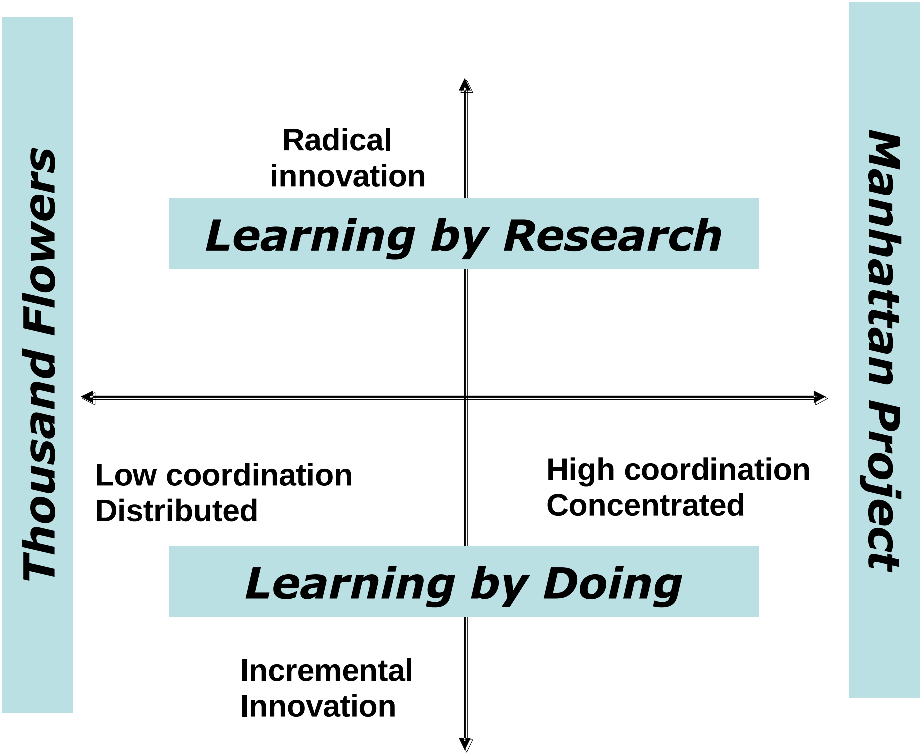
Learning Pathways Matrix

- **incremental-radical innovation** parameter to represent more technically-embedded features
- **concentrated / distributed co-ordination** to represent more institutionally-embedded features
    - **Radical innovation involves mostly learning-by-research**
    - **Incremental innovation involves mostly learning-by-doing**
    - **Distributed innovation involves learning by interacting**
    - **Concentrated innovation involves learning-in-house**



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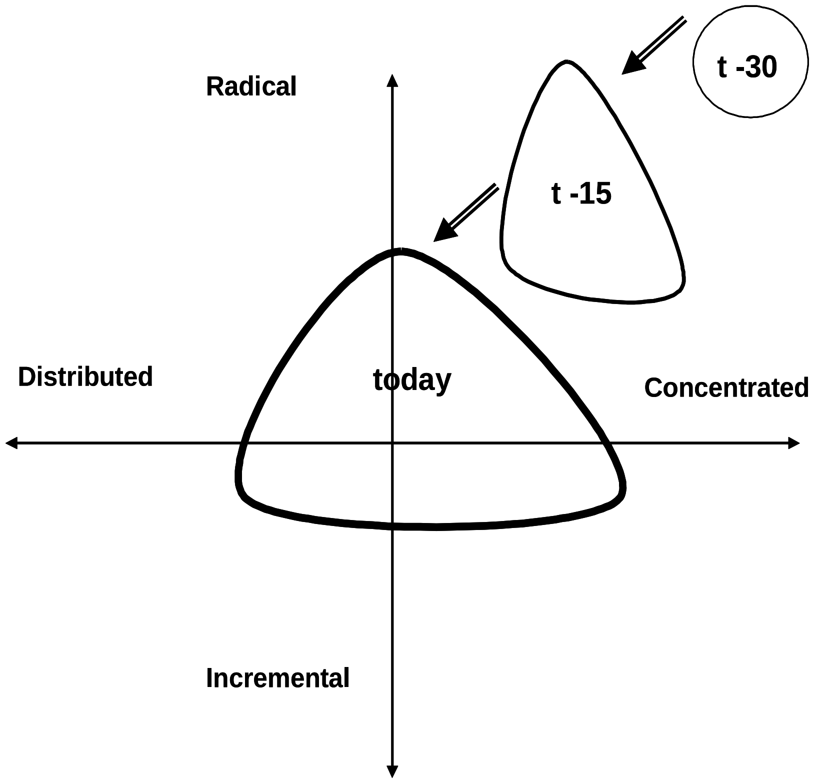
Solar PV learning pathway

•By contrast, Solar PV emerged as a tightly co-ordinated system associated with the US space programme, but has since diversified and become less tightly-co-ordinated.

•PV field now spans relatively incremental systems silicon-based power modules, to more radical thin-film and organic cells



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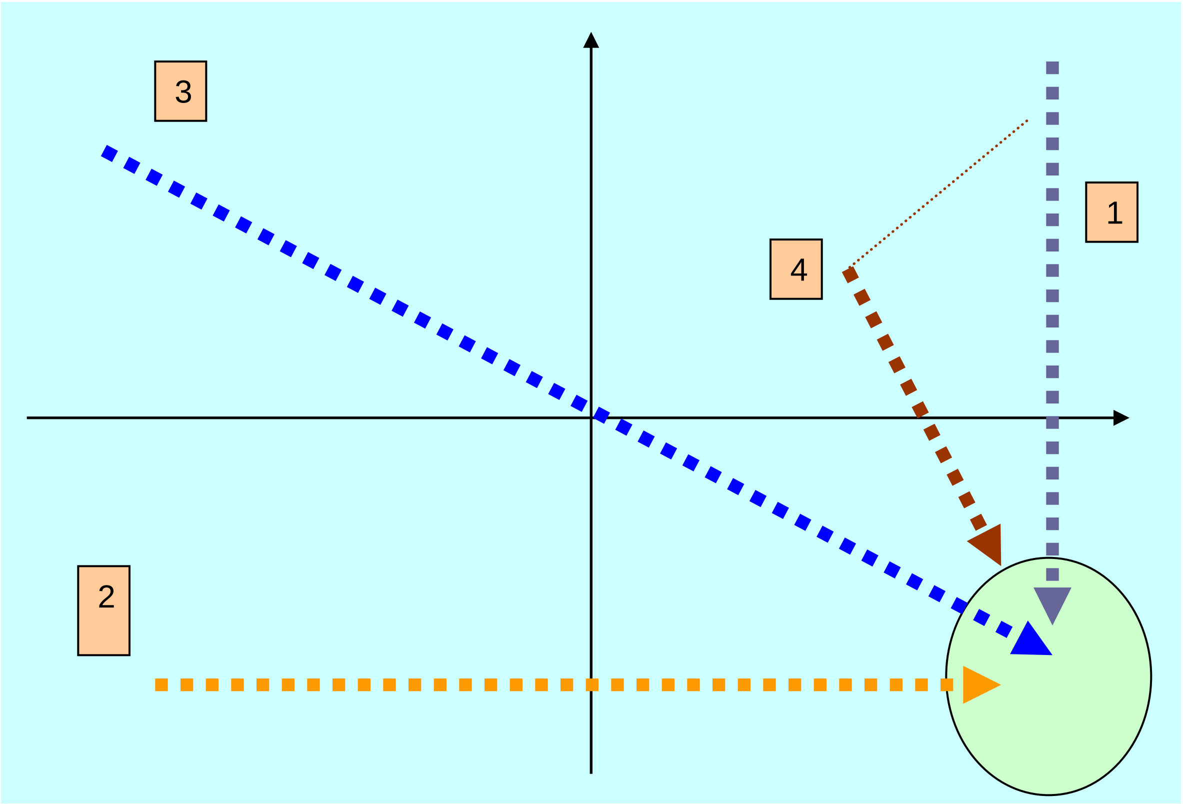
Idealised Learning Pathways

1: Concentrated learning-by-research (e.g. fusion)

2: Distributed learning-by-doing (e.g. wind power)

3: Distributed learning by research followed by concentrated learning-by-doing. (e.g. wave energy)

4: Learning-by-research followed by learning-by-adaptation (e.g. CCGT systems)



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Alternative Learning Pathways : Wave Energy

RED Route

1: SME efforts at testing established concepts

2: Gradual improvement and upscaling under learning-by-doing

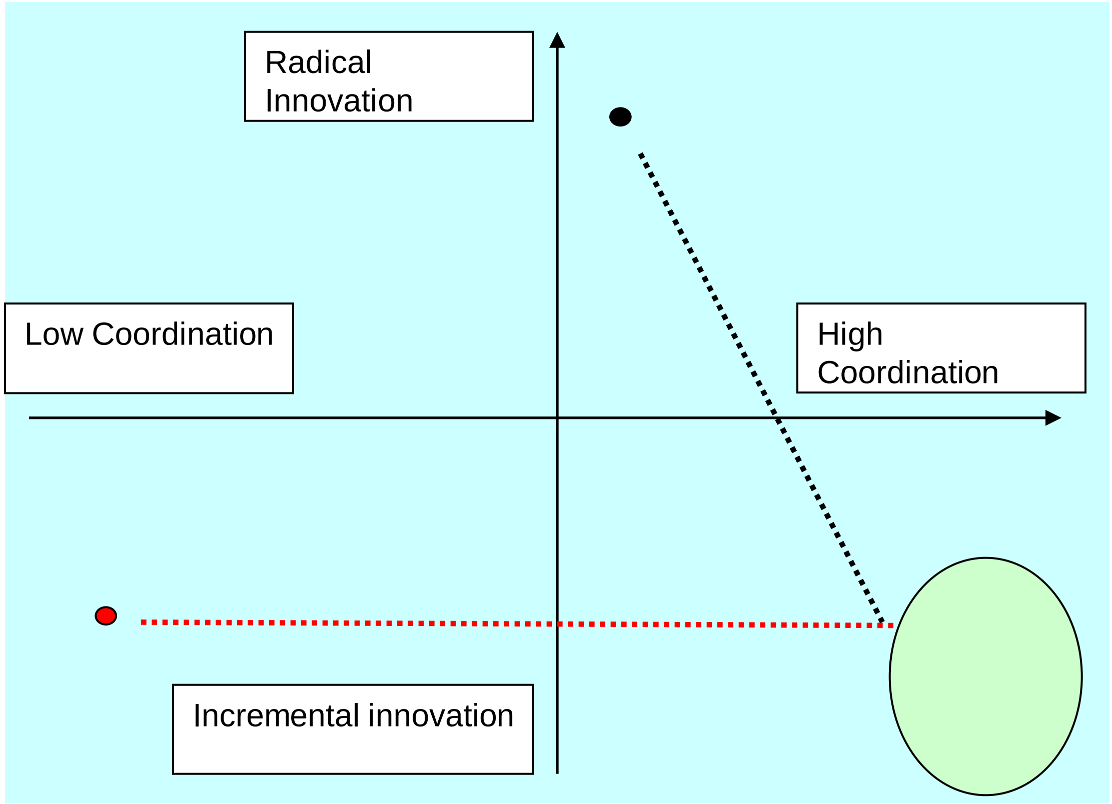
3: Technology maturity, commercial status

BLACK Route

1: Large firms / research projects develop radical concepts.

2: breakthrough and new dominant design

3: Technology maturity, commercial status



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