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THEATRICAL TECHNOLOGY ASSESSMENT : A ROLE-PLAY SIMULATION FOR BRIDGING THE GAP BETWEEN TECHNOLOGY AND SOCIETY IN INTERDISCIPLINARY ENGINEERING EDUCATION

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Theatrical Technology Assessment: A Role-play Simulation for Bridging the Gap between Technology and Society in Interdisciplinary Engineering Education

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ABSTRACT

Grand societal challenges ask for the education of engineers who can develop new technologies for and with society. To make a difference, engineers do not only need to learn about technology, but also about how they can productively incorporate stakeholders' viewpoints and societal dynamics in their design processes. In practice, it proves difficult for engineering students to learn how to bring technology and society together. Especially when it concerns newly emerging technologies, which bear great promises but are also characterized by much uncertainty and ambiguity, it is often hard for students to imagine lines of action that go beyond linear implementation plans that hubristically push new technologies through society. This working paper presents a novel educational method – Theatrical Technology Assessment (TTA) – which combines insights from Constructive Technology Assessment and improvisational theater in a role-play simulation that enables engineering students to explore the socio-technical dynamics around emerging technologies, and to obtain insights about these dynamics and the role of different stakeholders, which they can incorporate in their designs and innovation processes.

We developed and tested this method in a pilot with students of an honours bachelor programme in Technology and Liberal Arts & Sciences at the University of Twente, in the context of a semester project on emerging energy technologies. Students were involved as players of the role-play simulation, but also as co-designers and role-instructors. In the design of the roleplay simulation, we paid special attention to the selection and internalization and of the roles, to the tasks and roles of the teachers as moderators and process supervisors, to the involvement of students, to the balancing of fact and fiction, and to the use of conceptual frames to make sense of the emerging dynamics.

This pilot study corroborates that a role-play simulation can be a powerful means for students to learn about the complexity of societal interactions around emerging technologies. The results indicate that students learn about differences in stakeholder perspectives to new technologies and ways to anticipate or transcend these, about patterns in socio-technical dynamics, and in some case about their own identity as an engineer. These insights are relevant for students' understanding of socio-technical dynamics, but also for their development into engineers who can deal with complex and uncertain interdisciplinary challenges.

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1. INTRODUCTION

To cope with grand societal challenges, such as the transition to cleaner energy production, the anticipation of climate change, or the cleaning of the oceans, an effort across disciplinary and societal borders is required, involving engineers, scientists, governments, companies, citizens, and others. Engineers can contribute by developing new technologies that help to mitigate these challenges, but to have a positive impact on society they have to collaborate beyond the borders of their discipline. Yet, interdisciplinary collaboration is challenging, particularly due to the often mono-disciplinary education of engineers and other professionals (Fischer et al., 2011) and the variety in interests, values and practices between different actors. Especially the gap between engineering and society appears hard to bridge (Borrego & Newswander, 2008). Several engineering programmes in higher education have taken up this challenge (Goldberg & Somerville, 2014; Bucciarelli & Drew, 2015), by offering courses related to business and society, or by enriching their curriculum with interdisciplinary projects, in which engineering students engage with students of social science disciplines and societal partners to address complex problems (Stephens et al, 2008).

Such courses and projects are meant to provide engineering students with an understanding of the socio-technical nature of grand (and smaller) challenges and insights into how they, from their discipline, can successfully contribute to coping with these challenges and have an impact on society. This is an educational challenge (Grasso & Burkins, 2010). Especially reaching the more advanced levels of interdisciplinary learning, related to the creation of solutions that transcend specific technical and social disciplines, and to the development of a critical understanding of the role of an engineer (Boix Mansilla, 2016), is difficult. Understanding the complex relation between technology and society, and incorporating this in solutions and processes that take both societal and technological opportunities and limitations seriously, is hard. This becomes prominently visible in education on 'emerging technologies', technologies that bear a promise of contributing to the mitigation of grand challenges, but are in an early phase of development and inherently uncertain and ambiguous (Bowman et al., 2017). In projects and assignments related to these emerging technologies, engineering students often tend to deal with complexity by bracketing the societal dynamics, acting as 'technocratic modernists' who push new technologies through society with technological roadmaps, 'tell & sell' implementation plans, and marketing campaigns. For instance, students working on emerging technologies such as thorium reactors, hyperloops, or high altitude wind-turbines, understand that there are technological uncertainties, legal issues, public concerns, and competitive dynamics in play, but they tend to frame these as problems to be solved by more research and development, and resistance to be overcome by lobbying and better explaining the technology and its benefits to the people. The future then becomes a straight line of technological success and societal acceptance. For programmes with ambitions to educate engineers who can effectively cope with societal complexities and have an impact on the mitigation of grand challenges through new technologies, this is not satisfactory (cf. Byrne & Mallally, 2014).

In this working paper, we present a novel educational method – a role-play simulation named Theatrical Technology Assessment (TTA) – which aims to enable engineering students to explore and anticipate the socio-technical dynamics of emerging technologies, and to find ways to integrate their insights in nuanced innovation plans. This role-play simulation is developed with a Teaching Fellow grant of the Comenius programme of the Netherlands Initiative for Education Research (*NRO*). Conceptually, the role-play is rooted in Constructive Technology Assessment (CTA), a method aiming to assess and steer technological developments in society (Rip et al, 1995). CTA enables learning of real-world stakeholders from different disciplinary and societal perspectives around emerging technologies, and creates opportunities to steer and anticipate the development of new technologies and their embedding in society (Te Kulve, 2011). Using techniques from improvisational theater, we mimic and extend Constructive Technology Assessment in a role-play simulation that can be used in interdisciplinary engineering education.

In this working paper, we describe, explain and reflect upon our first experiences with this novel educational method. We will first describe the background of Theatrical Technology Assessment and the development of the role-play simulation. Subsequently we will describe the pilot we conducted in a project on sustainable energy technologies with teachers and students of a bachelor's programme in Technology and Liberal Arts & Sciences. Details on the content and protocol of the role-play simulation will be provided. After that, we will present and discuss the results of the pilot, both regarding student learning and the workshop design. The paper will end with conclusions, limitations, and directions for further research and development.

2. THEATRICAL TECHNOLOGY ASSESSMENT

2.1. CTA Background

Theatrical Technology Assessment has its conceptual roots in Constructive Technology Assessment. CTA was developed in the last decades of the 20th century as a method for the prospective and reflexive steering of the development of emerging technologies (Rip et al, 1995; Rip & Robinson, 2013; Rip, 2018). Where traditional approaches of Technology Assessment focus on predicting and evaluating the impact of novel technologies on society, CTA aims to foster anticipatory learning among stakeholders in an early phase of the development, when options for steering are still open yet uncertainty and ambiguity prevails (Collingridge, 1980). The approach has been applied in a variety of studies related to, for instance, electric vehicles (Hoogma, 2000), nanotechnology (Parandian, 2012), sensor technology (Te Kulve & Konrad, 2017), battery technology (Versteeg et al, 2017) and knowledge-intensive climate services (Visscher et al., forthcoming). The basic idea is to bring relevant actors together and to introduce scenarios based on an in-depth analysis of the technology and its societal context, in order to facilitate anticipatory learning (Rip et al, 1995; Rip & Te Kulve, 2008). These scenarios are 'endogenous futures', stemming from an analysis of the state-of-the-art and current dilemmas in the field. They are not utopian or dystopian sketches of far-away futures, but plausible stories of relatively nearby developments, including viewpoints of different actors, systemic factors, and important tensions. Stakeholder interaction in CTA normally takes place in workshops, which are designed as 'micro-cosmoses', condensed representations of the stakeholder field. These workshops are 'bridging events' between 'enactors' and 'selectors' (Garud and Ahlstrom, 1997). Enactors are the promoters of a new technology, such as engineers, scientists and entrepreneurs, who consider the development of the technology as progress, often identify with the product, and think of opposition in terms of barriers to overcome (Rip & Te Kulve, 2008). Selectors, such as consumers, regulatory agencies and big companies, have a broader scope and evaluate various technological options in comparison. By staging constructive confrontation between enactors and user organizations, regulators, and other stakeholders, CTA reduces the costs of 'trial & error' learning. It provides scientists, engineers and entrepreneurs with a basis to develop integrated plans for the societal embedding of their technologies, and gives other stakeholders the opportunity to prepare for future developments and to steer technology in a desirable direction in an early stage.

In educational settings, one cannot simply copy CTA formats. These workshops are carried out in real life settings with experts and other participants with an actual stake in an emerging technology. Students are not (yet) really involved in the development of a new technology. The emphasis in the learning processes is also different. With practitioners, learning focuses on anticipation of future dynamics and reduction of trial-and-error in innovation efforts (Parandian, 2012). In educational settings, learning focuses on understanding and the development of competencies to deal with new technologies in complex and uncertain situations. Besides, CTA workshops are costly and labor-intensive events, tailored to specific technologies and groups of participants, while in educational settings, the format should be reusable and useful for student groups with diverse interests.

2.2. Role-play Simulation

To facilitate engineering students to learn about the socio-technical dynamics of emerging technologies, we developed a role-play simulation in which a CTA workshop is being mimicked. Role-play simulations are powerful means for students to learn about the complexity of technical and societal decision making (Mayer, 2009; Rao & Stupans, 2012; Doorn & Kroesen, 2013; Rumore et al, 2016). They enable students to experience stakeholder positions from the inside, learn to face conflicts with other stakeholders, and explore options for bridging the gaps between different positions and disciplines. A role-play can stage ‘constructive controversies’ (Tjosvold, 2008) around alternative interests, problem diagnoses and solutions, and enable students to transcend these differences. To make the role-play simulation into an authentic CTA-like learning experience, students need freedom to act in line with their stakeholder role, while a clear structure is needed to allow relevant and realistic stakeholder dynamics to arise (Duchatelet et al, 2019). It is important to include a variety of stakeholder positions. Just like in real CTA workshops, enactors as well as selectors (Garud and Ahlstrom, 1997) should be present, preferably covering academia, industry, government and civil society, the so-called quadruple helix (Carayannis & Campbell, 2009).

Because students are not really stakeholders, but play them, the risk is that they only play on the basis of their assumptions and conjectures about stakeholder behavior and opinions, which may result in interactions that have little resemblance with the world outside the classroom. Each role-play simulation needs a certain verisimilitude (Duchatelet et al, 2019). Therefore, role descriptions are required, based on research of the field, which stipulate the main goals that stakeholders want to accomplish, their position in society, and the criteria with which they assess new technologies. Besides, sufficient knowledge of the state-of-affairs of the emerging technology and society should be made available and enacted in the role-play to make it realistic.

2.3 Improvisational Theater

To make the role-play simulation into an engaging learning experience, we enriched it with techniques from improvisational theater. Improvisational theater is characterized by ‘yes-anding’, which means that players accept each other’s actions in the play as ‘real’ and build on that, resulting in quick interactions, path-dependency, and opportunities for path creation (Van Bilsen et al, 2013). Adding improvisational theater to the role-play simulation can make students more confident in their roles and the interactions quicker and more interesting. Improvisational theater allows for experimentation and adds to the dynamism and outcome variability of the simulation. It also opens up opportunities that are not possible in real CTA workshops, like making a jump into the future, or changing the political context. Rather than trying to become 'almost real life' (Rao & Stupans, 2012), the theatrical setting surpasses reality and gets characteristics of a 'hyperreality' (Wagenaar, 2008; Van Bilsen, 2010). CTA workshops, which are already considered 'microcosmoses', are further 'condensed' and 'amplified'. The condensation means that interactions between stakeholders are played out in a limited amount of time, the amplification implies that tensions between positions become visible more clearly. The freedom to play with time, stakeholder constellations and alternative futures makes it possible to explore different scenarios. As we added improvisational theater to the CTA role-play simulation, we named it Theatrical Technology Assessment (TTA).

What adds to the theatrical experience is that a TTA simulation is played out in front of an audience. In a real CTA workshop, the participants' interactions are often observed by an analyst, for instance as part of PhD research, who articulates insights about the dynamics among stakeholders. In TTA, fellow students, teachers, and potentially external stakeholders observe the interactions in the role-play and form their opinions and ideas. They do this more from a distance than the students who are involved as a specific stakeholder. Bringing players and observers together contributes to the articulation of learning points.

3. PILOT STUDY

To test and develop this method, a pilot was carried out within the context of a semester project within the Technology and Liberal Arts & Sciences bachelor programme (ATLAS) at the University College Twente, which is part of the University of Twente. This programme is a young and ambitious honours programme, aiming to educate 'new engineers' (Goldberg & Somerville, 2014): Engineers who combine technology and social science to analyze complex societal problems and design solutions for a range of contexts (Wits et al., 2014). Interdisciplinary learning is an important element of all Liberal Arts & Sciences programmes (Rhoten et al., 2006), while the emphasis on connecting technology and society is typical for the ATLAS programme. Further characteristics of the programme are the emphasis on self-directed learning, the absence of grades, an assessment as learning approach (cf. Dochy et al, 2018), and the central place of large, open-ended projects in the curriculum. The college employs teachers from a variety of engineering and social science disciplines, and aims to be a hotbed of educational innovation within the university.

3.1. Context: Project on Sustainable Energy Technologies

The project in the second semester of the first year of ATLAS focuses on emerging technologies that bear a promise of contributing to the transition towards a more sustainable energy system. These technologies can be related to the production, storage, and use of sustainable energy. Students explore different disciplinary and societal perspectives related to an emerging technology of their choice and integrate perspectives in (long-term) socio-technical scenarios, built upon an analysis of the current state-of-the-art. Furthermore, they design concrete (short-term) plans for advancing the new technology in a specific region or locality, and critically reflect on how these plans affect and are affected by different stakeholder groups, which negative or unintended consequences may arise, and how one can anticipate these.

In this project, students learn to deal with complex socio-technical problems related to sustainability in an interdisciplinary way. Concretely, the project has the following learning goals. After completing this project, students will be able to:

- Analyze socio-technical systems and emerging technologies from relevant societal perspectives and disciplines.
- Integrate societal perspectives and disciplinary knowledge in the designs of long-term scenarios and short-term plans to innovate the socio-technical system.
- Critically reflect on societal perspectives, disciplinary knowledge, and integrated socio-technical designs.

The project consists of different stages. Students start with an orientation to energy technologies. They explore emerging technologies, form groups (of about 8 students), and choose a technology on which they wish to work in this project. In the group, they make an analysis of the technology and the socio-technical system in which it is embedded, in order to assess the state of the art, recognize opportunities, expectations and bottlenecks, and to identify relevant disciplines and stakeholders. Subsequently, they study in pairs a certain aspect of the technology development from a specific stakeholder perspective. For this they carry out desk research and (when possible) interviews. After that, students construct two alternative socio-technical scenarios for the development of the technology, using a method based on Hofman and Elzen (2010). They identify important dimensions, tensions, and 'forks in the road' regarding the future development of the technology. After that, the Theatrical Technology Assessment role-play simulations take place, to help students further investigate stakeholder dynamics, to make an argued choice for one scenario based on arguments for or against their two alternatives, and to create a ground for the design of implementation plans. In the concluding phase of the project, students write an encompassing report about their scenario, including a concrete action plan for developing and embedding the emerging technology in coming 5 to 10 years.

In total this 9 EC project lasts 18 weeks. To support the project work, workshops are organized – on socio-technical scenario building, CTA, improvisational theater, interview techniques – and inspiring lectures are given related to the energy system. For guidance and feedback on deliverables, student groups have a pair of tutors, one with a engineering background and one with a social science background. Peer feedback is organized in the form of plenary presentation sessions and a world café. The project concludes with an intensive assessment session and an outreach session, in which students present a poster to other students and staff.

3.2. Design Process

For the development of the TTA role-play simulation in the context of this semester project, a grant was received from the Comenius Programme of the Netherlands Initiative for Education Research (NRO). Awarded was a Teaching Fellowship, which aims at relatively small-scale educational innovations. For the design process we took a pragmatic approach (Visscher-Voerman & Gustafson, 2004), which involves going through multiple cycles of reflection-in-action in the virtual world and the real world (Schön, 1987; Visscher & Fisscher, 2009) to create a working design. In such an approach, form and function of the design co-evolve. The form of the TTA role-play was designed by the receivers of the grant, together with a consultant on improvisational theater, and using input and feedback of four teachers and three students involved in the ATLAS programme. The process consisted of a series of small group discussions, over the period of months, about the function of the workshops in the semester project and the opportunities for mimicking CTA and using improvisational theater, followed by a co-creation session in April 2019. In this session, teachers, students, and the consultant created the general set-up of the simulation. This format was finetuned and elaborated (including instructions for students) in three consecutive rounds, based on feedback of students and teachers. In May 2019, five workshops were carried out in the course of two days. The workshops were audio-recorded. After the first, second, and fourth workshop, the teachers and the improvisation consultant reflected on the flow, content and outcomes of the sessions, and minor adjustments were made. The week after the workshop, the students submitted short reports, reflecting on their learning points.

To evaluate this pilot, we analyzed the reflections and learning points articulated by teachers and students. We also analyzed the recordings, to corroborate and substantiate the reflections, and to identify further learning points. This analysis was aimed at evaluating whether the role-plays increased students' understanding of the socio-technical dynamics around emerging technologies, and provided them with insights they could use to develop plans that integrate or transcend stakeholder perspectives. Moreover, we identified success factors and improvement points in the workshop format and the way it was implemented. To evaluate whether the learning of this workshop 'sticked', we also analyzed the assessment of the scenarios and plans produced in the final report of this semester project. This evaluation of the pilot had a developmental purpose: establishing which learning outcomes are possible with this role-play and identifying points for further improvement.

3.3 Role-play Simulation Design

The basic idea of this role-play simulation is that the process and context is pre-structured by the teachers, but that the content is provided by a group of students. They decide which stakeholders will be in the role-play and which issues will be on the table. They make instructions for the players, articulate their questions, and observe the role-play. We will call this group the 'instructor/observers'. The simulation will be carried out by another group of students, the 'players'. There are also two teachers involved. One teacher is inside the role-play simulation as 'moderator', facilitating and steering the discussions. During the role-play, this teacher is the linking pin between the instructor/observers (with their questions) and the players. Another teacher supervises the overall process, starting and stopping the simulation, and leading the instructions before and the reflective sessions after the role-play.

The role-play simulation consists of two rounds of playing, one in which a CTA workshop is being mimicked (with room for divergence of opinions regarding the emerging technology and for tentative conclusions) and one which is a pressure-cooker (aiming for convergence and direct action). Both playing rounds are preceded by a preparation phase and followed by a reflection and debriefing (cf. Joyner & Young, 2006; Croockall, 2010; Duchatelet et al, 2019). A theatrical rehearsal phase is added to enhance the quality of the role-playing. In more detail, the different phases of the role-play simulation look as follows:

Preparation (15 min): As input for the role-play, students of the instructor/observer group have written a short introduction to their technology, and have made an overview of the roles they want to be played, stipulating the formal position, the main goals that their stakeholders want to accomplish, and the main criteria with which these evaluate emerging technologies. This overview has been shared with the teachers the day before, and with the players at the start of the workshop. While the players prepare and absorb the information relevant for their role, the teachers discuss with the instructing/observing group about the main tensions and issues, and their main questions regarding stakeholder dynamics. A list of questions had already been sent to the teachers day before. The teacher playing the role of moderator makes a list of attention points for the simulation.

Role rehearsal (15 min). The roles are divided among the players, who are individually instructed by students of the other group. They receive additional information on the core values their stakeholders cherish, and on what triggers their enthusiasm or stubbornness in interaction with others. The players do not know this of each other. Also body language and attitude (e.g., dominant, shy, worried, activist) are transferred, by 'showing' rather than 'telling'. This helps players to make a persona out of their roles. They also choose a name they will use during the role-play. When the players are acquainted with their persona, they introduce themselves to the other players.

Session 1: CTA workshop (20 min). The setting is a CTA workshop. Players sit around a table, with their nameplates in front of them. To set the stage, the workshop moderator uses standard opening sentences, which explain the aims and the set-up of the workshop, acknowledge the uncertainties related to the emerging technology, and stress the need for mutual learning, reflection and (possibly) steering by a heterogeneous group of stakeholders in an early stage. "*This emerging technology is in an early stage of development. It bears great promises for making the energy production more sustainable, but has also potential risks. There are still many uncertainties, bottlenecks and possible roads to take, but if we wait till all is clear we are too late to steer. As society, we need to find ways to deal with this new technology, thus the minister (or European commissioner) has asked us to organize this workshop. I am very happy that you are here, representing A, B and C. You normally do not meet each other, but you are all important stakeholders for this technology, so it great to have you around one table. We have two sessions today. In this first session we would like to learn more about your views about this new technology, what you think is promising or risky, in the short run and the long run, and where your preferences lie. It also gives you the opportunity to learn from each other*". After an introductory round, experts (i.e., students from the observing group) are invited to pitch alternative scenarios. What follows is a moderated discussion of pros and cons, problems, opportunities, and preferences from different stakeholder perspectives. Participants can question each other, learn from each other, and explore options for aligning actions. The moderator safeguards attention for the main questions of the instructing/observing group and for tensions in the alternative scenarios. When no new standpoints or arguments come up, and saturation is reached, the discussion is closed by the supervising teacher.

First reflection (10 min). Players, instructor/observers and teachers discuss about the first session. What did you see happen? What are learning points regarding scenarios and stakeholder dynamics? Have the questions of the observing group been answered? Which new questions pop up?

Coffee break & Preparation session 2 (15 min): The players take a break, while the teachers discuss with the observing group which issues they wish to focus on in the second session, given their newly gained insights, and the questions they want to be answered. The setting is changed accordingly (e.g., by making a time-lapse of 5 or 10 years, changing the stakeholder constellation by letting someone retire or change jobs, or adding facts such as a failed or successful pilot project with the technology).

Session 2: Pressure cooker (15 min). This second session goes beyond what is normally done in a CTA workshop. The players are asked to converge and delineate a concrete plan on a short notice, for instance in terms of an investment scheme, implementation plan, design, etc.. The players are welcomed again by the moderator and notified of the changed circumstances (e.g., we are two years further, you are still in your position, but the pilot you proposed last time has not led to the results you hoped for). Then the aim of meeting is stated: "*Last time we openly discussed scenarios and explored options, but now it is time to act. The minister has requested you to do something, and preferably not alone, but with each other. I do not know whether consensus and concerted action is possible here. Will you agree on a desirable future for this technology and how to get there, or will you end up in adversarial positions. An important and difficult question, and the minister wants an answer in 15 minutes*". The moderator then leaves the table and joins the observers. The difficult challenge, time-pressure, emphasis on collaboration, and absence of the moderator create a setting in which players experience more freedom to play and the pace and creativity of the interactions is enhanced, leading to less predictable processes and outcomes. Participants may choose to take the lead, form coalitions, use power play, introduce (alternative) facts, commit themselves, leave the room, etc. Only if the process bogs down, the moderator might enter to add complexity, or stir the discussion. The session ends when the moderator comes back in, and the group presents its outcome.

Second reflection (15 min): Players, observers and teachers discuss to articulate learning points regarding socio-technical scenarios, stakeholder dynamics, alignments of interests, ways to solve tensions, plans of action, and the main questions of the project group. Players may also give a personal reflection on how they experienced their role. The session concludes with general reflections regarding interrelations between technology and society, and the possibilities to integrate perspectives.

A full role-play simulation takes about 1 hour 45 minutes. In this pilot, we play five TTA role-plays with five different technologies. Table 1 provides an overview, indicating the emerging technologies of the project groups, the stakeholder roles, and the issues to be discussed.

Technology	**Stakeholder roles**	**Issues for discussion**
Molten Salt Reactor	Political leaders of liberal and Christian-conservative party; Leader of an NGO (Greenpeace); Inhabitant of a town with a nuclear reactor; CEO and engineer of a company that produces reactors; CEO of a green energy provider; Energy researcher at a university.	Technically/economically optimal solution vs compromise acceptable for society. Full energy supply with MSR vs using a variety of sources Centralized vs decentralized energy system
Space Solar Power Systems	Project leader of US university research programme into SSPS; Project leader of a Japanese industrial research programme into SSPS; Environmental activist; Political leaders of the US and Japan; Investors.	Strict control vs loose regulation National vs international control Protests for riskier options vs general acceptance of safer options
Piezoelectric roads	CEO of a large energy provider; CEO of a smaller, green energy provider; Aldermen of a municipality, responsible for sustainability and mobility resp;	Efficiency piezo vs wind/solar vs grey energy sources Local vs national implementation Public vs private funding

	Representative of a national association of car owners.	Promotional gadget vs economically viable energy source
AI Grids	CEO of a grid operator; CEO of an energy provider; Minister of Economic Affairs and Climate Policy; CEO of a large software developing company; CEO of a hospital; Head of a household (with solar panels)	Public costs vs private profits Privacy vs accuracy of the AI Strict control vs loose regulation
Solar updraft tower in arcology systems	CEO of an energy company; CEO and employee of a construction company; Two potential inhabitants (a recent graduate and a single mom)	Short-term investments vs long-term profits Updraft vs other (green) energy sources Self-sufficiency vs connection to other grids

Table 1: Overview TTA role-plays

4. STUDENT LEARNING

To analyze student learning we draw on what students reported orally during the reflection, and in writing in the assignment. This is complemented with data from the assessment of the semester project. Learning points differed between the instructor/observers (i.e., the project group that had prepared the scenarios and the stakeholder roles for the technology of their project and instructed the players) and the players.

4.1. Instructor/observers

The instructor/observers, who had worked on the technology in their semester project for already three months, came in with specific questions and expectations about the dynamics they would observe. They wanted to know, for instance, whether and with which arguments an activist member of an NGO could be convinced, or whether stakeholders with opposite viewpoints would converge towards a large-scale or small-scale implementation of an energy source. These specific questions were not known by the players, but the moderator used them to steer the discussion, for instance by highlighting the activist’s arguments or inviting opposing parties to search for consensus. The workshop interactions often matched with the observers’ expectations, thus corroborating the research they had done before. But the groups also reported new findings they could use for the development of their scenarios and plans. These were partly related to the influence of a certain stakeholder or the attention for a certain issue being bigger or smaller than expected. One observant group realized, for example, that companies can be made more open to arguments related to health and safety of employees and clients than expected, while another found out that the decision-making in the end focused on costs and return on investment, to which aspect they had not yet paid much attention.

Other new insights stemmed from the creative processes in the workshop: Some players came up with political compromises or plans to act upon critical stakeholders, others proposed new technological solutions to deal with societal concerns. For instance, the play on AI grids suggested that privacy could be solved by collecting data per block rather than individually and by making the government owner of the data rather than the companies. The solar updraft tower players proposed a smaller arcology design, which is technologically and economically not optimal, but is better able to deal with societal concerns regarding health and safety and gives potential users opportunities to try it out.

Particularly interesting were the new insights that were articulated related to the non-linear pathway of the emerging technologies. This was clearly the case in the piezoelectric roads workshop, where stakeholder dynamics and the time-lapse showed the working of a 'hype cycle' or 'wow-yuck pattern' (Rip, 2006). Because of the high expectations raised by the promoters of this technology in the first round of the role-play, all parties joined a pilot enthusiastically (wow), but when the results were less than expected in the second round of the role-play, most stakeholders were disappointed (yuck) and abandoned the technology instantly. The group reports this was something they had not thought of before, and responded by taking more time for pilots and urging the enactors of this technology to be more modest in their communication strategies. Also in the molten salt reactor workshop, new insights about the socio-technical dynamics emerged. Triggered by critique that this nuclear energy source is not fully renewable, stakeholders found each other in the framing that molten salt can serve as a temporary stepping stone towards really sustainable energy production such as wind and solar, and they decided to build one. In the pressure cooker session, students played out a situation ten years later in which the technology was successfully implemented, but in which wind and solar also conquered a large part of the energy market. Somewhat to the surprise of the observing group, the stakeholders almost collectively abandoned the technology. They realized that the successful diffusion of molten salt reactors did not so much depend on the success of their own technology, but on that of competing, fully renewable technologies. This was an eye opener.

It must be added that not all novel insights were considered useful by the observers. In the Space Solar Power System workshop, and in less extent the molten salt reactor workshop, certain emerging interaction patterns were not considered plausible. However, the observing groups were generally positive about the experience. Seeing your own project being played out by others helps to look critically at your own assumptions. As a student formulated it: '*It was also really helpful that this workshop put my (our) own thoughts into perspective. I think that being exposed to someone else's view opens your eyes in one way or another*'.

4.2. Players

The playing students generally found the roleplays an enjoyable experience revealing relevant insights, for themselves and for the instructor/observers. A student who was quite skeptical at the start, wrote '*At the beginning, I honestly thought that this workshop would be useless, but I changed my mind halfway through. We had to make decisions the project group could not make themselves. We were able to do that because we are more objective and less involved than the project group. To continue the discussion, we had no choice but to make decisions*'. Several students mentioned that it was particularly interesting to act from just one stakeholder perspective rather than taking a helicopter view and looking at the general picture. A student wrote it was an '*interesting learning experience for me as it allowed me to see from the perspective of a single stakeholder and, for lack of a better word, be selfish and argue for my own interest as opposed to keeping all the aspects and perspectives in mind when forming an opinion*'. Although one student felt somewhat restricted by his role, others experienced it as more realistic and complete to be able to argue from a specific position, which also allowed them creative actions to achieve their objectives. Obviously, students lacked part of the factual knowledge their real-world counterparts would have, but most players did not feel restricted by this. On the contrary, one student stated: '*Although we, as a group, lacked deeper knowledge about the* *technology we still could easily air our concerns and thoughts about the technology. […] sometimes knowing less is an advantage. We gave the project group that organized our role play some interesting new insights into their technology and the use of it*'.

The role-playing experience also had added value for their understanding of socio-technical dynamics. Students experienced, for instance, the impact of differences regarding return on investment timeframes (between public and private stakeholders), or regarding the main function of a pilot study (learning about the technology vs getting media attention vs testing commercial viability). The above mentioned 'wow-yuck' cycle in the piezoelectric roads case '*was really interesting to experience*', one student wrote, as she recognized how her arguments and opinion changed radically during the workshop. Another student found it fascinating to experience how much influence he could exert and how much he was trusted in his role as 'professor', especially when the discussion centered around technological uncertainties and he had access to some additional facts. Also negative experiences could be insightful. A student playing an inhabitant felt frustrated that she was marginalized and had little influence on the decision making. And a student who played a minister really felt very uneasy when he was urged to make a decision when so much was still uncertain, while realizing that not making a decision was not an option either, because then he would be too late. These patterns, such as the hype-cycle and Collingridge dilemma, can be learned from literature, but experiencing them in a roleplay may help to make them stick.

Furthermore, some students learned about themselves. They experienced being more or less comfortable with playing a certain role such as CEO or technical expert, and sometimes discovered communication and negotiation talents they did not know they had. In that sense, the role-play served as a playground for professional development. Students who managed to play a more dominant part in the role-plays seemed to be more outspoken about this experience than others.

4.3 Project Assessment

The final deliverable of the semester project was an encompassing report presenting and justifying an analysis of the current state of affairs regarding the emerging technology, an integrated vision of the future in the form of a long-term socio-technical scenario, and besides, a concrete, well-argued plan for technological development and societal embedding in the coming years. The learning experiences of the TTA role-plays could contribute in particular to making a convincing long-term scenario and short-term plans, including different stakeholder perspectives. Assessment was based on the report and an oral defense, carried out by two assessors per group. A single point rubric was used, stipulating 'the expected honours level' on different criteria, providing room for feedback about what was considered to be below, at, or above this level. Overall, all project groups finished their project at expected level, but – as can be expected – there was room for improvement. Table 2 presents a collection of anonymized remarks from the assessment forms, regarding different groups, which relate to themes addressed in the TTA role-plays.

	Elements below expected level	*Elements at expected level*	*Elements exceeding expected level*
Socio-technical scenario	The interactions over time between technology and society are minimal.	The storyline of the scenario is plausible, substantiated, and based on research.	Stakeholder analysis was systematic using a model, and thorough.

	The "social strategy" seems to exist only of polls on public opinion, political lobbying & active promotion (propaganda). Counterpropaganda is not really considered. The assumptions and conditions for public acceptance are rather superficial. […]	Multiple levels and system elements are covered with sufficient depth, and interactions over time between technology and society […] are articulated	The various actors and their interactions, and some level dynamics, are addressed, and a coherent story is presented (although not completely convincing).
Short-term plans to innovate the socio-technical system	The interaction between technology and society is one-way and straightforward, lacking complexity. A top-down approach that suggests the persuasion of the 'public' rather than a deliberative process or seeking for alliance. The plans to convince stakeholders to participate could be less abstract and more nuanced.	The prescriptions are concrete and convincing for 'real world' stakeholders; They align actions on technology and society, and address producers as well as the users and regulators; The prescriptions are concrete regarding intended outcomes and argued (e.g., by making use of roleplays)	The short-term plan is very good: there the stakeholder deepenings and roleplay results are combined to a concrete innovation plan that is well motivated.

Table 2: Excerpts from the assessment of long-term scenarios and short-term plans.

On the basis of these remarks it is not possible to pinpoint the precise effect of the role-play simulations on the quality of the end product, also because there is no comparison with groups who did not do TTA. Given the critical comments by the assessors, it is clear that participation in TTA as such was not sufficient to reach the expected level on the full range of criteria. On the other hand, the critical remarks relate to issues that mostly had been addressed in the role-plays, which suggests that there is room for improvement in how students use the insights of the role-plays in their final product of the semester project.

5. GUIDELINES FOR THE ROLE-PLAY SIMULATION DESIGN

The TTA role-play simulations were aimed at increasing students' understanding of the socio-technical dynamics around emerging technologies and to provide them with insights that help to develop integrated plans. The design of the simulation has enabled students to achieve these goals, as was demonstrated in the previous section. Based on a reflection upon our experiences, we can, in hindsight, distill the following seven guidelines for the role-play design.

5.1. Internalization of roles

The dynamics around emerging technologies are more interesting and more visible when players internalize their roles and act them out convincingly. Also the players appear to learn more when they can really identify with their stakeholder. The prepared role descriptions are important for this. The stakeholder's position, interests and values should be clear and simple enough for the players to grasp in a short time, yet allow enough freedom to be able to learn from other stakeholders during the workshop and to come up with new ideas. Furthermore, for fruitful interactions, knowing a role is not enough. Players should be able to play it out convincingly and give their role a personal twist. It seems to help when students have a personal 'click' or interest that fits with the role. When a role is very well-known (like the Dutch prime-minister or the US president), this makes the internalization easier, but complicates the play, as this tends to lead to impersonations rather than role-playing. For internalization, the role rehearsals are crucial, and also the introductory round during the session, with small talk or a first reaction to the theme (and some feedback on their playing), add to that. Preparation should not be too serious: Bringing in some fun and playfulness reduces shyness and sparks creativity. In our experience, preparation and rehearsal took more time than anticipated, but it paid off during the play. Students do not have to be good actors, but they should dare to play and make themselves heard in order to create a condensed reality of the stakeholder field. Being silent and modest (or extravert and dominant) may be part of a role, but if it stems from the lack of confidence or overconfidence as an actor, it distorts the simulated stakeholder field.

5.2. Moderation as part of the role-play

The discussion moderator plays an important role, to set the stage for the discussion, to invite players to voice their opinions and react to each other, and to articulate tensions and emerging consensus or conflict. The moderator is part of the play and should not step out of this role (e.g., for meta-level remarks regarding simulation or the way of acting). What worked well is that the moderator starts out actively, as a 'talk-show host', to make sure that all stakeholders are heard and the issues relevant for the observing project group get on the table. The interactions in this stage mostly corroborate what the observing project group expects to happen on the basis of their research, and as such it works as a kind of calibration. After that, the moderator has to step back a little to let stakeholders interact with each other directly rather than via him. This gives the players more freedom to act and increases the chances of novel insights. The occasional interventions are then aimed at stirring things up, focusing attention on unexpected problems or creative solutions, changing topics in repetitive discussions, and in the end, steering towards closure. In the second role-play session – the pressure cooker – the moderator even steps out completely. This gives the players even more freedom to act according to their own insights and interests, and makes power dynamics among stakeholders visible. As the moderator is the linking pin between the instructing/observing group and the playing group, it is important to align before and after the sessions with the observers about their questions and new insights.

5.3 Involvement of spectators

Watching a role-play simulation is not necessarily an interesting learning experience. It is easier to keep the attention when the sessions are played out well from a theatrical perspective, but this is not sufficient to learn from it. In our workshop, the spectators were engaged as they made role descriptions and scenarios, and prepared questions, but still we could see the attention of some of them drifting, in particular when the discussion proceeded along lines they already expected. We dealt with that by granting a little more freedom to players, focusing more on novel issues emerging in the role-play sessions, and discussing beforehand more explicitly the kind of questions the group had (more open ones for the first role-play session and more specific ones for the second). Besides, the spectators were given an active role in the reflective discussions between and after the role-play sessions, and in deciding how the situation after the time-lapse would look like. This appears to have increased their engagement.

5.4 Balance between facts and fiction

In order to convincingly mimic stakeholder interactions in the CTA session, a factual basis is required, both regarding the technology and other background knowledge of the different stakeholders. In each workshop, a scene developed in which different stakeholders (typically the selectors) started questioning scientists and engineers about the technology, in an attempt to reduce their uncertainty. In the first workshop, the scientists made up answers, which – according to the observing group – led to less realistic interactions. In the other workshops we therefore introduced 'whisperers', students from the instructing/observing project group who could, on request, inform the players without disrupting the role-play. This worked relatively well, although at a few instances, it took the flow out of the play, and once, when the whisperer started addressing all the players directly, it brought the play to a standstill. An alternative solution would be to provide the essential information as much as possible on paper. A point of discussion among the students was how much factual knowledge the players need. Most players appeared quite comfortable with not knowing all the numbers, but observers remarked in several cases that a certain stakeholder had been 'wrong' and would have reacted differently if he had known all the facts. These observing students clearly identified with the 'enactors' of the technology, in particular the scientists. Others pointed out that it is not only about facts, but also about values, trust and power play. For many stakeholders, the 'facts' are not decisive, especially since emerging technologies are riven with uncertainties, and for some of them (e.g., populist politicians, or activists) ignoring them or introducing 'alternative facts' may even be part of the game. Thus, making a play less 'factual' can make it more plausible. Moreover, what is now a technological or societal fact may change in the course of time, and emphasis on sticking to the facts may limit the creativity of the players and lower the chances that novel ideas emerge about what could be possible. The challenge for the workshop designers and moderator is to enable a productive balance between facts and fiction.

5.5 Selection of stakeholders

The interactions that take place during the workshops, and thus the opportunities to learn about socio-technical dynamics, are to a large extent dependent on the stakeholders that are selected to participate. There should always be propagators of the technology (scientists, entrepreneurs) at the table as well as people who can choose to include the technology in their portfolios or practices (e.g., big energy firms, investors, government, users), and sometimes activists or political actors who actively support or opposed it. Which roles are selected makes a difference. Having two actors from the same category (e.g., two leaders of different countries, two energy firms, or two politicians of different parties), foregrounds the competitive dynamics in the discussions. Having predominantly local stakeholders around the table gives a different discussion, with other kinds of arguments, than having national or international leaders present. Including a strong adversary of the technology in the workshop also strongly influences the dynamics. The selection can be tailored to the kind of dynamics the group is specifically interested in. Besides, the number of participants plays a role. Having eight players around the table, which was done to make sure that all relevant stakeholders were covered and all students had the opportunity to have the playing experience, may complicated the interactions and slowed down the play a bit. With a smaller group of players it may be possible to make the stakeholder dynamics more easily visible.

5.6 Playing scenarios

In the workshops, the instructing/observing project groups introduced two short alternative scenarios to ignite the discussions. These scenarios were summaries of the socio-technical scenarios they developed in their semester project. In real CTA workshops, the introduction of a scenario plays a central role. In our workshops, the scenarios were mostly too complex to grasp for the players in a very short period. This was partly mended by the moderator, who had seen the alternative scenarios beforehand, by highlighting the main tensions and differences, and focusing the discussion on these. More importantly, we used the time-laps in the pressure-cooker session to create and act out a scenario on the spot. Thus, rather than telling a scenario and having stakeholders react to a pregiven storyline, as was the original idea, we created a situation in which we let a storyline emerge in the first session, based on a diagnosis of the current state of the technology and the stakeholder situation, and played out the 'plot' of the scenario (e.g., successful implementation, failure, strict regulation) in the second session. This appeared to work quite well.

5.7 Productive frames

Important instances of learning are related to what can be called the 'framing of the social-technical dynamics' or the 'emplotment of the scenario'. With these frames or plots, the participants grasped on a more abstract level which dynamics were enrolling. Examples are the framing of the Space Solar Power System development as a 'space race', the identification of a 'hype cycle' and 'fear of missing out' in the piezo-electric roads discussion, and the framing of molten salt reactors as 'stepping stones' towards fully sustainable energy production. These frames were not put into the workshops beforehand, but emerged and provided a common frame for the interactions among stakeholders. The space race and the stepping stones were introduced on the spot by players, as metaphors that others took over; the hype cycle was articulated by teachers in the reflective sessions, linking the interactions in the workshop to an existing model. Whether these frames can be inserted beforehand or should emerge during the play is an open question, but having a frame helps to articulate learning points in the reflective sessions.

6. CONCLUSION

In this working paper we presented a novel educational method, based on insights from constructive technology assessment, improvisational theater and role-play simulations, which we coined Theatrical Technology Assessment (TTA). This method aims to enable engineering students to explore the socio-technical dynamics around emerging technologies and to provide insights that they can incorporate in scenarios and plans that transcend disciplinary and social boundaries and contribute to the mitigation of grand societal challenges. The results of the pilot indicate that this method can indeed have the intended effects. Both participating in the role-play simulation as a player and observing the simulation of 'your' technology provides novel and meaningful insights related to differences in stakeholder perspectives, ways to anticipate or transcend these, and socio-technical dynamics in general. These insights are relevant for the specific technology projects students work on, but also more generally, for their development into engineers that are competent in dealing with complex, uncertain and ambiguous technological and societal challenges. Thus, TTA is a useful addition to the educational repertoire of teachers in the field of Technology & Society.

The pilot corroborates that role-play simulations can be powerful means for students to learn about the complexity of technical and societal decision making (Mayer, 2009; Rao & Stupans, 2012; Rumore et al, 2016). We have articulated important elements in the design of these TTA role-plays, related to role internalization, moderation, selection of stakeholder perspectives, involvement of observers, provision of facts, insertion of scenarios, and use of frames. Several of these elements have been described earlier in literature (e.g., Joyner & Young, 2006; Duchatelet et al, 2019), but in this pilot they have been adapted for the interdisciplinary engineering context and the goals of the role-play. What seems new to the literature on role-plays is the way in which students are involved. They are not only players and observers, but have an active role in shaping the content of the simulation and the flow of action. Besides, the use of improvisational theater strengthens the active role of the players. Techniques from theater have been used before in role-plays (e.g., Skye et al, 2014), but especially the improvisational aspect enhances the players' agency and the variability of the outcomes, which are important for the purpose of this role-play.

To further develop TTA, additional experimentation and a more elaborate evaluation of the effects on student learning is needed. A rather specific developmental question concerns the effectiveness of these role-plays in the context of the semester project on energy technologies in which it was embedded. The role-plays took place relatively late in the project, when students knew already a lot about their stakeholders and were about to integrate their knowledge in concrete plans. As such, the workshops were part of the converging stage of the project. As the simulation seems to work well for the exploration of stakeholder dynamics, it is worth considering to do the workshops earlier in the project. For the instructing/observing group, this may lead to more novel insights, which can then be further researched. However, the simulation should not be done too early, when students still have too little knowledge to make the setting plausible, and the insights might 'evaporate' before they start converging and integrating. The effect on the final product might then be less than intended.

A broader question relates to the use of TTA outside the context of the specific semester project. It can be adapted for use in other projects on scenario development and emerging technologies, or in courses on technology and society. In these setting, there may not be enough time to involve students as co-designers and instructors of the roles. This would require the development of cases that can be used more stand-alone, with students as players and observers. To try out, we have elaborated the role-play on piezoelectric roads for an event with students, prospective students, and parents. A second trial was done with a group of master students from different disciplines (see Appendix A for an example: the educational material on piezoelectric roads). The broader application requires the development of a library of educational material, including introductions to the technologies, role descriptions, fact sheets, and guidelines for teachers. One should beware of workshops with unidimensional roles and strict scripts, in which the interactions can be fully foreseen, as the creative aspect and outcome variability of improvisation is core to this method, but some predictability helps to integrate the role-play simulation in less open-ended courses and projects. The effects on the learning of students in these different contexts need further study.

A next point of development relates to interdisciplinary learning. In our approach, stakeholder groups are taken as a starting point, not academic disciplines. Stakeholders draw on disciplinary knowledge and values (e.g., from physics, construction engineering, law, business administration). Besides, incorporating perspectives of stakeholders who are not directly coupled to an academic discipline (e.g., users, political leaders) is also important for interdisciplinary or transdisciplinary projects. However, in our pilot the relation between stakeholder perspectives and disciplinary knowledge has been hardly touched upon. This is due to the setting of the study, involving only first year bachelor students of a liberal arts and sciences programme. Doing the role-plays with more senior bachelor students or master students, who take on roles that match the professional profile of their programme, can add this dimension.

A last road for further development concerns inclusion of externals. If this method can provide new understandings for students, it may also produce novel and relevant insights for real societal stakeholders and contribute to their anticipatory learning around emerging technologies. In comparison with Constructive Technology Assessment, the TTA role-plays are much less expensive and time-consuming, and more accessible. Besides, they allow for more freedom to explore different scenarios. Externals could observe and reflect upon a play together with students. For top-notch experts, key decision makers, and corporate stakeholders with ample resources, other methods of exploring emerging technologies may be more suitable, but for local decision makers, young researchers, starting entrepreneurs, NGOs, and interested citizens, a well-prepared and well-played TTA workshop may lead to relevant insights for their daily practice. Moreover, the involvement of real-world stakeholders may further motivate participating students.

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7. APPENDIX A: TTA WORKSHOP PIEZOELECTRIC ROADS

The educational materials presented in this appendix were made for a trial with a group of master students from different disciplines.

Introduction of the workshop to the students:
This workshop is a role-play simulation, in which you will dive into the role of a stakeholder and explore the future of an emerging energy technology: Piezoelectric Roads. Piezoelectric energy harvesting in roads is a promising technology that can potentially contribute to the transition towards a more sustainable energy system. However, this emerging technology is surrounded by uncertainties, related to the technology and the embedding in business and society. Important questions include how much effort to put in the development of this technology, how to steer this development, and whom to involve? You will explore these questions, give arguments and counter-arguments from different stakeholder perspectives, develop preferences, and deal with other stakeholders to reach consensus (or not) and plan actions.

Using techniques from Constructive Technology Assessment and Improvisational Theater, this workshop will enhance your understanding of different disciplinary and stakeholder perspectives on emerging technologies and societal challenges, and of ways to overcome these differences. These insights will help you to design plans and scenarios for the responsible development of technologies that take stakeholder dynamics seriously.

Materials:
- Introduction to the Technology (shared with students before the workshop)
- Role descriptions and fact sheets (shared during the preparation phase during the workshop). Roles: 1. Professor of energy technology; 2. CEO of a large energy company; 3. CEO of a middle-sized green energy company; 4. Mayor; 5. Board member of the governmental body responsible for infrastructure; 6. Director of the association of car users.
- Notes for the moderator

Introduction to the Technology[1]

As fossil fuel supplies are diminishing and ambitious goals for harnessing climate change have been set, it is necessary to find new sources of renewable energy. One promising new source is piezoelectric energy harvesting from roads, which uses the energy of vehicles that would otherwise go to waste. This technology makes it possible to harvest vibrational energy of traffic and convert it into electrical energy. Figure 1 shows the working of the system.

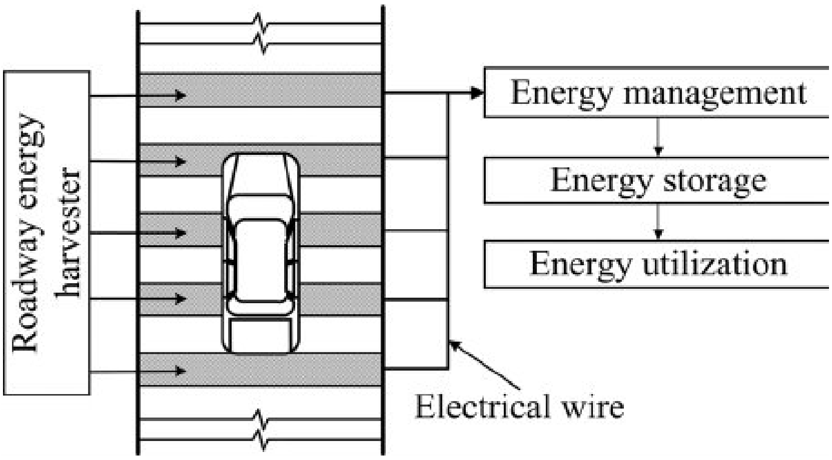


Figure 1: Piezoelectric energy harvesting (source: Xuezheng et al., 2014)

There have been a few pilot tests that implemented piezoelectric units in roads. A small scale test was done in Israel in 2009, where a 10 meter long strip of piezoelectric devices were implemented in the road at a depth of about 5 cm. This generated 2000 kilowatt-hours of electricity in one morning, from which the researchers extrapolated that a four-lane highway could produce enough to supply 2500 households. (The Green Optimistic, 2009). Other small scale tests have been done in Italy, Japan, Spain, United Arab Emirates, and the U.S., but the results from these studies are mainly confidential.

The technology appears able to generate a considerable amount of energy, but this is dependent on the frequency, speed, and type of traffic. More frequent, quicker, and heavier traffic leads to much better results. Questions related to longevity and maintenance, or to the total costs of the technology over its life-cycle have not yet been researched extensively. Because of that, there is uncertainty about investment costs and payback period. There is also still a lot unknown about what are technically and economically the best ways to implement this technology in road constructions and to connect it to the energy grid.

[1] This case is based on the semester project of Anne Rikhof, Katharina Kück, Klaske Houtsma, Maike Strijker, Nena Hendriks, Noa Schaafsma, Vincent Wolf and Vriti Kalia (ATLAS class of 2021)

Professor of Energy Technology

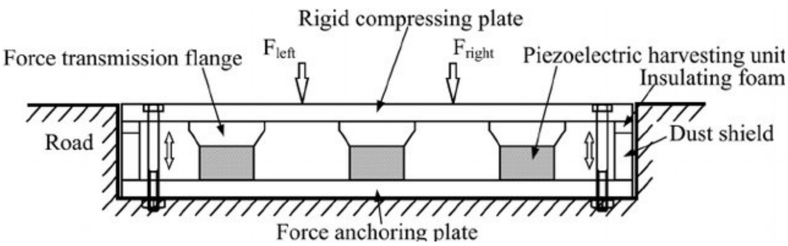
Role description

As a professor you are doing research and teaching students on energy technologies. You have received several prestigious grants for doing research on piezoelectricity in roads and have written a number of articles on the topic that are well-cited. Because of that you have quite a reputation in the field. You are head of a group at the Eastern University of Technology and are interested in doing more research on piezoelectricity in roads, in order to make the technology more viable (efficient, durable) and better understand how the technology works. Over the years, you have built good contacts with companies and government, and regularly give talks on piezoelectric roads to raise interest and increase chances to acquire funding.

Interests: Reputation and recognition, a working technology, a sustainable energy system
Irritated by: Irrationality, procrastination

Fact sheet

Working of the system (Xuezheng et al., 2014)**:**



Efficiency and output: Piezoelectric systems convert mechanical pressure of traffic into electric charge with more than 83.9% transition efficiency, which is higher than solar panels (15%) or wind turbines (40-60%) (Do, Xuan-Dien, et al., 2011). Doubling the speed from 60 km/h to 120 km/h increases the energy output with 400% (Kokkinopoulos et al, 2014).

Pilot Israel: The Innowattech Piezo Electric Generator generates electrical power up to 0.5 MWh in two-lane roadways. Connected to the grid this supplies 600-800 households. Compared to solar energy, the costs are half and the payback period a third (Sun, Shang, Zhang & Du, 2013).

Pilot Spain: The costs for installing are close to €1125,- per m2 , the costs of installation and wiring are € 70,- per m2 in addition . Initial costs lead to a cost price of €1.98 €/kWh, which is nine times the price of solar energy, and a 15-years pay-back period (Moure et al, 2016)

Construction: Installations that are in direct contact with cars are easier to implement than deeper installations, and they receive more vibrations, but they are also more prone to deformation (Duarte et al, 2016). Deformation of the pavement is an important factor in determining its feasibility.

CEO of a Large Energy Company

Role description

As the Chief Executive Officer of Energax you lead a private company that produces and buys grey and green energy (from coal, gas, wind and solar energy sources) and supplies this to over two million companies and households. The energy market is competitive, and the company has a large market share in several regions within the Netherlands. You are eager to keep this market position. A sustainable image is important for companies these days, but a low price and high reliability are also crucial. As CEO you are responsible for strategy and major investments. You have a keen interest in new energy technologies, in particular when these help to better satisfy customer needs, but within boundaries of what is economically feasible, of course. Most shareholders of this company are interested in long-term growth, but the last few years an active group of shareholders is putting pressure on the CEO to increase the profit of the company.
Interests: Long-term continuity of market position, short-term profits, satisfying customers
Irritated by: Uncertainty, lack of clarity

Fact sheet

Company figures: Revenues from energy sales and related activities exceed 4 billion euro. The yearly profit is about 140 mln euro. The company has 3000 employees and is active in the Netherlands, Belgium, the UK, and Germany.

Investments: The company invested about 120 million euro wind farms and solar parks last year. Besides, it invested in renovating a gas-fired plant. Together with other energy companies, it is shareholder in an offshore wind project that costs over 1 billion euro in total.

Payback period: In a somewhat older study (Garland, 2013), the payback period of piezoelectric systems (excl. manufacturing and installation costs) was estimated at 12 years. The payback period of solar panels, in comparison, is 5-7 years, the payback period of offshore windfarms is at least 14 years.

CEO of a Middle-sized Green Energy Company

Role description

As the the Chief Executive Officer (CEO) of Greenergia you lead a private company established 10 years ago, which produces and buys green energy (mainly wind, solar energy, and biomass) and supplies this energy to households in the Netherlands. The company serves half a million households and its market share is growing quickly, at the cost of the market share of established firms. A competitive price and high reliability is important, but the main driver is to go for an autonomous 100% sustainable energy system in the Netherlands. Right now, 95% of the energy the company sells is green. As CEO you are responsible for strategy and major investments. You have a keen interest in new energy technologies, in particular when these are sustainable, but within boundaries of what is economically feasible. This company is a daughter company of Greyergia, a large internationally operating energy firm that supports Greenergia to gradually build a good position in the Dutch energy market.
Interests: Long-term growth of market share and profitability, satisfying environmentally-aware customers, reaching sustainable development goals
Irritated by: Lack of ambition regarding renewable energy.

Fact sheet

Company figures: Revenues from energy sales are about 400 million euro. The yearly profit is about 10 mln euro. The company has 300 employees and is active in the Netherlands.

Efficiency: Piezoelectric systems convert mechanical pressure of traffic into electric charge with more than 80% transition efficiency, which is higher than solar panels or wind turbines (Do, Xuan-Dien, et al., 2011).

Payback period: In a somewhat older study (Garland, 2013), the payback period of piezoelectric systems (excl. manufacturing and installation costs) was estimated at 12 years. The payback period of solar panels, in comparison, is 5-7 years, the payback period of offshore windfarms is at least 14 years.

Mayor

Role description

As mayor you are head of the local government of Urbelo, a middle-sized town in the eastern part of the Netherlands. Together with a number of aldermen, you have executive power in the municipality. All local roads (excluding highways and provincial roads) are owned by the municipality. The local policy is to enhance the accessibility of the city center, both for inhabitants and for visitors (especially to the market and the shops). The municipality has set sustainability goals for 2030, including the increase of the use of green energy to 25%. There is little space nor much enthusiasm among the inhabitants for large windmills or solar parks in the municipality. Urbelo is the home-town of the Eastern University of Technology, and is active in marketing the city as vibrant and innovative, aiming to attract and retain high-tech firms and knowledge workers. The city has a difficult financial situation and has announced budget cuts of 7 million euro for the coming years (also for road maintenance). As mayor you stand above the political parties; the aldermen represent a broad coalition of conservative, liberal, socialist and local parties.

Interests: City reputation, financial health, satisfied citizens and city council, local contribution to sustainable development goals.
Irritated by: Rash decision making, plans that cause unrest among citizens.

Fact sheet

Inhabitants: Urbelo has 150,000 inhabitants, including 10,000 students.

Budget and policy: Urbelo has a yearly budget of 700 million euro. About 5 million is used for road maintenance. The municipality owns 8 million m2 of roads and has over 20 roadwork projects scheduled for the coming years. The municipality has reserved 400,000 euro for making the city more sustainable and climate-resilient. This includes 16 different projects related to renewable energy. There are no projects scheduled related to piezoelectricity.

Board Member of the Governmental Agency Responsible for Infrastructure

Role description

As board member you represent the executive agency of the Ministry of Infrastructure and Water Management. You are director of the transport infrastructure, responsible for all highways (over 5000 km) and waterways in the Netherlands. The agency does not construct or maintain roads itself, but commissions this to private companies and consortia. You closely cooperate with municipalities, companies and research institutes to stimulate innovation. Sustainable mobility is an important goal of the central government and thus, of your agency. As you spend public money, total costs of the road infrastructure (measured over the whole life-cycle of the roads) are also important to consider. Renovation and maintenance of highways is essential for a high-quality infrastructure, but disturbance of the traffic flow should be minimized. In the past, the agency stimulated many radically innovative pilot projects, but recent studies showed that most of these pilots have not been implemented more broadly. Therefore your agency is now reconsidering how to deal with pilots of new technologies.

Interests: safe and smooth flow of traffic, alignment with national government policy, reputation as stimulator of innovation.
Irritated by: plans that cause unrest among politicians, costly projects with little impact.

Fact sheet

Budget: The agency has a total yearly budget of 4 billion euro. It spends about 1 billion euro on road infrastructure.

Innovation Policy: The agency aims to make more effective and efficient use of existing resources. In addition to mobility, themes such as safety and sustainability also require a lot of attention. The agency is chasing applicable innovations in all these areas and stimulates application both within and outside the organization. Together with its partners, it has an initiating role in getting innovations off the ground, and an important role in the application of the innovations developed. Important subjects at the moment are the development of new materials such as ultra-quiet road surface, improving the replacement and renovation of asphalt, adaptation of infrastructure to climate change, improvement of traffic models and smarter maintenance of roads by making better use of data.

Director of the Association of Car Users

Role description

As director you are head of ACU, a Dutch Non-Governmental Organization that focuses on lobbying and service provision to its members in the field of mobility, spare time and holidays. Most car-owners in the country are a member of your association. Members are represented in a council, consisting of more than 100 people representing provincial departments. This council advises you as the director. You lobby with the government in The Hague for the (short-term) interests of car drivers, but you also have a long-term vision: a mobility system that is clean, affordable, safe, comfortable, easy to use and healthy. You are willing to promote technologies that contribute to reaching this vision, for instance by using your own magazine.

Interests: safe, affordable, smooth and sustainable car traffic, satisfaction of members, reliable reputation.
Irritated by: picking on car-drivers (e.g. negative attention in the media, extra taxation, pollution).

Fact sheet

Figures: The association has 4.5 million members, 3500 employees, and 50,000 volunteers. Yearly turnover is 1 billion euro.

Fuel: Cars may use a little more fuel when driving over a piezoelectric road.

Notes for the Moderator

Protocol (see also section 3.3 of this paper)

Preparation (15 min)

- Instruct students to study their role description and fact sheets, and to think of how they will play their role. They will make fictitious name-plates.

Role rehearsal (15 min)

- Warming up exercise
- Arrival: Students enter as their character, introduce themselves to others, respond to some small-talk (the journey, building, lunch, etc.)

<u>Session 1: CTA Workshop (20 min)</u>

Opening: "*Piezoelectricity is a technology in an early stage of development. The application in roads bears great promises for making energy production more sustainable, but there are still many uncertainties, bottlenecks and alternatives roads to take. If we wait till all is clear we are too late to steer. As society, we need to find ways to deal with this new technology, thus the minister has asked us to organize this workshop. I am very happy that you are here, representing experts and potential users, the public and private organizations. You normally do not meet each other, but you are all important stakeholders for this technology, so it great to have you around this table. In this session we would like to learn more about your views about this new technology, what you think is promising or risky, in the short run and the long run, and how you think this technology should be further developed. It also gives you the opportunity to learn from each other*".

Potential discussion points

- Evaluating piezoelectricity in comparison with wind/solar and grey energy sources in terms of efficiency (positive), energy price (uncertain: positive/negative), and payback period (uncertain: probably negative)
- Local roads versus national highways implementation (risks, reputation, disruption, impact)
- Public funding versus private funding , public-private cooperation
- Promotional project versus economically viable energy source
- Economic gains versus sustainability gains.
- More, quicker and heavier vehicles (less sustainable) lead to much higher output of piezoelectric roads, but are less sustainable.
- Cars need a little more fuel when driving over piezoelectric roads.
- Newcomers versus incumbent firms (entrepreneurial spirit, resource dependency).

First Reflection (10 min)

Coffee break & Preparation session 2 (15 min)

- Deciding on the change of situation after the time lapse.

Session 2: Pressure cooker (15 min).

Opening: "*X years ago we openly discussed scenarios and explored alternative options. In the mean-time, we have learned that…., and now it is time to act. The minister has requested you to do some-thing, and preferably not alone, but with each other. I do not know whether consensus and concerted action is possible here. Can you agree on a new action plan for this technology, or will you end up in stalemate. An important and difficult question, and the minister wants an answer in 15 minutes*".

Second reflection (15 min): Potential dynamics and patterns

- Fear-for-missing-out versus Waiting games.
- Gartner Hype-cycle/wow-yuck cycle
- Transformation, niche to regime level

Articulation of learning points regarding (10 min)

- Sociotechnical dynamics around emerging technologies
- Stakeholder & disciplinary perspectives
- Students' projects
- TTA Roleplay Design

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