Dissertationes Forestales 135

Bioenergy knowledge, perceptions, and attitudes among young citizens – from cross-national surveys to conceptual model

Pradipta Halder

School of Forest Sciences
Faculty of Science and Forestry
University of Eastern Finland

Academic dissertation

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Author: Pradipta Halder

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Thesis Supervisors:
Professor Paavo Pelkonen
School of Forest Sciences, University of Eastern Finland (UEF), Joensuu, Finland
Dr. Sari Havu-Nuutinen
School of Applied Educational Science and Teacher Education, UEF, Joensuu, Finland
Dr. Janne Pietarinen
School of Educational Sciences and Psychology, UEF, Joensuu, Finland
Professor Liisa Tahvanainen
School of Forest Sciences, UEF, Joensuu, Finland.

Pre-examiners:
Dr. Ville Hallikainen
Finnish Forest Research Institute, Rovaniemi Research Unit, Finland
Prof. Shin-Cheng Yeh
National Taiwan Normal University, Taipei, Taiwan, Republic of China

Opponent:
Dr. George Dyer, The James Hutton Institute
Aberdeen, Scotland, UK

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ABSTRACT

Bioenergy is expected to play a significant role in the global energy mix of the next decades, transforming the current fossil fuel-based economy into a low-carbon energy economy. There is a significant research gap in our understanding of the societal aspects of bioenergy and it becomes even limited in the context of evaluating young citizens' awareness of bioenergy from an international perspective. This dissertation has investigated young students' knowledge, perceptions, and attitudes related to bioenergy with the help of cross-national data (Paper I, II, and III) and used statistical models to explain their intentions to use bioenergy (Paper IV). A self-constructed survey instrument was used in the study to collect data from 15-year-old 1903 school students in Finland, Taiwan, Turkey, and Slovakia.

The study found that the majority of the students appeared to have basic level of bioenergy knowledge, whereas only a minority among them demonstrated a higher level of such knowledge (Paper III). The study did not reveal any statistically significant gender and living area differences related to the students' knowledge of bioenergy (Paper I & III). The students appeared to be very critical in their perceptions of forest-based bioenergy production; however, they demonstrated their positive attitudes to bioenergy including their intentions to use it in the future (Paper III). It became apparent that the students with a higher level of bioenergy-knowledge were more critical in terms of their both perceptions of and attitudes to bioenergy than those with a shallow knowledge of it. The study has found that school, home, and media discussions of bioenergy, as perceived by the Finnish students, have significant effects on their knowledge, perceptions and attitudes related to bioenergy (Paper II). One of the most significant findings to emerge from this study is the key dimensions of the students' perceptions of and attitudes to bioenergy. The study found three key dimensions from the cross-national data depicting different facets of the students' perceptions of and attitudes to bioenergy (Paper III). The results from the study further suggested that the internal consistency of these key components differed across the countries. This implies that young students' perceptions and attitudes are multidimensional on bioenergy issues and they could vary from one country to another country. The conceptual models based on regression analysis revealed that the students' intentions to use bioenergy in general could be explained by considering their perceptions of the societal aspects related to bioenergy (Paper IV).

Fostering the awareness of bioenergy among young students, we need to share the educational methods among home, school, and media. It is recommended that the bioenergy policy makers and professionals must raise the awareness of bioenergy among young students in our society and regard them as an important target group while formulating bioenergy policies. The results of this research support the idea of increasing collaboration between bioenergy policies and bioenergy education strategies for school students. However, it is suggested that further research should be undertaken in these issues to have a deeper understanding of young citizens' knowledge, perceptions, and attitudes related to bioenergy with more country specific contexts.

Keywords: Attitudes, bioenergy, conceptual model, knowledge, perceptions, policy

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Joensuu, November 2011

Pradipta Halder

LIST OF ORIGINAL ARTICLES

This thesis consists of a summary and the following four Articles, which will be referred in the text by Roman numerals, I–IV. The Articles I–III are reprinted with the kind permission of the publishers or with the right retained as author, while the Article IV is the author version of the submitted manuscript.

I Halder, P., Pietarinen, J., Havu-Nuutinen, S. & Pelkonen, P. 2010. Young citizens' knowledge and perceptions of bioenergy and future policy implications. Energy Policy 38: 3058–3066.
doi:10.1016/j.enpol.2010.01.046

II Halder, P., Havu-Nuutinen, S., Pietarinen, J. & Pelkonen, P. 2011. Bio-energy and youth: Analyzing the role of school, home, and media from the future policy perspectives. Applied Energy 88: 1233–1240.
doi:10.1016/j.apenergy.2010.10.017

III Halder, P., Prokop, P., Chang, C-Y., Usak, M., Pietarinen, J., Havu-Nuutinen, S., Pelkonen, P., & Cakir, M. 2011. International Survey on Bioenergy Knowledge, Perceptions and Attitudes among Young Citizens. BioEnergy Research, in Press.
doi: 10.1007/s12155-011-9121-y.

IV Halder, P., Havu-Nuutinen, S., Pietarinen, J., Pelkonen, P., Chang, C-Y. Prokop, P. & Usak, M. 2011. Knowledge, Perceptions and Attitudes as Predictors Youth's Intentions to Use Bioenergy – a Cross-national Perspective. Manuscript.

Pradipta Halder had the main responsibility for analyzing and writing all the Articles I-IV. The co-authors and supervisors participated in formulating the research tasks and commenting on the manuscripts. Data for the Articles III & IV were collected by the co-authors in Taiwan, Turkey, and Slovakia.

TABLE OF CONTENTS

1 INTRODUCTION

1.1 Emergence of bioenergy

Energy, a fundamental component of modern society, plays a critical role in the development of economy (Baños et al. 2011, Nakata et al. 2011). The continuous increase of energy consumption has generally improved the standard of living but it has also caused serious environmental problems. Since the beginning of the pre-industrial revolution, burning fossil fuels during energy production processes has been the main source of anthropogenic emissions of greenhouse gases (GHGs), causing global climate change with potential negative impacts on climatic systems, natural environment, and human society (IPCC 2007, IEA 2008). In this context, renewable energies (REs) have emerged as sustainable and environmental friendly sources of energy, which can satisfy our current and future socio-economic needs (Panwar et al. 2011). REs include hydro, biomass, solar, geothermal, wind and ocean energies. Furthermore, the World Energy Outlook (2010) has projected a global increase in the share of the REs from 19% in 2008 to almost 33% in 2035, thus reflecting the world's growing dependence on the REs.

Traditional use of wood for producing heat has been in the practice for millennia. However, it is in the recent years that bioenergy has become one of the most dynamic and rapidly growing sectors of the global energy economy (UN-Energy 2007). The acceptance of bioenergy has increased together with many modern ways to utilize it, especially in many of the industrialized countries. The use of bioenergy instead of fossil fuels is an attractive option to reduce fossil-fuel dependency and mitigate global climate change. At present, bioenergy is the largest global contributor to the REs and meets about 10% of the global annual energy demand (IEA 2010). It accounts for almost 80% of the total primary energy supply in many developing countries and less than 5% in the industrialized countries (Keam and McCormick 2008). Three main categories of bioenergy resources globally used are forestry biomass, agricultural biomass and wastes biomass. There exist forest and agriculture-based highly developed bioenergy sectors in countries such as Finland, Sweden, Germany, Austria, Brazil, and the United States of America (McCormick and Kåberger 2007). The spread of the modern bioenergy sector is, however, still in its primary stages in many of the developed and developing countries in the world.

There are numerous policy measures, both voluntary and mandatory, in various countries to increase the share of solid, liquid, and gaseous forms of bioenergy in their energy portfolios. Governments in many countries have provided a huge stimulus to the demand of liquid biofuels by introducing compulsory blending of 5-10% bioethanol with petrol and 2-5% biodiesel with diesel fuel (Robbins 2011). However, the development in the bioenergy sector, particularly in the 'first generation' liquid biofuels derived from the edible parts of food crops, has been facing serious controversies, and therefore they have been subject to critical attention around the world. A considerable number of scientific studies revealed that the 'first generation' biofuels were responsible for increasing food prices and decreasing food availability in many developing countries (see UNCTAD 2007, FAO 2008, Mitchell 2008). They also affected water availability (see Gerbens-Leenes et al. 2009), increased deforestation, and accelerated emissions of the GHGs in tropical countries (see Laurence 2007, Fargione et al. 2008, Searchinger et al. 2008).

The debates on bioenergy and mixed perceptions of it among public have raised the demand to improve our understanding of public perceptions and attitudes that have evolved with the development of bioenergy sector in different countries. These concerns gain more

relevance considering the belief that public perceptions and attitudes are significant social factors to take into consideration in developing future energy systems (Owens and Driffill 2008). In this regard, the availability of the latest scientific information among public about the consequences of the use of bioenergy appears to be a key driver that can affect their choice of bioenergy as an alternative to fossil fuels in the future (Robbins 2011). Today's young generations such as school students are the future decision makers on all aspects of our society including the energy choices. Therefore, their perceptions of and attitudes to bioenergy along with their intentions to use it will determine the broader societal attitudes to this energy technology in the future.

1.2 The trend in societal awareness of bioenergy

Studies that have analyzed various dimensions of societal perceptions of and attitudes to bioenergy are not many to date and thereby a critical knowledge gap is discernible. It is generally acknowledged that bioenergy stands across the borders of several policy sectors (Panoutsou 2008) as bioenergy is more complex and heterogeneous in its forms than the other REs. It is a limited resource usually with a cost attached to the feedstock. It has potential to be used for producing heat, electricity and transport fuels, and the geographical along with social implications of bioenergy can be much wider than those of the other REs (Kerckow 2004, Thornley and Cooper 2008). This complexity brings special challenges to the formulation of bioenergy policy, which will be generally accepted by its stakeholder groups (Peelle, 2001). Therefore, it is not the case that policy structures, which are effective for developing other forms of the REs, will be equally relevant to bioenergy development (Thornley and Cooper 2008). In this regard, public awareness of and support for bioenergy is an essential pre-requisite for policies promoting bioenergy (Rohracher and Späth 2004).

There exist different definitions of the term 'awareness' and in many cases the term has been used to imply 'having knowledge' or 'being conscious' (see Thellufsen et al. 2009). Moreover, it is considered that environmental awareness includes five components: environmental knowledge, environmental values, environmental attitudes, revealed willingness to act, and actual behavior (see Zsóka 2008). The present study, however, in its domain refers to young students' bioenergy awareness, which involves their knowledge of bioenergy, their perceptions of and attitudes to bioenergy, and their revealed intentions to use bioenergy. The concept of environmental awareness has been defined as a multidimensional construct (Maloney and Ward 1973) and it suggests that there is a need for comprehensive studies on this multidimensionality related to bioenergy among young citizens such as school students along with analyzing the broader societal contexts that can affect this construct globally. Since bioenergy is a global issue, this information is particularly important for developing the concept of collaboration between bioenergy policies and educational systems in many countries. Previous studies related to public perceptions of and attitudes to energy issues have revealed a lower awareness of bioenergy among public than the other forms of the REs in various countries (see Table 1). However, it gives an impression that public awareness of bioenergy has been changing in Europe. In a recent Eurobarometer (2010) survey, 72% of the Europeans supported biofuels and 83% showed positive attitudes to the development of sustainable biofuels in Europe.

Table 1. Public awareness of bioenergy from previous energy related surveys.

Study	Theme	Target group	Findings related to awareness of bioenergy
Eurobaro-meter 2002	Analyzing attitudes of the EU (European Union) citizens to energy and energy technology issues	Aged 15 and over, N=16,032	Bioenergy (wood) was included as a component of the REs although no specific finding on bioenergy was reported. However, Europeans showed positive attitudes to the REs
Rohracher and Späth 2004	Improving public perceptions of bioenergy in the EU	Bioenergy experts in the EU	Lower public awareness of bioenergy than the other REs. Heterogeneity of the notion of bioenergy is difficult to communicate to public at general level
Segon et al. 2004	Raising awareness of bioenergy benefits	N=1500 in Croatia and N=1000 in the UK	Lower awareness of and support for bioenergy than the other REs
Eurobaro-meter 2006	Attitudes towards energy	Aged 15 and over, N=29,430 EU – 25	No specific mention of bioenergy; however, Europeans supported the increase of the REs although many of them were not willing to pay more for the REs
Eurobaro-meter 2007	Energy technologies: knowledge, perceptions and measures	Aged 15 and over, N=24815, EU-25	Knowledge of the use of bioenergy was underestimated (including Finland and Sweden); both present and future preferences to bioenergy were lower compared to solar, wind, and nuclear energies
Adelle and Withana 2008	EU and US public perceptions of environment, climate change and energy issues	General public	Low public awareness of bioenergy in the EU and the US
BERR 2008	Renewable energy awareness and attitudes	Aged 16 *plus*, N=1947, Great Britain sample	Awareness of bioenergy increased from 45% in 2006 to 59% in 2008. However, it was still lower than solar (86%), wind (79%), and hydro (78%)
Thornley and Prins 2008	Public perceptions and bioenergy	General public	Low awareness of bioenergy – 2% in Ireland and 8% in the Netherlands; only 16% supported biomass in the UK
EECA 2008	Public perceptions of renewable energy	N=1000, New Zealanders	About 60% were positive toward bioenergy though it was lower than wind (91%) and solar energy (89%)

The consumption of energy has witnessed an increase among young people and at the same time, their concerns with the environmental impacts of their energy-intensive lifestyles have grown up (Intelligent Energy Europe 2009). Science educators and policy makers all over the world are emphasizing on increasing young students' awareness of the adverse consequences of using fossil fuels and informing them of the benefits of using the REs as an alternative to the fossil fuels. It seems that socio-economic and cultural differences often play an important role in determining energy attitudes and behaviors among young students. Yuenyong et al. (2008) substantiated these phenomena from their study by revealing that 15-year-old students in Thailand deemed energy issues important for the economic development in their country, which perhaps suggested an attitude common among students from developing countries. On the other hand, the students from New Zealand, being from a developed country, considered energy issues as associated with the environmental conservation rather than with the economic development in their country.

Furthermore, gender and locality differences in young students' attitudes to the REs appeared in a number of studies. The BERR (2008) survey revealed that young women were less aware of the REs than young men in the UK. Similarly, rural and urban differences in the preferences to the REs appeared among the respondents in Scotland (see Bergmann et al. 2008). Previous results also suggest that young people appear to be ambivalent about many issues surrounding the REs (BERR 2008), though there is evidence that they are more in favor of the REs than the older people are (Greenberg 2009). Taken together, these findings suggest that raising young generations' awareness of energy issues particularly of the REs promises and secures the existence of responsible energy-conscious consumers in the future (Zografakis et al. 2008).

The above findings though provide us with some general perspectives of young students' awareness of energy issues including the REs, they do not reveal in details their knowledge, perceptions, and attitudes related to bioenergy from both national and cross-national perspectives. In this regard, the Eurobarometer (2010) survey revealed that in Europe those aged between 15 to 24 years were more supportive of sustainable biofuels than those aged 55 years and more (76% vs. 63%). However, those findings came from a public survey on European citizens' opinions on biotechnology, and therefore it did not focus entirely on bioenergy. Modern bioenergy technologies include several socio-economic and environmental dimensions and demand special attentions from both energy and educational policies to raise its awareness among young citizens.

An area, which has not received adequate attention from the researchers, is the exploration of young generations' knowledge, perceptions, and attitudes related to bioenergy from a cross-national perspective. Cross-national data on these issues can help energy policy makers and educators understand the global awareness of bioenergy among young generations that in turn would enable them to formulate sound policies on bioenergy in the future. Moreover, in order to develop the cooperation in the energy sector among different countries, there is a need for cross-national data from countries that differ from each other not only socio-economically and environmentally but also in terms of modern bioenergy development.

1.3 Social environments of young students to become aware of bioenergy

Social environment is an often-used term in educational research generally related to the learning of environment at schools and society. It is argued that education is a key factor for technology development and an attempt at dealing with the impending energy issues has to

focus on education from primary to graduate level for an effective solution (Chedid 2005). In the context of the REs, education is perhaps an effective way to construct an integrated knowledge and background to cultivate critical thinking both for the REs and for their particular applications (Liarakou et al. 2008). However, earlier studies found a considerable gap in the delivery of quality bioenergy education and training to various target groups and suggested the need to develop effective bioenergy education and training in countries particularly those with a strong bioenergy potential (Guest et al. 2003, Healion et al. 2005). The ThermalNet (2007) survey on investigating the educational needs for the bioenergy sector also indicated a consensus among the respondents on starting undergraduate and graduate level bioenergy courses. In the delivery of bioenergy related education, which is a decontextualized one, schools are important agencies for the inculcation of values and attitudes in students that go beyond the teaching of specific knowledge and skills. The role of teachers is also important, which suggests that when teachers are knowledgeable with positive attitudes to the REs, only then they can incorporate necessary knowledge and values into the learning processes, by providing students with appropriate capabilities to deal with the energy issues in their daily life (Liarakou et al. 2008). Therefore, the present situation suggests that school education will have a great challenge to introduce a multidisciplinary topic like bioenergy into their course curricula.

It is not only a school's environment that has an influence on a student's learning and developing attitudes to scientific matters such as the energy issues, but parents also play a key role in a young student's education and daily life (George and Kaplan 1998). Parental attitudes, educational aspirations, and socio-economic status are all related to a student's home environment. A student's home environment is considered an agency that aids in the construction of a student's attitudes to particular issues (Martin 1996). Several factors have effects on young students' science attitudes such as teachers, learning environment, self-concept, peers, and parental influence (Morrell and Lederman 1998). Therefore, further research is relevant to reveal how parental influences work on young students' perceptions of and attitude to bioenergy.

In addition to schools and parents, the role of media is crucial in informing society on all aspects of our lives, including the developments in science (Holliman 2004). Media not only reinforces and activates existing opinions, but also creates new opinions. Extensive media diffusions of a particular issue have been found to affect public opinions of that issue regardless of the content of media messages and the content of an individual's existing opinions (Yin 1999). Involvement of mass media has become widespread in both energy conservation and various national campaigns for reducing emissions of the GHGs in Europe (see Staats et al. 1996, Viklund 2004). The Eurobarometer (2002) survey revealed that the main sources of information on energy issues and related technologies to the public were television (80%), newspapers (47%), radio (27%), and the internet (10%). However, that particular survey also suggested that young people especially the students frequently used the internet as a source of information. For the past few years, bioenergy has been receiving enormous media attention due to its position at the intersection of the three great challenges of the world such as energy security, climate change, and poverty reduction (FAO-GBEP 2007). Consequently, a great deal of information, both positive and critical, related to bioenergy especially liquid biofuels have appeared in print media as well as on the internet. This situation has perhaps created an attitudinal ambivalence among young students toward bioenergy. Conceptually ambivalence reflects a co-existence of both positive and negative evaluations of an attitude object (Nordgren et al. 2006) and ambivalent attitudes generally denote weak attitudes since they are less predictive of behavior, less stable, and less resistant to persuasion (Armitage and Conner 2000).

1.4 Young students' knowledge, perceptions, and attitudes related to bioenergy – conceptual insights

The study of relations among knowledge, perceptions, and attitudes is one of the most examined topics of socio-psychological studies (Milfont et al. 2010). In a number of such studies, the concept of knowledge has appeared as a construct formed by interlinking numerous intellectual components comprising various theories and hypotheses (Spuzic et al. 2008, Abhary et al. 2009). Fryxell and Lo (2003) have attempted to define environmental knowledge as "knowledge of facts, concepts, and relationships concerning environment and its major ecosystems". Nevertheless, there is a difference between knowledge and information. Nonaka (1994) suggests that knowledge is generally created and organized by the flow of messages that constitutes information. On perceptions, White (1988) describes them as initial thoughts of a phenomenon and perceptions along with attitudes are crucial components of learning and have a causal relationship with it. Nevertheless, the very thought that perceptions imply consciousness has been challenged by various authors and they have argued that perceptions can occur when there is no awareness of perceiving (see Merikle et al. 2001). The sense of environmental citizenship among young students is much relevant to the energy issues, particularly with respect to the REs. In the context of bioenergy, young students' environmental awareness (i.e. knowledge, perceptions, attitudes, and revealed intentions) and the sense of environmental citizenship can guide them to make informed decisions while choosing bioenergy instead of fossil fuels. Environmental citizenship can be regarded as the ultimate outcome of education for sustainable development that can change people's behaviors by affecting their attitudes, providing access to knowledge and developing skills (Hawthorne and Alabaster 1999).

There are a number of factors such as gender, personality traits, and curriculum variables determining students' attitudes to science and environmental issues (Trumper 2006). Gender appears to be an important factor that affects young students' attitudes to scientific topics (Osborne et al. 2003). Various studies have reported that boys appear to have more positive attitudes to science than girls have (Jones et al. 2000, Osborne et al. 2003, Trumper 2006, Miller et al. 2006). There are also findings, which indicate that females are more concerned with environmental issues than males are (Schahn and Holzer 1990, Zelezny et al. 2000, Goldman et al. 2006). Previous cross-national study such as the PISA (2006) observed that girl students in New Zealand performed very well in identifying scientific issues whereas they were very weak in providing scientific explanations of various phenomena compared to boys. However, the same study in Thailand found that girls outdid boys in terms of both identifying scientific issues and proving scientific explanations of those phenomena (see Coll et al. 2010). These observations related to gender differences in the performance of science subjects perhaps also suggest a large gap in socio-economic and educational contexts in different countries (developed vs. developing) that influences their scientific knowledge of and attitudes to environmental issues including pro-environmental behaviors.

Scientific knowledge is an important component of environmental literacy and it can help citizens participate in debates on socio-scientific issues (e.g. energy and environmental issues) that have come to dominate much of the modern life (Coll and Taylor 2008). Various social and educational researchers have argued that social environment and educational contexts in which learning occurs exert significant influence on teaching and learning of young students (see Lave 1991, Coll et al. 2010). The PISA (2006) study has substantiated this fact by suggesting that the students who are coming from more developed socio-economic backgrounds tend to have higher scores in science-subjects compared to

students living in the disadvantaged socio-economic groups (see Coll et al. 2010 for a comparison between students from New Zealand and Thailand). However, in terms of students' attitudes to engage with science and their awareness of environmental issues, the PISA (2006) study reported that the Thai students, though lacked in some environmental awareness issues, were more eager to learn science than the students from the socio-economically advanced countries (see Coll et al. 2010). In addition to the socio-economic and learning contexts, an individual's residence appears to affect his/her environmental attitudes. It has been found that urban residents are generally associated with greater environmentalism than rural residents are since they have more exposure to environmental degradation (Buttel, 1992). However, urban-rural gap in influencing environmental attitudes has not appeared in a study by Bogner and Wiseman (1997) and possible reasons could be the improvements in mass communication, standard of living, education, mobility, and convergence of lifestyles (Pauw and Petegem, 2010). Nevertheless, the residency differences affect the environmental attitudes of both adults and children from the developed and developing countries (Bechtel et al.1999, Van Petegem and Blieck 2006).

Kaiser et al. (2007) have emphasized on an attitude-behavior gap that appears to limit any attempt of identifying a person's attitudes by means of inspecting his/her behaviors. Previous research has found that though awareness and knowledge are important, they have limited influence on attitudes and behaviors of public (Douglas et al. 1998). Besides, culture and values often play a role in determining public attitudes and this link has appeared in a cross-national study by Franke and Nadler (2008). Moreover, there are also contradictory findings that question whether an increased understanding of a new technology can actually affect a student's perceptions of and attitudes to the use of that technology (Dawson and Schibeci 2003). In this regard, Wegner and Kelly (2008) have drawn our attention to the idea that the understanding of the adoption of technology requires an understanding of how public attitudes and beliefs are formed or changed, as well as the implications of these changes on social norms. This is perhaps due to the complexities of attitudes, behaviors and the relationship between the two as suggested by Owens and Driffill (2008).

The relationship between knowledge and attitude is significant and it has become evident in several studies related to environmental issues (see Tikka et al. 2000, Weaver 2002, DiEnno and Hilton 2005, Prokop et al. 2007). Although attitude is not necessarily a behavior, there are evidences that show a relationship between attitude and behavior exists when attitude measured is compatible with the behavior to be predicted. Compatibility means that both the attitude and behavior refer to the same action, target, context, and time. However, not all attitudes are equally influential to predict a behavior and only stronger attitudes that are less likely to change are the best predictors of behaviors (Ajzen and Fishbein 2005, Wegener and Kelly 2008). Wegener and Kelly (2008) have reinforced the above discussions by suggesting that a person's positive attitudes to the use of biofuels could emerge if that person is actually driving a car that runs on biofuels instead of being based on receipt of information on biofuels from various sources. There are several environmental attitudinal scales considered useful for predicting behaviors (see Dunlap and Van Liere 1978, Stern et al. 1993). However, it has been argued that many of these scales are not useful to reveal ambivalent attitudes toward pro-environmental actions and *neutral* attitudes are different from purely ambivalent attitudes (see Costarelli & Colloca 2004). The measurement of attitudinal ambivalences becomes even more challenging in cross-cultural studies (Peng and Nisbett 1999) as different cultural moderators can significantly influence an individual's evaluative tensions. Therefore, the present study has regarded young students' limited capacity for evaluating various aspects of bioenergy as their ambivalent perceptions of and attitudes to bioenergy.

The above discussions indicate that the technologies for bioenergy need public support in two important aspects. First, there is a need for strong positive public attitudes to bioenergy. Secondly, public also need to have strong positive intentions to use bioenergy. Such positive intentions could emerge from using bioenergy instead of fossil fuels and by paying an extra price for green electricity produced from biomass. In the absence of such a strong link between positive intentions and actual behaviors among public, policies related to bioenergy will find various societal challenges to overcome during their implementation phases. In reality there is, however, a wider gap between people's general positive attitudes to the REs and their specific intentions to pay more for them. In this regard, previous evidences from Sweden suggest that though a higher number of individuals expressed positive attitudes to green electricity from the REs, only 1% made voluntary purchase of green electricity by actually paying a higher price for it (see Hansla et al. 2008). In this context, it is important to understand that an individual's positive attitudes to a technology can be regarded as an intention to use that technology and actively support its development in the society (Hansla et al. 2008). Therefore, it can be implied that the young students need more information on bioenergy to give their perceptions of and attitudes to bioenergy a concrete shape, which in the future would determine their intentions to use bioenergy.

1.5 Aims of the study

The main aim of the study was to explore school students' knowledge, perceptions, and attitudes related to bioenergy in Finland, Taiwan, Turkey, and Slovakia, and explain their intentions to use bioenergy. More specifically, the following research tasks were carried out:

i) To describe and determine young students' knowledge, perceptions, and attitudes related to bioenergy with an analysis of the implications of the social environments on them in Finland (Paper I & II);
ii) To compare and analyze the international variations in young students' knowledge, perceptions, and attitudes to bioenergy by expanding the study in Taiwan, Turkey, and Slovakia (Paper III); and
iii) To develop models to explain young students' intentions to use bioenergy based on their knowledge and perceptions of, and attitudes to bioenergy (Paper IV).

The results of the study are expected to contribute to policy recommendations for increasing interactions between energy and education policies so that the young students in various countries can participate in bioenergy-related discussions and increase their awareness of bioenergy.

2 METHOD AND DATA

2.1 General framework for the thesis

The general framework for the thesis is presented in the Figure 1. It illustrates the connection among all the papers from Paper I to IV, moving from the descriptive analysis to the more profound analysis to reveal the relations and structures of young students' knowledge, perceptions, and attitudes related to bioenergy. The Paper I and II are setting the background for the Paper III, which analyzes the variations in the cross-national data on the key issues related to bioenergy. Additionally, the Paper IV, which is built upon the Paper III, develops conceptual models to explain young students' intentions to use bioenergy. The implications of the findings for both bioenergy policies and related energy education strategies are part of the discussion in all the Papers (I-IV).

2.2 Materials and method

2.2.1 Inception in Finland

The study was a comparative study in nature and it started with the collection of data in Finland. The data for the Paper I & II came through a self-constructed questionnaire survey among ninth-grade 15-year-old students in Finland. This served as the background for the

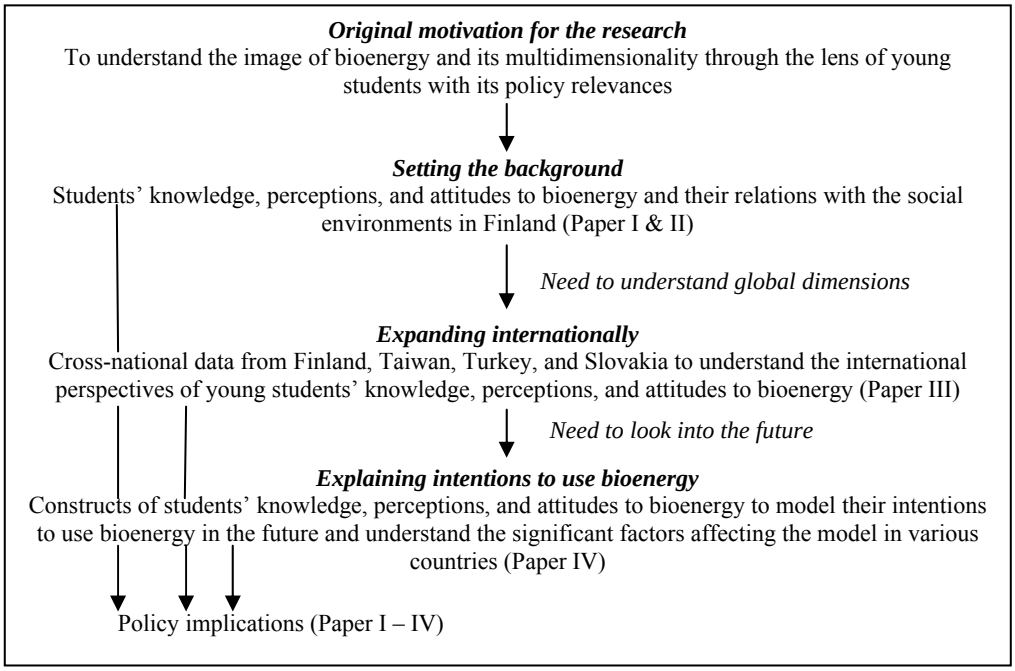

Figure 1. Development of the study from original motivation for research to interlinking the papers I-IV.

subsequent surveys in Taiwan, Turkey, and Slovakia. The questionnaire consisted of both close (5-point Likert-type scale) and open-ended items (see Appendix). The first step in designing the survey instrument was to analyze the Finnish National Core Curriculum for Basic Education designed by the Finnish National Board of Education (2004). This core curriculum specifies the objectives and core contents of cross-curricular themes, subjects, and subject groups in compulsory basic education in Finland. According to this core curriculum, ninth grade students learn sustainable development, biodiversity and environmental protection topics through courses in Biology and Geography. At this stage, they become aware of topics related to heat and electricity and they are able to give examples of converting energy through various processes, such as the burning of wood. Curriculum analysis was a necessary step in the selection of the appropriate items in the questionnaire for the ninth-grade 15-year-old students in Finland.

The open-ended items in the questionnaire consisted of knowledge-related items on different forms of the REs (solar, wind, hydro, and bioenergy) and on particular bioenergy types like wood pellets, billets (firewood) and liquid biofuels. In addition, there were both open and close-ended items to investigate the social environments (school, home, and media) from the perspectives of the students in Finland and relate them to their knowledge and perceptions of, and attitudes to bioenergy. There were 18 items on the Likert-type bioenergy perceptions and attitudes measurement scale (strongly agree to strongly disagree). The items on the Likert-type scale consisted of two sub-scales: students' perceptions of bioenergy (11 items) and their attitudes to bioenergy (7 items). A pilot test was conducted among a group of ninth grade students in a school in Finland to improve the final version of the questionnaire used in the study. Please see Paper I&II for detailed discussions regarding the study design, instrument construction, and its reliability testing for the Finnish study.

2.2.2 Expansion in Taiwan, Turkey, and Slovakia

The Finnish study was expanded into Taiwan, Turkey, and Slovakia to explore young students' knowledge, perceptions, and attitudes related to bioenergy from an international perspective (Paper III). These countries were selected on the basis of their variations in the field of bioenergy development and socio-economic contexts (see Paper III for country-wise descriptions). Although these countries belonged to a previous research network that facilitated to collect data within a short period, the variations in socio-economic contexts in these countries contributed to generate the required data to fulfill the objectives of the study. An analysis of the national course curriculum of school education was also carried out in these three countries. On the basis of this analysis, 15-year-old students studying in either ninth or tenth grade were selected from Taiwan, Turkey, and Slovakia to maintain a comparable sample group in all the four countries (see Paper III for a detailed discussion on the method). It appeared from the analysis of the course curriculums that the students had studied biology, physics, chemistry, and other environmental science oriented topics in all these countries. However, there was no topic in their syllabi related to the REs. Students from both urban and rural area schools participated in each country in the study. The urban and rural classification in each country was based on the statistics issued by each country and the researchers in each country guided the selection of the schools. No differences in the course curriculum appeared in the urban and rural schools in any of these countries since each country followed a common national guideline for basic school education.

The international survey employed an instrument, which was a little modified version of the instrument that was employed in the Finnish study. In Taiwan, Turkey, and Slovakia, the researchers did pilot tests to improve the final version of the instrument. In the final

version, there were total 17 Likert-type items to measure students' perceptions of (10 items) and attitudes to (7 items) bioenergy. Furthermore, it also included open-ended questions to measure the students' knowledge of the REs including bioenergy. The study in these three countries excluded the questions that could explore the students' perceived awareness of bioenergy from school, home, and media discussions. The reason was that those particular questions in the pilot tests conducted in those countries received few responses from the students. Perhaps the contextual variations in those countries and the form of the questions played a role in this regard. The same reason was taken into consideration while excluding also the questions that could measure the students' knowledge of wood pellets, billets (firewood), and biofuels in the survey in those countries. Ethical questions were also taken into considerations while collecting data among the young students in all the countries (see Paper III).

2.3 Data collection and analysis

A total 1903 students participated in the study from 19 schools (11 urban and 8 rural) in the four countries (Table 2). The mean age of the students was 15 years. About 71% of the students were from urban area schools while 47% were boys. The survey questionnaire administered among the students was translated into the local languages in each country and the researchers did the translation back into English for the analysis. Experts for maintaining a linguistically equivalent translation later validated them. The open-ended items were coded according to a codebook by one researcher in Finland to avoid any potential biases with inter-rater reliability. The quantitative analyses were conducted with the SPSS v.17.0 program. During the analysis of the data, the open-ended questions on measuring the students' knowledge of the REs were categorized as *low*, *medium*, and *high* levels. A *low* level of knowledge was considered when a student demonstrated some basic information about a particular type of the RE. Similarly, a *medium* level of knowledge was considered when a student showed some basic knowledge of a particular RE with some understanding of the process of producing it. Likewise, a *high* level of knowledge was considered when a student provided reasonable information about a particular type of RE, its production process and examples of its advantages and disadvantages. A detailed discussion on the developing of conceptual models to explain students' intentions to use bioenergy has been provided in Paper IV and an overview has been presented in chapter 3.3 in this summary.

Table 2. Characteristics of the school students (N=1903) in the study (Paper III)

Country	Number of respondents (response rate)	School area	Students' residence distribution (%)	Mean age (SD)	Gender (%)
		Urban (Rural)	Urban (Rural)		Boy (Girl)
Finland	495 (79%)	4 (4)	75 (25)	15.24 (0.51)	51 (49)
Slovakia	166 (100%)	2 (1)	66 (34)	15.32 (0.73)	25 (75)
Taiwan	897 (98%)	4 (2)	73 (27)	15.43 (0.54)	45 (55)
Turkey	345 (95%)	1 (1)	61 (39)	15.28 (0.47)	57 (43)

3 SYNTHESIS OF RESULTS

This chapter first describes the findings of the cross-national comparative study measuring young students' knowledge, perceptions, and attitudes related to bioenergy that are based on the pooled data from Finland, Taiwan, Turkey, and Slovakia (Paper III). Subsequently, it presents a detailed assessment of the students' knowledge and perceptions of, and attitudes to bioenergy in Finland and relates them to their perceived experiences with bioenergy discussions in school, home, and media (Paper I & II). Finally, the results of the model-based explanations of the students' intentions to use bioenergy are presented at the end of this chapter (Paper IV).

3.1 Cross-national perspectives of students' knowledge, perceptions, and attitudes related to bioenergy (Paper III)

The study of students' knowledge and perceptions of, and attitudes to bioenergy in Finland, Taiwan, Turkey, and Slovakia revealed that only a small percentage of the students appeared to have high level of bioenergy knowledge and this was also consistent with the other REs such as solar, wind, and hydro (see Paper I, Table 2). The Finnish students demonstrated the highest level of knowledge in all the REs including bioenergy compared to their counterparts in the other countries. The issue of gender and living area did not have any statistically significant effects on the students' bioenergy-knowledge. The majority of the students rated their bioenergy-knowledge as *poor* and the effect of gender was statistically significant on their rating of own bioenergy-knowledge. About 66% of the girls rated their bioenergy-knowledge as *poor* compared to 56% of the boys whereas 10% of the boys rated their bioenergy-knowledge as *good* against 5% of the girls.

The study employed a five point Likert-type scale to measure the students' perceptions of and attitudes to bioenergy (see Paper III, Table 3). The students appeared to be critical in their perceptions of forest-based bioenergy production. They did not agree that wood energy would be a major source of bioenergy in the future and that the production of energy from wood was environmental friendly. They did not also appear to justify the felling of trees for energy production and they considered the production of bioenergy from forests as globally unsustainable. The number of students who agreed on the issue that the increase of bioenergy production would decrease food production exceeded the number of students who disagreed on it (25% vs. 19%). Similarly, a slightly higher percentage of the students did not agree that the increase in the use of bioenergy could mitigate global warming problems compared to the students who agreed on such a proposition. However, the results showed that more students agreed than who disagreed to the following propositions: *bioenergy could replace the use of fossil fuels in the future* (37% vs. 30%); *tree plantations should be established for bioenergy production* (33% vs. 31%); *growing awareness of bioenergy in the society* (34% vs. 24%); and *politicians should support research and development of bioenergy in the society* (34% vs. 25%). A large number of the students showed their inability to confirm their agreement or disagreement to the items that measured their bioenergy perceptions, which can be termed as the students' ambivalent perceptions of bioenergy. On the contrary, the students demonstrated greater positive attitudes to bioenergy than their perceptions of bioenergy. Nevertheless, about one-third of the students and even more appeared to be ambivalent in their attitudes to bioenergy. The

results showed that the students were not only positive about the learning of bioenergy from various sources, they were also very eager to use bioenergy (e.g. driving a biofuel car and using bioenergy at their homes).

The issue of gender and living area appeared to have statistically significant effects on the students' overall perceptions of bioenergy. The boys and the students from the rural areas' schools demonstrated more critical perceptions of bioenergy than the girls and the urban areas' school students did. However, in terms of the students' overall attitudes to bioenergy, the study did not find any statistically significant differences in gender and residence. In terms of the students' overall perceptions of bioenergy, each country differed significantly from the other. It emerged that the Finnish students were the most critical of bioenergy, whereas the Slovakian students were the most positive in their perceptions of bioenergy. However, statistically significant differences related to the students' attitudes to bioenergy emerged between Finland and Taiwan (Taiwanese students were more positive than the Finnish students); Taiwan and Turkey (Taiwanese students were more positive than the Turkish students); and Finland and Slovakia (Slovakian students were more positive than the Finnish students). Overall, the Taiwanese students demonstrated the most positive attitudes to bioenergy while the Finnish students were the most critical of it. It became apparent that the students with a higher level of bioenergy-knowledge were more critical in terms of their both perceptions of and attitudes to bioenergy. On the other hand, the students with a lower level of bioenergy-knowledge were rather ambivalent about bioenergy.

The pooled data in this study revealed three key dimensions from the students' perceptions of and attitudes to bioenergy. The three key dimensions were termed as *practical*, *motivation*, and *critical*. The *practical* dimension consisted of items that identified the practical ways of using bioenergy as well as suggested political support for the development of bioenergy. The other aspects of this dimension represented some elements of favor for bioenergy in replacing fossil fuels in the future. However, it also showed some elements of skepticism of the role of bioenergy in mitigating the global warming problem. The *motivation* dimension consisted of items that showed students' positive attitudes to learning bioenergy through different possible ways. The *critical* dimension included items that cast some doubts upon the present methods of producing bioenergy from forests, which many considered as unsustainable, unjustified and environmentally harmful. These three key dimensions differed significantly across the countries and presented the evidence of multidimensionality of the students' perceptions of and attitudes to bioenergy.

3.2 Students' knowledge and perceptions of, and attitudes to bioenergy and their relationships with the social environments in Finland (Paper I & II)

In the first part of the research study, it analyzed students' knowledge and perceptions of, and attitudes to bioenergy in Finland. The results showed that more than half of the students demonstrated rather basic level (either low or medium) of bioenergy-knowledge and only about one-tenth of them demonstrated a higher level of such knowledge (see Paper I, Table 1). Similar patterns appeared in their level of knowledge for the other REs (e.g. solar, wind, and hydro). However, no statistically significant gender and living area differences appeared in terms of their knowledge of bioenergy. Further analysis of the students' knowledge of wood pellets, billets (firewood), and biofuels revealed that more than two-

thirds of the students had basic level of knowledge of these items and only a minority of them actually demonstrated a higher level of knowledge of them (see Paper I, Table 2). The effect of neither gender nor living area was statistically significant on their level of knowledge of these three bioenergy items. About one-tenth of the Finnish students rated their knowledge of bioenergy as *good* while more than half of them rated that as *poor* (see Paper I, Table 3). A statistically significant gender difference appeared among the students when analyzing their rating of bioenergy-knowledge, which showed that more girls rated their bioenergy-knowledge as *poor* than the boys did.

The results from this study indicated that the Finnish students were very critical of bioenergy as they generally disagreed with some of the proclaimed positive attributes of bioenergy such as bioenergy could mitigate global warming problems and it would replace the use of fossil fuels in the future (see Paper I, Table 4). In addition, the students disagreed to the propositions that *wood energy will be a major source of bioenergy in the future*; *wood energy is environmentally friendly*; *production of bioenergy from forests is sustainable in Finland*; and *tree plantations should be established for bioenergy production*. The students were rather critical of forest-based bioenergy production and they did not agree that the awareness of bioenergy was growing in the society. Their criticism of bioenergy also appeared on the debate on food vs. fuel issues. The results showed a state of ambivalence among the students as approximately one-third of them were not able to confirm either their agreement or disagreement to the items measuring their perceptions of bioenergy. It appeared that the students with a higher level of bioenergy-knowledge were more critical of bioenergy than the students with lower level of such knowledge. The study found that there was no statistically significant gender difference in the students' overall perceptions of bioenergy. However, gender difference appeared to be statistically significant in some of the perceptions related items (see Paper I, Table 5). The effect of living area appeared to be statistically significant on the students' perceptions of bioenergy as the students from urban areas' schools were more positive in their perceptions of bioenergy than their rural counterparts were.

In general, the students' attitudes to bioenergy appeared to be more positive than their perceptions of bioenergy (see Paper II, Table 1). Their positive attitudes were reflected in terms of their interests to learn bioenergy from various sources. However, they did not show such positive attitudes toward the use of bioenergy. The effect of gender was statistically significant on the students' overall attitudes to bioenergy whereas the effect of living area was statistically insignificant. In general, the boys and the students from the urban areas' schools showed more positive attitudes to bioenergy than the girls and the rural areas' school students did. Similar to the students' perceptions of bioenergy, the students with higher level of bioenergy-knowledge showed lack of positive attitudes to bioenergy including their attitudes to use it. A Principal Component Analysis extracted three principal components from the students' perceptions of and attitudes to bioenergy (see Paper II, Table 2). They were termed as *motivation* (students' eagerness to obtain more information on bioenergy), *considering sustainability* (students' perceptions of the sustainability issues associated with the forest-based energy production), and *utilization* (students' intentions to use bioenergy in the future).

Additional analyses were carried out in order to explore the Finnish students' awareness of bioenergy through their perceived discussions in school, home, and media and how those affected their knowledge and perceptions of, and attitudes to bioenergy. It appeared that only a minority of the students discussed bioenergy with their parents at home, whereas about half of them had such discussions in their schools. However, the media discussions appeared to be the most common source of information on bioenergy to the students (see Paper II, Table 3). The majority of the students did not perceive positively that schools

would be able to provide more information on bioenergy (i.e. bioenergy learning opportunities in schools). However, those who perceived such possibility in school provided some examples such as i*ntroducing a bio-energy module in the course curriculum; showing videos on bioenergy in school; and visiting a wood pellet factory in their region*.

The effects of school, home, and media appeared to be statistically significant on the students' knowledge and perceptions of, and attitudes to bioenergy (see Paper II, Table 4). Results revealed that the students who perceived bioenergy discussions from school, home, and media were highly critical of bioenergy. Similarly, information received on bioenergy from these sources also increased their level of bioenergy knowledge. Further analysis suggested that the students with a higher level of bioenergy-knowledge were less positive in their attitudes to obtain more knowledge of bioenergy than the students with relatively lower level of bioenergy-knowledge were. In addition, the students with higher level of bioenergy-knowledge were also less interested in using bioenergy than the students with lower level of such knowledge.

3.3 Model-based explanation of young students' intentions to use bioenergy (Paper IV)

This paper aimed at building models to explain young students' intentions to use bioenergy with the help of multiple regression analyses. The cross-national data from the Paper III formed the basis for this study. The results revealed two key components from the perceptions related items and were termed as *contribution* and *critical* (see Paper IV, Table 1). The *contribution* component consisted of items that reflected the students' general perceptions of the future contributions of bioenergy in mitigating global warming problem and replacing fossil fuels. On the other hand, this component also indicated the contribution expected from policy makers to support bioenergy research and development in the society. This component reflected broader societal aspects related to bioenergy. The *critical* component consisted of the items that denoted the environmental and sustainability dimensions of bioenergy. However, the 'criticality' in this context had been interpreted as the students' critical perceptions of those environmental and sustainability aspects of bioenergy.

Two key components also emerged from the attitudes items and they were termed as *motivation* and *intentions to use*. The *motivation* component consisted of the items that reflected the students' motivations to communicate and learn bioenergy from various sources such as visiting a bioenergy plant, studying and discussing bioenergy with teachers, parents and classmates. The *intentions to use* component reflected the students' attitudes to use bioenergy. These two components indicated a broader individual decision making among the students in the bioenergy related issues.

In multiple regression analyses, the *intentions to use* component was treated as the criterion (dependent) variable whereas the predictors (independent variables) were the *contribution*, *critical*, and *motivation* components. The regression model was statistically significant ($F_{3, 1875} = 694.81$; $p<.001$; Adj. $R^2 = 0.53$). All the three predictors were included in the model and their effects were as follows: *contribution* ($\beta = 0.67$; t-value=39.92; $p < .001$), *motivation* ($\beta = 0.16$; t-value=9.83; $p < .001$) and *critical* ($\beta = -0.10$; $t = - 5.88$; $p < .001$) (see Paper IV, Table 3). The results indicated that *contribution* and *motivation* had positive relationships with the criterion variable *intentions to use* while *critical* had negative relationships with it. From the magnitude of the t-statistics, it was clear that the predictor *contribution* had much larger impact on the model outcomes than *motivation* had. With regard to the students' level of bioenergy knowledge, it appeared that the students

with a *high* level of bioenergy knowledge had a strong impact on the outcome of the model ($F_{3, 241} = 141.65$; $p < .001$; Adj. $R^2 = 0.63$) as it explained a high variance in the students' intentions to use bioenergy (see Paper IV, Table 4).

In addition, a set of multiple regression analyses from each country (see Paper IV, Table 5) showed that the predictor *contribution* had significant impacts on the model outcomes in all the four countries. The predictor *motivation* had such impacts in Finland, Taiwan, and Slovakia but not in Turkey. The predictor *critical* was only included in the model in Taiwan, although it showed a negative relationship with the criterion variable *intentions to use*. In Turkey, the model excluded the predictor *motivation*. In Finland, critical perceptions did not affect students' intentions to use bioenergy. The issue of criticality was insignificant in determining the students' intentions to use bioenergy in all the countries though in Taiwan it had slight impact. In Finland and Turkey, the students' perceptions of bioenergy as a societal phenomenon were significant and they affected their intentions to use bioenergy. Slovakian students appeared to be very ambivalent as there were no strong predictors. Motivation to discuss and learn bioenergy slightly explained the intentions to use bioenergy, but it seemed that its power would not be very strong in influencing the students to choose bioenergy in the future.

4 DISCUSSION AND CONCLUSIONS

4.1 Conclusions of the empirical results

Bioenergy is expected to play a significant role in the global energy mix of the next decades, transforming the current fossil fuel-based economy into a low-carbon energy economy (Beringer et al. 2011). Therefore, the future bioenergy systems should ensure long-term sustainability of this field by taking into account the environmental, economic, and social dimensions (Londo and Deurwaarder 2007). However, there is a significant research gap in exploring the role and social acceptance of bioenergy while implementing bioenergy projects around the world (McCormick 2010). Current research on this topic is limited and it becomes rare in the context of evaluating young citizens' awareness of bioenergy from a cross-national perspective. This dissertation has investigated young students' knowledge, perceptions, and attitudes related to bioenergy with the help of cross-national data from Finland, Taiwan, Turkey, and Slovakia. Moreover, the study attempted to find implications of its findings for bioenergy policies and related education strategies.

In terms of students' knowledge of bioenergy, the study has found a similarity among the students across the four countries. The majority of the students seemed to have basic level of bioenergy-knowledge, whereas a minority among them demonstrated a higher level of such knowledge. The study has experienced an especially low response rate from the students to the question intended to measure their knowledge of bioenergy. In this regard, the present study confirms previous findings (see Rohracher and Späth 2004, Segon et al. 2004, Eurobarometer 2007, Adelle and Withana 2008, BERR 2008, Thornley and Prins 2008, EECA 2008) and brings new evidences that suggest that young students have lower knowledge of bioenergy than the other forms of the REs. The present study provides additional evidences confirming that low level of bioenergy-knowledge among young students is due to the fact that the images of solar and wind energies are more visible to public as solar panels and wind mills, whereas modern bioenergy concept is more at the abstract level to them (Paper I). Therefore, it appears that there is a need for raising young students' understanding and experiences of this emerging energy technology. Whilst this

study has not suggested any statistically significant gender and living area differences related to the students' knowledge of bioenergy (Paper I & III), it partially substantiated the higher male preferences for technologies (see Jones et al. 2000, Brotman and Moore 2008) as more girls rated their own bioenergy-knowledge as poor than the boys did (Paper III).

The evidences from this study suggest that the students were critical of forest-based bioenergy across the countries (Paper III). Using forest biomass for energy production is generally considered to be in agreement with the principles of sustainable development, (Stupak et al. 2007) though various studies have challenged this concept by considering its risks on environment (see European Environment Agency 2007, Werhahn-Mees et al. 2011). In this study, the appearance of the students' critical perceptions of the sustainability issues related to forest-based bioenergy production could have emerged from two possible reasons. First, their limited bioenergy-knowledge did not help them to understand the complex issues of 'sustainability' in the context of forest-based bioenergy production. Therefore, they were either critical of or ambivalent about bioenergy and it shows a typical example of perceptions without awareness. Secondly, the study has found that the students who showed higher level of bioenergy knowledge were more critical of bioenergy than the rest. Probably a higher level of knowledge of the subject among them created more skepticisms than beliefs in their minds regarding the widely discussed concept of sustainable bioenergy production from forests. These findings confirmed to some extent the previous findings, which indicated that an increase in students' level of knowledge would generally increase their critical thinking skills (Harlen 2006, Brown et al. 2010). Previous studies have represented critical thinking as a necessary life skill and have argued that it creates the habit of reflection and questioning in every aspect of life, which are essential for success in the contemporary world (King 1995, Marin and Halpern 2011). However, in the contemporary world where the realm of knowledge is expanding in leaps and bounds it is difficult to suggest the best learning process, which can result into critical thinking for school students (Moseley et al. 2005, Marin and Halpern 2011). This challenge becomes even larger when dealing with a decontextualized topic like bioenergy and other emerging energy technologies. Ku (2009) has suggested, "students to develop critical thinking skills must go beyond absorbing textbook knowledge and learn to build up skills involved in judging information, evaluating alternative evidence and arguing with solid reasons". The same idea can be applied to the development of students' critical thinking skills for bioenergy and related sustainability issues.

The evidence revealed through this study perhaps reflects a global trend in public perceptions of bioenergy especially when it comes to young students. It may imply that critical perceptions of bioenergy among young generations could make them more inquisitive of bioenergy, which in turn would increase their awareness of bioenergy and guide their future choice of it as an alternative to the fossil fuels. The study has suggested that the students demonstrated not only positive attitudes to learn more about bioenergy but also positive intentions to use it (Paper III). Moreover, it has shown that there are country level differences in this attitudinal aspect related to bioenergy among the young students. For example, the Finnish students did not demonstrate positive attitudes to the use of bioenergy, although they were very interested in learning bioenergy. It was perhaps due to the reason that though they demonstrated the highest level of knowledge of bioenergy among all the countries, they were less interested in the use of bioenergy considering its adverse impacts on the environment. On the other hand, the students from the other countries, who were less aware of bioenergy, considered bioenergy as new and thrilling to use. The empirical findings in this study provide a new understanding of the relationship between attitudes and intended behavior in the context of bioenergy. The results differ from those of previous studies on environmental attitudes, which showed a fragile link between

attitudes and intended behavior (see Kollmuss and Agyeman 2002, Rohracher and Späth 2004).

The study explored the effects of school, home, and media discussions of bioenergy on the students' knowledge, perceptions, and attitudes related to bioenergy in the Finnish context. It emerged that school, home, and media discussions of bioenergy, as perceived by the students, had significant effects on their perceptions of and attitudes to bioenergy (Paper II). The findings suggested that the students became critical of bioenergy when they received bioenergy information from school, home, and media. This suggests that perhaps the majority of the students became aware of the adverse impacts of bioenergy on environment particularly on biofuels through those discussions. The students perceived media as the most important source of receiving information on bioenergy and popular media discussions on bioenergy particularly on biofuels have been critical on the debate on food vs. fuel (see McCormick 2010). Therefore, the media discussions on bioenergy were perhaps influencing the young students to be highly critical of bioenergy in Finland. However, it should be mentioned here that the study did not distinguish among different forms of the media (for example, the internet, newspaper, radio, and television), and therefore it is not known which form of the media had the strongest effects on the Finnish students. It is also worth mentioning here that bioenergy production in Finland is largely dependent on the forestry sector, whereas the debates on food vs. fuel emerge where food crops are utilized for the production of liquid biofuels. Nevertheless, in reality, it seems that this distinction was not comprehensible to the students and they were critical of bioenergy regardless of its source of production.

In general, it seems that the students in Finland did not recognize very well their home environments as an important provider of bioenergy related information to them despite the fact that bioenergy is commonly used in various indoor activities in Finland. This finding suggests that perhaps the students failed to perceive the indoor use of firewood or wood pellets as a source of bioenergy and were unable to differentiate between the modern use of bioenergy and the traditional way of burning wood. The findings of the study from the Finnish context do not necessarily indicate that home environment is unable to provide bioenergy related information to young students as home environment generally plays an important role in young students' perceptions of and attitudes to different scientific and environmental issues (Martin 1996, George and Kaplan 1998). It was not possible to explore these aspects in the other three countries, which resulted in some gaps in our current understanding of how these aspects would vary in those countries. Therefore, the findings from the Finnish context will serve as a base for future studies to provide deeper understanding of the societal contexts and their implications on young students' knowledge, perceptions, and attitudes related to bioenergy.

One of the most significant findings that emerged from this study is the key dimensions of the students' perceptions of and attitudes to bioenergy. The study found three key dimensions from the cross-national data and they were termed as *practical*, *motivation*, and *critical* depicting different facets of the students' perceptions of and attitudes to bioenergy (Paper III). The results from the study further suggested that the internal consistency of these key components differed across the countries. This implies that young students' perceptions and attitudes are multidimensional on bioenergy issues and they could vary from one country to another country. The study has also attempted to explain the students' intentions to use bioenergy by taking into considerations the key dimensions of their perceptions of and attitudes to bioenergy (Paper IV). Explanatory models with the multiple regression analysis suggested that the students' intentions to use bioenergy could be better explained by considering their perceptions of the societal aspects related to bioenergy. It showed that the students' attitudes to communicate and learn more on bioenergy had both

positive and significant impacts on their intentions to use bioenergy, however, the relationship was weak. In addition, the results indicated that the students' criticality of bioenergy did not have any impact on their intentions to use bioenergy. Further evidences from this study suggested country-wise variations in the predictors to explain the students' intentions to use bioenergy. This has supported the existence of multidimensionality among the students' perceptions of and attitudes to bioenergy. The effects of the term in the model on R^2 were reasonable and it showed higher explanatory power than previous studies in explaining people's revealed intentions to pro-environmental behaviors. For example, private and public environmental protection behavior (see Feng and Reisner 2011), public attitudes to underground carbon capture and storage (see Sharp et al. 2009), and attitudinal ambivalence on pro-environmental behavioral intentions (see Costarelli and Colloca 2004). However, the country-wise models in the study revealed low explanatory powers in accounting for the variance in students' intentions to use bioenergy. It suggests that there might be key country specific socio-economic and demographic determinants of students' awareness of bioenergy that these models were not able to capture.

4.2 Policy implications and general recommendations

The current findings add to the growing body of literature on societal perspectives of energy issues particularly of the REs. It is because energy is an essential commodity of modern industrial society and education has a vital role to play in the development of a sustainable society (Jennings 2009). The current study reinforces the suggestions by Dias et al. (2004) and Managenergy (2004) that educational policies on energy should target children since they are more receptive to new concepts and can act as educational agents and opinion leaders at home while growing up as environmental conscious citizens. Energy education has two dimensions – the first one focuses on developing energy professionals and the other one emphasizes on producing a more energy literate society via primary and secondary education (Newborough et al. 1991 as quoted in Zografakis et al. 2008). This implies that policy makers and educators should try to improve the awareness of bioenergy among young students while formulating future policies on bioenergy. They will help young students to increase their awareness of bioenergy as well as encourage them to use it when they consider that it has been produced sustainably. The results of this research support the idea of increasing collaboration between bioenergy policies and related education strategies for young students. One such example could be the introduction of a sustainable energy module, which can deal with all kinds of the REs at schools as suggested by Zografakis et al. (2008). In addition, the development of interactions among bioenergy producers, students and their families, and schools at local level will also be beneficial for young students.

Bioenergy lies at the intersection of several policy domains (e.g. energy, economy, environment, and social), which makes it a much complicated issue to address effectively. Therefore, introducing a module on bioenergy in school curricula as per the above suggestion and relying on it to enhance young students' awareness of bioenergy may not produce the desired results. In this context, the findings from the present study suggest a stronger application of the STS (science, technology, and society) approach for school science-teaching in subjects that need multidisciplinary approaches to understand such as bioenergy. It has been found that in contrast to traditional science-teaching, the STS science- teaching approach is more oriented toward students, provides concrete examples of scientific concepts and instills more behavioral changes among students (Aikenhead 2005). Furthermore, a significant number of studies also reported that the use of the STS improved

both students' concepts of science in new situations, particularly those in real-life settings and their attitudes to scientific issues (see Daas 2005). However, the present study goes one-step further and opines that the STSE (science, technology, society, and environment) approach of teaching scientific matters such as bioenergy might be more relevant than the STS approach. Though the STSE approach originates from STS education, it places greater emphasis on the consequences of scientific and technological developments and relations on environment. It encourages students to explore scientific developments from multidimensional perspectives such as economic, environmental, social, ethical, moral, and political (see Kumar and Chubin 2000, Pedretti 2005).

The evidences from this study assert that it might be challenging to encourage young students to take part in energy related discussions, particularly in the discussions of a decontextualized topic like bioenergy. However, in this regard household communications can play an important role to overcome this challenge by conveying information on energy and environmental issues to their children (Hondo and Baba 2010). However, it means that parents and other senior members of the family should themselves become aware of the emerging energy technologies such as modern bioenergy systems. This research will serve as a base for future studies on knowledge, perceptions and attitudes of parents regarding bioenergy since they usually take decisions at homes in the choice of energy technologies. Besides, policy makers should encourage debates on both the advantages and disadvantages of the emerging energy technologies such as bioenergy to make public aware of the use of bioenergy considering its impacts on sustainable development.

Media campaigns are among the policy tools that serve as one of the most effective means to influence public opinion of various issues of importance such as the energy issues (Viklund 2004, Sampei and Aoyagi-Usui 2009). The importance of production and utilization of bioenergy and its implications for sustainable development is a globally important issue, which can hardly go unnoticed in the future. Therefore, the empirical findings from this study provide a new understanding and suggest to media, schools, and parents to raise the awareness of bioenergy, particularly of forest-based bioenergy and its contribution to sustainable development among young students. It seems that the future forest policies must reach the young citizens and make them aware of the role of forests as a source of environmental friendly energy.

One of the important conclusions of the study points out that if government actions in raising awareness of bioenergy are entirely based on the 'information deficit model', they may not dramatically influence young students' perceptions of and attitudes to bioenergy though it can increase their knowledge of the topic. However, policy makers should consider broader societal and cultural factors to change people's attitudes and behaviors toward energy issues as suggested by Owens and Driffill (2008). In addition, involving students in campaigns related to environmental and energy issue may have long-term positive impacts on their perceptions of and attitudes to these issues.

4.3 Methodological limitations and future research needs

The purpose of the current study was to explore young students' knowledge, perceptions, and attitudes related to bioenergy from a cross-national perspective. Although the findings from the study have enhanced our understanding of those aspects, certain limitations need to be taken into account. The objects of the study have been very generally expressed as either 'young students' or 'young citizens' and the author is aware of the fact that generalization such as this will set great demands on the data (for example, definition of the population, sufficient and representative sampling, and so on). Therefore, the data in the

study represent actually cases. Sampling is a problematic issue in a work like this, which is closely related to the generalization of the results. The schools were selected on the basis of their rural-urban locations in each country. However, rural and urban characteristics greatly vary across the countries and so do the characteristics of the respondents. Therefore, caution must be taken while considering the schools as a pure random sample and generalizing the results within a country and across the countries.

The statistical analyses are closely related to the sampling. Due to the concern with normality of the data, mostly non-parametric methods of statistical analyses have been used in the study. The parametric methods have been applied to the 'sum variables' assuming that they would follow normal distribution. Therefore, while interpreting the statistical results these considerations must be taken into account. The use of multiple regression analysis in the Paper IV can be improved by using hierarchical modeling (also known as multilevel modeling) as the within-subject correlation (for example, students inside classes, classes in schools, schools are in school areas, school areas are in countries) may affect a pseudo-replication in regression analysis. However, determining the sufficient sample size at the group level is a problematic area in hierarchical modeling as group-level sample size is always smaller than the individual-level sample size (see Maas and Hox 2005). Moreover, the general regression models though showed reasonable explanatory effects, the country-wise models were rather weak indicating an average effect size. Nevertheless, small effect sizes are common in research in the field of social sciences and they can be practically important (see Milfont and Gouveia 2006).

It is recommended that further research should put more efforts to determine the societal contexts and their impacts on the students' knowledge, perceptions, and attitudes related to bioenergy. Future research should also investigate these phenomena among parents and teachers to determine how they are related to young students' awareness of bioenergy. There is also a need to improve the current research design to carry out future cross-national studies in the field of bioenergy. Bioenergy is a generic term that includes several feedstocks (e.g. energy crops, wood, waste, and biogas) with different end uses (e.g. heating, electricity, and transport fuels), which generally vary across countries. Therefore, the future cross-national studies, which explore young students' knowledge, perceptions and attitudes related to a particular bioenergy feedstock that exists in all those countries, will produce better comparative results and establish construct equivalence. In addition, longitudinal studies could be helpful in the investigation of the changes in young students' knowledge, perceptions, and attitudes related to bioenergy over a period. However, considering the span of observation time for a longitudinal study, which is indeed a crucial point along with questions such as measurement of error and attrition of individuals from observation (see Rajulton 2001), it was beyond the scope of the present study.

Reliability and validity are often two problematic issues in cross-national studies. The overall reliability of the survey instrument in the study showed adequate level of internal consistency (expressed as the statistical power of the Cronbach's alpha). However, it varied between the two sub-scales ('perceptions' and 'attitudes' measurement scales) and among the countries. Although researchers have not yet developed a standardized statistical test in order to compare the power of reliability tests (Parameswaran and Yaprak 1987), future studies could use the technique of the *multiple group structural equation modeling* in measurement of equivalence analysis (see Myers et al 2000). Similarly, other methods such as *decentered scales* and *triangulation* could also help in the measurement of equivalence analysis (see Craig and Douglas 2000).

The study formulated open-ended questions to measure young students' knowledge of bioenergy. Although open-ended questions contain very rich information, the consistent analyzing and coding of a large set of data into different categories is challenging (Kleij and

Musters 2003). Therefore, future studies can consider a better combination of both close and open-ended questions, complementing each other, to measure young students' knowledge of bioenergy as it may produce better results and decrease the rate of non-responses. In addition, a combination of existing software products for text analysis and other procedures such as correspondence map may be a successful approach to the analysis of textual data (Kleij and Musters 2003).

The study attempted to explore the role of school, home, and media in the students' knowledge, perceptions, and attitudes related to bioenergy through their perceived awareness of these information sources. This approach though generated interesting information from Finland, it was unable to do the same in the other three countries, which was evident from the pilot tests in those countries. In this regard, applying the method of cognitive-interviewing during the pilot tests could help to find out to what extent survey questions have similar meanings in different languages and cultures (see Priede et al 2010). Information generated through this process could be useful to develop the survey questions to ensure that respondents are able to understand them clearly (Willis 2005). It can also improve the external validity of the survey instrument. It is recommended that media should be classified into different forms (for example, internet, radio, television, newspaper, so on) so that the results should reveal the particular form of media, which has the strongest influence on students' knowledge, perceptions, and attitudes related to bioenergy in different countries. Finally, future survey instruments should include additional socio-economic and cultural parameters related to the students such as their living conditions, home environment, school environment, and extra-curricular activities such as hobbies in order to improve the explanation of their intentions to use bioenergy.

In spite of the above-mentioned limitations and future research needs, it should be noted that the current study is amongst the first attempts that investigated young students' knowledge, perceptions, and attitudes related to bioenergy from a cross-national perspective and analyzed the implications of the findings for the future bioenergy and related educational policies. It can therefore be said, as Yaprak (2003) believes, "our long journey into discovery is only beginning and we need to learn much more along this sojourn".

4.4 Final remarks toward a 'greener earth'

The successful development of bioenergy and other technologies related to the REs requires public acceptance, which serves as a prerequisite for energy policy and young citizens are certainly an important target group from the perspectives of bioenergy policies. More efforts are needed across the world to enliven the positive image of bioenergy and create more opportunities to disseminate information on bioenergy among young students to enhance their awareness of it. It will be a gain for our society if young generations become aware of bioenergy, make critical evaluation of it and use it when it is sustainably produced. Besides, public perceptions of and attitudes to environmental matters and related technological developments are not static; they do change over time and in case of young students' perceptions of and attitudes to bioenergy, the change may occur soon in the future. Therefore, it can be suggested that the bioenergy policy-makers should take into consideration various socio-economic and psychological uncertainties that influence public perceptions of and attitudes to energy and environmental issues. It is only a sound energy policy that can motivate the current fossil fuel-based society to make use of bioenergy and other 'green' energies; thereby keeping our promise of making the earth a greener place for the future generations.

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APPENDIX

Questionnaire for measuring students' knowledge, perceptions, and attitudes related to Bioenergy

Not to be filled in by the respondent

Name of the school:	Name of the city/county/municipality:	Urban/Rural:

A. Profile of the respondent

1. Your name (optional):

2. How old are you? _____ Years

3. Are you a girl or a boy?

☐Girl ☐ Boy

B. Respondent's knowledge of bioenergy and other renewables

4. What do you know about the following sources of renewable energy? Please describe in short.

(a) Solar energy

(b)Wind energy

(c) Hydro energy

(d) Bioenergy

5. Which of the above sources of renewable energy is the most important to you in terms of its wider applicability?

6. What do you know about the following sources of bioenergy? Please describe in short[1].

(a) Wood pellets

(b) Billets

(c) Biofuels from agricultural crops

7. Which of the above sources of bioenergy is the most important to you in terms of its wider applicability[2]?

8. How do you rate your knowledge of bioenergy? Please select only one answer from the following options.

☐ Very good ☐ Good ☐ Cannot say ☐ Poor ☐ Very poor

C. Respondents' perceptions of bioenergy

9. Please indicate whether you agree with each of the following statements? Please select only one option under each statement. There is no right or wrong answer.

Statements	Strongly Agree	Agree	Do not know	Disagree	Strongly Disagree
Increased use of bioenergy can mitigate the global warming problems	☐	☐	☐	☐	☐
Bioenergy can replace the use of fossil fuels in the future	☐	☐	☐	☐	☐

Increasing bioenergy production will decrease food production	☐	☐	☐	☐	☐
Wood energy would be a major source of bioenergy in future	☐	☐	☐	☐	☐
Production of energy from wood is environmental friendly	☐	☐	☐	☐	☐
Cutting of trees for energy production is justified	☐	☐	☐	☐	☐
Production of bioenergy from forests is sustainable in Finland[3]	☐	☐	☐	☐	☐
Production of bioenergy from forests is globally sustainable	☐	☐	☐	☐	☐
Tree plantations should be established for bioenergy production	☐	☐	☐	☐	☐
There is growing awareness of bioenergy in the society	☐	☐	☐	☐	☐
Politicians should support research and development of bioenergy in the society	☐	☐	☐	☐	☐

D. Respondents' attitudes to bioenergy

10. Please indicate whether you agree with each of the following statements? Please select only one option under each statement. There is no right or wrong answer.

Statements	Strongly Agree	Agree	Do not know	Disagree	Strongly Disagree
I would like to drive a car in future that runs on biofuel	☐	☐	☐	☐	☐
I would like to visit a bioenergy plant in my region	☐	☐	☐	☐	☐
I would like to study more about bioenergy in the future	☐	☐	☐	☐	☐
I would like to discuss more about bioenergy with my teachers	☐	☐	☐	☐	☐
I would like to discuss more about bioenergy with my parents	☐	☐	☐	☐	☐
I would like to discuss more about bioenergy with my classmates	☐	☐	☐	☐	☐
I would like to use bioenergy at home in the future	☐	☐	☐	☐	☐

E. Bioenergy discussions in school, home, and media[4]

11. Have you ever discussed bioenergy in your school with your teachers and /or classmates?

☐ Yes ☐ No

If your answer is ‘yes’, please describe in short what you have discussed.

12. Have you ever discussed bioenergy with your parents?

☐Yes ☐No

If your answer is ‘yes’, please describe in short what you have discussed.

13. Do you think you would you be able to learn more about bioenergy in your school?

☐Yes ☐No

If your answer is ‘yes’, please describe in short what you have discussed.

14. Have you ever found discussions related to bioenergy in the media such as radio, TV, internet, newspaper, etc.?

☐Yes ☐No

If your answer is ‘yes’, please describe in short what you have discussed.

15. What is your main source of receiving information on bioenergy? Please select only one answer from the following options?

☐ School ☐Home ☐ Media ☐ Other (please specify) ☐ None of these

****End of the questionnaire****

[1,2,3,4] These questions were excluded from the survey in Taiwan, Turkey, and Slovakia