CHAPTER 1

General introduction
High-voltage power lines (HVPLs) are necessary to transport energy from generation sources to electrical substations more closely located to its users. Because of increasing demand for reliable and renewable energy supplies, new HVPLs are being introduced into the environment [1-3]. In most countries power is generated at remote locations and electricity has to be transmitted over long distances. Overhead lines supported by pylons are generally used for this matter. In spite of their necessity, the construction of new HVPLs can have a negative impact on residents living nearby. Burdens that have been identified include visual intrusion and negative effects on property values and land use [4]. Another important burden is the potential health risk of exposure to extremely low-frequency (ELF) electromagnetic fields (EMF) emitted by HVPLs.

**Health effects of ELF-EMF emitted by power lines**

EMF are emitted by natural (e.g. the sun, the earth) and man-made sources (e.g. HVPLs, mobile phone base stations). When it comes to the assessment of health effects of exposure to EMF, it is important to make a distinction between ionizing high-frequency EMF and non-ionizing low-frequency EMF (see Figure 1). Ionizing EMF, like X-rays, have the ability to break bonds between molecules and are considered carcinogenic [5]. Lower-frequency EMF, like the ones emitted by mobile phones and HVPLs, do not have the ability to break bonds of molecules. As a consequence, there is no direct plausible mechanism for these lower-frequency EMF to cause cancer [6,7].

Despite the lack of a plausible biophysical mechanism for ELF-EMF of HVPLs to cause health effects, pooled analyses of epidemiological studies indicate a small association with childhood leukemia and exposure to magnetic fields from HVPLs [8-10]. In addition, single studies have reported associations between proximity to power lines and Alzheimer's disease [11], and non-specific health complaints such as headaches [12]. The interpretation of these findings differs between experts [13]. Some interpret the scientific evidence as very weak [14], while others believe there is at least some reason for concern based on the association between ELF-EMF from HVPLs and childhood leukemia [7,15]. The International Agency for Research on Cancer (IARC) has classified magnetic fields from HVPLs as 'possibly carcinogenic' [16].

The health risks of perceived exposure to an uncertain risk

Besides the uncertain effects of exposure to an environmental risk on health, the perception of being exposed to an uncertain health risk can cause health effects in itself [17-20]. In the medical field, an increase in reported health complaints after an inert treatment is called a nocebo response [21,22]. Such a response is often seen in clinical trials when patients in the placebo condition report side effects of their medication, while they were in fact only getting a treatment without active ingredients [23,24]. It is believed that these effects occur when patients have negative health expectations of a treatment [25].

A similar kind of process may operate when one perceives to be exposed to a potentially hazardous environmental agent, such as ELF-EMF from HVPLs. Previous research has shown that between 1.5% to 13.4% of the general population report to
Figure 1. Full spectrum of electromagnetic fields (source: Kennisplatform Elektromagnetische Velden en Gezondheid).
suffer from electromagnetic hypersensitivity and attribute non-specific health complaints, such as headaches and concentration problems, to EMF from various sources (e.g. mobile phones, power lines) [26]. Although their health complaints may be associated with serious functional impairments [27,28], experimental double-blind provocation studies demonstrate that exposure to EMF does not trigger symptoms in these self-diagnosed patients under controlled laboratory conditions [29]. It has, therefore, been suggested that nocebo mechanisms might explain health responses to equipment emitting EMF [30,31].

Risk governance of new power lines
Although the evidence for health effects of ELF-EMF exposure is limited, the majority of the European population believes power lines affect their health to at least some extent [32]. Residents associate an uncomfortable feeling with power lines [33] and are concerned about the health effects of exposure to ELF-EMF [34-37]. These concerns play a role in opposition of residents against new power lines [38] and local opposition is an important reason for difficulties in siting new lines [39]. Governments struggle with how to deal with residents’ health concerns when planning new HVPLs and policies regarding ELF-EMF exposure of power lines differ between countries.

The Dutch situation
In the Netherlands, a large infrastructural operation is currently being carried out which will result in 350 kilometers of new overhead HVPLs in the near future. The Dutch government applies the precautionary principle when new HVPLs are planned to be built. New pylons to carry the transmission lines were designed in such a way that the magnetic field zone is reduced (see Figure 2). Planners need to avoid that households or other ‘sensitive’ locations (i.e. schools or day care facilities) are exposed to an average magnetic field strength higher than 0.4 µT (generally < 55 meters from the heart of the line), which is suggested as a cut-off value for a higher relative risk of childhood leukemia [9]. If for some households this cannot be achieved, residents receive an offer to sell their home to the government.

Need for prospective field studies
The introduction of new HVPLs in the Netherlands provides the unique opportunity to study the effects on residents’ health perceptions under natural conditions. Laboratory studies have suggested that nocebo responses occur when people believe they are exposed to EMF from wireless technologies [40,41], but these results may not apply to EMF exposures outside of the laboratory, where people are exposed to other stressors that might harm their health as well. However, some cross-sectional field studies have also indicated that nocebo responses may occur with EMF emitting equipment such as mobile phone base stations [30], or power lines [35]. The lack of a pre-exposure measurement makes it, however, difficult to interpret these findings. A prospective field study would allow to better capture the dynamics and focus on changes in people’s perceptions over time, instead of only relying on reports of residents after a HVPL is already installed. This is why researchers have called for
more prospective studies into responses to uncertain environmental health risks [42-44]. The main aim of this thesis was therefore to investigate the effects of a new HVPL on health perceptions of nearby residents in a prospective manner. In addition, we aimed to study the psychosocial mechanisms operating during the introduction of a new HVPL, which might lead to the development of health complaints.

AIMS AND OUTLINE THESIS

All chapters in this thesis, except Chapter 7, describe the results of a quasi-experimental prospective field study into health responses to the introduction of a new overhead HVPL in the Netherlands. In Chapter 2 we describe the design and rationale of this study. We present a conceptual framework outlining the most important factors that we hypothesize to play a role in explaining health responses to power lines and describe the questionnaires we used to measure these concepts.

In Chapter 3 we focus on the question whether symptom reports increase after the introduction of a new HVPL. In addition, we investigate whether the belief that these symptoms were caused by a power line changed after the new line was put into operation. If nocebo mechanisms would play a role in responses to a new HVPL, one would expect symptoms and causal beliefs to increase after a new HVPL is put into operation. Previous cross-sectional studies on the relationship between power line proximity and health perceptions of nearby residents found mixed results. One study reported a small effect on reporting headaches [12], and two other studies did not find a relationship between proximity and symptom reports [35,45]. In this chapter we present the results of the first prospective investigation of the relationship between proximity to a new HVPL and residents’ health perceptions.
In **Chapter 4** we look closer at perceived somatic health complaints of residents living close to a newly introduced HVPL. We assessed the feasibility of a multi-dimensional bi-factor approach to the analysis of somatic symptom reports in the general population. Such an approach has the potential advantage of distinguishing between effects on general somatic symptom reporting and effects on the reporting of specific symptoms (e.g. gastrointestinal or musculoskeletal complaints). We re-analyzed the effect of the introduction of a new HVPL on somatic symptom reports as reported in Chapter 3, but now in line with a bi-factor model. We report a comparison of the results and discuss the findings in the broader context of symptom report assessments after exposure to an uncertain environmental health risk.

In **Chapter 5** we investigate the mechanisms through which symptom reports may increase after a new HVPL is put into operation, and followed up on our results described in Chapter 3. We studied whether nocebo mechanisms were operating during the introduction of a new HVPL through application of longitudinal mediation analysis (see [46]). If an increase in reported symptoms after the introduction of a new HVPL is mediated by beliefs about the negative health effects of power lines, this is an indication that nocebo mechanisms are operating.

In chapters 2 to 5, we focused on nearby residents as a potential group at risk to develop health responses to the introduction of a new HVPL. However, it might be the case that subgroups of nearby residents respond in different ways to the introduction of a new HVPL in their vicinity. This would have important implications for research and practice. In **Chapter 6** we try to identify different health response patterns and explore whether we can distinguish between these patterns on the basis of residents' personal characteristics (e.g. socio-demographics, personality, perceived health). We provide a typology of residents' health responses on the basis of these individual characteristics to generate new hypotheses for future research and inform policy-makers involved in risk governance.

The chapters 2 to 6 describe the health responses of residents *after* construction of a new HVPL in their vicinity. However, residents are also affected *before* the construction of a new HVPL. Before the construction can start, a long period of planning precedes the decision where a new HVPL is planned to be built. It has been suggested that communications during this planning process between local residents and other parties (e.g. policy-makers, developers, media, neighbors, pressure groups) play an important role in how residents respond to the introduction of a new HVPL [2,38,47]. This process has, however, rarely been empirically studied. In **Chapter 7** we present the results of a qualitative study where we interviewed residents about their experiences with the planned introduction of a new HVPL near their homes. We let residents reflect on the planning process and identify dominant themes in their experiences and explore how communication with other parties played a role in these themes. Based on these findings we provide concrete suggestions to improve the planning process of new HVPLs, which might potentially contribute to reducing health responses after the construction of a new HVPL.

In the final chapter (**Chapter 8**), we summarize and discuss the main findings presented in this thesis and provide recommendations for future research and risk management practices.
REFERENCES


