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Saved by hydrogen? The public acceptance of onshore wind in Norway

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ABSTRACT

Achieving the green energy transition is not without difficulty. This is also the case for the deployment of renewable energy infrastructures. Among these, onshore wind has often been contested. Taking the case of Norway where opposition to onshore wind has grown, this article evaluates how different production, financial, and end-use schemes can mitigate opposition. One factor stands out: that the wind farm is used not only to produce emission-free hydrogen but that this hydrogen is also sold locally to decarbonize sectors such as transport and industry. In other words, hydrogen on its own will not "save" onshore wind from contestation, but hydrogen *with a local purpose* will render citizens more supportive of these projects, even when situated in their own municipality. This effect is particularly strong among younger and more educated citizens. However, it transcends the rural-urban divide which often structures attitudes towards onshore wind projects.

1. Introduction

Wind farm installations have grown. They have become larger and more numerous. Much of this has been driven by a global demand for renewable energy and efforts to diversify the energy supply. This growth has not been unproblematic. Local resistance to wind energy infrastructure – and especially onshore wind – is a frequent issue for developers and policymakers. The social acceptance of onshore wind projects appears to have declined in many countries and the topic has become contested among citizens and in the media (Wüstenhagen et al., 2007). Whilst there is abstract support for the idea of renewable energy infrastructure, there is often some local resistance to concrete projects when these are being planned or built (Enevoldsen and Sovacool, 2016: 180). Regarding onshore wind farms, the discontent is rooted in the fact that they generate conflicts of interest in the surrounding environment, such as interfering with untouched nature, decreasing the value of properties, or causing visual and acoustic discomfort (Gibbons, 2015; Roddis et al., 2018). This is also the case in Norway, where wind energy opposition has risen (Vasstrøm and Lysgård, 2021a, 2021b). Here, there are strong arguments about wind farms harming local ecosystems and biodiversity as well as hindering the use of nature for recreational purposes.

A relatively new element in the wind energy debate is hydrogen. Hydrogen itself is not new. But its salience and prominence in energy discussions have grown. And within the context of renewable energies, it is becoming increasingly important. This is because it can provide a solution to the issue of the intermittency of renewable energy whilst being emission-free. Usually, the energy produced from wind farms is supplied to an electricity grid for immediate use. Hydrogen, however, offers a solution to store this energy (Sazali, 2020; Yukesh Kannah et al., 2021). It can then be used as clean energy for transportation, heating, and other industry specific purposes. Despite its promises, hydrogen as a fuel or for energy storage is yet to become a commercial technology. Consequently, we know less about its public acceptability compared to more widespread energy infrastructures (Gordon et al., 2022b: 7).

Combining these strands of research on onshore wind and hydrogen, one notices that the literature is somewhat sparse when it comes to the effect of hydrogen production on attitudes towards onshore wind farms. This is probably because opposition to onshore wind farms has only recently (i.e. mostly these past two decades) been rising and that public awareness of hydrogen tends to be comparatively low (Emodi et al., 2021). Hence, the interaction between onshore wind and hydrogen production has not been a central concern to either literatures. The literature on the social acceptance of onshore wind does not usually refer to hydrogen production (e.g., Cowell et al., 2011; Fournis and Fortin, 2017; Lundheim et al., 2022; Rand and Hoen, 2017). Similarly, much of the literature on hydrogen acceptance does not particularly focus on its production from onshore wind energy (e.g., Emodi et al.,

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2021; Gordon et al., 2022a: section 4; Schönauer and Glanz, 2022; Scott and Powells, 2020), although many studies do highlight that the energy source for hydrogen production – ranging from wind to solar, geothermal, gas, nuclear, coal, or biomass – can impact its acceptance (e.g., Gordon et al., 2022b: Table 10). However, these studies focus on the acceptance of hydrogen, as opposed to how hydrogen production can affect onshore wind acceptance.

In this article we analyze support for local onshore wind deployment in Norway. We do not seek to propose or test a grand theory of onshore wind acceptance. Rather, we evaluate meso-level expectations derived from past research. More specifically, we assess whether coupling onshore wind with hydrogen production affects support for onshore wind. We further examine whether two types of financial and end-use schemes affect support. The financial schemes regard compensation (property value compensation) and benefits (electricity bill discount). The end-use schemes distinguish between general electricity use (increased share of renewable electricity in the power market) and local hydrogen use (selling hydrogen to decarbonize transport and industry locally). Finally, we consider whether these characteristics activate age, educational, and urbanization divides within the population. We implement this research agenda through a survey experiment on a representative sample of the Norwegian population. The case of Norway is interesting since opposition to onshore wind has been increasing.

We find that Norwegian citizens are mildly opposed to the construction of an onshore wind farm in their home municipality. Adjoining hydrogen production hardly affects levels of opposition. Financial schemes do matter in the sense that property compensation frightens citizens by highlighting the negative consequences of the farm on the value of their property. However, opposition morphs into mild support when electricity discounts are offered locally. Opposition is strongest when no information is provided regarding the end-use of the local wind farm. Indicating that the wind farm will increase the share of renewables in the electricity grid makes respondents sit on the fence, between support and opposition. Support is overall highest, however, when wind-generated hydrogen is distributed locally, for example by being sold to transport and industry, so as to decarbonize these sectors.

Overall, these findings indicate that hydrogen on its own will not “save” onshore wind from local opposition. However, when the hydrogen is redistributed locally with a clear purpose, then citizens change attitude: mild opposition switches to mild support. Additionally, these findings stress the relevance of age, education, and urbanization effects. But with a twist. Age effects highlight a clear divide, between the younger generation which tends to be supportive, and the rest of the population which is more skeptical. Educational effects underline that higher educated citizens are distinctively supportive of installations coupled to hydrogen production. Hydrogen, however, seems to transcend the rural-urban divide. It triggers an unlikely alliance of village and city people. Such an alliance is unusual in the climate and energy debate. That the adjoining of hydrogen to onshore wind can partially break the rural-urban contestation continuum is of relevance for the ongoing energy transition. Indeed, the rural-urban cleavage has been pivotal regarding renewable energy deployment. Its partial deactivation may smoothen deployment as well as help alleviate difficult questions of fairness and justice.

The rest of the article is structured as follows. First, we present our hypotheses on hydrogen production, financial schemes, and end-use schemes, as well as their conditional effects within the citizenry (along the age, education, and urbanization dimensions). Then, we provide information on the survey experiment and its implementation. We subsequently assess our main hypotheses as well as their conditionality. We conclude with a discussion of this research’s implications.

2. Theory and hypothesis

Many factors affect opposition and support dynamics towards wind farm projects. We here focus on three attributes. First, the coupling of wind energy and hydrogen production, second financial schemes, and third end-use schemes. Additionally, we highlight that some citizens may respond differently to these attributes. Indeed, the literature emphasizes the relevance of background conditions such as age, education, or rurality (see, among others, Bergmann et al., 2008; O’Garra et al., 2008; Poortinga et al., 2019; Rand and Hoen, 2017; Segreto et al., 2020; Tarigan et al., 2012). Finally, and when relevant, we contextualize these (otherwise general) hypotheses to the case of Norway.

2.1. Wind energy and hydrogen production

Adjoining hydrogen production is a recent and alternative pathway for wind energy. The process of green hydrogen production is achieved through electrolysis, where water and electricity (from a wind farm or another renewable energy source) together form hydrogen, with oxygen and heat as the only byproduct. However, we know relatively little about the public acceptability of hydrogen coupled with wind energy (Gordon et al., 2022b: 12–3). And, to the best of our knowledge, there is currently no scientific literature that directly investigates the impact of hydrogen production on onshore wind acceptance or support.

There are, nevertheless, numerous studies on the social acceptance of hydrogen itself. Both Scovell (2022) and Emodi et al. (2021) have reviewed work published between 2005 and 2021 on the acceptance of hydrogen technology. Most of these studies investigate hydrogen vehicles and filling stations, usually focusing on the knowledge, awareness, and risk perception of hydrogen as a fuel (Huijts and Van Wee, 2015; Tarigan et al., 2012). Although it is still unclear how people value the different types of production methods, some studies have found evidence that people seem to favor renewable or green hydrogen compared to fossil or grey hydrogen (Gordon et al., 2022b; Helle, 2022; Lambert and Ashworth, 2018).

However, although citizens seem to favor green hydrogen and the idea of renewable energy, many are concerned about possible damages to landscapes, fauna, and flora that renewable energy installations often entail (Scovell, 2022: 10454) – even more so in the case of onshore wind (Jones and Richard Eiser, 2010). In some cases, these concerns may in turn decrease support for hydrogen produced from onshore wind energy, compared to other forms of low-carbon energies (Gordon et al., 2022b: Table 10).

Overall, however, studies that analyze hydrogen acceptance found that most people seem supportive, despite not deeming themselves to have sufficient knowledge about the technology (Achterberg et al., 2010; Zaunbrecher et al., 2016). In line with these findings, a group of Norwegian hydrogen clusters uncovered, through a survey conducted in 2020, that most Norwegians report limited knowledge of hydrogen (for more details, see Opinion, 2020). This echoes existing international research (Gordon et al., 2022b: Table 2). Optimistically, they perceived few barriers for implementing it and most viewed it as important for reaching future climate goals (Opinion, 2020).

One element which could dampen support for the deployment of hydrogen in Norway (and elsewhere) is safety issues. An accident took place at a hydrogen fueling station in Sandvika close to Oslo (Norway) in 2019. It attracted the attention of the media (Hansen, 2020). Occurrences like these could cause the public acceptance of hydrogen to decrease and hence dampen any positive “hydrogen effect” on the acceptance of local wind farms. Similarly, if hydrogen installations were to grow and spread, these might also become less popular as a consequence (as has been the case with onshore wind in Norway, see section 3.1 below).

Overall, past research indicates that citizens tend to be supportive of hydrogen deployment despite their lack of knowledge about it and possible safety issues (Scovell, 2022: 10446–7). Moreover, they tend to be especially positive towards renewably produced hydrogen compared to other forms of hydrogen (e.g. grey or blue hydrogen). This leads us to expect that adjoining hydrogen production to a wind farm could increase support for (or at least lessen opposition to) local onshore wind projects.

Type of energy – hypothesis 1:

H1. *Adjoining hydrogen production to a wind farm will increase local support for its construction.*

2.2. Financial schemes: local compensation and benefits

The negative impacts of an onshore wind farm can be manyfold. They are often magnified by questions of place attachment (Devine-Wright, 2009; Devine-Wright and Howes, 2010). If one simplifies, many of these negative impacts are related to localized environmental and sensory issues. These constitute onshore wind's most obvious negative externalities. Externalities are an action's consequences (positive or negative) as experienced by a third party. These can be direct effects (e.g., overfishing depletes fish stocks) or side-effects (e.g., pollution due to industrial activities). In this case, residents experience externalities in the area where a wind farm is built. Whilst positive externalities related to wind farms tend to be more diffuse, such as reduced CO_2 emissions or increased employment in that industrial sector, negative externalities tend to be more localized and tangible such as harm to local flora and fauna, disruption of animal migration paths, and visual and acoustic impacts in the surroundings (Bigerna and Polinori, 2015). Often, these negative externalities generate local opposition to wind farm projects.

Some of these negative externalities might be offset, or at least mitigated, through localized financial schemes. These schemes can be established to increase distributive energy justice and public acceptance in the hosting communities (Cowell et al., 2011; Herrera Anchustegui, 2020; Saglie et al., 2020). We expect that the presence of such schemes will increase support compared to a situation where no information is provided about these schemes. Two types of financial schemes are particularly widespread: community benefits and compensation mechanisms.

Community benefits are essentially contributions by developers to the local community to compensate the negative impacts of renewable energy development. They can also be viewed as an indirect redistribution of value from a wind farm. They come in a variety of forms, such as yearly donations to community funds, educational programs, shared ownership, and electricity bill discounts (Herrera Anchustegui, 2020; Singh Ghaleigh, 2013). Such community benefits have been implemented in countries like Denmark, Germany, the UK, and the Netherlands (García et al., 2016; Rudolph et al., 2018).

Compensation schemes have to do with monetary payments to local communities to compensate for wind farm nuisance (Leer Jørgensen et al., 2020). An example of this is property compensation, which has a legislative history in Denmark. Value losses of the properties located close to a wind or solar park are eligible for compensation (VE-loven, 2021). The Danish compensation model has been designed to generate local support and has been subject to revision many times throughout the years (VE-loven, 2021). Currently, in Denmark, developers must also donate a fixed sum to the hosting municipality and provide annual bonuses to close neighbors. In addition, energy developers are required to buy the properties of nearby residents if they chose to sell them within one year after the plant has started to produce electricity.

Community benefits and compensation schemes are not without flaws. Although these schemes are believed to increase distributive justice, some have been viewed as a form of bribery, because they are putting a price tag on non-monetary values, such as the beauty of the landscape, noise pollution, or animal life (Aitken, 2010: 6071). In addition, recent research has highlighted that local compensation schemes were sometimes viewed as more controversial by the public compared to community benefits like an electricity discount, although both types of schemes have sometimes been rejected as attempts to bribe citizens (Leer Jørgensen et al., 2020: 3, 7).

In Norway, there is no legislation on local benefits or compensation schemes for onshore wind energy. The situation is different when it comes to offshore wind, as financial compensation is provided to fishermen in cases of financial losses caused by offshore energy plants, and is even legislated for in the Offshore Energy Act (Havenergiloven § 9, 2010). Nonetheless, regarding onshore wind in Norway, there have been some instances of voluntary financial schemes, such as payment agreements in return for noise in Tysvær, Sirdal and Egersund[1] or the establishment of a fund to benefit the local community in Lutelandet.[2]

We here select two types of financial schemes and contrast them to a situation where no information is given about such schemes. Regarding community benefits, we focus on electricity discounts. These represent a tangible and local benefit, already implemented in different countries, such as the Wryde Croft wind farm in England[3] or the Westermeerwind wind farm in the Netherlands.[4] Regarding compensation schemes, we focus on property compensation. Loss of property value in the farm's vicinity has come across as a concrete negative externality generated by such farms (Gibbons, 2015; Sims et al., 2008). We expect that financial schemes will increase support for (or at least lessen opposition to) local onshore wind projects.

Financial schemes – hypothesis 2:

H2a. *Electricity discounts will increase support for the construction of a local wind farm.*

H2b. *Property compensation will increase support for the construction of a local wind farm.*

2.3. End-use schemes

The end-use of the energy produced from a wind farm asks about the "for what?" and "where?" of that energy. In other words, about its purpose. We expect that specifying an end-use purpose for the generated energy will increase support. We specify that energy from a wind farm can take the form of either (renewable) electricity inserted in the national power grid or of (green) hydrogen used for a particular purpose. Both scenarios are similar as they highlight the provision of clean energy. However, they differ in terms of the "for what?" and "where?" dimensions.

If a wind farm produces electricity, then that electricity will increase the share of renewable electricity in the power market. In Norway, the electricity from a commercial, large scale wind farm is required by law to be supplied to the national grid. Norway is also part of the Nordic and European power market. Hence, when one supplies electricity produced from a wind farm to the grid, one increases the share of renewable electricity in both Norway and in Europe. Previous studies on the acceptability of renewable electricity generation have found that people are generally supportive of this (Park, 2019; Ribeiro et al., 2014).

If a wind farm produces hydrogen instead, then that hydrogen can be used a) locally and b) for a specific purpose (as opposed to simply increasing the share of clean energy in the grid). Hydrogen can be used in sectors such as transport and steel production which are traditionally reliant on fossil fuel. In other words, green hydrogen from a wind farm can replace fossil fuels, help avoid emissions, whilst decarbonizing a variety of sectors. In addition, instead of being supplied to the national grid, hydrogen can be sold to local players, hence generating positive externalities locally.

There is relatively little knowledge about the effects of (green) hydrogen production on support for onshore wind farm construction (Scovell, 2022). However, some research on the social acceptance of

[1] See https://www.vg.no/nyheter/innenriks/i/kRakJa/de-hemmelige-stoeyavtalene [last accessed: 24.08.2022].

[2] See https://www.sfe.no/konsern/kraftproduksjon/vindkraft/lutelandet/vind-vinn/[last accessed: 24.08.2022].

[3] See http://www.wrydecroft-windfarm.co.uk/community-benefits/local-electricity-discount-scheme-leds [last accessed: 24.08.2022].

[4] See https://www.westermeerwind.nl [last accessed: 24.08.2022].

hydrogen in Japan indicates higher levels of support under two conditions: a) when the hydrogen is used locally and b) when it is green (i.e. produced without emissions). Indeed, Irie and Kawahara (2019) found that fueling stations for hydrogen received a stronger favorability when they generated benefits in the local area, such as helping the local economy to grow, creating more jobs, and increasing the energy security. They also found that, when sold at a filling station, local renewable production of hydrogen was perceived differently than imported hydrogen produced from fossil fuels. Green hydrogen had a slightly higher favorability and was perceived to be safer and better for the environment.

Based on this literature, we formulate a third hypothesis on the end-use of the wind farm's energy and whether this is communicated to citizens or not. We contrast three scenarios: when no end-use is specified (i.e., no communication), when the end-use is specified as increasing the share of renewable electricity in the power grid (i.e., renewable electricity communication), and finally when the end-use is specified as locally producing and then distributing the emission-free hydrogen by, for example, selling it to traditionally fossil-dependent sectors such as transport and industry (i.e., local hydrogen communication). We expect that the specification of these last two end-use schemes will increase support for (or at least lessen opposition to) local onshore wind projects.

End-use – hypothesis 3:

H3a. *Wind-generated electricity increasing the share of renewables in the power grid will increase support for the construction of a local wind farm.*

H3b. *Wind-generated hydrogen decarbonizing local industries and transport will increase support for the construction of a local wind farm.*

2.4. Conditional effects in the citizenry

The above attributes of hydrogen production, financial schemes, and end-use schemes may well affect different citizens differently. Whilst we expect average effects to be instructive, we also expect that different sub-groups within the citizenry may be more or less convinced by these three attributes. In other words, we expect heterogenous effects according to certain conditioning factors (Leeper et al., 2020).

Both the general climate and energy literature and the more specific onshore wind literature have highlighted that individual-level factors such as age, education, or urbanization may well condition the effect of differing policy attributes. Indeed, opposition to onshore wind energy has been linked to differences in urbanization levels, as they generate conflicts of interests between rural and urban citizens (for more details see, among others, Bergmann et al., 2008; Phadke, 2013; Rand and Hoen, 2017). Meanwhile, support for renewable energy development and climate change mitigation policies are often associated with younger age groups and higher levels of education (Gregersen, 2022; Poortinga et al., 2019; Segreto et al., 2020). Similarly, regarding hydrogen, many studies have detected that younger and higher educated people tend to be more accepting of hydrogen technologies (O'Garra et al., 2008; Tarigan et al., 2012; Thesen and Langhelle, 2008).

Following this literature, we formulate expectations related to the conditioning effect of age, education, and urbanization. We expect younger, more educated, and more urbanized respondents to react more favorably (than the rest of the population) to hydrogen production, financial schemes, and end-use scheme.

Conditional effects – hypothesis 4:

H4a. *Younger citizens will react more favorably (than the rest of the population) to hydrogen production, financial schemes, and end-use schemes.*

H4b. *More educated citizens will react more favorably (than the rest of the population) to hydrogen production, financial schemes, and end-use schemes.*

H4c. *More urban citizens will react more favorably (than the rest of the population) to hydrogen production, financial schemes, and end-use schemes.*

Since we also collected information on respondents' gender and region (for representativity and weighing purposes), we report these conditional effects in the online appendix too, though mostly for our curiosity's sake (see A-9 and A-10).

3. Case, data, and methods

3.1. Norway and onshore wind

In Norway, energy production from onshore wind power has been growing rapidly (NVE, 2022). As illustrated in Fig. 1 (installed capacity and energy production), this growth kicked-off shortly after the introduction, in 2012, of the electricity certificate scheme which made it more profitable to develop renewable energy. This scheme boosted the production of onshore wind energy, which has dramatically increased across the past decade (Fig. 1).

As a result of its rapid growth, opposition towards onshore wind deployment has become significant. Strong movements have emerged in communities located close to wind farms (Vasstrøm and Lysgård, 2021a, 2021b), mainly due to the generated noise, obstruction of views, and interference with nature. Some of this discontent led to legal actions, such as regarding the Fosen wind farms. This is one of the largest onshore wind infrastructure in Europe. The Norwegian Supreme Court deemed that the licensing and the expropriation decisions regarding two of its wind farms (Storheia and Roan) contradicted the rights of reindeer herders and were hence in violation of the International Covenant on Civil and Political Rights (article 27), thereby rendering these decisions invalid (Norges Domstoler, 2021). More generally, local opposition to onshore wind farms as well as broader dissatisfaction with licensing procedures led the Norwegian government to freeze the licensing process for all new onshore wind farms in 2019 (Aasland, 2022). This licensing process was re-opened in 2022 but only for municipalities that consented to it. At the time of writing, the Norwegian government is revising the onshore wind legal framework to address ongoing discontent.

A recent survey conducted in 2021 by the Norwegian Citizen Panel (NCP) revealed that Norwegians have become split when it comes to onshore wind deployment (Ivarsflaten et al., 2021b). Interestingly, when asked in 2014, Norwegians were similarly favorable to both onshore and offshore wind. However, the support gap between onshore and offshore has increased over time, most likely due to the fast deployment of onshore installations since 2016 and the inexistence of any significant offshore deployment during the same time interval. As illustrated in Fig. 2, support levels for onshore and offshore wind were

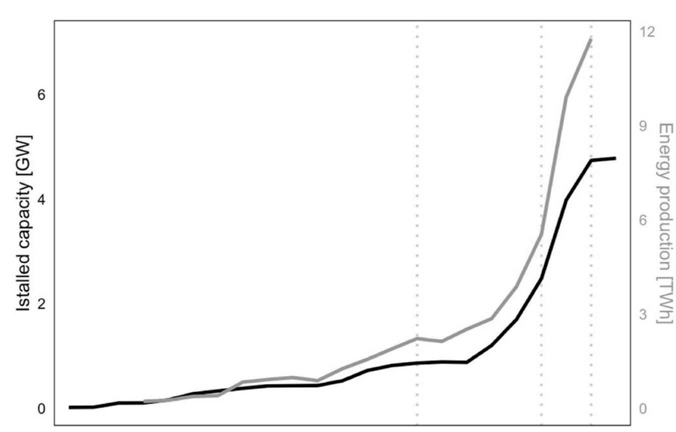

Fig. 1. Time-series data on onshore wind in Norway.
Notes: Installed capacity in gigawatt (GW, black line) and energy production in terawatt hour (TWh, grey line) (data from: NVE). Vertical dotted lines in 2014, 2019, and 2021 indicate when citizens have been surveyed by the Norwegian Citizen Panel (NCP) on onshore and offshore wind (see Fig. 2 below).

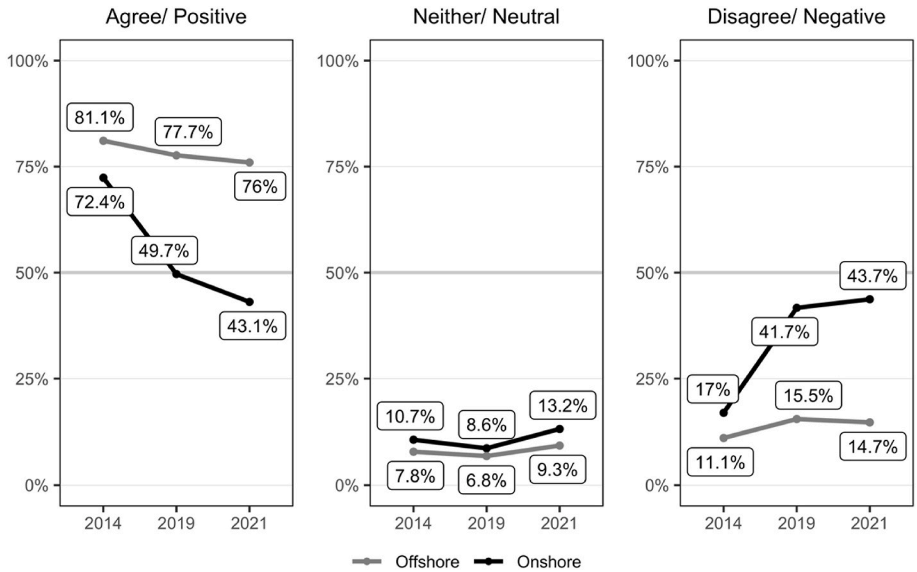

Fig. 2. Opinion polls on onshore and offshore wind energy in Norway in 2014, 2019, and 2021.
Notes: Citizens were asked how positive/negative they are regarding increased government support for wind power on land and at sea (2014) and whether they agree/disagree that more land-based/sea-based windmills should be built in Norway (2019, 2021) (Ivarsflaten et al., 2020, 2021a, 2021b). Colour version in appendix A-11.

comparable in 2014. Over 70% of respondents were generally positive towards both wind energies. Since then, opposition towards onshore wind has increased, whilst offshore wind has remained relatively popular. As illustrated by combining Figs. 1 and 2, onshore wind contestation has taken-off in parallel to the take-off of its deployment. These developments make Norway interesting as a case study of attitudes towards onshore wind.

3.2. Vignette survey experiment

Vignette survey experiments allow researchers to analyze the effects of different attributes in a fictive scenario (Aguinis and Bradley, 2014; Hainmueller et al., 2015a). The design we adopted in this study is best described as a single-profile multifactorial vignette experiment, which is one of the most widely used factorial survey design in the social sciences (Hainmueller et al., 2015b: 2396).

We asked respondents to imagine a proposal to build a wind farm in their home municipality. For each attribute of the experiment, the respondents were split randomly (according to the number of levels within each attribute). This means that a random half of the respondents was told that the wind farm produces emission-free hydrogen, whilst the other half was given no such information. This corresponds to Attribute 1, which tests for the hypothesis on energy type (H1). One third of respondents was given information about a community benefit (discount of electricity bills), another third was informed about a compensation scheme (property value compensation), and a final third was provided no such information. This corresponds to Attribute 2, which tests the hypothesis on financial schemes (H2). Finally, we exposed some respondents to information about end-use schemes. This attribute depends on the first attribute (no hydrogen vs. hydrogen). If the first attribute was a wind farm that produces hydrogen, then half of these respondents (i.e. 25 % of the total) was informed that the hydrogen will be sold to local players to decarbonize transport and industry. The other half (i.e. 25% of the total) was presented with no information. If the first attribute was only a wind farm (no mention of hydrogen), then half of these respondents (i.e. 25% of the total) got further information about how the electricity from that wind farm would increase the share of renewables in the national grid, whilst the remaining half (i.e. 25% of the total) got no information about end-use. This means that an equal proportion of respondents were presented with a) end-use information (either renewable electricity or local hydrogen: 25% each, 50% overall) and b) no end use information at all (50% overall). This corresponds to Attribute 3, which tests the hypothesis on end-use (H3).

Hence, all respondents were randomly attributed a scenario and were asked to what extent they would support or oppose the proposal to build an onshore wind farm in their home municipality, considering the given characteristics of the wind farm. They expressed their levels of support or opposition on a seven-point scale ranging from (1) very strongly oppose to (7) very strongly support. It is this variation in support and opposition that this study analyzes. The survey experiment can be found in the supplementary appendix A-1, both in the original language and translated to English. So as to test the conditional effects of the three attributes and their levels, we further collected data on citizen age-groups, educational levels, and urbanization levels. These data are reported in appendix A-2. They allow us to test for the conditional effects hypotheses (H4).

3.3. Implementation and methods

We fielded the survey by purchasing question time in the Norwegian Citizen Panel (NCP) round 22 in November 2021 (Ivarsflaten et al., 2021b). These data are unrelated to the data presented in Fig. 2 and stem from a different round of the NCP. The NCP is an academically administered non-profit panel that carries out online surveys about societal matters. It uses random sampling from the Norwegian population register to recruit respondents and provides weights to account for demographic imbalances between sample and population. These weights correct for sample biases regarding age, gender, geography, and education (for a full discussion, see Skjervheim et al., 2021: 13–15). 1961 people in total responded to this survey experiment. Descriptive information is provided in the appendix (see A-2 and A-3).

Fig. 3 shows the distribution of the experiment's attributes and levels. These were randomly assigned (see section 3.2) and seem rather uniform in their occurrence. As specified in the previous section, scenario 3-A Null stands out since it is allocated to 50% of respondents (a random half of 1-A Wind and a random half of 1-B Hydrogen) whilst the remaining 50% are split according to the 1-A/3-B and the 1-B/3-C dyads.

These data were analyzed using marginal means (MMs). MMs are frequently used for the analysis of survey experiments. They represent the mean outcome across all appearances of a particular feature level, averaging across all other features (Leeper et al., 2020). The calculation of MMs entails no particular modelling assumptions. These are simply descriptive quantities of interest. For continuous and ordinal outcomes, MMs can take any value in the full range of the outcome, in our case values ranging from 1 to 7 (in forced choice conjoint designs the MMs

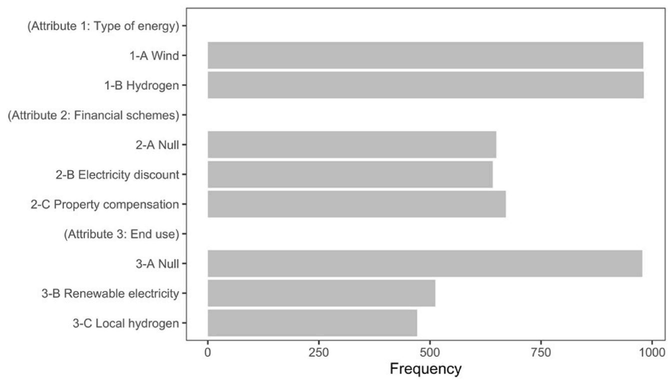

Fig. 3. Distribution of the attributes' levels.
Notes: n = 1961; table version in appendix A-4.

are centred around 1/number of profiles per choice task; which is not the case in a single-profile vignette study as this one). The analysis was implemented using Leeper's cregg package available in the R environment (Leeper, 2020: code at https://github.com/leeper/cregg).

Since comparisons between sub-groups are of interest as well as comparison between attributes' levels, we report marginal means rather than average marginal component effects (AMCEs). Indeed, AMCEs require the definition of a reference category. Such a reference category has no meaningful bearing on estimation but it can affect interpretation when subgroups are compared, especially across attributes (Leeper et al., 2020). In some instances both the size and even the direction of subgroup differences can be misleading when presented as differences in AMCEs (Leeper et al., 2020). For readers more accustomed to AMCEs, we report them in the appendix (see A-6) but with the above caveat. For readers more accustomed to different analytical procedures, we also report Tukey's Honestly Significant Difference test in the appendix (see A-7) as well as Welch's t-tests and Cohen's d effect sizes (see A-8). These tests return less conservative results than the MMs estimates. Hence, in the trade-off between Type I and Type II errors, we are erring on the side of a Type II error (i.e., false negative). In the body of the text, we focus on the MMs results and discuss other approaches in the appendix. Finally, when reporting MMs, we plot both 95% and 84% confidence intervals. The latter is recommended by Julious (2004) for the comparison of estimates within experimental settings where non-overlapping 84% confidence intervals indicate that differences between estimates are significant at the 0.05 level (see also Cumming (2009: 206), Greenland et al. (2016: 344), and MacGregor-Fors and Payton (2013) for more details).

4. Results and discussion

We first present results regarding the direct effects of energy type, financial schemes, and end-use (hypotheses 1–3) and then the results regarding conditional effects depending on age, education, and urbanization (hypothesis 4).

4.1. *Tipping the balance: hydrogen with a local purpose*

Fig. 4 shows the distribution of support and opposition among respondents. The average Norwegian mildly opposes the construction of an onshore wind farm in their home municipality. Indeed, the grand mean is situated at 3.88 which corresponds to mild opposition, verging on neutrality (i.e. neither/nor).

Fig. 5 reports the marginal means for each attribute's level. The 95% confidence intervals are used to compare estimates to a given threshold (such as 4, indicating neutrality) whilst the 84% confidence intervals are used to compare estimates among themselves, be it across attributes' levels or across sub-groups, where non-overlapping 84% confidence intervals indicate estimates significantly different at the 0.05 level (for more details see Cumming, 2009; Greenland et al., 2016; Julious, 2004; MacGregor-Fors and Payton, 2013).

When faced with the prospect of an onshore wind farm being built in their municipality, respondents express mild opposition (MM = 3.82). Adjoining hydrogen production to such a wind farm hardly affects their preferences (MM = 3.94). In fact, the difference between a wind farm with and without hydrogen is statistically insignificant. There is hence no evidence supporting hypothesis 1. It might well be that people are positively predisposed towards hydrogen (Achterberg et al., 2010; Zaunbrecher et al., 2016), but this is insufficient by itself to change their views on local onshore wind.

Results regarding financial schemes are more contrasted (hypothesis 2). Promising financial compensation for losses in property value seems to frighten citizens by highlighting the negative consequences of the farm on their property. Loss of property value is a documented direct consequence of onshore wind deployment (Gibbons, 2015; Sims et al., 2008). Financially compensating for this does not generate much support and instead reminds citizens of the negative impact the facility will have on property value (Aitken, 2010; Leer Jørgensen et al., 2020). However, providing an electricity discount for nearby residents significantly increases support compared to property compensation (MM = 4.11, CI(84) = 3.90–4.31 compared to MM = 3.68, CI(84) = 3.54–3.81). This seems to suggest that creating positive externalities (e.g. cheaper electricity) might weigh more heavily than correcting for negative externalities (e.g. property compensation). Although these two scenarios are statistically different from one another, one should not read too much into this as neither are significantly different from the null

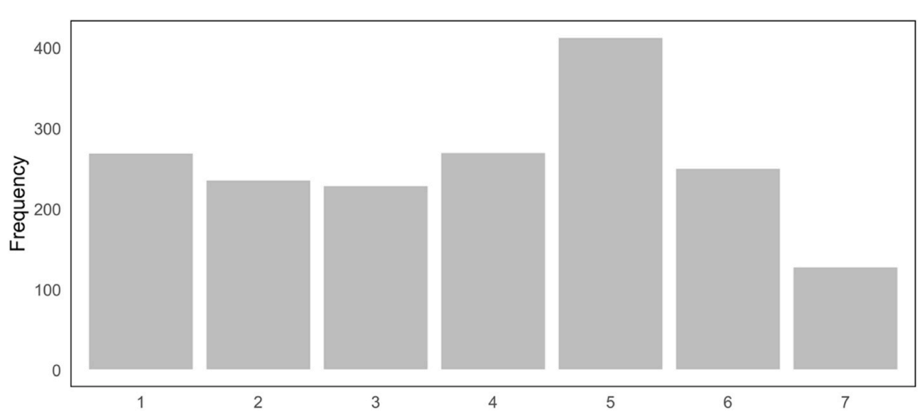

Fig. 4. Support for building an onshore windfarm in your home municipality.
Notes: distribution of answers, n = 1961, where 1 = "Very strongly oppose", 2 = "Strongly oppose", 3 = "Somewhat oppose", 4 = "Neither support nor oppose", 5 = "somewhat support", 6 = "strongly support", and 7 = "Very strongly support". Mean of the distribution = 3.88. Table version in appendix A-3.

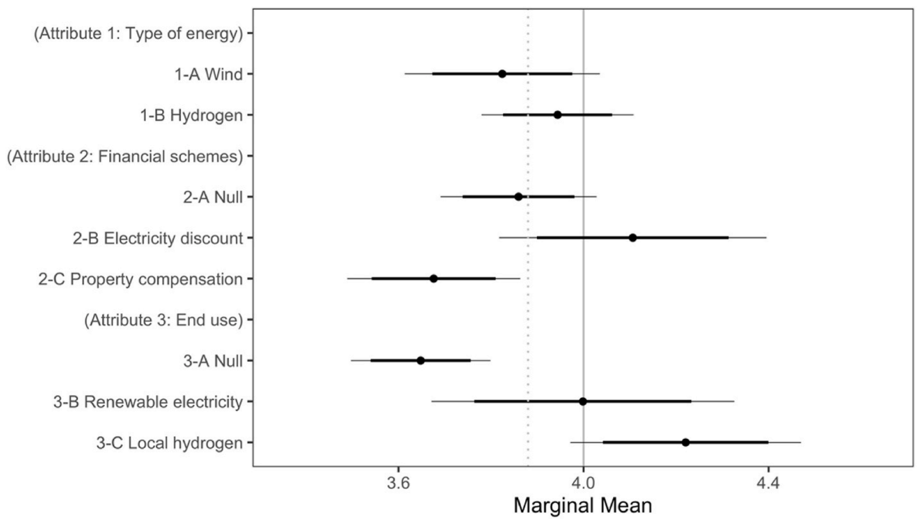

Fig. 5. The effects of type of energy, financial schemes, and end-use on support for building an onshore windfarm in your home municipality.
Notes: marginal means (n = 1961). Dotted vertical grey line corresponds to the grand mean (3.88), solid vertical line corresponds to neutrality (4). Outer confidence intervals are 95% and inner are 84%. 84% confidence intervals are recommended by Julious (2004) for the direct comparison of point estimates within experimental settings (see also Cumming (2009: 206), Greenland et al. (2016: 344), and MacGregor-Fors and Payton (2013)). Table version in appendix A-5. a.

scenario of no information on financial schemes (MM = 3.86, CI(84) = 3.74–3.98). This might be due to the fact that many citizens perceive any financial scheme as a form of bribery to buy support (Aitken, 2010; Leer Jørgensen et al., 2020). Nonetheless, the take-home message is that if developers need to choose between different financial schemes, providing localized benefits, such as electricity discounts, might be a fruitful avenue to garner support.

Results are much clearer when it comes to the effect of different end-use schemes (hypothesis 3). Providing no information on the end-use of the electricity elicits the least favorable response from citizens (MM = 3.65, CI(84) = 3.54–3.76). Underlining that the wind farm will increase the share of renewable electricity in the power market shifts respondents from mild opposition to neutrality (MM = 4.00, CI(84) = 3.76–4.23). However, the scenario generating the highest level of support for the whole experiment is when the wind farm produces hydrogen which is then sold to local players to replace fossil energy in sectors such as transport and the industry (MM = 4.22, CI(84) = 4.04–4.40). Crucially, the provision of emission-free hydrogen to local actors makes a difference. Whilst respondents mildly oppose the building of a wind farm in their municipality (scenario 1-A Wind), they mildly support this same wind farm when it has a clear purpose benefiting the local community (scenario 3-C Local hydrogen). Hence, whilst hydrogen on its own cannot save onshore wind from opposition, hydrogen *with a local purpose* might. The effect size is rather small (Cohen's d = 0.21) but it is significant and instructive. Similarly to the provision of an electricity discount, it seems that citizens respond better when localized positive externalities are generated. Developers and policymakers would be wise to bear in mind that local communities will be more open to hosting energy infrastructures when these not only serve a common good, but also generate local benefits. These benefits need not necessarily be financial, but may be more abstract, such as decarbonizing the local transport and industry sectors through hydrogen provision.

4.2. Entrenching age and educational effects but transcending the rural-urban divide

Whilst studying average effects is instructive, subgroup analysis can also shed some light on where support gaps are more likely to emerge within society. As highlighted above (hypothesis 4), much of the literature indicates that support gaps often emerge across age and educational groups, regarding renewable energy and hydrogen technology (Gregersen, 2022; O'Garra et al., 2008; Poortinga et al., 2019; Segreto et al., 2020; Tarigan et al., 2012; Thesen and Langhelle, 2008).

This study reinforces these findings. As illustrated in Fig. 6, the

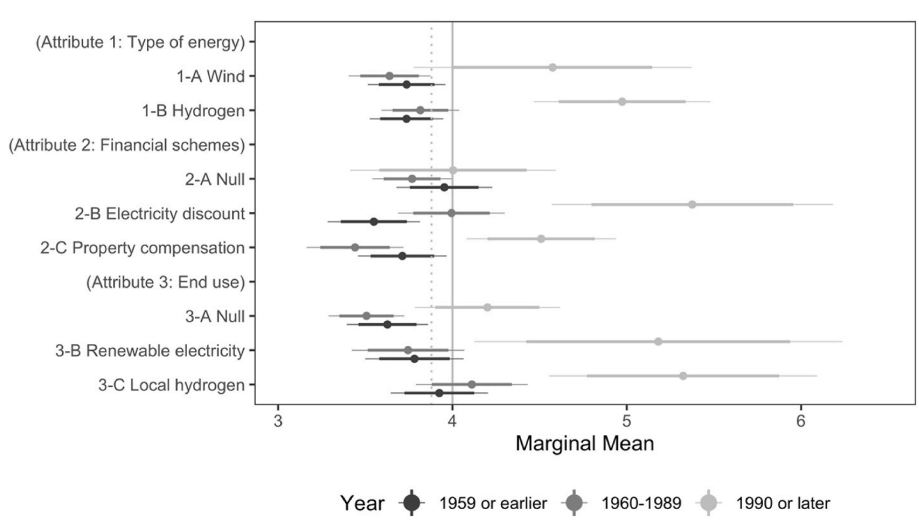

Fig. 6. Marginal means by age-group for building an onshore windfarm in your home municipality.
Notes: marginal means (n = 1961). Dotted vertical grey line corresponds to the grand mean (3.88), solid vertical line corresponds to neutrality (4). Outer confidence intervals are 95% and inner are 84%. Colour version in appendix A-11. Table version in appendix A-5. b.

younger generation is mostly supportive towards the building of a wind farm in their municipality. The only exception is when no information is provided about financial schemes (2-A Null), which makes younger citizens sit on the fence. In all other cases, these under-31 support such a construction project, from mildly to enthusiastically (MMs range from 4.20 to 5.38). Older generations tend to be statistically indistinguishable from one another, with the exception of electricity discounts, to which the 32–61 years old respond more favorably than the 62+. This research thereby reaffirms the notable climate divide between younger citizens and the rest.

Results are slightly more nuanced when it comes to educational effects. These are presented in Fig. 7. High school graduates are generally less favorable to a wind farm being built in their municipality. Apart from the scenario of an electricity discount, they are systematically unfavorable. The college/university educated exhibit significantly higher levels of support in five scenarios, two of which are particularly noteworthy: adjoining hydrogen to the wind farm and selling the produced hydrogen locally. In both instances, they report decisively positive attitudes towards the construction project. For them, simply adjoining hydrogen production is already enough to gain their support. Local distribution and decarbonization is an additional bonus. These findings confirm the important role of higher education on attitudes towards both renewable energy and hydrogen.

Findings regarding urbanization are perhaps more novel. They are reported in Fig. 8. Opposition to renewable energy infrastructure, and especially to onshore wind, has been linked to differences in urbanization levels as they generate conflicts of interests between rural and urban citizens (see Bergmann et al., 2008; Phadke, 2013; Rand and Hoen, 2017). And indeed, for five scenarios out of eight, we can observe a positive and quasi-linear relationship between urbanization levels and support for building a wind farm in one's municipality. This linear relationship, however, is upset in three scenarios. First, when hydrogen production is adjoined to the wind farm, the village and small/mid-sized town people become positive, and villagers become significantly more supportive than their suburban peers. A similar situation occurs regarding electricity discounts, which break the linearity from sparsely populated areas to big city folk. Finally, local hydrogen with a purpose reshuffles support levels, pitting sparsely populated areas and suburbanites on one side, and villagers, small/mid-sized townies, and big city dwellers on the other side.

This represents a new finding. Whilst attitudes towards onshore wind usually follow the urbanization continuum (see 1-A Wind and the above literature), hydrogen reshuffles the cards (see 1-B Hydrogen and 3-C Local hydrogen). It partly deactivates the rural-urban divide. Of course, urbanization still matters, and the hierarchy is not completely upset. At either ends of the spectrum, sparsely populated areas are still predominantly negative and big cities usually positive. But the rank-ordering at intermediate levels is upset. This is especially clear for villagers and suburbanites. Future research may want to explore why this is the case. But at any rate, suburbanites seem to be put off by electricity discounts, hydrogen production, and local hydrogen distribution. Conversely, villagers respond particularly well to these three scenarios. That villagers become significantly more supportive towards a windfarm when it distributes hydrogen to local players is an important finding. Many onshore wind projects are located in less populated areas. Gaining the support of village people maybe not be trivial as efforts to deploy renewable energy installations intensify.

5. Conclusions

Results from this study are striking in two ways. First, they highlight that, under certain conditions, negative attitudes towards local onshore wind projects can be changed into positive attitudes. Hydrogen on its own is insufficient to provoke the switch, but hydrogen *with a local purpose* might. In this experiment, this takes the form of a small but nonetheless important change in attitudes. It seems that citizens have grasped that green energy infrastructures have localized negative externalities despite their globalized positive externalities. For local negative externalities to be better accepted by residents, these should be offset by some benefits. Whilst financial benefits often increase support, it seems that decarbonizing local activities, such as transport and the industry, is also appealing. Citizens are more supportive when there are clear local benefits to an infrastructure which otherwise serves a larger purpose. In other words, local externalities should also be positive. Policymakers would be well-advised to devise renewable energy infrastructures which have locally beneficial purposes and that these are clearly communicated to citizens.

Second, whilst age and educational effects corroborate past research (e.g., Poortinga et al., 2019; Segreto et al., 2020), the urbanization effects provide some novel insights. Indeed, the hydrogen dimension seems to transcend the rural-urban divide. The rural-urban divide structures many attitudes in the climate and energy debate and is especially pronounced on the question of onshore wind as it disproportionally affects rural areas (Bergmann et al., 2008; Phadke, 2013; Rand and Hoen, 2017). It is quite remarkable that adjoining the local distribution of green hydrogen to a wind farm triggers an alliance of village and city people. In the climate and energy debate, these are strange bedfellows. Indeed, many climate and energy policies seem to activate the rural-urban divide and prompt questions of fairness within the citizenry (e.g., Tatham and Peters, 2022). It is noteworthy that local

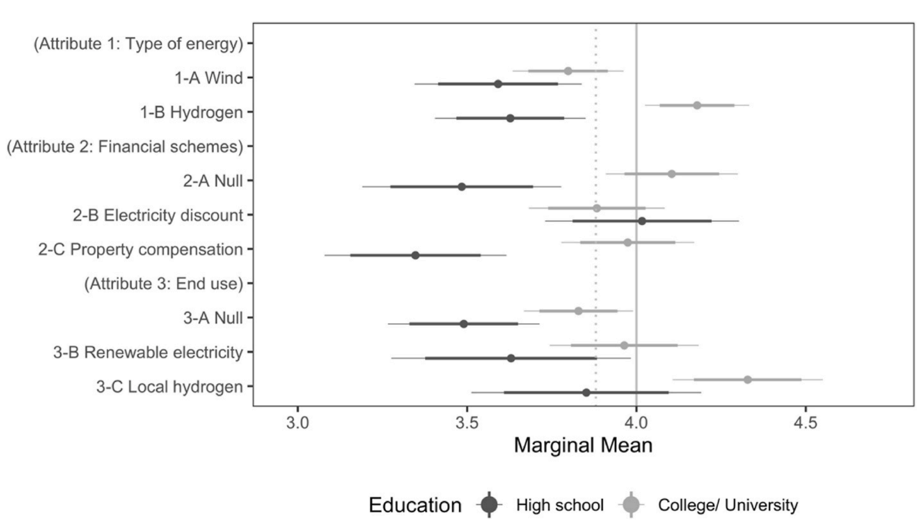

Fig. 7. Marginal means by education-level for building an onshore windfarm in your home municipality.
Notes: marginal means (n = 1828). Dotted vertical grey line corresponds to the grand mean (3.88), solid vertical line corresponds to neutrality (4). Outer confidence intervals are 95% and inner are 84%. A third education category contains respondents with primary education only/no education at all. This category was excluded as it relies on too small a number of unweighted responses to be reliable (i.e. <5%). Colour version in appendix A-11. Table version in appendix A-5. c.

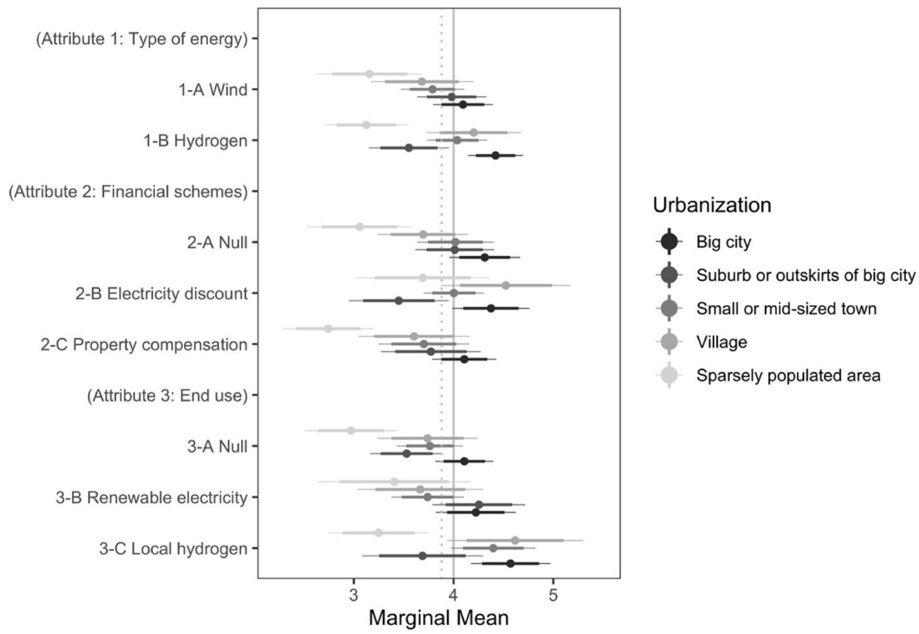

Fig. 8. Marginal means by urbanization levels for building an onshore windfarm in your home municipality.
Notes: marginal means (n = 1639). Dotted vertical grey line corresponds to the grand mean (3.88), solid vertical line corresponds to neutrality (4). Outer confidence intervals are 95% and inner are 84%. Colour version in appendix A-11. Table version in appendix A-5. d.

hydrogen distribution in part deactivates this cleavage on the issue of onshore wind.

We recommend further research in at least two directions. First, whether adjoining hydrogen production can boost support for other types of energy infrastructures such as solar parks or nuclear power plants. This would answer the question of the extent to which these results travel beyond onshore wind. Second, we encourage scholars to study whether other types of locally distributed benefits can also boost support for onshore wind. Past research has already explored the effects various financial schemes. Money certainly matters, but our findings indicate that citizens may also be sensitive to non-monetary forms of local benefits. More research on this would be welcome.

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CRediT authorship contribution statement

Sunniva Petersen Jikiun: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing. **Michaël Tatham:** Conceptualization, Formal analysis, Funding acquisition, Methodology, Project administration, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing. **Velaug Myrseth Oltedal:** Conceptualization, Methodology, Project administration, Supervision, Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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Appendix A. Supplementary data

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