A Technological Innovation System Analysis of the UK Wave Energy Sector using SNA

Angus Vantoch-Wood, University of Exeter

School of Engineering, Mathematics and Physical Sciences, ☎: +44 (0) 1326 254188, 🖳: av225@exeter.ac.uk, www.eprofile.ex.ac.uk/AngusVantoch-Wood

Introduction:

The field of Technological Innovation Systems analysis has proved a valuable theoretical frame work in helping to understand the means by which technological advancement occurs within different industrial fields. Its strengths lie in its provision of a conceptual and applicable framework in which to assess what is a stochastic process among heterogeneous stakeholders (who often hold differing motivations).

Within all innovation literature, knowledge creation, diffusion and the concept of 'interactive learning' between agents are seen as core processes in enabling innovative activity. It is therefore vital that policy makers can measure and assess these levels in order that policies can be put in place to ensure that the system fulfils its maximum potential.

Current indicators focus upon formal, codified forms of knowledge such as; patent records, publication analysis, firm/university reports and R&D spend. Although these indicators provide valuable insights, they ignore many 'informal' innovative outputs and the actual process of systemic knowledge generation and diffusion is at best assessed through formal collaborations but often simply left as part of the 'black-box' of innovation, leaving analysts to make tacit intuitive assumptions about whether 'enough' interaction is occurring within the system (see centre middle diagram).

This factor, (among others) has resulted in growing articulation of the limitations and drawbacks which current indicators hold in allowing researchers and policy makers to understand some of the outputs of innovation activity which we know to occur, (see top centre box).

My research focuses on exploring the feasibility of directly quantifying the flows of interaction between system actors at the meso-scale of industry activity using the emerging field of social network analysis (SNA). By directly asking stakeholders to quantify their perceived levels of interaction with other actors, a clear network map of system interactions can be constructed and standard SNA tools (see right side panel) can be applied. This methodology is applied to the emerging UK Wave Energy industry in the hope that it can provide both practicable application and useful insight into the industry's emergence.

Additionally, SNA has been used to provide more structural insight into some of the quantitative data that is present, specifically it is applied to patents where I have used it to evaluate historic influences on current state-of-the-art.

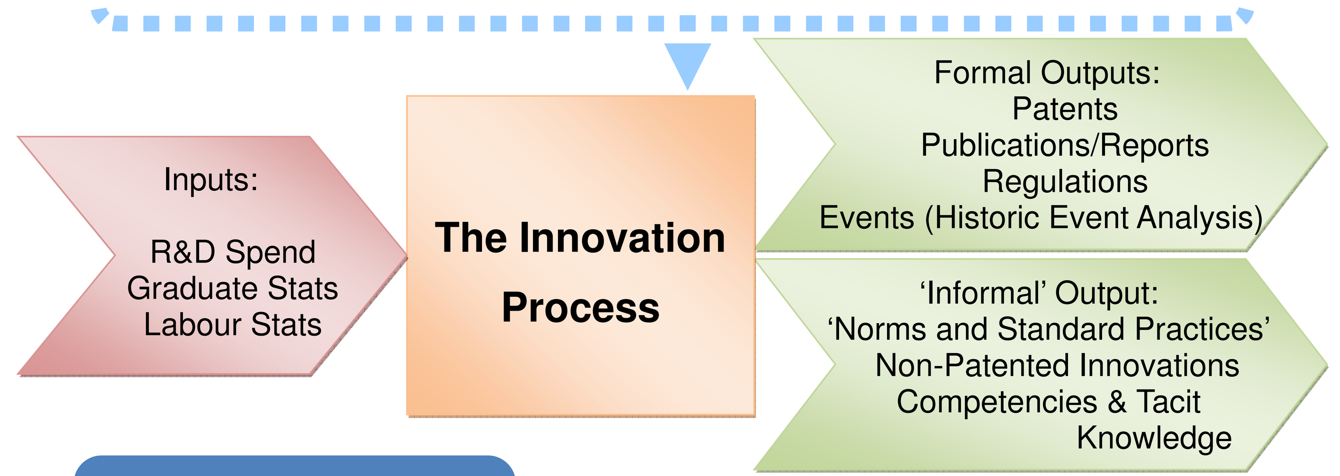
Criticisms of the Innovation Systems approach:

- "Systems of innovation approaches… have traditionally started from empirical case studies that examine factors. Though these serve to illustrate the complexity of these interactions, they have been criticized for failing to provide clear guidance to entrepreneurs and policy makers." (Foxon et al., 2008).
- "The 'systems of Innovation' approach is still associated with conceptual diffuseness" (Edquist, 2005).

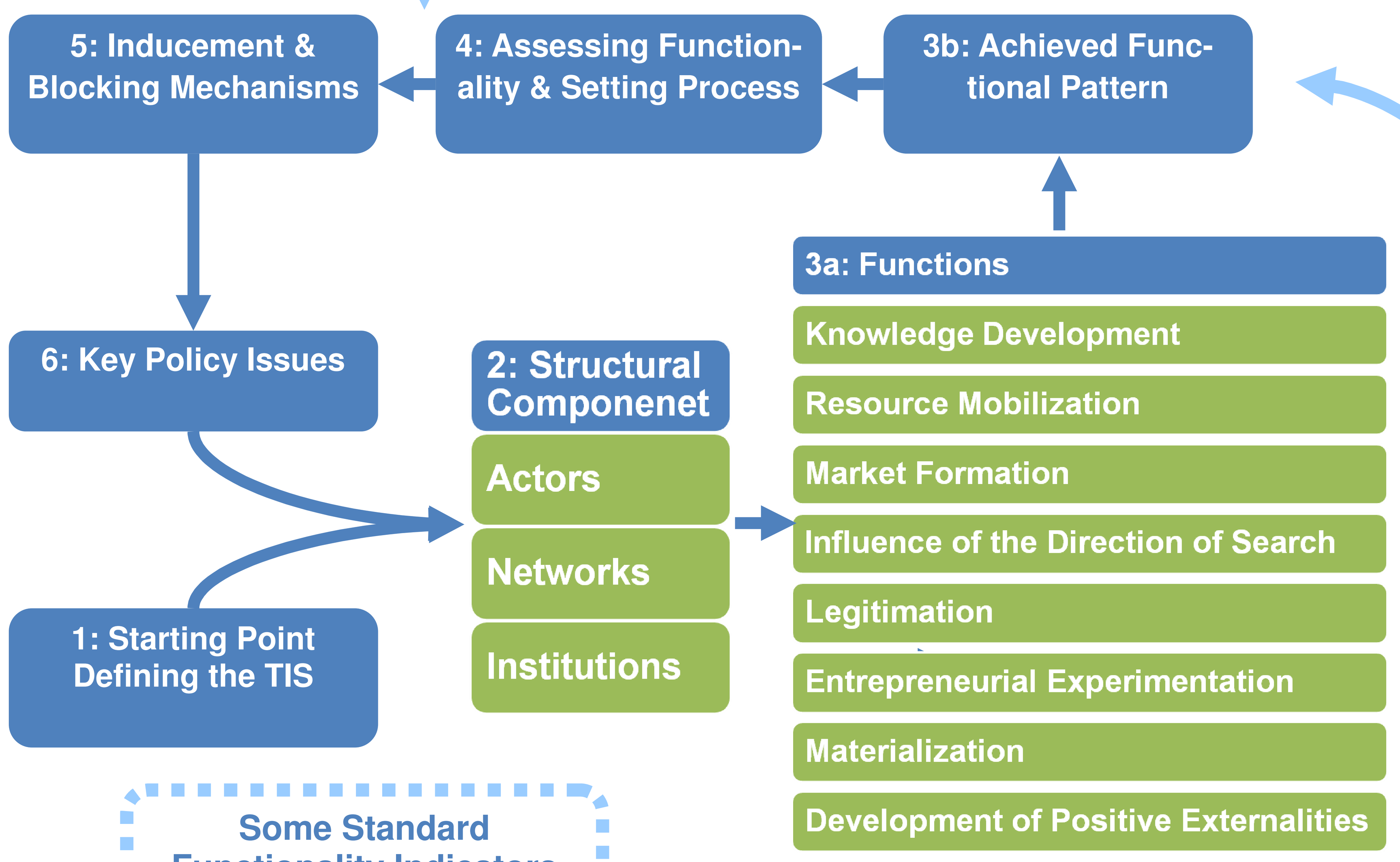
Criticisms of current Indicators for Knowledge Generation and Diffusion:

- "Present R&D statistics are really a measure of the professionalisation of this activity" (Freeman, 2007). They do not include 'informal' innovation
- "The drawbacks of patents as innovation indicators are well-known. Many innovations are not patented, and some are covered by multiple patents; many patents have no technological or economic value, and others have very high value" (OECD, 2005).
- 'Tragedy of the anti-commons' theory suggests that over patenting can in fact lead to a lack of efficiency within the market as fragmented IPR excludes all users from making progress within the sector. (Heller, 1998a, Heller, 1998b, Dosi et al., 2006).
- "The role of knowledge diffusion is much more difficult to map. We have been able to measure the events where knowledge diffusion is likely to take place, such as workshops, conferences and technology platforms. However, the actual knowledge diffusion process could not be measured in this way." "Much knowledge diffusion takes place in dyadic relationships that are not reported in the literature" (Hekkert and Negro, 2009).

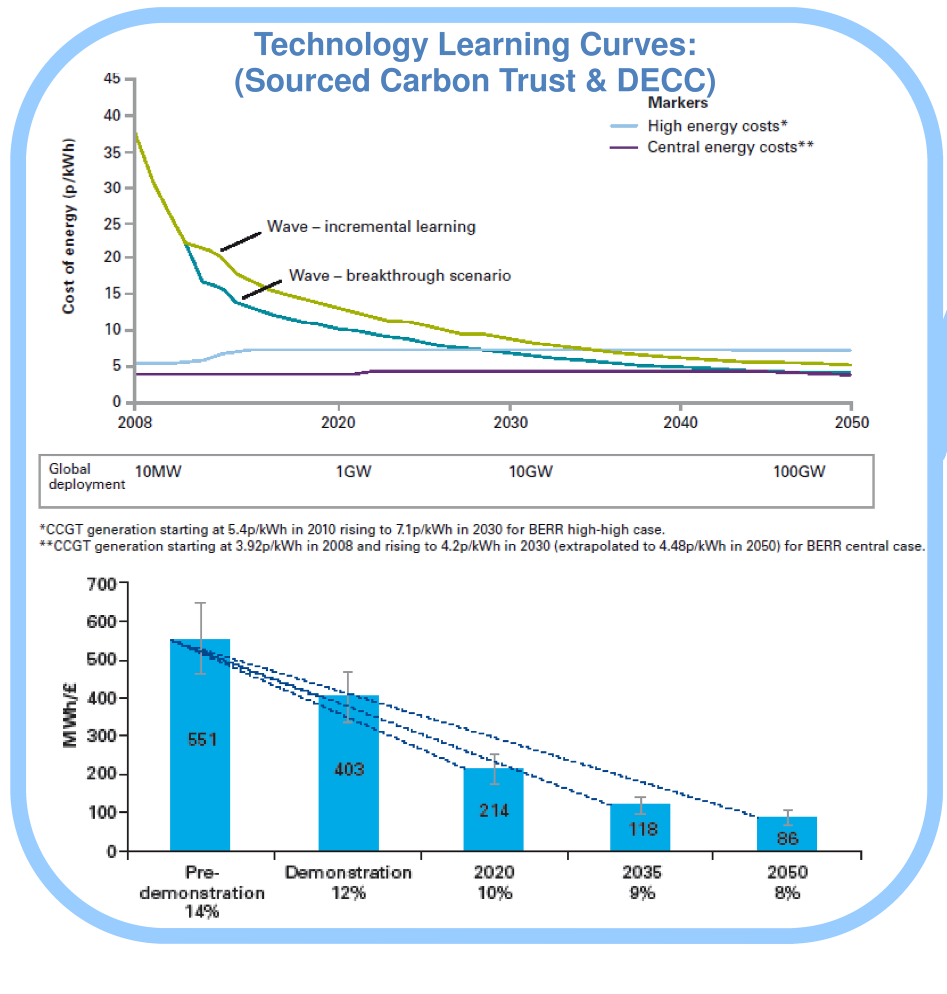
Current Innovation Indicators: Measurable and 'Informal' (Below)

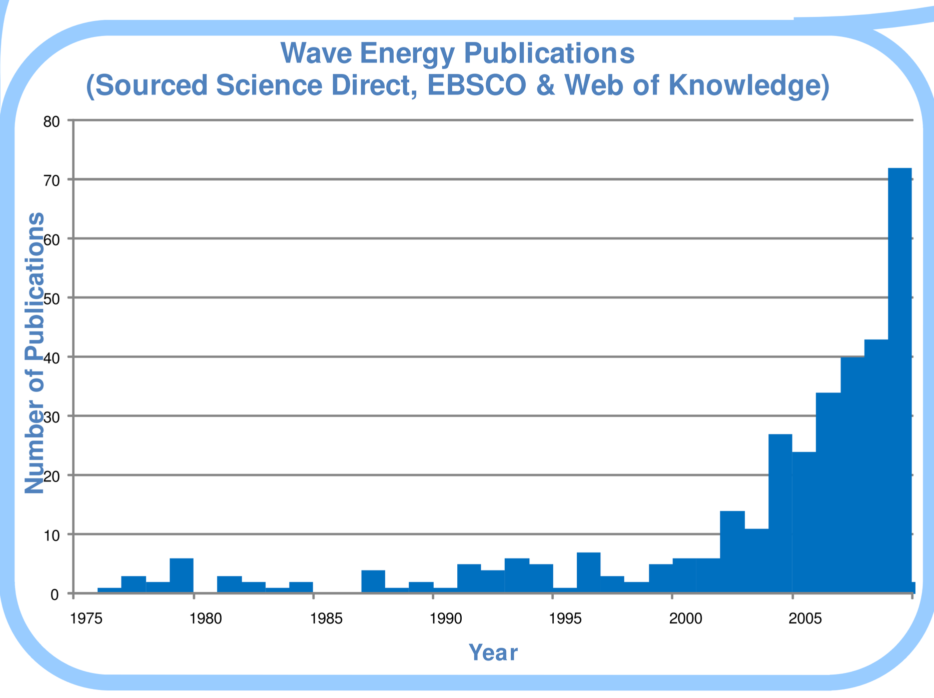


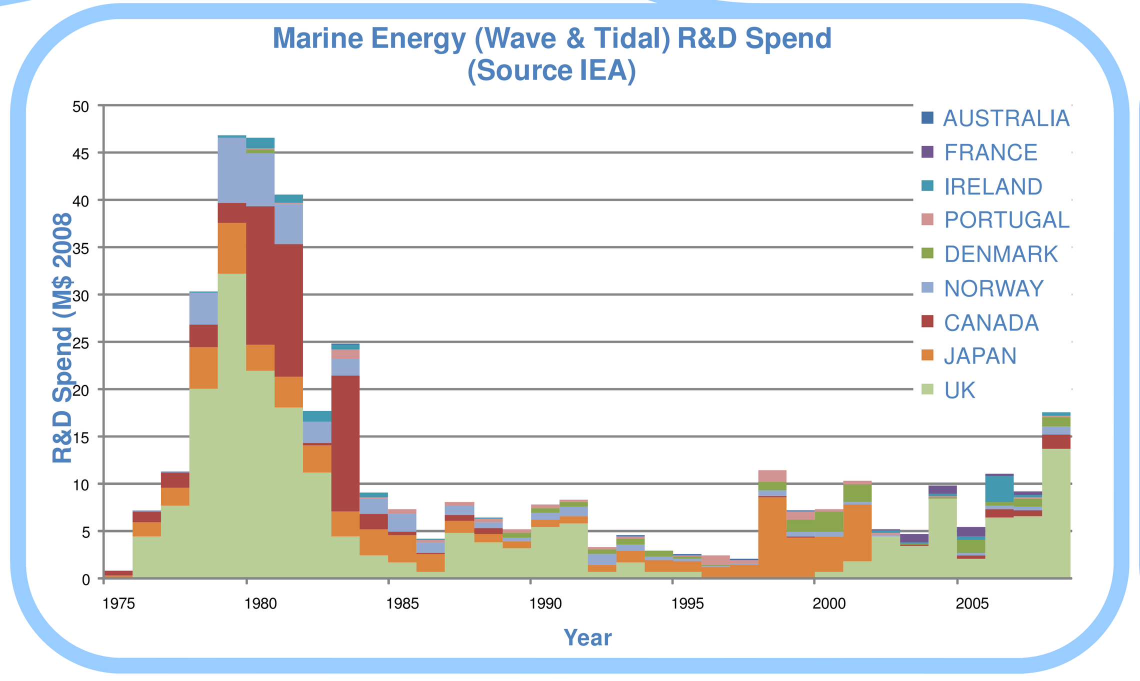
The Technological Innovation Systems Model (Below) Developed by Bergek et al.

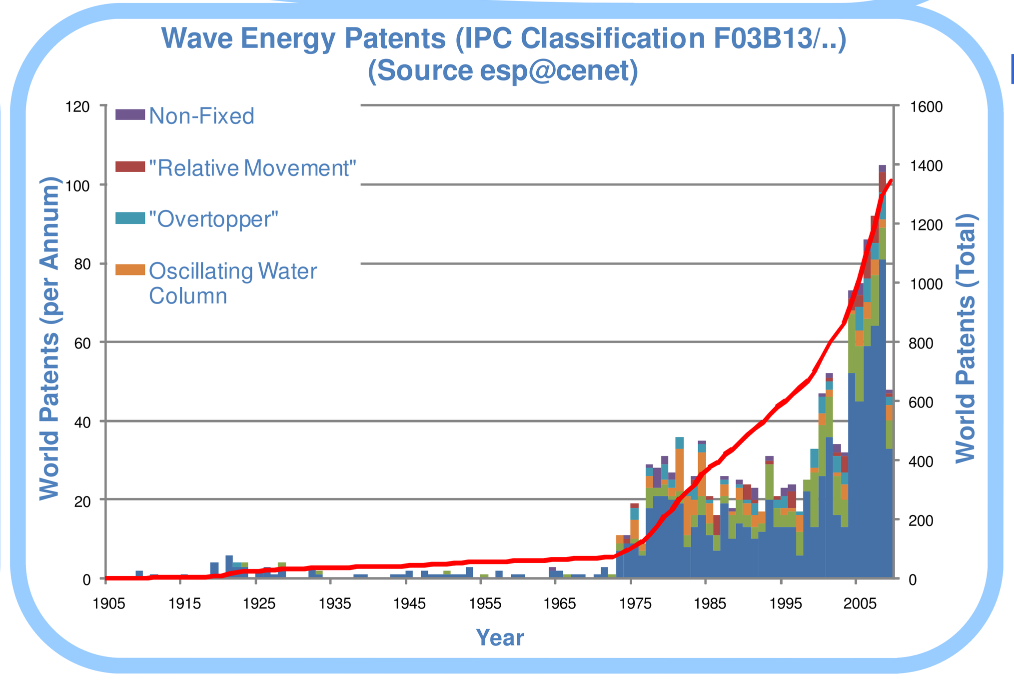


Some Standard Functionality Indicators (Below and left)









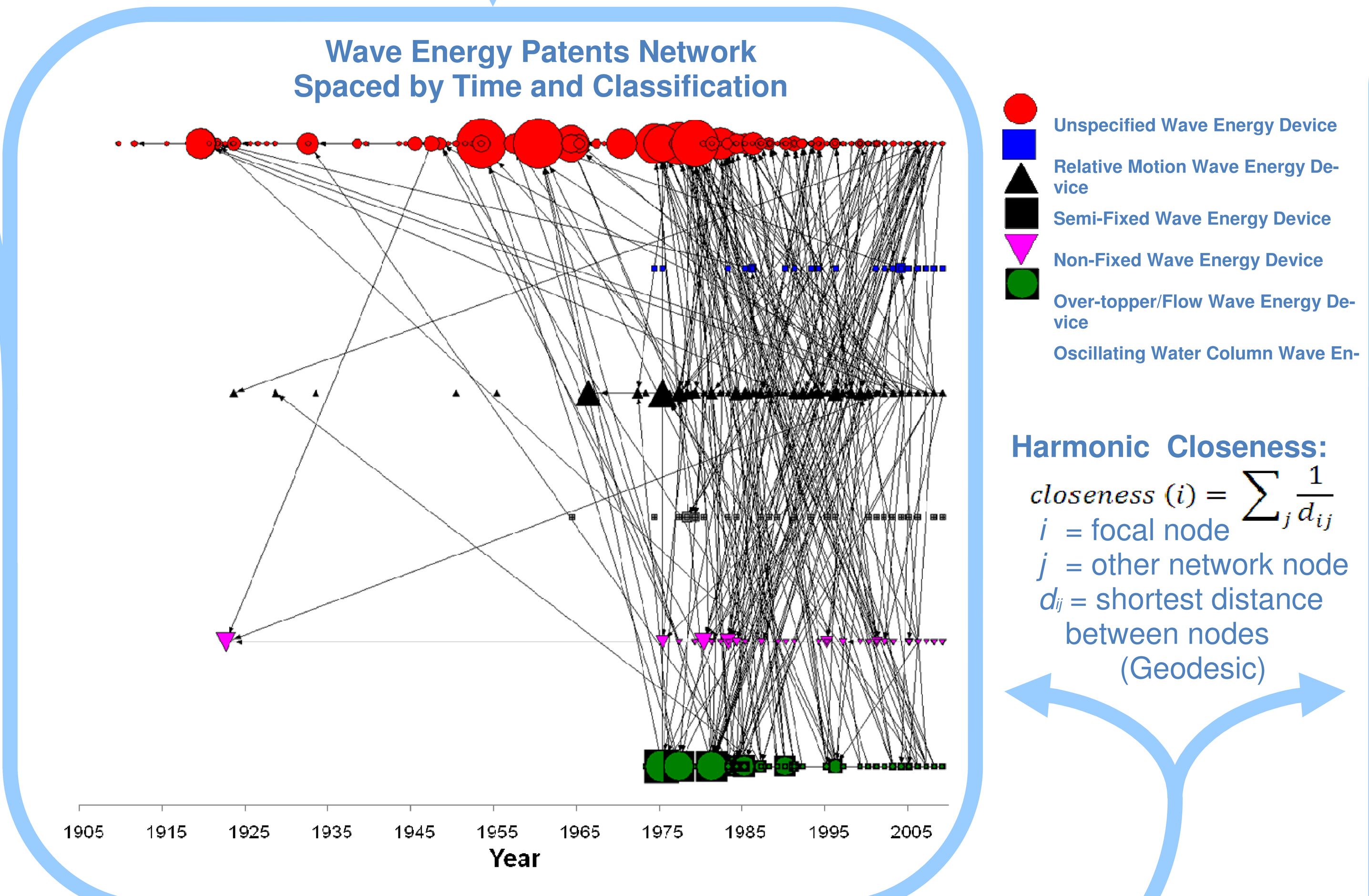
Application of Social Network Analysis:

Using Social Network Analysis to analyse a sector involves clearly defining stakeholders to the system and conducting a complete analysis until a full (saturated) network map of all included actors is completed. Various levels of resolution can be applied, (i.e. binary or numerical strength relations, directed or mutual relationships etc.) Different methods for data gathering can be used (direct interviewing, informant system, desk based search of relationships etc.) and different system boundaries can be used, (i.e. including/excluding technology developers, government bodies, universities etc.) Each holds differing pros and cons which need evaluating prior to commencement. However a balance is usually required between the resources committed to the study, the size of the system and the level of detail required such that 'systemic externalities' are kept to a minimum and a realistically achievable study is conducted.

The graphs below show patent data seen as a network in which the nodes are individual patents and the links, (edges) show which prior patent(s) have been referenced during patent application. Node shape and colour represent the type of patent sub-classification and size of node represents the 'harmonic closeness' of the patent. This is a measure of centrality that the patent has to all other patents in the network and gives an indication of how influential the patent has been. On the left side, positioning has been allocated by time, (x axis) and sub-patent classification (y axis). On the right, it has been done using a multidimensional spacing matric which effectively relates to the 'structural similarity of the patents'.

As can be seen from the two diagrams, there is a stronger cohesion and patenting culture among Oscillating Water Column (OWC) devices which have clearly been more influential, (specifically from the late 70s and early 80s). Over-topping device types however have a more disjointed and sporadic patenting culture. This may be inherent to the technology type itself (a diverse technology set) but could also indicate a poorly connected 'technology community'. Isolated patents (i.e. without reference) have been removed from the right diagram and non-wave energy sector referenced patents have also been removed for visual clarity.

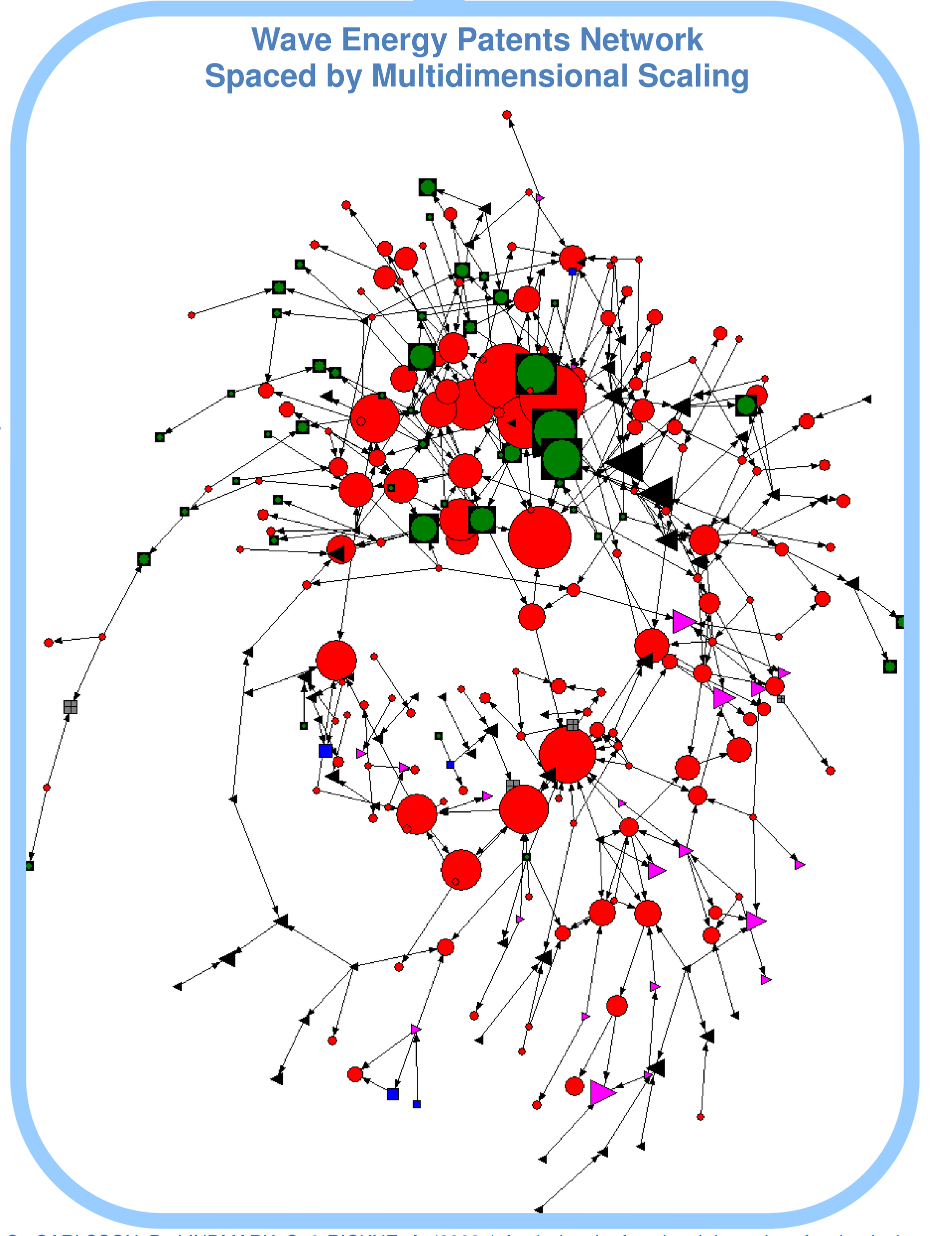
Improved Functionality Indicator? SNA Diagrams (Below & Right)



Harmonic Closeness:

$$closeness\ (i) = \sum_j \frac{1}{d_{ij}}$$

i = focal node
j = other network node
d_{ij} = shortest distance between nodes (Geodesic)



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