Energy Policy 112 (2018) 305–315

Contents lists available at ScienceDirect

Energy Policy

journal homepage: www.elsevier.com/locate/enpol

Public acceptance of high-voltage power lines: The influence of information provision on undergrounding

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A R T I C L E I N F O

Keywords:
Underground cable
Public acceptance
Grid expansion
Information provision
Energy transition

A B S T R A C T

In Switzerland, the planned transformation of the energy system creates a need for grid expansions. However, grid expansion projects often confront social acceptance issues. The public prefers high-voltage power lines (HVPLs) to be buried underground. Despite the perceived advantages of undergrounding, underground HVPLs can leave visible traces on the surface and are accompanied by electromagnetic field emissions. Given the importance of visual and health impacts on public acceptance of HVPLs, the present study investigates whether providing people with relevant information on these aspects of undergrounding influences people's perception. The results show that, after receiving this information, participants viewed underground HVPLs with lower acceptance, lower perceived benefits, higher perceived risks, and less positive feelings. Although public acceptance remained higher for underground HVPLs compared with overhead HVPLs, our study reveals that information provision reduces perceived differences between the two technologies. Furthermore, our results show that affective reactions to underground HVPLs have an indirect effect on public acceptance. We conclude that providing people with relevant information on possible drawbacks related to undergrounding is a necessary precondition for informed decision-making in the context of grid expansions.

1. Introduction

1.1. Swiss energy strategy

Traditionally, the Swiss energy system has mainly relied on hydroelectric and nuclear power, with over 90% of the country's electricity production stemming from these two sources. However, following the nuclear accident at Fukushima in 2011, Switzerland decided to make fundamental changes to its energy system. As part of the new energy strategy, the government plans to shut down the country's five operational power plants until 2050. The share of the electricity portfolio provided by nuclear power is supposed to be replaced by an increase in renewable energy. These developments – along with other measures, such as increases in energy efficiency – are commonly referred to as the "energy transition" in Switzerland. However, the transition from an energy system that is heavily dependent on a few large-scale nuclear power plants to a more decentralized system based on solar and wind power comes with a number of challenges. For instance, the further promotion of renewable energy sources requires adaptations and expansions of the electricity grid. Not only do the renewables themselves need to be connected to the existing grid, but the fluctuating power production of renewables also requires additional electricity storage sites. These storage sites in turn must be connected to the electricity grid, further increasing the need for high-voltage power line (HVPL) expansion (Swissgrid, 2012).

To overcome these infrastructural challenges, the Swiss Federal Council has formulated a new strategy for the development of the electricity grid (Bundesrat, 2013) and has passed an amendment that aims to optimize administrative proceedings in the context of grid expansion projects (Bundesrat, 2016). However, while the optimization of these proceedings constitutes a necessary step toward shortening the duration of planning processes, grid expansion projects also often confront social acceptance issues (e.g., Battaglini et al., 2012; Cohen et al., 2014; Devine-Wright, 2013; Steinbach, 2013). This often results in public opposition, which can lead to delays in or even the abandonment of projects. Since this poses a serious threat to the successful implementation of the energy transition, it is necessary to take a closer look at the factors influencing public acceptance of transmission lines.

1.2. Public acceptance of overhead high-voltage power lines

Besides the influence of project-related factors such as procedural justice (Keir et al., 2014; Zoellner et al., 2008) or trust in authorities (Bronfman et al., 2012; Devine-Wright, 2013; Siegrist et al., 2012),

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http://dx.doi.org/10.1016/j.enpol.2017.10.025
Received 8 March 2017; Received in revised form 11 October 2017; Accepted 14 October 2017
Available online 05 November 2017

public acceptance of technology infrastructure projects is mainly influenced by people's perceptions of risk and benefit (Bronfman et al., 2012; Huijts et al., 2012) and their affective reactions to the technology in question (Slovic et al., 2004). According to the affect heuristic (e.g., Finucane et al., 2000; Slovic et al., 2007), negative feelings towards a given technology can lead to lower perceived benefit, higher perceived risk, and consequently, lower public acceptance. Affect has also proven to be a relevant factor in the context of HVPL expansions. Lienert et al. (2017), for instance, showed that the presence of overhead HVPLs negatively influences the affective evaluation of landscapes. Furthermore, thinking about HVPLs evokes negative feelings, which is related to a decrease in public acceptance (Lienert et al., 2015).

In addition, several externalities related to HVPLs can negatively influence the perceived benefits and risks of grid expansions (for overviews, see Cain and Nelson, 2013; Furby et al., 1988). Besides noise emissions, effects on property values, and endangerment of local wildlife, two aspects are of special importance: Health concerns due to electromagnetic fields (EMFs) and the negative impact of overhead HVPLs on the landscape.

1.2.1. EMFs

From a scientific point of view, it is widely disputed whether electromagnetic fields caused by HVPLs have a negative effect on human health. While some studies link EMF exposure to an increased risk of childhood leukemia (e.g., Draper et al., 2005; Kheifets et al., 2010), no underlying biological mechanism has been identified that could explain this finding, and no etiological relation between chronic diseases and EMF exposure has been established (Ahlbom et al., 2001). Despite this questionable scientific support, EMF emissions nevertheless play a major role in people's perceptions of HVPLs. A survey conducted in 2010 (Eurobarometer, 2010) showed that 70% of European citizens believed that their health was affected at least to some extend by HVPLs, and almost half were either very concerned or fairly concerned about the potential health risk from EMFs. In line with this, in a qualitative study Elliott and Wadley (2012) showed that EMFs were rated the most severe HVPL-related issue.

1.2.2. Negative impact on landscape

Another important reason for the low public acceptance of HVPLs is their negative influence on landscapes. Tveit et al. (2006), for example, found that HVPLs are characterized by a lack of contextual fit with their surroundings, which leads to a disturbance of the visual quality of the landscapes in which they are sited. This is in line with findings from Batel et al. (2015), who argue that HVPLs are perceived as an intrusion on the landscape, especially in rural surroundings, and from Soini et al. (2011), who determined that residents perceive HVPLs as a negative landscape element. The significance of the visual impact of transmission lines on their surroundings is further underlined by Bertsch et al. (2016). They identified the degree of landscape modification as the most important driver of acceptance of different energy-related technologies, including overhead HVPLs.

1.3. The alternative of underground HVPLs

Given the number of problems related to overhead HVPLs, it does not come as a surprise that there are calls for possible alternatives. One of the main arguments of opponents to grid expansion projects in this context is to bury power lines underground (Akademien der Wissenschaften Schweiz, 2012; Menges and Beyer, 2014). While most lower voltage power lines are already sited underground, the Swiss transmission network (220 kV/380 kV) currently consists exclusively of overhead HVPLs. This situation is comparable with other European countries, where higher voltage underground cables are rarely used (Buijs et al., 2011). This is because transmission network operators are often reluctant to bury HVPLs underground since their installation is highly complex and underground HVPLs are much more expensive than overhead HVPLs (National Grid, 2015; Navrud et al., 2008; Swissgrid, 2017).

However, when it comes to public perception, people seem to favor underground cables to overhead HVPLs (e.g., Menges and Beyer, 2014; von Winterfeldt et al., 2004). In a study conducted in England and Wales, Atkinson et al. (2006) reported that 87% of respondents preferred underground cables to overhead HVPLs. Similarly, Bertsch et al. (2016) stated that underground cables were met with much higher acceptance than overhead lines. This strong preference for undergrounding might be explained by people viewing underground cables as a way to reduce both the visual and the health impacts accompanying HVPLs. Navrud et al. (2008), for example, stated that the avoidance of negative aesthetic impacts constituted a main social benefit of burying power lines. Regarding EMF emissions, von Winterfeldt et al. (2004) found that residents favored undergrounding as a solution to reduce the health effects of HVPLs.

In the face of the perceived advantages of undergrounding and given the fact that both health and visual impacts are among the most important drivers of HVPL acceptance, it is understandable that underground cables are preferred to overhead HVPLs despite the higher costs associated with them. However, there are also some visual and health drawbacks related to undergrounding that people might not be aware of.

1.3.1. EMF emissions caused by underground HVPLs

Just like overhead HVPLs, underground HVPLs create electric and magnetic fields. Nevertheless, due to the special characteristics of cabling, the two technologies have a number of dissimilarities in this regard. While the electric field of underground HVPLs is completely screened out by the cables' insulation, the magnetic field remains unaffected and occurs on the surface. Since the distance between conductors is much smaller in the case of undergrounding as opposed to overhead HVPLs, the magnetic field falls more quickly with distance. This suggests that the magnetic field of overhead transmission lines is stronger than that of underground HVPLs at distances farther from the conductors. However, right above and a few meters to the side of an underground line, the magnetic field is stronger than right below an overhead line (National Grid, 2015; Swissgrid, 2015; von Winterfeldt et al., 2004).

1.3.2. Visual impact of underground HVPLs

Underground cables can replace overhead infrastructure such as pylons and are thus often seen as a means to avoid a negative visual impact on landscapes. However, depending on the circumstances, underground power lines can also come with considerable landscape changes (Bertsch et al., 2016). While the claim that underground HVPLs are invisible on the surface is true in more urban regions where the ground is made out of concrete, this might not be the case in more rural regions. In those areas, trees and other deeply rooted vegetation need to be permanently cut down to prevent their roots from interfering with the cables and causing outages. Hence, especially in forested areas, undergrounding may result in visible surface corridors (ECOFYS, 2008; Swissgrid, 2017).

Another reason why underground lines can come with a considerable visual impact is derived from the fact that they are currently used mainly for shorter distances (e.g., Buijs et al., 2011). This means that, in order to cover longer distances, they are often used in combination with overhead HVPLs. As a result, sealing-end compounds are needed to connect the two technologies. Due to their size, these can also have a considerable impact on the landscape (National Grid, 2015; Swissgrid, 2014, 2017).

1.3.3. Uncertainty related to the perception of underground HVPLs

Despite the fact that underground HVPLs are accompanied by EMF emissions and have a negative impact on the landscape, research on the topic is scarce. Although some empirical studies have tried to assess the perceived benefits of undergrounding by looking at people's willingness to pay for this alternative (Atkinson et al., 2006; Navrud et al., 2008; Tempesta et al., 2014), they have tended to disregard the visual and health impacts of underground cables. For example, in a literature