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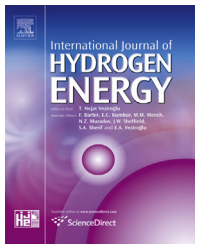

Expert hydrogen perspectives for technological innovation: A Q-method study

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ARTICLE INFO

Article history:
Received 22 May 2014
Received in revised form
25 June 2014
Accepted 26 June 2014
Available online 31 January 2015

Keywords:
Q methodology
Hydrogen
Perspectives
Technological innovation systems
Futures
Participation

ABSTRACT

There are currently a number of fundamental sustainability challenges which impact upon a variety of social, economic and environmental domains. One of these is energy supply where significant uncertainties exist in how best to tackle the multi-dimensional problems being raised in each of these areas. Because of this uncertainty, normative approaches to the development of low-carbon technological innovations will always contested. Q methodology, an established form of discourse analysis, was therefore undertaken in order to explore the competing visions and perspectives of experts working in the radical technological field of hydrogen production from waste. This is the first time that the perspectives of expert stakeholders involved in a technological innovation system (TIS) for hydrogen have been investigated using Q methodology. These contributors revealed limited awareness of each other. From this, we conclude that improvements need to be made to policies aimed at boosting the networks being used by the broad community of hydrogen-from-waste professionals. In particular, efforts should be centred on the skills required to manage the dissemination of communication regarding successful innovation.

Introduction

We are currently faced with a number of fundamental sustainability challenges in a variety of different domains (Stern, 2006). Energy supply is one of these and it raises issues that include the depletion of natural resources, air pollution and greenhouse gases (GHGs). Linked uncertainties relate to both short- and long-term security of supply [1,14] as well as contributions to climate change. The Intergovernmental Panel on Climate Change [10–12] states that, without action to reduce emissions of GHGs, there is a significant probability that global average temperatures will increase by more than 2 °C compared to pre-industrial times. This is considered likely to result in substantial changes in regional climate and damaging consequences for human welfare and ecological systems over the course of this century and beyond.

Hydrogen energy involves radical rather than incremental technological solutions to providing low-carbon energy and has been described as "a long term and highly uncertain option for enabling deep decarbonisation of the energy system" [15]. Research throughout much of the 20th Century has led to

Abbreviations: EPSRC, Engineering and Physical Sciences Research Council; GHG, Green House Gas; H_2, Hydrogen; Q sort, Q methodology surveys; TIS, Technological Innovation System; EfW, Energy from waste.

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http://dx.doi.org/10.1016/j.ijhydene.2014.06.171
0360-3199/

periodic reconsiderations of the role that hydrogen might play in low carbon energy and transport systems of the future [2,3,16] Since the 1990s, more focused efforts to commercialise a number of hydrogen energy technologies have taken place. This has run in parallel with the rise of a heuristic about the nature of entrepreneurial activity: technological innovation systems or TISs [6]. This evolutionary approach from Innovation Studies focuses on knowledge production and diffusion. This model of innovation has a neo-functionalist orientation and draws on the technological expectations literature which is of direct relevance to this research [5,9].

In this study, Q methodology, a form of discourse analysis, was conducted to explore the visions and perspectives of experts working in the technological field of hydrogen production from waste. Experts participating in the analysis were professionals working in hydrogen production, waste management, energy management and energy from waste. Q methodology offer important opportunities to the participants, particularly the act of learning within a participatory situation, including the chance to discuss their own understandings of a subject and consider statements generated by other participants that may or may not fit with their world view. The research reported here seeks to establish how significant the process of reflection is during Q-sorting and whether or not it can help one particular group of technology stakeholders contemplate how their views fit into a potentially larger picture and thus how they might form new relationships with other stakeholders [4] In the case of technological innovation in hydrogen production from waste these social processes may be especially important given that different stakeholders in this emerging sector are likely to have limited awareness of each other.

Method

When applied to improving understanding of contested and controversial issues, Q methodology can be combined with conventional qualitative methods known as R methods, or with traditional survey techniques in order to broaden the population being examined [21]. Q methodology can also be used with other participatory techniques, such as scenario development, that allow for a more critical view of the subjective nature of a particular topic. This can include future environmental and energy concerns as well as suggested scenarios based upon normative changes to society. The Q methodology employed in this study has clearly defined steps which produced a Q methodology survey:

1. **Development of the Q sort** - twelve face-to-face interviews have been conducted with experts working in hydrogen from waste and associated sectors. Statements from these interviews were extracted for use in the Q sort, which is the process of sorting statements in the Q methodology survey.
2. **Identification of the study population** – experts were identified from the fields of hydrogen futures, hydrogen technologies, energy policy, waste management and policy, NGOs and regulators.
3. **Data collection** – twenty-five Q-sort surveys were carried out face-to-face and the results recorded in both hard copy and digitally.
4. **Data analysis** – The results were analysed using PCQ factor analysis software
5. **Production of factor identities** – three expert identities were uncovered: hydrogen from waste advocates, cautionary environmentalists and hydrogen technologists [21].The statements for the Q-sorts were taken from a number of different sources that made up the concourse, which is the discussion and debates surrounding a subject; these included academic and grey literature, seminars and, as noted above, twelve semi-structured interviews which were conducted with experts in the fields of hydrogen futures, waste management, hydrogen technologies and energy management.

Initially over 250 relevant statements were generated from these different concourse sources, providing insights into the many different perspectives surrounding this field. Through an inductive analytical approach the concourse was sorted into five themes covering:

- Energy from waste and waste management
- Energy and innovation policy
- Sustainable energy futures
- Hydrogen technologies
- Risk and public acceptability

With the five themes in place, the 250 total statements were reduced to thirty-five, ensuring that the emerging discourses were captured with the most valuable statements from the themes. In the first stage of selecting the statements, duplicate or weaker statements that could not be easily interpreted or were considered overly complicated were removed. The final list of statements for the Q sort is given in Table 1.

The Q-sorts were carried out between March and May 2012.

Data collection procedure

Participants were contacted by email and telephone and, as noted, the majority of surveys were carried out at their place of work, or at group meetings and conferences.

Participants were asked to sort 35 cards with the statements on with the following guidance:

> "Please complete the survey based on your view of hydrogen production from waste now and into the future with −4 being least like how you think/ feel and +4 being most like how you think or feel."

An additional request was given at the time of the Q-sort to "*Base your sort on what you believe to be most important.*" This request was added because many of the statements would be agreeable to all participants, however, not necessarily of greatest importance depending on their interpretation or knowledge of the statement and the sector they represented. Participants were asked at the time of the survey to provide their personal view and not that of the organisation they