Challenges in the research of public acceptance of energy technologies, infrastructures and applications

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July, 2014

Working document produced in the context of the European Energy Research Alliance (EERA), Sub-programme 1: *Public perception and engagement*

GOBIERNO DE ESPAÑA · MINISTERIO DE ECONOMÍA Y COMPETITIVIDAD · Ciemat Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas

CENTRO DE INVESTIGACIÓN SOCIOTÉCNICA (CISOT)

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Abstract:

In the last three decades, a number of studies have investigated the societal and public reactions towards energy technologies, from nuclear to wind energy, CCS or fracking in multiple contexts (countries, regions, towns). Usually based on survey methodology and case study research, these studies have researched a variety of issues, from the general societal acceptance towards a new technology at the country level to the public attitudes towards a proposed infrastructure in a particular community or the adoption of a new energy application by the end-users.

Although research has significantly contributed to understanding the factors influencing the social acceptance of technologies, there are still a number of definitional issues that need resolution before research can meaningfully contribute to the analysis of social and public acceptance. In order to contribute to this debate, we first review the concept of social acceptance and its role in technology implementation and adoption. Then, we provide a working definition of social acceptance, characterize the three levels at which it is usually considered (general, local and individual), as well as its basic components (public, political and stakeholder). Then, we focus on the concept of public acceptance; provide an operational definition of public acceptance and discuss the ways of measuring it via survey questionnaires. In a third section, we discuss some of the methodological challenges that, in our view, the research in this field faces.

Retos en la investigación sobre aceptación pública de tecnologías, infraestructuras y aplicaciones energéticas

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Resumen:

En las últimas tres décadas, numerosos estudios han investigado las reacciones sociales y públicas hacia las tecnologías energéticas, desde la energía nuclear a la energía eólica, el CCS o el *fracking* en múltiples contextos (países, regiones, ciudades). Por lo general, a partir de encuestas y estudios de caso, estos estudios han investigado una variedad de temas, desde la aceptación social general hacia una nueva tecnología en un país a las actitudes públicas hacia una infraestructura en una comunidad particular o la adopción de una nueva aplicación energética por parte de los usuarios finales.

Aunque la investigación ha contribuido significativamente a la comprensión de los factores que influyen en la aceptación social de las tecnologías, todavía hay una serie de cuestiones de definición que necesitan solución antes de que la investigación pueda contribuir de manera significativa al análisis de la aceptación social y pública. Con el fin de contribuir a este debate, en primer lugar revisamos el concepto de aceptación social y su papel en la implementación y adopción de la tecnología. A continuación, ofrecemos una definición operativa de la aceptación social, caracterizamos los tres niveles en los que, por lo general, se considera (general, local e individual), así como sus componentes básicos (pública, política y de las partes interesadas). A continuación, nos centramos en el concepto de la aceptación pública; proporcionamos una definición operativa y discutimos las formas de medirla a través de cuestionarios. En una tercera sección, se discuten algunos de los problemas metodológicos que, en nuestra opinión, enfrenta la investigación en este ámbito.

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1. Introduction

Social acceptance[1] is a key issue shaping the successful implementation of energy technologies, infrastructures and applications, as well as the achievement of sustainability and energy policy targets. But it is also a relevant issue for research in the social sciences. Energy technologies are not developed in isolation from society, but in a continuous interaction with individuals, collective actors, institutions, practices, regulations, etc. within households, communities and societies (Pool, 1997; Williams and Edge, 1996). This interaction produces observable impacts or processes both in the technology (the "social configuration of technology") and the society ("social impacts") that we need to understand. Among these processes, the reaction, the attitudes and behaviours of the members of society towards the technology is of particular importance.

In the last three decades, a number of studies have investigated the societal and public reactions towards a variety of energy technologies, from nuclear to wind energy, CCS or fracking in multiple contexts (countries, regions, towns). Usually based on survey methodology and case study research, these studies have researched a variety of issues, from the general societal acceptance towards a new technology at the country level to the public attitudes towards a proposed infrastructure in a particular community or the adoption of a new energy application by the end-users.

Although research has significantly contributed to understanding the factors influencing the social acceptance of technologies, there are still a number of conceptual issues that need resolution before research can meaningfully contribute to the analysis of social and public acceptance. Definitions are both the objective of empirical research activity and a requirement for such activity to be effective (Rowe and Frewer, 2005). The more precise our definitions, the better (more reliably, validly) we can conduct research.

We are, of course, not the first researchers to outline the need for a more systematic conceptualization of social and public acceptance. Already in 1987, the Technical Change Centre (TCC, 2013) in a book entitled *Public Acceptance of New Technologies. An International Review* pointed to the "significant definitional problems attached to each of the concepts "public", "acceptance" and "new technologies" and provided

[1] We understand acceptance as one of the various dimensions of the attitude or reaction. Acceptance would refer to the positive response or reaction towards a proposed technology. We understand that the construct under study is the "reaction" or "attitude", instead of acceptance. In this sense, acceptance, independently of misuse of the term by stakeholders (see Batel, Devine-Wright and Tangeland, 2013 for a broader discussion on this) is just one of the potential dimensions to be analyzed in the interaction between individuals, communities and societies and technologies.

working definitions of these concepts. More recently, various authors have recognized the need for more systematic research on public acceptance, driven by coherent theoretical frameworks, explicit definitions of concepts and the use of innovative methodological tools (Assefa and Frostell, 2007; Dowd et al., 2011; Devine-Wright, 2008; Wüestenhagen et al., 2007; Stern, 2014; Moula et al. 2013).

Attitudinal and behavioural dimensions in the interaction between a society or a community and an energy technology

Attitudinal	Behavioural
Acceptance	***Private sphere behaviours***
Support	Decision to vote against or in favour
Evaluation as good vs bad	Search? for information
Interest	Decision to pass legislation
Favourability	Buying
	Adoption (installation)
	Construction
Other attitudinal related factors	***Public sphere behaviours***
	Activism_ , write a letter to express support/opposition; Sign a petition)
Risk perception	Media coverage
Trust	
Beliefs about benefits	***Behaviours within organizations***
Emotions	Investment
	Lobbying

Why is researching social acceptance challenging?

Researching public attitudes towards energy technologies is subject to various limitations. Some of these limitations are common to other fields of attitudinal and behavioural research. But some others are specific of this field of research, and are related to the specificity of the interactions between individuals and technologies, infrastructures or applications.

A first challenge is, in our view, **the conceptualization of social and public acceptance of technologies.** As indicated, for example, by Wolsink for the study of the public acceptance of wind energy, "attitudes towards wind power are

fundamentally different from attitudes towards wind farms, and this distinction is at the heart of most public attitude misunderstanding" (Wolsink, 2007: 1191). The same applies to other technologies. Social acceptance, public acceptance, community acceptance and the acceptance by home-owners are used as interchangeable concepts, when they refer to different processes. We will further develop this idea in the report. **A second definitional issue is related to the need to differentiate between social and public acceptance of technologies.** While social acceptance, in our view, should refers to the reaction by the set of collective and individual actors (decision makers, experts, organizations, media, opinion leaders, lay people) within a society, public acceptance should specifically refer to the position or reaction of the lay public (also named citizens, individuals, lay public, general public or population).

Beyond definitional issues, there are also a number of methodological challenges when researching public acceptance of energy technologies. Some of these challenges are specific of this research area, but some other are common in other filed of behavioural and social research (e.g. when researching the social acceptance of alcohol consumption, abortion, etc.). In particular, we will cover the **nine** of the most relevant methodological challenges such as the definition of the unit of analysis; the problem of pseudo-opinions; population vs case oriented research.

About this report

The objective of this report is to develop a coherent analytical framework for studying the social and public acceptance of energy technologies that:

- Proposes a **definition** of social and public acceptance
- Identifies the **levels** at which social and public acceptance can be studied – depending on the **object** of acceptance: general-energy, local-infrastructure and individual-application level
- Establishes three different **components** of social acceptance at each level – depending on the **subject** of the acceptance (public, political and stakeholder acceptance).

In order to produce this report, we reviewed a number of studies dealing with the social and public acceptance of energy technologies. We conducted searches in Google Scholar combining the keywords "social acceptance", "public acceptance", "public attitudes" "energy technologies" and a number of specific energy technologies. We did not aim at providing a comprehensive review of studies on social acceptance of technologies (this is not a systematic review). A key aspect of our methodology was the consideration of a number of comparative cases. In particular,

we examined studies on a number of energy technologies (we selected seven energy technologies) at the three different levels:

- Wind power
- Carbon capture and sequestration (CCS)
- Biomass
- Nuclear fission and fusion
- Tidal
- Hydrogen
- Solar energy

We also reviewed conceptual articles dealing with the concepts of social acceptance, public attitudes and public acceptance as well as reviewed articles on specific technologies (see **Appendix Table 1**)

The report begins by defining and characterizing social acceptance, its levels and its components. The bulk of the article then focuses on defining public acceptance and discussing how it can be measured. Finally, the report discusses some of the key methodological challenges facing psico-social research on public acceptance.

2. Social acceptance

We can define the social acceptance of an energy technology as "the favourable or positive reaction towards the implementation or adoption of a proposed technology by the members (individuals and collective actors) of a given society (country or region, community or town and household)".

Acceptance is considered here a particular dimension or an evaluative category of the societal attitude or reaction towards a specific technology. Acceptance implies that something (the attitude object; an energy technology, infrastructure or application, in our context) is proposed. In that sense, acceptance may have a passive connotation.

As we will further discuss in the section on public acceptance, acceptance is only a particular dimension under a broader research object, the ***attitude, position or reaction*** towards energy technologies[2]. In this sense, the attitude or reaction may be composed of linked but different dimensions such acceptance, support, the evaluative category *good* vs *bad*, level of *interest*, willingness to behave in favour, admiration, repulsion, etc.

We can establish three general **ideas** about social acceptance of technology:

I. Social acceptance is a critical factor for the **adoption** and introduction of new technologies; but it is a differentiated process from technology implementation.
II. The social acceptance of a technology can be analysed at **three levels** (general or country level, community or town level and household or organization level), depending on the **object** of the acceptance (an energy technology, an energy infrastructure or installation and an energy application)
III. Social acceptance includes various **differentiated components** – depending on the **subject** of the acceptance:
    i. Public acceptance (lay citizens, end-users)
    ii. Stakeholder acceptance (including not-for-profit organizations and profit organizations)
    iii. Political acceptance (national and local governments, political parties)

[2] We understand Batel and Devine-Wright (2013) concerns that "if we keep focusing on this term (social acceptance)—either purposefully or not—we are not only perpetuating the normative top-down perspective on people's relations with energy infrastructures, but we are also potentially ignoring all the other types of responses to those, such as support, or uncertainty, resistance, apathy, among others". We consider that in analytical terms and independently from spurious utilizations, the term acceptance simply defines one of the potential dimensions or categories of the "attitude" or "reaction" towards technologies.

2.1. Social acceptance as a critical factor in technology implementation or adoption

Social acceptance is sometimes equated to technology implementation or adoption. However, in our analytical framework, social acceptance and technology implementation are different but related processes. According to the model of technological adoption developed by Rogers (2010), social or individual acceptance is produced in the third stage of the adoption process, once individuals, stakeholders and decision makers have been exposed to the technology. The knowledge of the technology by the members of a society or community is the first step in the adoption process. The confirmation, the stage when the individuals, stakeholders and decision makers finalize their decision to continue using the technology, is the last step of the process.

So, the knowledge of a technology, its acceptance and its confirmation are different processes in the technology implementation. **Technology adoption** and confirmation (see the figure below based on Rogers, 1964) are the processes by which a technology is actually implemented/developed/ installed/bought/ in a society (community or household), while **acceptance** is a previous process related to the conscious decision by individuals and collective actors of accepting or rejecting the technology. A priori, in order for a particular technology to be implemented in a country, in a city or in a household, it has to be first accepted by the members of this country, city or household. The inverse direction is also possible.

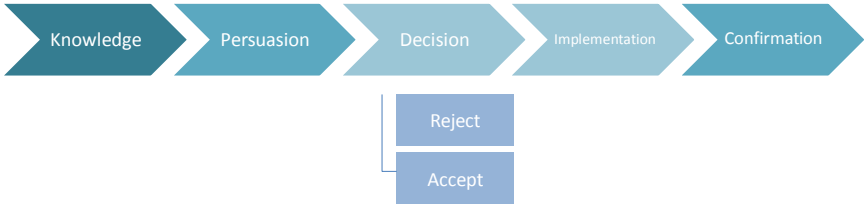

Figure 1. *Stages in the decision innovation process*

Indeed, social acceptance is not the only critical factor in technology implementation. There are other elements outside the control of the members of a society that can

hinder the adoption of a technology. For example, the technology might not be ready, it may be unknown to the majority of the members of society or its costs might be too high. In general terms, other critical factors in technology implementation and adoption are:

- Scientific and technological feasibility
- Energy and economic feasibility
- Regulatory feasibility
- Other non-technological issues (organizational, communication factors),

2.2. Three levels of analysis of social acceptance

The term social acceptance is often used without a clear conceptualization to refer to different levels of analysis. We can read, for example, that Germany rejects nuclear energy, or that a local community is opposed to a particular energy infrastructure or that homeowners are deciding to install small-scale wind energy applications. All these processes refer to the social acceptance of specific technologies. But they refer to different levels of social acceptance as well as to different components of social acceptance. In our view, distinguishing between the three levels of analysis is the first main definitional issue.

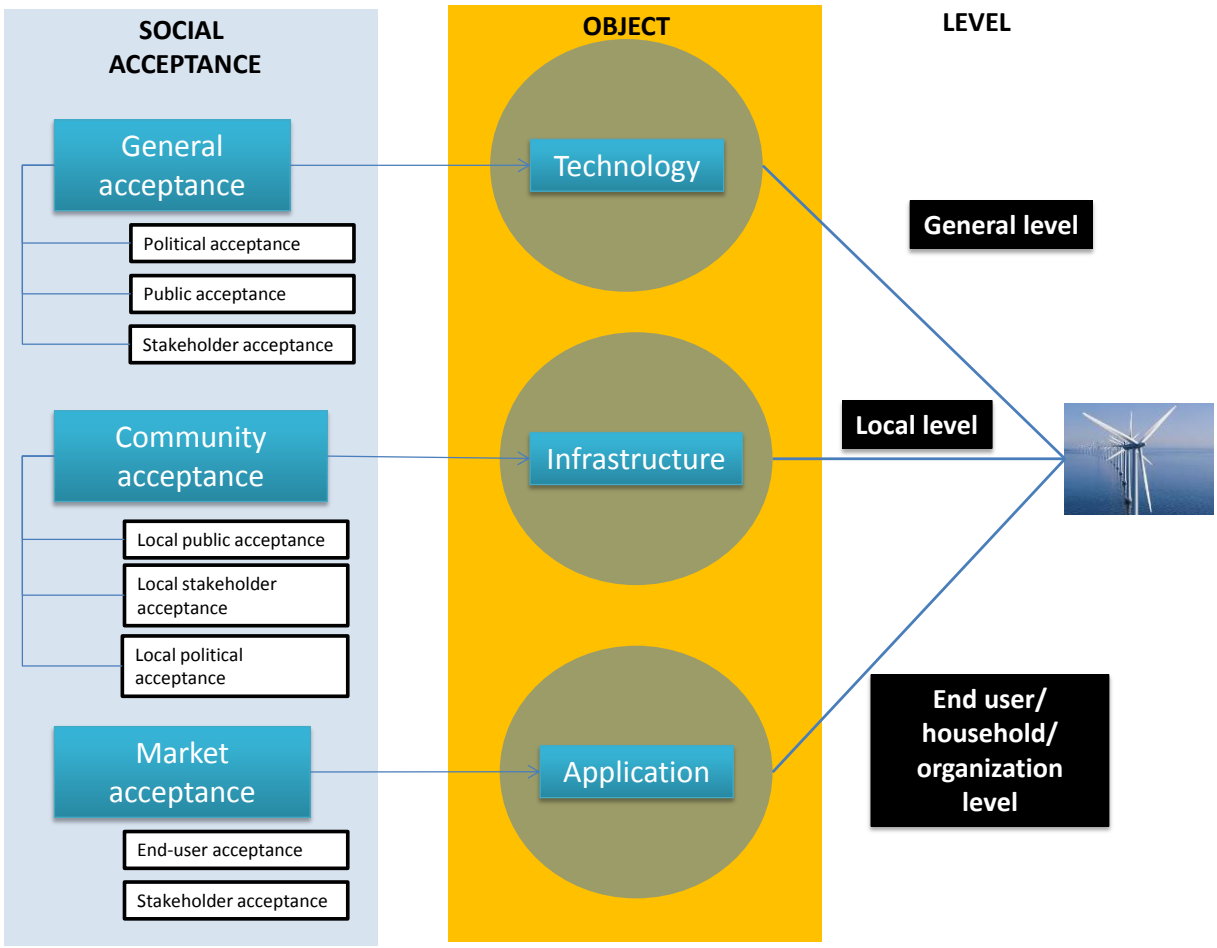

Figure 2. *Three levels of social acceptance*

Previous efforts to conceptualize social and public acceptance and attitudes towards technologies have been carried out by researchers such as Devine-Wright (2008), Wüstenhagen et al. (2007) or Wolsink (2007), Stern (2014). Although none of these authors have provided a unique classification of the levels of social acceptance, they all refer to three **levels of analysis of social acceptance:**

1. The ***general social acceptance*** of an **energy technology** or energy option (e.g. Wind, nuclear, solar, carbon) at the **general or country** level. In this level, we try to understand the reaction of societies (including the general public, policy makers, civil society organizations, experts, private organizations, etc. within a country or region) towards a particular energy technology. The technology is considered in this level as a whole. For example, a particular country may or may not promote (invest, support, etc.) a specific energy technology. Individuals and representatives in this country may perceive that the technology may, or may not, chime in with preferred ways of life; that is or is not an acceptable investment; that

is or is not good for the environment, that is or is not good for the economy or the national security, that it is worth to research, etc.

There have been a number of studies on the public acceptance and on stakeholder acceptance of energy technologies at the general or country level. But very few studies have integrated all the components of social acceptance at the general level.

2. The ***community acceptance*** of an **energy infrastructure** or facility at the **local or town** level. In this level, we try to understand the reaction of communities (composed by local decision makers, local stakeholders and local citizens) towards a proposed (usually by politicians or private companies) energy infrastructure. In this level, the research question is related to the reaction of a community (a city, a small town, etc.) towards a specific energy infrastructure. For example, we can investigate the reaction of a community towards a wind park, a proposed CO2 site, etc. The issue here is that a community (including the individuals and the stakeholders that shape it) interact with a physical infrastructure or project.

Upham and Shacley (2006), for example, studied the social acceptance of a proposed 21.5MWe biomass gasifier in Winkleigh, Devon, Uk by interviewing members of the public and stakeholders.

3. The ***market acceptance*** of an **energy application** at the **individual** (end user/household/organization**)** level. In this level we try to investigate the reaction by the end-users and the various stakeholders towards a particular energy application (e.g. residential solar technologies, biomass, etc.). The object of social acceptance is here a specific energy application that can be installed at home, that can be bought by end-users. People in a particular household or organization may find the energy application useful or beneficial and be willing to install it. They might also reject the application for a number of reasons. But also technicians, government officials and other stakeholders in the market might have a reaction towards the application.

Mallet (2007), for example, studied the social acceptance (by technicians, industry representatives, local government officials, community representatives/end users) of solar water heaters in Mexico City.

2.3. Components of social acceptance

Social acceptance is defined in this report as multicomponent phenomenon. Social acceptance may refer to the reaction of any actor in a society, from the lay public to the groups of the civil society (community groups, non-governmental organizations (NGOs), labour unions, indigenous groups, charitable organizations, faith-based organizations, professional associations, and foundations), companies and industry associations, politicians, the academia, etc. We will generally refer to three types of acceptance that conform social acceptance: public acceptance, political acceptance and stakeholder acceptance.

COMPONENTS OF GENERAL ACCEPTANCE

Social acceptance at the ***societal or country level*** is a function of:

- Acceptance by the decision makers (**political acceptance**)
- Acceptance by the stakeholders, including market and nonmarket (**stakeholder acceptance**).
- Acceptance by the general population (**public acceptance**)

COMPONENTS OF COMMUNITY ACCEPTANCE

Social acceptance at the ***community or town level*** is a function of:

- Acceptance by the local decision makers (**local political acceptance**)
- Acceptance by the key local stakeholders, including market and nonmarket (**local stakeholder acceptance**)
- Acceptance by the local population (**local public acceptance**)

COMPONENTS OF MARKET ACCEPTANCE

Social acceptance at the ***end-user/household/organization level*** is a function of the acceptance of the members of the household or the organization.

- Acceptance by end users (**end-user acceptance**)
- Acceptance by other stakeholders (technicians, industry representatives, politicians) (**stakeholder acceptance**)

3. Public acceptance

3.1. Conceptualizing public acceptance

The public acceptance of energy technologies has been the object of a number of studies from the 1970s. In one of the first published works on public acceptance of energy technologies, Otway, Maurer and Thomas (1978), studied public attitudes towards nuclear energy and observed a lack of a clear definition of attitude towards energy infrastructures.

A potential definition of public acceptance of a technology is the following: "Favourable or positive attitude or behavioural response towards the implementation or adoption of a proposed technology held by the lay public of a given society (country or region or town)". Three main ideas ground this definition:

1. Acceptance is one of the evaluative dimensions conforming the attitude, response or reaction that individuals within societies and communities might have towards a specific technology. Acceptance is different from support (Batel et al., 2013), being the first a more passive component of the attitude, but also from admiration, appreciation, tolerance, repulsion, etc.
2. The term "public" refers to the members of the lay public, citizens or the general population, to differentiate them from the policy makers, experts, representatives of companies, organizations, interest groups, etc.
3. Public acceptance is not static and may change over time. Public acceptance may fluctuate over time and change from rejection to acceptance or vice versa (see e.g. Wolsink, 2007).

Public acceptance can be studied at the three levels of **social acceptance**. In the general level, public acceptance refers to the acceptance of a specific **energy technology** by the general population (the citizens of a country or region). Jan Zoellner, Petra Schweizer-Ries and Christin Wemheuer (2008), for instance, assessed public acceptance of renewable energies in Germany. In the local level, public acceptance refers to the acceptance of a proposed or existent **infrastructure** by the local population of a city or town. Devine-Wright (2011), for example, investigated the local public acceptance of a tidal energy project. In the household level, public acceptance refers to the acceptance by home-owners or end-users of a **particular energy application**. Chelsea Schelly (2014), for example, investigated the adoption of residential solar electric technology by home-owners.

Table 1. *Indicators of public attitudes (obtrusive and unobtrusive measures) towards energy technologies*

Level of analysis	Attitudinal (beliefs, emotions)	Behavioural intention	Behavioural response
Technology-General	Attitudinal acceptance Support Perception that it is a good idea Level of interest Perceived usefulness Level of support	Intention to vote for a party which wanted to change the decision	Public sphere behaviours Vote
Infrastructure-Local	Attitudinal acceptance Support Perception that it is a good idea Level of interest Perceived usefulness Level of support	Intention to vote in a possible future local referendum about the infrastructure	Activism Wrote a letter to express support/opposition Sign a petition
Application-End-user/ household/ organization	Attitudinal acceptance Perception that it is a good idea High interest level Perceived usefulness	Intention to install the application Searching for information Intention to use	Buying the application (individual adoption) Engaging with the application

3.2. Measuring public acceptance

Usually, public acceptance is measured by means of survey questionnaires (obtrusive measures). Researchers have developed a variety of scales to measure acceptance. Individuals are asked to report their level of acceptance to a particular technology, infrastructure or application. But as argued by Batel and Devine-Wright (2013: 3) "the lack of consensus on how acceptance is measured and the often non-correspondence between the measures used and the concept defining them, may be problematic to advance the debate and understanding about the social dimension of

low carbon energy technologies, since studies can arguably be measuring different things". Let's review some of the questionnaire-based measures of public acceptance.

Sjoberg (2008), for example, studied the local public acceptance of a nuclear repository. "Acceptance of the facility" was measured through six questionnaire items (see the following table), including one measuring the intention to vote for or against the facility. As indicated by the author: "Voting is a way of expressing acceptance of a facility. A number of related items measuring acceptance were also included in the design of the present study".

Items measuring public acceptance at the local level (Sjoberg, 2008)

(five-category scales from " Agree absolutely " to " Absolutely disagree ")

1. A nuclear waste repository in my municipality would be totally unacceptable.
2. A nuclear waste repository in my municipality would certainly make me move somewhere else, if I had a chance to do so.
3. A nuclear waste repository in my municipality would make me vote for a party which wanted to change the decision.
4. It would be irresponsible not to take the chance to site a nuclear waste repository in our municipality.
5. I cannot under any circumstances accept a nuclear waste repository in our municipality.

In addition, the respondents were asked to indicate, on a five-category scale, how they would vote in a possible future local referendum about a repository: pro or con

Devine-Wright, in a study of the local public acceptance of a tidal energy project, measured acceptance of the project using four items drawing on Walker, Devine-Wright, Hunter, High, and Evans (2010), (e.g. 'I support the SeaGen tidal energy project'). The response format ranged from 1 to 5, with 5 meaning 'strongly agree', 3 being 'neutral', and 1 indicating 'strongly disagree'. It also included a number of behavioural responses as an indirect measure of acceptance.

Items measuring behavioural acceptance. (Devine-Wright. 2011)

(Yes, no)

1. Attended a meeting
2. Attended a public exhibition

3. Signed a petition in favour of the project
4. Signed a petition against the project
5. Wrote a letter to a politician to express support
6. Wrote a letter to a politician to express opposition
7. Wrote a letter to a newspaper to express support
8. Wrote a letter to a newspaper to express opposition

Jan Zoellner, Petra Schweizer-Ries and Christin Wemheuer (2008) assessed public acceptance of renewable energies in Germany. They developed one "acceptance scale" measuring as dependent variable the self-reported acceptance of the individual.

Items measuring public acceptance at the general level **(Zoellner et al., 2008)**

(Likert scale)

1. I approve wind turbines in general.
2. All things considered, I am an opponent to wind turbines.

More recently, for instance, Soland et al. (2013) measured public acceptance of biogas plants in Switzerland by the following three items.

Items measuring local and general public acceptance **(Soland et al., 2013)**

(6-point Likert scale)

1. I'm happy with the fact that there is a biogas plant in my neighbourhood.
2. I'm against a biogas plant being operated in my neighbourhood.
3. How do you rate the biogas plant in your neighbourhood?

Aas et al. (2014), measured general and local public acceptance towards high-voltage power lines in Norway, Sweden and the United Kingdom. The developed the following two item scale:

Items measuring local and general public acceptance (Aas et al., 2014)

(5-point Likert scale)

1. In general, I accept overhead powerlines – mean (S.E.)
2. To what extent would you accept the construction of a new high-voltage power line near your community

Visschers et al., 2012 analyzed the public acceptance of nuclear power among a representative sample of the population in Switzerland. Acceptance was measured by three items.

Items measuring general public acceptance **(Visschers et al., 2013)**

(5-point Likert scale)

1. Switzerland needs a lot of electricity; people should therefore accept nuclear power stations.
2. According to me, we can renounce nuclear power stations without any problems.
3. We need nuclear power stations because renewable energy sources alone do not produce sufficient electricity.

Kim et al., 2014, from an international survey developed by the IAEA, measured public acceptance of nuclear power in 14 countries. Acceptance was measured as a categorical variable.

Item measuring general public acceptance **(Visschers et al., 2013)**

(One option possible)

a) "Nuclear power is relatively safe and an important source of electricity, and interested countries should build new nuclear power plants" (acceptance)
b) "Countries with nuclear power plants should use the ones they already have but no one should build new ones" (reluctant acceptance)
c) "Nuclear power is dangerous and we should close down all operating nuclear power plants in the world as soon as possible" (opposition)

It is very clear from the examples that, for various reasons, there is not a unique measure of acceptance of technologies. Items such as: "In general, I accept…", or "I approve…", or "A __ in my municipality would be totally unacceptable" are clearly

measuring the core of the acceptance construct (at least in terms of face validity). But other items in the studies reviewed seem also a valid as a measure of acceptance and related attitudes. If we compare to other psychological and sociological constructs such as, for example, neuroticism, organizational climate or subjective social status, this lack of a universal measure may surprise. However, this lack of agreement on a unique measurement is normal in other fields of applied attitudinal research.

3.3. A proposal to measure public acceptance to energy technologies and infrastructures

Should a public acceptance of technologies scale be developed? In our view, the development of a general technology acceptance scale would have a positive impact on future research. We think it would be useful to develop a broader attitudinal model of "public acceptance of energy technology model", or a "public attitudes to energy technologies model", similar to the Health Belief Model (see e.g. Rosenstock, 1990), and including several dependent and independent variables and the items for the measurement of these variables. This model should include causal paths among a number of variables such as: perceived benefits, perceived risks, affect, trust and knowledge. Such a model would provide a coherent analytical framework to understand the internal attitudinal structure of public acceptance.

As a preliminary attempt, we propose a "public acceptance of energy technologies model" based on previous research in the fields of public attitudes towards energy technologies, public acceptance and risk perception (Siegrist and Cvetkovich, 2000; Visschers et al., 2011; Sjöberg, 2008; Wiedman et al., 2009; Poortinga and Pidgeon, 2006). The model outlines the main attitudinal variables that characterize the public attitudes towards energy technologies. We consider acceptance and related dimensions (e.g. support, tolerance) as the main variable in the model. We consider acceptance as associated to prior emotions (affective component) and beliefs (cognitive component) and to behavioural intentions.

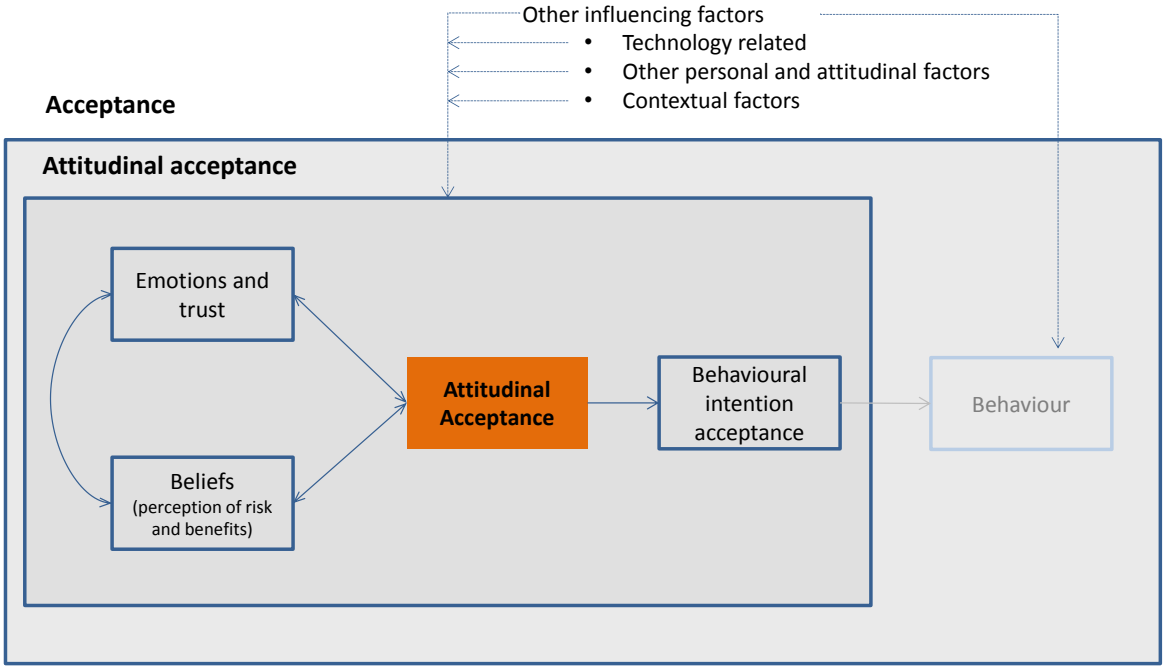

Figure 3. *Heuristic model of acceptance*

A potential questionnaire to measure public acceptance according to the proposed model should include items regarding the following dimensions: Perceived benefits, risk perception, emotions, trust, acceptance, behavioural acceptance, other personal and attitudinal factors (See the following table). The questionnaire is only aimed at measuring the attitudinal factors included in the model. The other contextual (media awareness, social networks, actions by social groups), attitudinal (epistemic trust, risk sensitivity, etc.) and personal factors (familiarity, prior knowledge, awareness, personality, sociodemographics) influencing public acceptance, and potentially collected by means of survey questionnaire, have not been included in the instrument at this stage, given the diversity of variables that could be included.

Table 2. *Dimensions to be included in a future instrument under the framework of the "public acceptance of technologies" model*

Dimension	Definition
Perceived benefits	Beliefs about the benefits from the technology/ infrastructure/ application
Risk perception	Beliefs about the risks from the technology/ infrastructure/ application
Emotions	Assessment of a number of emotional reactions (anger, fear, worry, satisfaction)
Trust	Trust in the organizations promoting/regulating the technology
Acceptance	Degree of acceptance of a proposed technology/ infrastructure/ application. Attitudinal and behavioural intentions
Other personal and attitudinal	It might include measures of knowledge, interest, familiarity, etc.

4. Methodological challenges in the analysis of public acceptance

Beyond definitional and measurement issues, there are a number of methodological and analytical challenges in the study of the social and the public acceptance of energy technologies. In this section, we review some of these challenges and propose some practical recommendations. The research challenges we address are the following:

1. ***Recognizing the variety of research methods***
2. ***Clarifying the unit of analysis***
3. ***Population oriented and case oriented research***
4. ***The problem of pseudo opinions***
5. ***Understanding the factors influencing public acceptance at the various levels***
6. ***Multilevel modelling***
7. ***Capturing attitudes and behaviours in the real world***
8. ***Longitudinal analysis***
9. ***Interdisciplinary research***

The challenges identified do not represent an exhaustive list of the areas where research social and behavioural research should progress, but a list of issues that in the view of the authors of this reports should be addressed in future research.

4.1. Recognizing the variety of research methods

Empirical studies of public attitudes towards energy technologies are usually associated with survey research methodology. However, research on public attitudes towards energy technologies relies on a variety of research designs and methods.

	Design	Method	Example
General	Experimental	▪ Survey questionnaire ▪ Online questionnaire	▪ (L'Orange Seigo et al., 2011 (CCS)
	Quasi-experimental	▪ Questionnaire	▪ Showers and Shringley, 1995 (nuclear energy)
	Observational-correlational	▪ Survey ▪ Survey with specific questionnaires (eg. ICQ)	▪ De Best-Waldhober, 2009 (CCS)
	Qualitative	▪ Focus groups	▪ Horlick-Jones et al.,2012 (nuclear

			fusion)
Local	Experimental	▪ Survey questionnaire	▪ Terwell et al., 2014 (CCS)
	Quasi-experimental	▪ Survey questionnaire	▪ Terwell and Daamen, 2011 (CCS)
	Observational-correlational	▪ Survey with specific questionnaires (e.g. ICQ	▪ Devine-Wright, (2011)
	Qualitative	▪ Case study ▪ Qualitative field study (interviews, focus groups)	▪ Feenstra et al., 2010 (CCS) ▪ Upham and Shackley, 2006 (Biomass) ▪ Venables et al. 2009 (nuclear)
End user/ household/ organization	Experimental	▪ Questionnaire	▪ Sulyma et al., 2008 (residential energy use)
	Quasi-experimental		Not found
	Observational-correlational	▪ Survey research	▪ Domestic solar power system
	Qualitative	▪ Qualitative field study with interviews	▪ Schelly, 2014 (residential solar)

A first challenge emerge from the need to reconcile the range of research methods available for studying public acceptance as well as to explore potential combinations among them (mixed methods). All research methods have limitations and rigorous research that combines complementary methods will be superior to research that relies on any single method (Gray et al. 2007).

4.2. *Clarifying the unit of analysis*

At the general level, studies of public acceptance, often labelled as public 'perceptions' or 'attitudes' studies, typically carry out questionnaire surveys where the unit of analysis is the individual as a member of a country. However, the unit of analysis can be also the country or the region, if the data from individuals is aggregated. Let's imagine, for example, that we are interested in understanding the variation in the levels of public support to an energy technology in the various EU

states. Although the registry of the data is produced at the individual level, the unit of analysis is, here, the state-level and not the individual.

	Unit of analysis
Society level	• Country/region • Individual as a citizen of a country
Local level	• Town • Individual as a citizen of a city/town
Household/organization	• Household/ Organization • Individual as an end-user

At the local level, the situation concerning the unit of analysis is very similar. The main unit of analysis of survey research is the individual, but the town can become the unit of analysis in an study where we are comparing levels of support to energy technology across towns or in case-oriented research (although the concept of unit of analysis does not apply to qualitative research) where we are interested in a particular community. Finally, when we are dealing with the individual as an adopter of an energy technology, the unit of analysis can be the individual or the household.

Quantitative research should favour analysis at the individual level, given the limitations of analysis with ecological data (Robinson, 2009). However, this issue should be taken into account.

4.3. Population oriented and case oriented research

Social researchers conceptualize in contrasting ways when they pursue explanation in particular cases (case-oriented research) versus large populations (population-oriented research) (Mahoney, 2008). When researchers study large populations of cases (individuals, communities or countries), they seek to identify causal effects in overall populations carrying out statistical analysis that apply to populations as a wholes (e.g. what is the association between voting to party A and rejecting nuclear among citizens?). By contrast, practitioners of case studies design often provide detailed descriptions of the state of affairs and the processes through which developments took shape. Case-oriented researchers seek to identify the causal mechanisms involved in particular outcomes in specific cases (e.g. why a wind

infrastructure generated a local protest in a rural community?), so they need to be sensitive to time, place, agency and process (Ragin 1987; Allardt, 1990).

Population-oriented research is often based on survey research where individuals are the unit of analysis. Individuals vary in their level of acceptance of a technology, and this variation can be attributed to a number of factors (as discussed above). For instance, a population-oriented research based may find that individuals living closer to an energy infrastructure are more supportive than those living far away; that individuals that are offered a specific economic compensation are more reluctant to accept the technology, etc. Population-oriented research could be also carried out with communities or countries as the unit of analysis. For instance, one could investigate the influence of population density on the aggregated level of public acceptance in 50 communities.

Case study research can be defined as "a research strategy which focuses on understanding the dynamics present within single settings" (Eisenhardt, 1989). It often involves the in depth investigation, by means of various research tools, of a case or a limited number of cases. Case study research is of a qualitative nature but can be based on a combination of qualitative (observation and interviews) and quantitative data (e.g. questionnaires). The main feature of case study research is the orientation to pursue explanations in particular cases versus large populations (population-oriented research). It allows for a holistic study of a phenomenon. For instance, a qualitative case study could be implemented to investigate the dynamics of a local protest around a specific fracking project in order to provide a deeper description of the phenomenon, to explore potential causal factors, or in order to understand the causal mechanism in a previously proven (with quantitative research) causal effect. It is hard to make generalizations on the basis of detailed case study (Sartori, 1994: 45), but this research is critical for providing in-depth descriptions, generating hypotheses and improving our understanding of causal mechanisms

Between population-oriented research and case-oriented research, some authors advocate for the use of a variety of small-N cross-case methods for analysing necessity and sufficiency. This is the case of the qualitative comparative analysis in which whole cases are compared as configurations of parts. This method of analysis allows the researchers to preserve the complexity of the case studies and generality of population research design (Ragin, 1987). Using Mill's methods of agreement and differences, typological theories, counter-factual analysis, Boolean algebra, and fuzzy-set analysis we could improve the understanding of the dynamics of public attitudes

towards energy technologies and, especially, energy installations might also be useful in the analysis of public acceptance of energy technologies studies.

In our view, social research on the public acceptance of energy technologies would benefit from combining case-oriented and population-oriented research. In general, studies have separately achieved relevant results to improve the understanding of public acceptance and its determinants, drawing the strengths of each approach but also the limitations. Some researchers tend to favour population-oriented research (with the individual as a unit of analysis) while other researchers tend to favour case-oriented research. But research on social and public acceptance would benefit from a wider integration of both types of research. Both perspectives are needed and complementary.

4.4. The problem of pseudo opinions

A key issue when assessing public acceptance of emerging energy technologies is the fact that, often, they are not well known yet, which produces the so-called problem of "pseudo opinions" and "non attitudes" (de Best-Waldhober et al. 2009; L'Orange et al. 2011). This problem is particularly clear in the case of some public perception surveys that measure no more than "pseudo opinions". For instance, it is common that despite the fact that survey participants know little about some energy technology (like CCS, Hydrogen or nuclear fusion), they express an opinion. Consequently, their views tend to be unstable and very responsive to contextual change (de Best-Waldhober et al. 2009; Fleishman et al. 2010; Malone et al. 2010).

An essential methodological challenge in research on public acceptance of energy technologies is, hence, to avoid assessing merely pseudo opinions. At present, there are at least three strategies in the academic literature that should be worked on in future research: i) using Information-Choice Questionnaire (ICQ) (de Best-Waldhober et al. 2009) or similar questionnaires (Oltra et al. 2012) where participants are provided with neutral information about the technology; ii) the use of focus groups (or reconvened focus groups) with stimulus materials (Fleishman et al., 2010; Horlick-Jones et al., 2012); and iii) the analysis of automatic mental associations and implicit attitudes (Galdi et al., 2008), aimed at capturing instinctive reactions to attitudinal objects.

4.5. Understanding the factors influencing public acceptance at the various levels

Understanding how various determinants influence the public acceptance of technology at the various levels is a key challenge in explanatory research in this area. Research on public acceptance has tried to identify and estimate the effect of various influencing factors, from psychological to socio-demographic or contextual. There are many causal models available in the literature. A general classification, taking into account previous classifications (Prades and Oltra, 2009; Devine-Wright, 2008), can be the following:

- Technology-related factors: Any attribute of the technology, the infrastructure or the application under consideration that affect its acceptability.
- Personal and attitudinal factors. This includes socio-demographics and personal capabilities, as well as attitudinal factors (beliefs, emotions and norms directly or indirectly related to acceptance such as prior attitudes, perceived risks, perceived benefits, trust and affect. These factors might vary depending on the level and object of analysis (e.g. the factors involved in consumer behaviour (see, e.g. Jackson, 2005) might not apply to public attitudes towards a proposed infrastructure).
- Contextual. This include a broad range of issues related to the societal context in which public acceptance is developed, from mass media reporting to family and peer-group pressure and engagement issues.

Technology-related	***Personal and attitudinal***		***Contextual***
Visual impact Stage of development Catastrophic potential	Knowledge Age Sex Social Class Educational level Personality	Prior attitudes Perceived risks Perceived benefits Trust Affect Position towards the government Familiarity	Type of promoter Cultural and media messages Media framing Socio-political context Planning (level of participation) Justice and fairness issues Compensation/ ownership Policy frameworks Campaigns by action groups Type of landscape in which the technology is sited

Technology-related factors are relevant in the three levels of acceptance. For instance, those technologies posing a hazard for public or environmental health are less likely to be accepted by the public. Energy applications that are cheaper are more likely to be installed by home-owners. But ultimately, is how these factors are perceived by the public and the stakeholders what is relevant for acceptance. In this context, psycho-social influencing factors may include the various "outrage" factors (Covello and Sandman, 2001), prior attitudes (Poortinga et al. 2006), risk perception and benefit perception (Visschers et al., 2011), emotions (Sjöberg, 2007). When we are interested in the study of social acceptance of a site, we should consider additional personal and psychosocial factors such as the potential significance of affective aspects of people-place ("place attachment", Brown, and Perkins, 1992) or the perceptions of fairness and level of trust, etc. (Zoellner, Ittner and Schweizer-Ries (2005), as well as a number of contextual factors. Some of these factors have an institutional root (ownership structures; the distribution of benefits; the use of participatory approaches) while others are related to the characteristics of the community (regional and local context; spatial proximity) or the socio-political context.

The determinants of public acceptance, considering the multiple technological, psycho-social and contextual factors, are rarely considered as a whole in social research studies (Devine-Wright, 2008; Mulan et al. 2013; Stern 2014). Some interesting studies have, for instance, the interactions among these factors by comparing, in the same study, public acceptance levels in various communities facing various technologies (Rogers, 1998; Zoellner et al., 2008; Soland et al., 2013). In our view, only by explicitly embracing potential multifactorial interactions among the various influencing factors can researchers understand the inherent complexity of public acceptance.

4.6. Multilevel modelling

The analysis of public acceptance of emerging energy technologies may require the ability to study a phenomenon that is multilevel in nature. Multilevel studies begin from hierarchical models in which individual behaviour influences, and is influenced by, proximal and distal contextual factors (Van de Vijer et al. 2008). People (level 1) may live in specific and formally defined households (level 2) which may be found within communities (level 3) which may in turn be located within specific states, regions, or nations (levels 4-k of the hierarchy).

Since the pioneering studies of Robinson (1950) scientists working on the interface of individual and culture have a long-standing interest in conceptual issues of multilevel models. However, the statistical treatment of the data has always been problematic. Classical regressions models could not combine individual and structural level predictors and dependent variables. In fact, no statistical tools were available to link structural factors to individual outcomes in a statistically adequate manner. However, in the last few decades, statistical techniques have been developed in two directions. First, they are now ready to test the identity of the structure shown by an instrument at different levels of aggregation (Hox, 2002; Muthén, 1991, 1994). Second, recent statistical advances have made it possible to address the identity of relationships across different cultural contexts (Hox, 2002; Raudenbusch and Bryk, 2002). Thus, it can be established whether or not the difference produced at individual level in an attitude or behaviour is the same in all cultures, and the influence of factors on the relationship can be evaluated (Van de Vijer, 2008). This advance is particularly important since it is known that country-specific features may challenge the equivalence of a relationship between variables produced at individual level (Esping-Andersen and Przeworski, 2001).

The large majority of the studies of public acceptance of energy technologies have taken a quantitative approach and used questionnaire-based surveys. But we have not found any research project that has attempted systematically to contrast multilevel hypothesis in the study of the public acceptance of energy technologies. In some studies there is the implicit assumption that the relationships found at one level can be applied to the other level. But in the case of public acceptance the meaning of variables can shift between the levels, so this assumption is usually not correct.

The use of existing databases to perform a multilevel analysis of public acceptance of emerging energy technologies presents several difficulties, as there are substantial differences among the quantitative studies in terms of questionnaire design, in how the samples are selected and their size. As a consequence, cross comparisons are not straightforward with the existing databases. An option would be to design specific multilevel studies that collect data (by using the same questionnaire) from a number of locations and countries (an interesting example of this, for example, is the study by Soland et al., 2013 in which data was collected from the local residents in 19 of the 72 agricultural biogas plants in Switzerland). Multilevel modelling of emerging energy technologies attitudes remains a major methodological challenge.

4.7. Capturing attitudes and behaviours in the real world

One of the most significant roles that individuals play regarding energy technologies is the role as consumers of energy products and services. The potential for household actions to reduce energy consumption and carbon dioxide emissions is significant, and it is estimated that individuals, changing their behaviour, could reduce household emissions by 20% (Dietz et al. 2009). Some of these changes are related to the acceptance of energy technologies and their applications and its relationships with everyday life at home. But a comprehensive understanding of the dynamics of public acceptance in households remains elusive.

When properly designed, quantitative research based on surveys has the ability to provide a basic description of the attitudes of the population under study. However quantitative approaches have some disadvantages. First, they are unable to deal with the socio-cultural and familiar contexts in which values, beliefs, perceptions and behaviours related to emerging energy technologies are rooted. Much of the social science research on household energy use has ignored the fact that the decisions on individuals as energy consumers are produced in the context of everyday life. Therefore the acceptance and adoption of emerging technologies at the household level is mediated by social relations, habits and routines and everyday life experiences.

Survey research has a second disadvantage for capturing attitudes and behaviour in the real world. That is, the necessity to have prestructured questions leads to presenting respondents with issues that have already been "framed", not giving people the chance to frame the issues from their owe perspective (Ricci et al. 2008).

Future research on public acceptance at the household and organization level should develop innovative methodologies that complement current survey questionnaire research, and which are able to capture how individuals experience and engage with energy technologies in the context of everyday life (Horlick-Jones and Prades, 2014)

.***Longitudinal analysis***

Because attitudes may be dynamic, social researchers need to examine how attitudes are developing when people come into contact with technology. For instance, some researchers have suggested a U-shaped development of attitudes to wind power, in the sense that they usually range from very positive (when people are not confronted by the infrastructure in their neighbourhood), to much critical (when a project is announced), to positive again (under certain conditions and some reasonable time after construction) (Wolsink, 2007; Gipe, 1995; Devine-Wright, 2005; Pasqualetti,

2002). So, an important challenge in researching public attitudes arises due to this dynamic nature of public attitudes. For instance, we may obtain substantial differences in our estimation of the levels of public acceptance depending on the period of time when the data are collected.

A second problem related to the dynamic nature of public attitudes arises from the fact that public acceptance and the various influencing factors (independent variables) may interact in complex ways throughout time. For instance, it is possible to argue that the type engagement mechanisms implemented or the actions of the stakeholder could influence public acceptance of an infrastructure project. But it is also conceivable that an increase in public acceptance could lead to an improvement of engagement mechanisms.

Most studies serve as sources of cross-sectional data that prevent an accurate estimation of the timing between these components. Thus one of the main methodological challenges in the study of public acceptance of energy technologies is to ensure the absence of endogeneity in the explanations. Ideally, in the processes of drawing causal inferences, social researchers must ensure compliance with the assumption of "conditional independence". In other words, the values attributed to explanatory variables must be independent of dependent variables. Observance of this principle is often defined as the absence of endogeneity.

Endogeneity problems due to reverse causation affect several areas of psico-social research. Despite growing interest in the detection and correction of such problems in the social sciences (Hamilton and Nickerson, 2003), studies that have attempted to show the links between public acceptance of technology innovations and many determinants are not immune to this problem (Vancea and Boso, 2014). Since 1974, econometric techniques to control for endogeneity have greatly increased and developed (Heckman, 1974; Lee, 1978). Although these processes may help clarify the causal sequence of a problem as described above, the data provided by surveys of a cross-sectional nature remain poorly suited to overcoming this obstacle. In order to assess the factors affecting social acceptance of energy technologies, longitudinal data would improve our understanding of the causal links between the temporality of events.

4.8. Interdisciplinary research

Since the 1970s, there have been numerous studies of energy attitudes and behaviours from a wide range of disciplinary perspectives (reviewed by Lutzenhiser, 1993, Marechal, 2008 and Wilson and Dowlatabadi, 2007). These perspectives include

microeconomics and behavioural economics (e.g. rational choice models, pricing, market structure, bounded rationality, framing effects, decision heuristics); technology adoption models (e.g. diffusion theories, cognitive dissonance, theory of planned behaviour, self-efficacy, social communication); social and environmental psychology (e.g. the influences of information, pro-environmental attitudes, value-belief-norm characteristics, habits and external conditions); and sociological and anthropological research (e.g. organisational behaviour, embeddedness, environmental sociology, socio-technical systems and the energy decision-maker's cultural and social context, etc.) .

As suggested by various authors, researchers from social sciences have tended for the most part to frame their studies from their particular perspective (Wilson and Dowlatabadi, 2007), rather than engaging in an interdisciplinary, problem-oriented effort to develop an integrative understanding of public acceptance of energy technologies (Stern, 2014). No single analytical approach provides a framework for analysing more than a small portion of attitudes and behaviour, or for providing reliably successful policy interventions (Biggart and Lutzenhiser, 2007, Keirstead, 2006 and Wilson and Dowlatabadi, 2007, Stephenson et al. 2010, Stern 2014).

So, in our view, there is a need for interdisciplinary research to integrate and consolidate existing research, leading to a multi-level conceptual framework integrating the many factors identified as sharpening public acceptance of emerging energy technologies (Devine-Wright, 2007). Integrative research should look across categories of public acceptance of energy technologies and consider the multiple influences on attitudes and behaviours. This can help understand the relative and interacting effects of variables that especially interest researchers from different disciplines (Stern, 2014).

5. Synthesis of findings

In the previous sections we examined, first, the wider concept of social acceptance and its role in technology implementation and adoption. Inspired by the work by Devine-Wright (2008), Wüstenhagen et al. (2007), Wolsink (2007), Stern (2014) and by a number of empirical studies on the social and public acceptance of energy technologies, we provided a working definition of social acceptance, characterized the three levels, as well as the three components, of social acceptance. Then, we reviewed the concept of public acceptance; provided an operational definition of public acceptance and discussed the ways of measuring it via survey questionnaires. In a third section, we discussed some of the methodological challenges that, in our view, the research on public acceptance faces. Some of the main ideas we have been discussing are:

- Acceptance is understood as one of the main categories or dimensions of the attitude or reaction that individuals and communities might have towards a particular technology, infrastructure or application. Acceptance is produced in the interaction between communities and technologies. Acceptance can significantly influence technology implementation and adoption, but also the wellbeing of individuals and communities.
- The social acceptance of energy technologies can exist at three levels, depending on the object:
    - At the general level, when a society (e.g. a particular country) faces a particular **energy technology** (e.g. wind, nuclear, biomass).
    - At the local level, when a community (e.g. a town) faces a particular energy **infrastructure** (e.g. nuclear power plant, wind park, biomass power plant)
    - At the end-user level (individuals/household/organization), facing particular energy **applications** (e.g. residential solar, biomass installation, etc.)
- Social acceptance is composed of three components:
    - Political acceptance. Including the acceptance by **decision makers** in governments
    - Stakeholder acceptance. Including the acceptance by the members of the **stakeholders** groups (civil society and market)
    - Public acceptance. Including the acceptance by members of the **lay public**.

- Public acceptance has been defined as the "Favourable or positive attitude or behavioural response towards the implementation or adoption of a proposed technology held by the lay public of a given society (country or region or town)". Public, in this context, means the members of the general or the lay public (as opposed to members of stakeholder groups). A number of measures of public acceptance have been developed in past years. We propose an instrument to measure public acceptance based what we call the "public acceptance of technologies model", and developed from previous research.
- There are several methodological challenges that deserve consideration in researching public acceptance of energy technologies. Some of them, such as the problem of pseudo-opinions and the need to complement population-oriented research with case-oriented research are critical to research in this field.

Recommendations and suggestions for future research focused on public acceptance of energy technologies

1. *Clarification of the object of study*. Research on social and public acceptance of energy technologies will benefit from a proper clarification or research concepts. This conceptualization effort should include the specification of the object and the level of acceptance, the component of acceptance being researched, and the conceptualization and measurement of the variables or dimensions regarding public attitudes towards technologies being researched.

2. *Development and validation study of an instrument to measure public acceptance*. Future research should make the best use of existing questionnaires and measures in order to produce a new instrument to measure public acceptance to be applied in different technological and geographical contexts. As suggested in this report, the instrument could include measures of various dimensions of attitudinal acceptance as well as other influencing and/or related factors. A study of reliability and validity should also be conducted to validate the instrument.

3. *Consideration of the problem of "pseudo-opinions"* . Often, emerging energy technologies are not well known yet, which produces the so-called as "pseudo opinions" and "non attitudes". In the coming years, the development of new research tools should be developed in order to solve, or at least minimize this difficulty.

4. *Use of a combination of case-oriented and population-oriented research*. Social research on the public acceptance of energy technologies would benefit from combining case-oriented and population-oriented research.

5. *Combine different research methods*. Social scientist should work to reconcile the range of research methods available for studying public acceptance as well as to explore potential combinations among them (mixed methods). In fact, researchers have long been using multiple methods. But only in the last two decades, the idea of mixed methods has gained popularity. In the area of public acceptance of energy technologies, this becomes of special importance given the emphasis on the use of "opinion polls". Future research on public acceptance of energy technologies at the various levels should develop innovative methods that complement current survey questionnaire research, and which are able to capture how individuals experience and engage with energy technologies in the context of everyday life

6. *Aiming at multilevel studies*. Future research should consider the hierarchical nature of the public attitudes towards energy technologies. Applying multilevel modelling is a challenging issue for research that should be considered.

7. *Design longitudinal analysis when possible*. Social researchers need to examine how attitudes are developing when people come into contact with technology, capturing the dynamic nature of this process. Longitudinal data would improve our understanding of the public attitudes towards energy technologies. Longitudinal studies could be of special interest when researching public attitudes towards energy infrastructures at the local level.

8. *Favouring multidisciplinarity and transdiciplinarity*. There is a need for a better integration of the different analytical frameworks dealing with the relationships between technologies and individuals, communities and societies. Future research should aim at integrating the often disconnected findings and perspectives from behavioural and social research.

6. Conclusion

The study of social and public acceptance of energy technologies should be considered a central part of the efforts from the social sciences to understand the complex interplay between energy technologies and societies, and not only a matter of pragmatic consideration (e.g. the achievement of energy policy targets). In the last decades, a number of studies have investigated the societal and public reactions towards a variety of energy technologies at the general, the local and the end-user level. Although research has significantly contributed to understanding the variation on the levels of public acceptance across technologies, communities and societies, as well as to understanding the factors influencing social and public acceptance and the dynamics of public engagement, there are still a number of definitional issues that need resolution. We hope this report has contributed to identify some of the definitional and methodological challenges facing social research in this field.

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***Annex Table 1**. Descriptions of a selection of studies on the social and public acceptance of energy technologies reviewed for this report*

Author, year, reference	Location	Type of energy technology	Level of analysis	Object of the study	Research question	Method	Sample
Pomadere et al., 1995	USA and France	Nuclear energy (fision)	General	Public acceptance	To test the widespread assumption that the French show higher levels of acceptance for nuclear power production on their territory.	Survey	In each country, 1500 persons responded to a 155 item questionnaire
Steg et al., 2005	Groningen, The Netherlands	Energy policies and renewable energy technologies	General	Public acceptance	Examine factors influencing the acceptability of energy policies and technologies aimed to reduce the emission of CO_2	Survey	A total of 300 surveys were distributed at different locations and times in Groningen, a city in the north of the Netherlands.
Moula et al., 2013	Finland	Renewable energy technologies	General	Public acceptance	What is the level of awareness of energy efficiency efficiency in terms of renewable energy sources and technologies	Survey questionnaire	A survey of 50 citizens living in Helsinki, Espoo and Vantaa.
De Best-Waldhober et al., 2009	Netherlands	Different technologies	General	Public acceptance	How people would evaluate and choose between seven mitigation options after having been thoroughly informed.	Information-Choice Questionnaire (ICQ)	A representative sample of the Dutch public (n =971)
Visschers et al., 2011	Switzerland	Nuclear power stations	General	Public acceptance	To investigate a broad model to explain people's acceptance of nuclear power stations. They focus on people's risk and benefit perceptions, affective feelings and trust.	Survey	817 (66.8%) inhabitants of the German-speaking part of Switzerland and 405 (33.2%) inhabitants of the French-speaking part were interviewed, by telephone.
L'Orange et al. 2011	Switzerland	CCS	General	Public acceptance	Whether information about monitoring of CCS sites would have a reassuring or alarming effect on laypeople with little prior knowledge of CCS	Experimental Survey	A survey of 200 residents of Switzerland.
Kim et al., 2014	Cross-country	Nuclear energy	General	Public acceptance	To identify the influences that exist on the level of public acceptance and reluctant acceptance of nuclear power, and how the effects of these factors depend on experience in operating nuclear power plants and the geographical, environmental, and cultural conditions of a country	Survey	20,803 respondents from 19 countries
Achterberg et al. 2010	The Netherlands	Hydrogen	General	Public acceptance	The relationship between the information one has about the hydrogen technology, how one is culturally predisposed and the way one judge's hydrogen technology. Following "framing theory" argue that these cultural predispositions could be the key to understand why low levels of knowledge	Survey	*N*=2121 Representative sample of the Netherlands

					about hydrogen could in fact coincide with high levels of support.		
Aas et al., 2014	Norway, Sweden and the United Kingdom	High-voltage powerlines	General and local	Public acceptance	To investigate public responses to transmission lines in three selected countries, through considering some key factors relevantfor understanding acceptance or opposition, notably issues of trust, familiarity and distinctions between general and local acceptance	Survey	A representative sample of the adult population in the three countries (*N*: 5107)
Zoellner et al., 2008	Germany	Grid-connected larger PV ground-installed systems, biomass plants and wind turbines	General	Public acceptance	The article addresses the public acceptance of certain renewable energies (grid-connected larger PV ground-installed systems, biomass plants and wind turbines) from a socio-scientific perspective.	Mixed methods	Qualitative interviews have been conducted with members of local authorities, operating companies of PV ground-installed systems, nature protection organizations, and members of citizens' initiatives.
Soland et al., 2013	Switzerland	Biogas plants	Local	Public acceptance	Description and explanatory factors in local acceptance of existing biogas plants in Switzerland	Survey	A survey of 502 citizens living near 19 biogas plants
Devine-Wright, 2011	Strangford Lough, Northern Ireland	Tidal energy convertor installation	Local	Public acceptance	Description of public beliefs about a tidal energy convertor installed in Strangford Lough.	Mixed methods	313 residents from Portaferry and Strangford
Thesen and Langhelle 2006	Greater Stavanger, Norway	Hydrogen vehicles and filling stations	Local	Local public acceptance, and End-users acceptance	Awareness and acceptability of hydrogen vehicles and filling stations	Survey	Back yard (-1km filling station) and Greater Stavanger
Sjöberg, 2004	Four municipalities in Sweden	Nuclear waste repository	Local	Local public acceptance	To study the attitudes and risk perceptions of people in four municipalities in Sweden where HLNW siting was being intensely discussed	Survey	2,548 local residents
Hall et al., 2103	Australia	Wind Farms	Local	Local social acceptance	To explore the 'social gap' between publicly stated support and individual local acceptance	Qualitative	27interviews including representatives from wind development companies(9); local government (5); community members ('local opposition') (4);community members ('local support') (5); and turbine hosts(4)
Upham and S. Shackley, 2006	Devon, UK	Biomass plant	Local	Social acceptance	To describe the perceptions of the developer, agencies and local people involved in the planning of a proposed	Survey, interviews and focus groups	Local residents, stakeholders and protestors

					bioenergy gasifier		
Dütschke, 2011	Ketzin and Vattenfall, Germany	CCS	Local	Social acceptance and adoption	The cases of Ketzin and Vattenfall are compared regarding project properties, communication strategies and public perception, as well as local context and history in order to identify factors that contributed to the respective positive or negative reaction.	Interviews	Information on the cases was collected through internet sources, e.g. project web sites, internet sites of opponents, and media archives, mainly from local newspapers. 13 in-depth interviews were conducted with relevant stakeholders.
Venables et al., 2009	Bradwell-on-Sea and Oldbury-on-Severn, UK	Nuclear power plants	Local	Public acceptance	To explore the acceptability of nuclear power plants	Q-Methodology	People (n = 84) drawn from communities near to two nuclear power stations in the United Kingdom
Sinclair and Löfstedt, 2001	Sutton, UK	Biomass plant	Local	Public acceptance and trust	To investigate factors underlying trust in the various 'institutions' in the biomass planning debate.	Mixed methods	Sixty Sutton residents were interviewed on three consecutive days outside the village mini-supermarket using a convenience sample methodology. The sample included 36 females and 24 males with an age and education distribution representative of the area
Bollinger and Gillingham, 2012	State of California, USA	Solar Photovoltaic Panels	End-user, household	End-user adoption	Peer Effects in the Diffusion of Solar Photovoltaic Panels	Correlational study	Secondary data on solar PV installations
Schelly, 2014	State of Wisconsin, USA	Residential solar electric technology	End-user, household	End-user acceptance, market acceptance	What motivates homeowners to adopt residential solar electric technology	Semi-structured interviews	48 homeowners
Mallet, 2007	Mexico City	Solar water heaters	End-user, household	Market acceptance	The role of technology cooperation in the adoption of renewable energy innovations	Interviews	Stakeholders and end users
Wiedman et al., 2009	Germany	Renewable energies	En user, household	Public acceptance, End-user acceptance	To provide a detailed picture of the private end user's decision process, using the classical concept of attitude research to identify individual acceptances	Survey	182 residents from Germany
Chen et al., 2010	Norway	Biomass, pellet stoves	End-user, household	End-user acceptance and adoption	What influences households' decisions to invest in new heating equipment, and which factors determine what type of equipment they choose	Survey	1860 residents from Norway
Heagle et al., 2011	Ontario, Canada	Small wind turbine	End-user,	Social acceptance	Examine the social barriers, policies, and	Case study	Secondary data

		for residential usage	household		incentive programs for residential and small business small wind projects in Ontario		
Mourato et al., 2004	London	Hydrogen	End-user, taxi drivers	End-user acceptance	Investigation of attitudes towards hydrogen as a fuel, potential demand for joining a fuel cell hydrogen taxi demonstration project and the purchase intention of a future production fuel cell vehicle	Mixed methods	100 taxi drivers from London
Egbue and Long 2012		Electric Vehicles	End-user, individuals	End-user acceptance and adoption	What are the socio-technical barriers to consumer adoption of electric vehicles? How much influence does sustainability have on Electric Vehicles purchase decision?	Survey	The target population comprised mainly of current owners of CVs with the intention of capturing opinions, perceptions and attitudes of individuals who are prospective owners of EVs. 481 responses were used for further analysis.
Wüstenhagen et al., 2007	--	Renewable energy technologies	--	Conceptual	--	--	--
Devine-Wright, 2007	--	Renewable energy technologies	--	Conceptual	--	--	--
Batel et al., 2013	--	Highvoltage powerlines.	--	Conceptual			
Stern, 2014	--	Energy	--	Conceptual	--	--	--
Flyn, 2007	--	Energy, Hydrogen	--	Conceptual	--	--	--
Wolsink, 2007	--	Wind	--	Conceptual	--	--	--
Prades et al., 2008	--	Fusion energy	--	Critical/narrative review	--	--	--
Gupta	--	Technologies, general	--	Systematic review	--	--	--
Ricci, 2008	--	Hydrogen	--	Critical/narrative review	--	--	--
Prades et al. 2009	--	Wind Energy	--	Critical/narrative review	--	--	--