Dissertationes Forestales 270

Structural shifts, fossil fuel substitution and attainability of climate targets in the Nordic forest-based bioeconomy

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Academic dissertation

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ABSTRACT

European energy and environmental policies have extensive effects on the Nordic forest products market. This thesis focuses on four main questions. First, the effects of global changes in the consumption, production, and trade of Finnish and Swedish forest products market. Second, investigate the effects of the policies on the substitution of fossil fuel (coal) by a solid form forest-based biofuel. Third, compares and evaluates Nordic countries' research perception with the European Union's other regions', based on experts' perceptions on attaining the European Union's 2020 targets. Fourth, forecasts the interaction between the renewable energy and wood fuel energy production of Sweden, Finland, Denmark, and Norway. The first and fourth studies followed econometric analysis, the second study executes by developing a theoretical model, and third studies followed a questionnaire survey analysis. The results show that during 1981–2012, structural break years are 1991 and 1992 for the Finnish model and 2004, 2005, and 2006 for the Swedish model. The fossil fuel replacement study showed that combining tax and subsidies increases the aggregate demand for biofuel and increase substitution by about 19% and 31%, respectively. A regional assessment showed that with the Nordic countries' experts, an overwhelming majority (82–93%) from the European Union's other regions suggested for stable and adequate incentives to meet renewable energy targets for biomass and perceive that 2020 targets will not be achieved. Finally, estimation between renewable energy and wood fuel show that due to shocks, renewable energy had positive and the wood fuel had an always negative reaction to their own and mutual positive shocks. The thesis concludes that tax and subsidies together have a strong effect on the replacement of fossil fuels by forest-based biofuels, any unexpected shocks may increase renewable energy production and decrease wood fuel production, and consistent policy tools are necessary to achieve European Union targets.

Keywords: global change, mitigation strategies, energy policy, forest-based biofuel, renewable energy.

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Tahamina Khanam
Joensuu, 5 April 2019

LIST OF ORIGINAL ARTICLES

This thesis is based on data presented in the following articles, referred to by the Roman numerals I-IV.

I. Khanam T., Rahman A., Mola-Yudego B., Pykäläinen J. (2017). Identification of structural breaks in the forest product markets: how sensitive are to changes in the Nordic region? *Mitigation and Adaptation Strategies for Global Chan*ge 22 (3): 469-483. doi: 10.1007/s11027-015-9681-9

II. Khanam T., Matero J., Mola-Yudego B., Sikanen L., Rahman A. (2016). Assessing external factors on substitution of fossil fuel by biofuels: model perspective from the Nordic region. *Mitigation and Adaptation Strategies for Global Change* 21: 445-460. doi: 10.1007/s11027-014-9608-x

III. Khanam T., Rahman A., Mola-Yudego B., Pelkonen P., Perez Y., Pykäläinen J. (2017). Achievable or unbelievable? Expert perceptions of the European Union targets for emissions, renewables, and efficiency. *Energy Research & Social Science* 34: 144–153. doi: 10.1016/j.erss.2017.06.040

IV. Khanam T., Rahman A., Mola-Yudego B. Renewable energy production and wood fuel production in the Nordic region - can it be changed? Manuscript.

Author’s Contribution

Tahamina Khanam is the main and corresponding author for the four manuscripts. She is also responsible for the data collection, analysis, writing and compiling of all the manuscripts. The other co-authors, when stated, were participated in discussion of ideas and manuscript improvement. Papers I, II, and III are reprinted with kind permission of the concerning journal.

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LIST OF ABBREVIATIONS AND UNITS

ADF	Augmented Dickey Fuller
CHP	Combined heat and power
EC	European Commission
EE	Energy efficiency
EU	European Union
FAO	Food and Agricultural Organization
GHG	Greenhouse gas
IRF	Impulse response function
LR	Likelihood-Ratio test
OECD	Organization for Economic Co-operation and Development
RE	Renewable energy
RQ	Research question
RW	Roundwood
RSSr	Restricted Residual Sum of Squares
RSSu	Unrestricted Residual Sum of Squares
SW	Sawnwood
UNECE	United Nations Economic Commission for Europe
VAR	Vector autoregressive system
VECM	Vector error correction model
WF	Wood fuel
WTP	Willingness to pay
Mtoe	Million tonnes of oil equivalent

DEFINITIONS

Impulse response function (IRF): It represents the dynamism of the variable along a considered period after given an impulse or shock in a certain moment. Both the Vector autoregressive (VAR) and Vector error correction model (VECM) can be used.

Satisfaction level: It express the state of a customer's satisfaction to a product by associating his expectation with the product's perceived performance. Substitution occurs when customer's satisfaction level is equal with the product performance.

Shocks: In economics, shocks are unpredictable and unexpected incidents that can occur from inside or outside the economy, impacting the economy positively or negatively. By shocks, this study also means any form of shocks, i.e. macro or microeconomic shocks (e. g. Supply shocks, technology shocks, policy shocks – inflationary or currency devaluation, demand shocks etc.).

Substitutability: It occurs when one product is replaced by another product. The slighter level of substitutability is called imperfect substitution. The complete substitutability is called perfect substitution.

Vector autoregressive (VAR) system: All the variables in the VAR system are endogenous. Thus, in the VAR system, the numbers of models are based on the number of endogenous variables. In the two endogenous variables based VAR system, when one variable becomes dependent the other variable becomes independent. The VAR system model could be restricted (some variables are in one equation and rests are in another equation) and unrestricted (all variables are in each equation).

Vector error correction model (VECM): In the VAR system, if the considered two endogenous variables are co-integrated, one co-integration is needed to correct the equation. These type of system is called then VECM. In statistical viewpoint, the model has then no autocorrelation and no heteroscedasticity problem; and also considered that the variables are normally distributed.

Willingness to pay (WTP): It is the ultimate value of a product that a consumer is willing to pay or sacrifice as an alternative of getting it.

1 INTRODUCTION

The global forest product markets of this century are divergent from the earlier century's forest product markets. Industry consolidations, increasing wood supply, decreasing supply of low-cost energy, and China's emergence in global forest products markets have influenced the changing process (Roberts et al. 2004). Further, trade liberalization and the changing consumption level of wood and wood products have also influenced this supply and swapped investment growth from North America to Latin America and from Europe to Asia (Toppinen et al. 2010). Toppinen and Kuuluvainen (2010) claim that the input-output markets of the forest industry in Europe have encountered numerous internal and external structural changes during the past few decades. Globalization also reduces transportation costs and reliance on the supply of local forest industry raw materials (Nilsson 2007). These changes, both regionally and globally, offer new advantages to producers; for example, the Nordic forest product producers are investing in South America's forest plantations and pulp mills, while locating paper machines in Asia (FFIF 2005).

The European and the Nordic forests sectors are also one of the participants or contributors of these changing patterns. European forest products markets are affected by national economic growth, demographic structure, global forest product price trends, technological progress market players' performances, and investment strategies (Achard 2009). Lundmark (2010) attempted to determine the revealed comparative advantage between EU member states, finding that forest endowment, energy policies, and country-specific characteristics are important determinants for the differences in net trade between EU member states. As income increases with economic development, countries move up the ladder of demand, having fewer basic requirements (Ernst 1978). Demographically, after a certain age, the unemployed group increases labour costs, and higher labour costs then compel producers to invest in developing the technologies used (FAO 2008). Therefore, given the regional and global changes, the demand and trade for wood and wood biomass for producing energy is growing rapidly. Nevertheless, according to the equilibrium theory of perfectly functioning spatial markets, the continuous and increasing trade between two regions depend on the price differences between regions equalling transportation costs (Bolkesjø et al. 2006).

The forest industry is now using new investment strategies that are diversified between existing and emerging product markets or those producing completely new products (Achard 2009). Thus, in doing so, even some existing products markets are declining, such as the shrinking newsprint market, as digital media replaces print media. Further, the outcome of technological progress, that is to say, converting pulp and paper production units into different forms of bio-refinery outputs (e.g. ethanol, organic acids, starch, and polymers), also has a significant impact on the changes in the European forest products market (Jonsson 2011). The new technological innovations and improvements, therefore, contribute to the enrichment of forest industries by focusing on the diffusion of the new forest products and services through innovation in bioenergy, biochemical, and biomaterials.

This century's forest product market is now in a changing phase, as the consumption and production of forest product market is always shaped in the light of climate change (Hetemäki and Hurmekoski 2016). Kirilenko and Sedjo (2007) claim that the expected climate change has a direct effect on both natural and plantation forests. Hetemäki et al. (2010) also indicate a correlation between forest industry output and wood fibre-based energy production in Finland. Further, the Department of Communities and Local Government (2006) indicates that policies and regulations are linked with climate-change, and stimulate the use of renewable and energy-efficient supporting materials. Sjølie et al. (2010) analysed the situation in more detail, pointing out that, if the aim is to lessen greenhouse gas (GHG) emissions, providing subsidies to renewable energy sectors is less effective than imposing taxes on fossil fuels, because subsidies fail to implement the weight of negative externalities (GHG emissions) on the emitter. Baek (2006) also found that price instability in the Pacific Northwest in 1992, owing to imposing restrictions on federal timber harvests, caused structural shifts in the US and Canadian softwood lumber price structure. Jonsson (2011) concludes that all uncertainties in the forest sector derive mainly from two sources: national values being replaced by the broader patterns of regionalism or globalized values and concern having arisen on climate change (i.e. environmental issues).

Therefore, as of the preliminary step of this changing process, in 2007, the European Commission (EC) placed their targets for biofuel production at 15% and 20%, for 2020 and 2030, respectively (COM 2006). The EU energy and climate policies are currently demonstrating a noteworthy growth to attain the 2020 goal. Compared with the 1995 level, the carbon emission and energy intensity in the EU was reduced by around 24% in 2010 and 28% in 2011 (EC 2014b; 2014c). In 2014, compared with the 1990 level, the RE consumption share increased by around 13%, while the proportion of total energy consumption and GHG emissions decreased by around 18%. The EU's target attained scenarios for 2014 are represented in Figure 1. It is expected that RE consumption might reach 21% by 2020 and 24% by 2030. Therefore, GHG emissions might decrease by 24% in 2020 and 32% in 2030. The EC considered increasing the 20% target to a 30% target by 2020, which might increase costs by EUR 33 billion (EC 2010). Additionally, another analysis by the EC indicates that a 25% energy efficiency will be needed to reduce GHG emissions by around 40% by 2030 (EC 2014a). Nevertheless, in May 2010, after assessing the risk of carbon leakage, the cost and benefit analysis of reaching a 30% reduction target, the EC decided not to adopt it (EC 2012).

European public policy concerning forest products aims at increasing production to secure the energy supply, mitigate climate change, and to shift to a 'bio-economy' by reducing dependency on fossil fuels (van Ree 2010). In fact, the term 'bioeconomy refers to an economy that relies renewable natural resources to produce items such as energy, food, products, and services, so as to further reduce dependency on fossil fuel usage, and biodiversity loss, and simultaneously accelerate economic growth and job creation (Sustainable growth from bioeconomy 2014). Thus, in a simple way, the current century's changing forest products market is now focusing more on the value addition of the forest product and attaining bioeconomoy in a sustainable way.

According to Moiseyev et al. (2011), 24% (60 Mtoe) of the EU's Renewable Energy target has been fulfilled by forests and forest industries. Recently, Academia Europe recommended that excessive forest diminishing for energy production can damage forests' carbon stock (EASAC 2017). Thus, on accounting sustainability in bioenergy production, it is also essential to consider forest carbon stocking (EASAC 2017).

In 2017, the European Parliament and Council agreed to implement EU's 2030 climate objectives by accounting LULUCF (land use, land use change, and forestry) emission, which includes 27% share of renewable energy, 40% emission reduction, and 27% improvement in energy efficiency (EU statement 2017). Therefore, as an implementation, the Finnish government put restrictions on coal usage for energy production and targets to decrease a significant amount of oil usage by 2030 (National Energy and Climate Strategy 2016). However, according to a recent study represented in the EU, 82% of heat production uses solid biomass (EC progress report 2018).

The Nordic areas are now in the front-line of the bioeconomy transition phase. The Nordic countries, Finland and Sweden, accounted for around 67% and 57% of productive forest land in 2012 (LUKE 2012; SFA 2014). In 2010, the primary biomass and waste supply in Sweden, Finland, Denmark, and Norway were 124, 102, 26, and 15 terawatt hours (TWh), respectively (Eurostat 2012). Currently, the Nordic countries reflect an outstanding condition with respect to bioeconomy development. Nevertheless, a consistent and dynamic model that designates the economic relationships from the regional, forest, and energy market perspectives is still lacking (Lundgren et al. 2008; Toppinen and Kuuluvainen 2010). Thus, as of consequence, it was necessary to represent a concrete proof that explains changing the pattern of the Nordic current energy market scenarios and combined it with the forest market contribution; specially to investigate how tax and subsidies are performing in these markets. In addition, as of the part of the current market analysis, it was also necessary to evaluate the EU H2020 targets because the regional policies have an impact over the national policies. Since 2007 when the policies were undertaken, none of the studies critically evaluated those policies. Thus, to solve these problems, it was urgent to investigate how the Nordic and other European experts' percept about H2020 policies. Further, to adopt new policies in the energy sector it is also crucial to investigate the old forest market and energy market scenarios and forecast future scenario based on old scenarios. In the field of the forestry sector, especially in the Nordic perspective, these kinds of analysis are lacking. Therefore, this study bridges these gaps by analysing and modelling econometrically the recent structural changes in the Nordic multi-country markets by emphasizing the interactions between forest and energy sectors.

The overall objective of these studies is to identify past structural changes, represent the present scenarios of climate change and its consequences on the forest product market, and finally, to represent the possible future state of the Nordic changing forest products market. The more specific objectives of this thesis are: (I) to identify the structural breaks and their linkages to trade in the Finnish and Swedish forest products market; (II) to provide a theoretical model to represent the impacts of external factors (tax and subsidies) on the replacement of fossil fuels with biofuels; (III) to investigate and compare Nordic expert views with other regions in the EU regarding the achievement of the EU 20% target for GHGs, renewables, and efficiency; and (IV) to investigate how the production of renewable energy (RE) and wood fuel (WF) energy reacts after a shock. In this study, the term shock refers to any unexpected reactions that occur owing to any unexpected incidences.

Therefore, four papers were prepared based on the above-mentioned four objectives, and thus, to this end, time series data have been collected for resolving the first and fourth research objectives in order to execute an econometric analysis (i.e. Papers I and IV). A theoretical environment was developed from the current Nordic country perspective to resolve the second research objective (i.e. Paper II). The intention was to mathematically show how environmental policies were substituting fossil fuel with the solid form of forest-based biofuel. A questionnaire survey was used to collect experts' views so as to answer the third research objective (i.e. Paper III). How the results of these studies are useful in the adaptation of societal changes and contribute to policy development by providing support to researchers and decision makers are further shown in Figure 2.

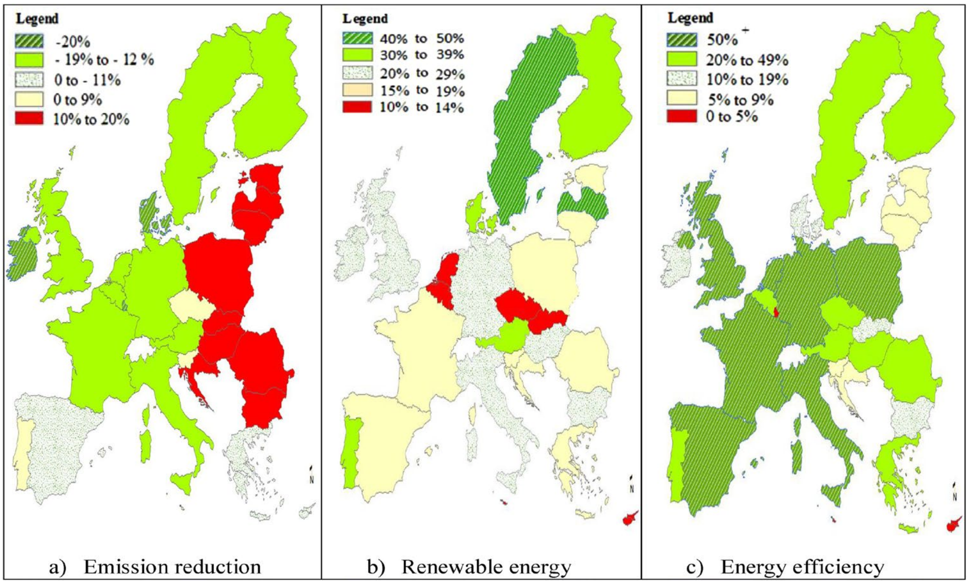

Figure 1. European Union's H2020 targets for emission reduction, renewable energy and energy efficiency (status in 2014).

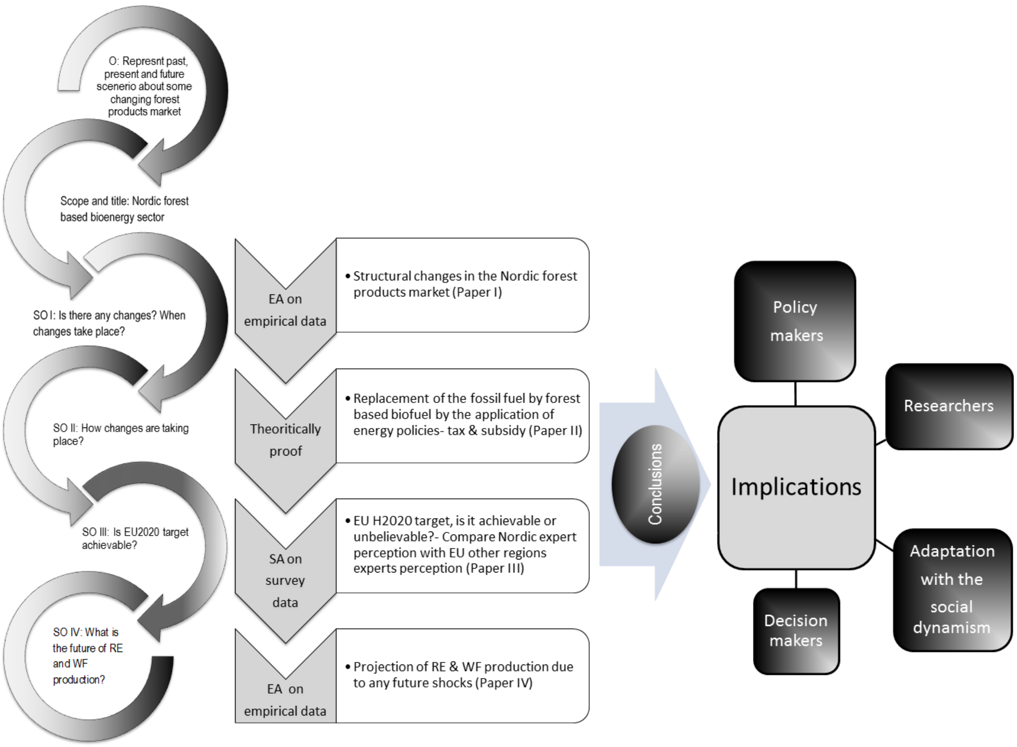

Figure 2. Illustration of the framework of the thesis. EA= Econometric analysis; O= Overall objective; SO= Specific objective; SA= Statistical Analysis

2 DATA COLLECTION AND ANALYSIS METHODS

2.1 Structural breaks identification

This study investigated the regional and global changes that influence the consumption, production, and trade in the Finnish and Swedish forest products market. For forest products, a total of 49 years (i.e. 1964–2012) of annual export–import data of roundwood (RW) and sawnwood (SW) removal of RW data of Sweden and Finland were considered. Finland and Sweden are more advanced than other countries in terms of forest resource usage because of the abundance and significance of this type of resource. Therefore, this study considers these countries as the study areas. To identify the structural break in Swedish and Finnish trade data, identical periods and variables were used in the respective models. The data were collected from the United Nations Economic Commission for Europe (UNECE) and the Food and Agriculture Organization Corporate Statistical (FAOSTAT) database. Specifically, the UNECE database provided the 1964–2009 dataset, and FAOSTAT, the 2010–2012 dataset (UNECE 2013; FAOSTAT 2013). The dataset includes coniferous and non-coniferous, industrial and non-industrial RW, and coniferous and non-coniferous SW (the datasets are expressed in 1 000 m^3 of volume.)

The stationarity or non-stationarity of variables were verified by the Kwiatkowski–Phillips–Schmidt–Shin (KPSS) test and Augmented Dickey–Fuller (ADF) unit root test. The full model (i.e. I, T) is considered for the ADF test equation. After the first differencing, if the variables fail to become significant, they will be considered non-stationary. However, a natural double-logarithmic model was considered, although many of the variables proved significant by the stationarity and non-stationarity tests. The restricted regression model based on the available empirical dataset is represented in equation 1:

$$\ln RRDC_j = \alpha + \beta_1 \ln RM_j + \beta_2 \ln SM_j + \beta_3 \ln RX_j + \beta_4 \ln SX_j + u \qquad \text{(Eq. 1)}$$

In the equation, $RRDC_j$ is the remaining RW for domestic consumption by country *j* (removals of RW by country j+RM_j−RX_j), where, RM_j and SM_j are the RW and SW imports by country *j*, RX_j and SX_j are the RW and SW export by country j, α is the constant, and *u* is the error term. The subscript *j* stands for $j \in (s, f)$, namely, *s* for Sweden and *f* for Finland. The aim of forming the $RRDC_j$ series is to identify the consequences of the structural changes on the corresponding countries' RW consumption. Statistically, this type of series may lead to measurement errors and, consequently, intensify the variance of the error term. Nevertheless, bias or endogeneity in the model appear only when the regressor is correlated with the error term (Wooldridge 2013). From the economic viewpoint, the assumption to build the relationship between trade and consumption is: the domestic consumption of a product is dependent on its availability; consequently, the availability of the product is dependent on trade and other issues (e.g. environmental degradation, energy policy, natural disasters, national economy, and demographic growth).

The Chow test was utilized to analyse structural breaks, as it is a non-parametric test and not biased with the non-normality of residuals, and since the breakpoint in the corresponding trade period is acknowledged. We presumed that owing to industrial revolution or technological progress, the changes in the consumption and trade patterns occurred after 1980 for both countries. In addition, the residuals of the findings of equation 1 also indicated us to divide the entire time period into two periods: t1 (1964–1980) and t2 (1981–2012).

2.2 Fossil fuel substitution

This study identifies the external factors that lead to substituting fossil fuels by forest-based bioenergy products in the Nordic areas. It also considers tax and subsidies as external factors. Three stages are represented: creating a utility function of a given consumer, and identifying the substitution criteria between two fuel categories. Therefore, a duopoly market structure model has been considered with two final products—solid type of biofuel and coal as fossil fuels. This study considers only the solid biofuel that produces electricity. In 2015, Finland and Sweden accounted around for 16.2% and 7% of the electricity generated from the solid biomass (Finnish Energy 2016; Environmental progress 2017). The assumptions of the study are that biofuel is not GHG neutral and that two differentiated products could be substitutes or complements, as in Dixit (1979) and Singh and Vives (1984).

In the first phase, a concave utility function has been utilized as per previous different studies (e.g. Shubik and Levitan 1980; Singh and Vives 1984; Liang 2012). The market equilibrium demand and price functions have been derived from the utility function. In the second phase, the substitution condition of Liang (2012) has been utilized in deriving demand and price functions. Evaluating the literature and present market situations leads to collecting numeric values on the unit basis tax and subsidies amounts, marginal production costs, total production costs per unit, price of per unit product, environmental benefit–loss ratios to utilize in the derived demand, and price functions.

The average values of the data from different countries and several studies were considered to replicate the Nordic fuel market scenario (e.g. according to Eurostat (2003), Sweden's CO_2 and Sulphur tax in 1991 was 0.03 EUR kg^{-1}, and it doubled during the following decade). In 1999, the excise tax on electricity in Finland and CO_2 tax on coal in Denmark were respectively, 0.69 and 0.036 EUR kg^{-1}. Further, willow plantation subsidies in Sweden were reduced to 537.63 EUR ha^{-1} in 1999 (Johansson et al. 2002). In Sweden, wood chips and coal price were 48.58 x 1 000 kg^{-1} and 67.00 x 1 000 kg^{-1}, and pellets price in 2009 was 0.31 EUR kg^{-1} (Pelletsatlas 2009a). In Finland, the consumer price for wood pellets in May 2012 was 0.051 (EMV 2012), while in Denmark, hard coal price in heat production (Excluding VAT) was 0.015 as of December 2007 (Pelletsatlas 2012). Therefore, local data are calibrated into average values, and do not include tax and subsidies. The remaining numeric values were selected based on researchers' assumptions. Therefore, three scenarios were included in the resulting equations: a situation without tax and subsidies, a situation with subsidy, and a situation with tax and subsidies. The phases of the model are:

a) Identify equilibrium price of products; and
b) Apply substitution criteria on the equilibrium price, and graphically explain outcomes.

2.3 Experts' perception

This study analyses experts' perceptions regarding the accomplishment of the EU H2020 targets, identifies potential differences in the geographic location of experts, and compares overall perceptions with the present status of the H2020 target. According to Carpenter et al. (2010), *perception is the process with which individuals detect and interpret environmental stimuli*. Further, Baker (2003) defined perception as the processing of information to interpret some selective stimuli that are supported and formed by attitudes, experiences, and motivation. From the environmental viewpoint, basic human perceptions are not homogeneous and vary across genders, countries, backgrounds (living areas), and study locations (Worsley and Skrzypiec 1998). Saylor (2015) found that expert perceptions are not always rational concerning the environment, as the perceptions are influenced by various tendencies and common biases. Bogner and Wiseman (1997) showed that, compared with rural pupils, suburban and urban pupils asserted greater verbal assurance to the environment. Perceptions are commonly regarded as social, self, and visual. The factor that biases social perception is *stereotyping*, which can be negative, positive, or neutral. A selective perception considers only the selective attention on some areas of the environment and indifference to others. Visual perception refers to encompassing more than just physical information, which could be frequently biased (Saylor 2015). Baker (2003) indicates that perception needs to become selective to be effective in the decision-making process. However, a study on waste management behaviour identified that environmental values and psychological factors have a substantial influence in forecasting perception (Barr 2007).

Survey design. In order to retrieve data concerning expert's perception on the accomplishment of the H2020 targets, a questionnaire is designed in an open- and close-ended format. The questionnaire contained 26 research questions (RQs) in English. The RQs were divided into four sections: respondent's profile, respondent's perception about GHG reduction (RQ5 to RQ12), respondent's perception about RE consumption (RQ13 to RQ19), and respondent's perception about EE (RQ20 to RQ25). RQ26 was formed to evaluate the correlation between the last questions of the all sections (except respondent's profile section). For the RQs 1 to 4, the nominal scale format was chosen and for the rest of the RQs, a *non-comparative- itemized rating Likert scale* format was chosen (*Strongly agree=1, Agree= 2, No opinion=3, Disagree=4* and *Strongly disagree=5*). Therefore, the negatively worded statements (RQ7, RQ8, RQ9, RQ17, and RQ21) were turned into positively worded statements when the surveyed results were coded or scored reversely (Sijtsma 2009). The weights assigned for the analysis were: *Strongly agree + Agree= Accept, No opinion= No opinion, and Disagree + Strongly disagree= Reject.* Those with expertise on energy policy or renewable energy personals were considered *Experts*. This included researchers from the different forest institutes (e.g. Croatian Forest Research Institute, Finnish Forest Research Institute, European Forest Institute, and Hungarian Forest Research Institute, among others), university professionals (researchers and professors related to energy policy from different EU universities), and different countries and institutional policy makers and government personals (e.g. Forestry, Environment, Federal Ministry of Agriculture, Natural resources and Water Management of Austria, and Czech Republic, among others). Thus, comprehensive lists of experts were also taken from available sources (e.g. from COST actions) and through own elaboration. The pilot survey was conducted on 17 randomly selected researchers and doctoral students to improve and incorporate the final version of the questionnaire which included their suggestions for interpretation and reduction of ambiguity in some questions. Therefore, the final form of the questionnaire was distributed to survey respondent's perceptions.

Data collection and analysis. Data were collected from the end of April 2014 to March 2015, both by requesting personal email and hand-to-hand deliveries to fill the questionnaires. The 187 respondents were from 25 EU nationalities, where the female respondents were 22% (40) and male were 78% (147). However, based on age groups, for 11% were ≤ 30 years, 44% were 30–45 years, 39% were 45–60 years, and 6% were 60+ aged experts. Occupation wise, environmentalists represented 2%, policy makers 3%, doctoral students and junior researchers 28%, senior researchers and professors 48%, and other categories 19%. Moreover, the EU was divided into five geographical regions as per Table 1. The Statistical Program for Social Sciences (SPSS) v21.0 was used for statistical analysis. Cross tabulations were used to calculate the percentages of respondents and Cronbach's alpha for the reliability testing of the questionnaire proposed by Nunnally (1978). Therefore, the Chi-square and Kruskal–Wallis tests were carried out to measure the level of significance for two and more than two variables. Finally, the relationship between the combined (RQ26) and single target (RQ12, RQ19, RQ25) were measured using correlation analysis.

2.4 RE and WF energy reaction

This study considers a 1960–2015 (i.e. 56 years) time series WF and RE data from the Organization for Economic Co-operation and Development (OECD) and Food and Agricultural Organization (FAO), respectively (OECD 2016; FAOSTAT 2017). The RE data include solid biogases and gasoline, biodiesels and fuels, other categories of liquid biofuels, and renewable segments from municipal waste, solar, tide, geothermal, wind, wave, and hydro energy (without pumped storage) sources. The WF data include charcoal, firewood, pellets, chips, sheets, and saw dust. This study covers four Nordic countries, that is, Sweden, Finland, Denmark, and Norway, because of their availability of wood resources and utilization of wood for fuel purposes. Furthermore, the large contribution to the production and consumption of RE was also a reason to study their RE and WF production sectors.

The stationarity of the variables has been checked by the Augmented Dickey–Fuller (ADF) unit root test. Among the three situations in the ADF test equations, this study considers the full model (i.e. intercept (I) and trend (T)). If the test of the full model (with level) fails to reject the null hypotheses, we move on to the first difference. Therefore, the variable will be considered non-stationary if the first difference of that variable fails to reject the null hypotheses. The ADF test of the variables represents that both variables RE and WF become stationary at the first difference of the ADF test and are co-integrated in the same order (i.e. I(1)). Therefore, as the variables are integrated in the same order, we may need to run restricted VAR or VECM. However, it is significant to mention that, before running VECM, we need to perform three steps: ADF test (each variable needs to be integrated in the order of I (1)), Lag selection, and Johansen test of integration. If the Johansen test of integration represents co-integration, only then we perform VECM; if not, then after lag selection, we continue with the VAR system. However, the intention of this system model is to investigate the reaction between RE and WF production. After the diagnostic check of the model, the results will further be used to estimate the shock for the given moment.

Table 1. Data distribution according to regions

Regions	Including countries	Data distribution
Central European countries (CEC)	Austria, Germany, Belgium, Netherlands	31
East European countries (EEC)	Czech Republic, Slovakia, Poland, Hungary, Bulgaria, Estonia, Latvia and Lithuania	34
Western European countries (WEC)	France, Italy, Spain, United Kingdom, Ireland	43
South-Eastern European countries (SEEC)	Croatia, Cyprus, Greece, Slovenia, Malta	20
Nordic countries (NC)	Finland, Sweden, Denmark	59

3 RESULTS

3.1 Finnish and Swedish forest products markets structural breaks

3.1.1 Restricted model

The restricted model results represent that RW imports and SW exports have significant positive impact on the Finnish remaining internal RW consumption. The single independent variables $\ln(SM_f)$ and $\ln(SX_f)$ are significant at the 5% and 1% levels. Therefore, based on p-values, two variables are significant among the four independent variables. Furthermore, the 0.836 value of the R-squared indicates that around 83.6% of the variation can be explicated by the four independent variables, meaning the model has an insufficient goodness of fit, but also a lower effect of external factors on the model.

The Swedish restricted model shows that $\ln(RM_s)$, $\ln(RX_s)$, and $\ln(SX_s)$ are significant at the 1% level and $\ln(SM_s)$, at the 5% level. The 0.85 value of the R-squared denotes that the four independent variables explain 85% of the fluctuations in the model and the model is well fitted. However, the residuals of both the models (i.e. Finnish and Swedish) have been verified using the histogram normality test (Jarque–Bera statistics), Breusch–Godfrey Serial Correlation Lagrange multiplier (LM) test, and heteroscedasticity test (Breusch–Pagan–Godfrey and White's test).

The null hypothesis of the model indicates no normality, autocorrelation, or homoscedasticity problems. Therefore, the null hypothesis will be rejected if the $p\text{-value} < 0.05$. The Swedish model demonstrates that, although it is free from heteroscedasticity and autocorrelation, it suffers from the normal distributed issue, as $p < 0.001$. However, serial correlation has been identified in the Finnish model. Despite this complication, we proceed, since the Chow test is a non-parametric test. Therefore, we also presume that, during 1964–2012, the breakpoint is known. Possible breakpoints might be the beginning of the 1970s (the oil crisis period), the 1980s (the industrial renaissance and employment creation period), and the 1990s (joining in the EU).

The F-statistic is utilized to identify the single break year as per Chow (1960). The gap between the fitted and actual residuals in the Finnish model was at its maximum in 1975, 1976, 1978, 1989, 1993, and 2009, with outliers in 1976, 1989, and 2009. For the Swedish model, the actual-fitted gaps were at their maximum in 2005 and 2006.

3.1.2 Unrestricted model and structural change

The total number of observations, T, of the restricted model has been separated into two sub-periods, t1 (1964–1980) and t2 (1981–2012) as $T \in (t1, t2)$, because the residuals of the Finnish model exhibit a negative tendency until 1980, and positive tendency and some outliers subsequently. The residuals of the $LRRDC_f$ study denote that 1964–1980 has a different slope than 1981–2012. The $LRRDC_s$ study of the Swedish model also implies the same situations as in the Finnish model. Therefore, the sub-sample regression model for the separate period is:

$$\ln RRDC_{j,t1} = \alpha_1 + \beta_{11} \ln RM_{j1} + \beta_{21} \ln SM_{j1} + \beta_{31} \ln RX_{j1} + \beta_{41} \ln SX_{j1} + u_1 \qquad \text{(Eq. 2)}$$

$$\ln RRDC_{j,t2} = \alpha_2 + \beta_{12} \ln RM_{j2} + \beta_{22} \ln SM_{j2} + \beta_{32} \ln RX_{j2} + \beta_{42} \ln SX_{j2} + u_2 \qquad \text{(Eq. 3)}$$

In the equations, α_1 and α_2 are constants and $u1$ and $u2$ are error terms across both the models. The other variables are the same as equation 1. The representations of the sub-period models represented that $\ln(RM_f)$, $\ln(SX_f)$, $\ln(RM_s)$, $\ln(RX_s)$ are significant for the t1 period of both the countries. Further, in *t2* period, $\ln(RM_f)$, $\ln(SM_f)$, $\ln(SX_f)$, $\ln(SM_S)$, $\ln(SX_S)$ are significant to explain the model relationships.

However, the F-statistics of the analysis represent that the regression in equation 2 is apposite if there is no parameter variability from equation 3 (by imposing restrictions $\alpha_1 = \alpha_2$, $\beta_{11} = \beta_{12}$, $\beta_{21} = \beta_{22}$, and so on). This implies that sub-period regressions are similar. However, the restricted residual sum of squares (RSSr) model is obtained by using equation 1 with T = 49 and df = (t1 + t2 - k) = 44 (here, k is the number of parameters estimated—five in the corresponding case). RSS_1 and RSS_2 can be added to attain the unrestricted residual sum of squares (RSSu) (Gujarati 2004). The RSSu ($RSS_1 + RSS_2$) for both models are estimated with df = (t1+ t2 - 2k) = 39 and t1 + t2 = 49. The assumption behind the Chow test is: the RSSu and RSSr should not be statistically different. Consequently, the F-ratio supports the null hypothesis (i.e. there are no structural changes in the model if the computed F-value does not exceed the critical F-value, Gujarati (2004)).

The computed F-values for the Finnish and Swedish models are obtained by utilizing F-statistics of the Chow test, and the critical F-value (with k = 5 and df = 39) is obtained from the F-table (Gujarati 2004). The results show that the RSSr and RSSu are different for the two countries (Table 2). In the Finnish model, the probability of the computed F-value is greater than the critical F-value at the 1% significance level. Therefore, in the Swedish model, the computed F-value is greater than the critical F-value at the 5% significance level. Hence, we can reject the null hypothesis. Thus, the Chow test indicates that both countries' RW and SW export–import structure affects the remaining RW for domestic consumption, denoting structural change for 1964–2012.

3.1.3 Breakpoint check: Chow test

The Chow breakpoint test is performed to identify the specific break year by examining equations 2 and 3. The null hypothesis of the model is: there are no structural breaks in the trade of Finnish and Swedish forest products market, and the alternate hypothesis is its opposite. The year-specific breakpoint check in t1 found breaks in 1975 and 1976 in the Finnish model, and no breaks for the Swedish model as the p-values of these analysed years are low and fail to reject the null hypothesis of the Chow test. The breakpoint test for t2 demonstrates that there are breaks in 1991 and 1992 in the Finnish model, and in 2004 (the null hypothesis is rejected at the 5% significance level), 2005, and 2006 (the null hypothesis is rejected at the 1% significance level) in the Swedish model (Table 3).

Table 2. Identification of structural changes

	RSSr	RSSu	Computed F	Critical F	Results	LoS
Finland	0.264	0.12	9.36	4.02	SC	1%
Sweden	0.232	0.17	2.90	2.69	SC	5%

SC= Structural change; LoS=Level of Significance

Table 3. Break point check by the Chow Test for t1 (Time period *1964–1980*)[a] and t2 (Time period *1981–2012*)[b]

	Finland				Sweden		
Year	F-statistic	Year	F-statistic	Year	F-statistic	Year	F-statistic
1969	0.128	1973	1.166	1969	0.894	1973	0.897
	(>0.98)		(>0.41)		(>0.53)		(>0.53)
1971	0.275	1975	**7.139**	1971	1.012	1975	2.186
	(>0.91)		**(<0.010)**		(>0.48)		(>0.17)
1972	0.469	1976	**8.544**	1972	1.099	1976	1.269
	(>0.79)		**(<0.010)**		(>0.438)		(>0.37)
1990	2.201	2001	0.455	1990	0.488	2001	1.022
	(>0.09)		(>0.81)		(>0.78)		(>0.43)
1991	**7.419**	2002	0.444	1991	0.604	2002	1.417
	(<0.001)		(>0.81)		(>0.69)		(>0.26)
1992	**4.084**	2003	0.447	1992	0.746	2003	1.779
	(<0.001)		(>0.81)		(>0.59)		(>0.16)
1993	1.305	2004	0.455	1993	0.777	**2004**	**2.664**
	(>0.29)		(>0.81)		(>0.58)		**(<0.050)**
1994	1.039	2005	0.456	1994	0.848	**2005**	**21.811**
	(>0.42)		(>0.80)		(>0.53)		**(<0.001)**
1995	1.043	2006	0.350	1995	0.934	**2006**	**3.009**
	(>0.42)		(>0.88)		(>0.48)		**(<0.030)**
1996	1.042	2007	1.118	1996	0.708	2007	0.697
	(>0.42)		(>0.38)		(>0.62)		(>0.630)

Parenthesis shows probability with F (5, 7) and result table represents only 1969 to 1972 for t1

Parenthesis shows probability with F (5,22) and result table represents only 1987 to 2008 for t2

3.2 Assessing substitution of fossil fuel by biofuels

This study assumes an economy with two consuming final products—forest-based solid-form biomass (mainly generates electricity) and non-forest-based energy product fossil fuel (coal). The study area comprises the forest rich countries of Sweden and Finland.

Therefore, the production of biofuels is completely dependent on national forest endowment, whereas the production of fossil fuel is based on imports. Two common energy promotion tools are considered as external factors (i.e. subsidies on biofuel and tax on fossil fuel). Therefore, the quadratic and concave utility function taken from Singh and Vives (1984) is:

$$U = fD_f + bD_b - \tfrac{1}{2}(\beta D_f^2 + 2\gamma D_f D_b + \beta D_b^2) - P_f D_f - P_b D_b \qquad \text{(Eq. 4)}$$

f and b are the consumer's willingness to pay (WTP) for the fossil fuel services and biofuels services respectively, P_f and P_b are the prices of fossil fuels and biofuels, respectively, D_f and D_b are the demand functions for the fossil fuels and biofuels, and γ is the substitutability between two energies.

Here, $\gamma \gtreqless 0$ *products might be independent, substitutes, or complements;* $\gamma = 1$ *means the products are perfect substitutes;* $\gamma > 0$ *means the products are not complimentary; and* $\gamma = 0$ *means the products are independent (firm has monopolistic market power).* β is the satisfaction level of the corresponding representative towards the aggregate demand. The study holds the assumption that substitutability (γ) is dependent on the country's economic growth, placing pressure on the development and application of policies into the energy sector (as $\gamma < \beta$), since both types of fuels have limitations in satisfaction level. Biofuel (b_f) and fossil fuel (f_f) can be split into two categories based on their price and quality. The low pricing approach offers positive satisfaction level, indicated by *h*, whereas h_f is the low pricing quality of fossil fuel and h_b the low pricing quality of biofuel. The low pricing approach means the products' low price is because of the low fixed or marginal costs.

Therefore, with no loss of generality, the study assumes that f_f producer offers lower prices for per unit fossil fuel compared to b_f producer. The situation can be described as $h_f > h_b$. Another characteristic is environmental friendliness, where b_f offers a friendlier environment than f_f, which is indicated by *e:* e_b for biofuel and e_f for fossil fuel. The fuel that generates less pollution during its usage offers a friendly environment. We obtain the condition of $e_f < e_b$, from which the WTP for both fuels can be written as $f = (h_f + e_f)$ and $b = (h_b + e_b)$.

The combination of low price biofuel and higher friendly operating environment in fossil fuel can cause substitution. Thus, the substitution (γ) will occur when: $\gamma =$ *(Minimum h + Minimum e)* or $\gamma = (h_b + e_f)$. *The expression represents the substitutable constituent between two types of fuels with condition* $\gamma < \beta$ *(Liang 2012). If* h_b *and* e_f *become zero, then substitutability will be 0, but when 1, products are perfect substitutes.*

The resulting proposition is that *external factors affect the price of the product, further impacting the quality of the product, and thus resulting in substitution.* Therefore, the substitution of fossil fuel by biofuel will occur when biofuels have lower prices than fossil fuels. On the other hand, if a friendlier operating environment is a characteristic of fossil fuel, the satisfaction level increases, although it is difficult to attain. Whereas developing technology can reduce the prices of biofuel and make it more environmentally friendly in the long run, imposing an emission tax on fossil fuel and subsidies on biofuel could accelerate this situation.

After assigning the substitutions forms to the equilibrium price functions or the Cournot– Nash equilibria derived from the utility function of equation 4, we have:

$$P_f^* = \frac{-(ef+hb)^2(ef+hf)+(cb-eb-hb)(ef+hb)\beta+2(cf+ef+hf)\beta^2}{-(ef+hb)^2+4\beta^2}$$

$$P_b^* = \frac{-(eb+hb)(ef+hb)^2+(cf-ef-hf)(ef+hb)\beta+2(cb+eb+hb)\beta^2}{-(ef+hb)^2+4\beta^2}$$

(Eq. 5)

Thus, the aggregate demands at equilibrium are:

$$D_f^* = \frac{\beta(-(ef+hb)^2(-cf+ef+hf)-(-cb+eb+hb)(ef+hb)\beta+2(-cf+ef+hf)\beta^2)}{(ef+hb)^4-5(ef+hb)^2\beta^2+4\beta^4}$$

$$D_b^* = \frac{\beta((cb-eb-hb)(ef+hb)^2-(ef+hb)(-cf+ef+hf)\beta+2(-cb+eb+hb)\beta^2)}{(ef+hb)^4-5(ef+hb)^2\beta^2+4\beta^4}$$

(Eq. 6)

In the equations 5 and 6, the variable c_f and c_b represent each unit marginal cost of fossil fuel and biofuel, respectively. The model ignores fixed costs in the short term, as it has no impacts on impending decision-making. However, the model results can be classified into three situations using the various numeric values based on the literature (section 2.2). At this stage, the marginal costs hold constant to imply freedom from the influences of the other factors. We assume that the substitutive variables are influenced by technological progress and other influential interrelated factors (e.g. cost of biofuel changes because of tax and subsidies). We further assume that, in the SR, technological progress is not possible, thus emission ratios are constant in all states.

Therefore, after placing all numeric values into equations 5 and 6, the results of the first state show the existing fuel market situation. The analyses showed that $D_f + D_b < 1$, that is, the demands for fossil fuel and biofuel are exclusive, since the total market size is 1. Therefore, there are no double users: a consumer is either using fossil fuels or biofuels. This also shows that these two types of fuels are neither complementary nor perfect substitutes.

The second state assumes that, if all other things remain the same, offering a subsidy on biofuel reduces the marginal cost of biofuel (c_b), consequently increasing the value of h_b (i.e. low pricing quality of biofuel) and, in turn, consumers buy more b_f. Hence, the total production cost of biofuel is lower than the previous price scenario, but still higher than the marginal cost of fossil fuel. The consumer might be still interested to pay for fossil fuel, because c_b is still higher than c_f. In this situation, offering further subsidies on biofuel will lessen the marginal cost of biofuel from 0.65 to 0.60 and increase customer's satisfaction level for biofuel from 1 to 1.10. The analysis demonstrates that, because of decreasing marginal cost of biofuel (c_b) by around 7.7%, the aggregate demand for biofuel increases by around 15% (i.e. from 0.13 to 0.15) and substitution by around 18%. The same analysis is also performed for customers' WTP for h_f. Although the demand for biofuel increased (because of applying subsidies on it), the demand for fossil fuel stays the same. In other words, by increasing h_b by around 10% (i.e. from 1 to 1.10), the biofuel demand curve shifts upward by around 25% and the substitutability of fossil fuel by biofuel by around 18%.

Finally, imposing tax on fossil fuel increases the marginal cost of fossil fuel from 0.50 to 0.60 (i.e. $c_f = c_b$) and reduces h_f from 1 to 0.90 ($h_f < h_b$). The further increase in the tax on fossil fuel will increase the marginal cost of fossil to 0.65 and decrease h_f at 0.85. Thereby, h_b will surge to 1.50 because it has a fixed marginal cost (i.e. c_b at 0.60). Therefore, the final situation is represented by $c_b < c_f$ and $h_f < h_b$. The analysis also establishes that, because of decreasing the biofuel marginal cost (c_b) by around 7.7% and increasing fossil fuel marginal cost (c_f) by around 8.3%, the demand for fossil fuel decreases by around 13% and the aggregate demand for biofuel increases by around 19%.

The reverse state is exhibited on the fossil fuel market. The analysis also shows that, in the long run, biofuels could substitute fossil fuels. The analysis also shows that, because of increasing h_b by 15% (i.e. from 1.30 to 1.50), biofuels substitute fossil fuels by around 31%.

3.3 Achievable EU 2020 targets? Comparing Nordic experts' views with those of experts from other regions

3.3.1 Regional survey results

The GHG perception study reveals that, according to NC experts, the other regions experts' opinions is that although EU's *GHG emissions policies are sufficient to meet the GHG reduction target in Europe* (RQ5), *EU's GHG reduction target for 2020 will be not successful* (RQ12) (except for WEC experts). Among all RQs, a highly supported statement (especially accepted by 80% WEC and NC experts) was that *using forest biomass for energy purposes will reduce GHG emissions* (RQ10). For GHG, the significant differences in the statement were: *using forest biomass for energy purposes will reduce GHG emissions* (RQ10, $X^2 = 11{,}884$, d.f. = 4, $p < 0.02$) and *implementing the CO_2 tax would lead to social welfare loss* (RQ8, $X^2 = 13{,}675$, d.f. = 4, $p < 0.008$).

Concerning RE in the opinion of NC experts, the experts from all regions were concerned and accepted that *the implementation of their national RE action plans* (RQ18) and on the *EU's RE target for 2020 being successful* (RQ19). Further, 82–93% of NC experts ascertain that *stable, consistent, and sufficient incentives are required to meet 2020 RE target from biomass* (RQ16) and *RE will ensure major sources for heating and cooling* (RQ14). SEEC and EEC experts also agreed with NC experts concerning the necessity of stable, consistent, and sufficient incentives in the EU to meet the 2020 RE target from biomass. In RQs 13 to 19, significant differences based on regions are found in *RE will ensure major sources for electricity generation in the EU* (RQ13, $X^2 = 10{,}076$, d.f. = 4, p < 0. 04) and *under current policies, demand for EU forest resources will exceed its supply* (RQ17, $X^2 = 23{,}283$, d.f. = 4, p < 0.001). Therefore, a large percentage of researchers in NC and CEC experts support the statement that *GHG emissions reductions should be more prioritized than the security of energy supply* (RQ20), while this is rejected by most experts in other regions.

The EE denotes that most experts in all regions either accept or provide no opinion concerning most of the statements. Similar to NC experts, other regions' experts also perceive that, to facilitate EU economic solvency, EE will reduce social costs (related to pollution) and help achieve the EU renewable energy target. However, two statements in the EE sections represent significant differences according to the Kruskal–Wallis test: *EE would reduce social costs related to pollution* (RQ22, $X^2 = 17{,}423$, d.f. = 4, p < 0.002) and *EE will facilitate EU economic solvency significant* (RQ23, $X^2 = 14{,}193$, d.f. = 4, p < 0.007).

Surprisingly, similar to NC experts, most experts in all other regions remain indifferent and provide no opinion perception regarding the sufficiency of the EE target by the EU energy and climate package (Directive 2009/29/EC) (RQ21). The age factor was not significant for any RQs except RQ8 (*implementing the CO2 tax would lead to social welfare loss* ($X^2 = 11.90$, d.f. = 3, p < 0.008)) and RQ12 (*EU's GHG reduction target for 2020 will be successful* ($X^2 = 8.72$, d.f. = 3, p < 0.03)). Concerning gender, except for RQ15 *(woody biomass will contribute a major share in RE for heating and cooling*, $X^2 = 9.505$, d.f. = 4, p < 0.05)) and RQ9 (*climate policies in EU may indirectly increase the emissions in the rest of the world (*$X^2 = 10.81$, d.f. = 4, p < 0.02)), no other RQs are significant.

A perception-based decision was taken to provide information on experts' perceptions (Figure 3). Regarding GHG related statements, the decisions are obvious from the researcher's perception. Like NC experts, the majority of experts from other regions believe that H2020 targets will not be successful. NC experts and other regions' experts also perceive that, under the current directives, GHG policies are not adequate to meet the targets. They also agree with NC experts that using forest biomass for energy purposes would reduce GHG emissions.

The RE study presents similar types of reactions (i.e. negative perceptions of experts from all regions, except WEC experts), as experts believe that the RE target of H2020 will be successfully achieved. Concerning incentives, different region experts perceive that stable, consistent, and sufficient incentives are necessary to attain the RE energy target. Therefore, a large percentage of experts from all other regions also have the same perceptions as NC experts in that woody biomass has a significant contribution to RE production (especially for heating and cooling). Regarding EE targets, the NC experts have pessimistic perceptions compared with other regions' experts.

3.3.2 Conflicted results of the different comparisons

A regional comparative analysis of all questions was performed by considering combined (RQ26 i.e. *EU 2020's RE, GHG and EE targeted will be achieved*) and individual targets (RQ 12, RQ19 and RQ25), according to the findings in Figures 1 and 3. The analysis identified mixed perceptions for NC and CEC experts. The contingency Table 4 shows that, on the achievement of GHG targets, the CEC experts perceived *No* (the target is close to being achieved by the EU in 2014), whereas, for the combined targets, the CEC experts perceived the target would be achieved. The most confusing result is found for NC experts: they answer *No* for all individual cases, but *Yes* for the combined cases.

Table 4. Regional comparison of H2020 target: achieved target versus researcher perception's

	CEC	WEC	SEEC	NC	EEC
GHG:					
Target achieved (based on status 2012)	-12% to -19%	0 to -20%	20% to -11%	-12% to -20%	20% to 0
Researchers perception (based on RQ12)	N(49)	N(58)	N(45)	N(46)	N(44)
RE:					
Target achieved (based on status 2012)	10% to 39%	15% to 29%	10% -19%	30% to 40%	10%-50%
Researchers perception (based on RQ19)	Y/N(42)	Y(44)	N(40)	N(44)	N(50)
EE:					
Target achieved (based on status 2012)	20% to 50%+	10% to 50%+	0 to 49%	10% to 50%+	5% to 50%+
Researchers perception (based on RQ25)	NO(39)	Y/NO(37)	NO(45)	NO(46)	NO(3)
Researchers GHG, RE and EE perception (based on RQ 26)	Y(48)	N(49)	N(40)	Y(42)	N(44)

CEC=Central European countries, WEC=Western European countries, SEEC=South-Eastern European countries, NC=Nordic countries, EEC=East European countries, GHG=Green House Gas, RE=Renewable Energy, EE=Energy Efficiency. Parenthesis represents percentage of total respondents

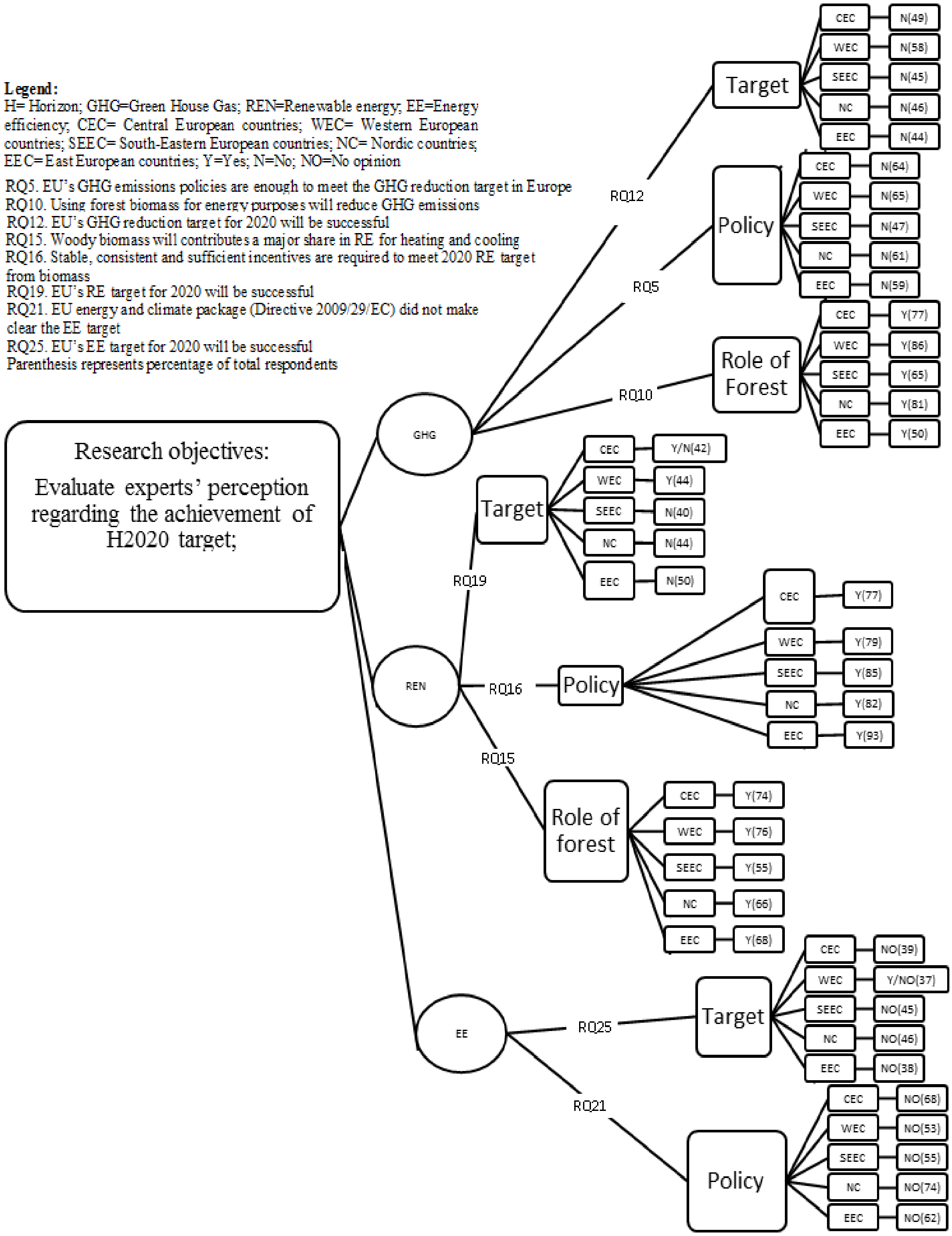

Figure 3. EU researchers perception about EU H2020 target, policy and role of woody biomass

3.4 Would renewable energy and wood fuel production change in the Nordic region?

3.4.1 Model specification and Johansen test of cointegration

There are numerous measures to decide lag lengths. These are- Schwarz information criterion (SIC), Hannan-Quinn information criterion (HQ), Final prediction error (FPE), Akaike information criterion (AIC) and Sequential modified LR test (LR). The selection criteria of the lag length in all the tests are, except LR test the lesser the test statistics, the better the model. After analyzing a VAR system model, SIC and HQ tests suggests lag 1 and lag 2 models are respectively good fitted models. Where the FPE, AIC and LR tests suggesting model with lag 5. Therefore, we suppose that a 5-lag expression model would deliver us the best model. The Johansen test of cointegration suggest that the evaluation process of the test according to Trace or Max-Eigen statistics are below 0.05 and that implies at most 1 cointegration is having in the model. However, we assumed that with the I(1) condition, a set of g (in the model, we have two) variables are cointegrated with lag 5 in a VAR system (Eq. 7).

Therefore, to resolve the cointegration problem, the VAR model is turned into a VECM system (Eq. 8).

$$D(RF_t)= C_1 (RF_{t-1}) + C_2 (RF_{t-2})+\ldots+ C_5(RF_{t-k})+ \varepsilon_t \qquad \text{(Eq. 7)}$$
$$\Delta(RF_t)= \mu(RF_{t-k}) + \beta_1 \Delta(RF_{t-1}) + \beta_2 \Delta(RF_{t-2})+\ldots+\beta_{k-1}\Delta(RF_{t-(k-1)})+ \varepsilon_t \qquad \text{(Eq. 8)}$$

In the equations,

$\mu = (\sum_{i=1}^{k} Ci) - I_g$ or long-run coefficient matrix

$\beta_i = (\sum_{j=1}^{i} Cj) - I_g$

RF= Σ (RE + WF) production and ε_t = the error term

In first difference form, VAR has g variables and $k - 1$ lags of the dependent variables on the left- and right-hand sides, respectively. Each dependent variable (with k−1 lags) is also associated with the corresponding coefficient matrix β. At equilibrium, all $\Delta(RF_{t-1})$ will be zero. Then, after locating ε_t, their anticipated value will be $\mu(RF_{t-k}) = 0$ (Brooks 2008). The VECM (5) system of equation 8 can be formed as two equations (since the model has two variables). The newly formed models with the substituted coefficients are:

$$D(RE) = \{A_{(1,1)}*(B_{(1,1)}*RE(-1) + B_{(1,2)}*WF(-1) + B_{(1,3)}\} + \beta_{(1,1)}*D(RE(-1)) + \beta_{(1,2)}*D(RE(-2)) + \beta_{(1,3)}*D(RE(-3)) + \beta_{(1,4)}*D(RE(-4)) + \beta_{(1,5)}*D(RE(-5)) + \beta_{(1,6)}*D(WF(-1)) + \beta_{(1,7)}*D(WF(-2)) + \beta_{(1,8)}*D(WF(-3)) + \beta_{(1,9)}*D(WF(-4)) + \beta_{(1,10)}*D(WF(-5)) + \varepsilon_{(1,11)} \qquad \text{(Eq.9)}$$

$$D(WF) = \{A_{(2,1)}*(B_{(1,1)}*RE(-1) + B_{(1,2)}*WF(-1) + B_{(1,3)}\} + \beta_{(2,1)}*D(RE(-1)) + \beta_{(2,2)}*D(RE(-2)) + \beta_{(2,3)}*D(RE(-3)) + \beta_{(2,4)}*D(RE(-4)) + \beta_{(2,5)}*D(RE(-5)) + \beta_{(2,6)}*D(WF(-1)) + \beta_{(2,7)}*D(WF(-2)) + \beta_{(2,8)}*D(WF(-3)) + \beta_{(2,9)}*D(WF(-4)) + \beta_{(2,10)}*D(WF(-5)) + \varepsilon_{(2,11)} \qquad \text{(Eq.10)}$$

Here, RE and WF represent renewable energy and wood fuel production, respectively. The second bracket portion indicates the cointegration correction model of equations 9 and 10. $\beta_{(1,1)}$, $\beta_{(1,2)}$, ……, $\beta_{(1,10)}$ and $\beta_{(2,1)}$, $\beta_{(2,2)}$……, $\beta_{(2,10)}$ are the corresponding variable's coefficients and $\varepsilon_{(1,11)}$ and $\varepsilon_{(2,11)}$ are error terms. In the system of equations, a change (also called innovation, shock, or impulse) in the residuals affects D(WF(-1)), which the affects D(WF(-2)), and the effects continue until D(WF(-5)). This status again affects RE(-1), which then impacts RE(-2), and so on until RE(-5). Therefore, an impulse in the residuals affects the entire VECM system.

3.4.2 VECM explanation and coefficient diagnostics

In the VECM system, coefficient β(1) or the speed of adjustment for the long run equilibrium is positive and insignificant. In the LR causality, the coefficient sign has to be negative and the concerning p-value significant. In addition, if the p-value of the particular variable is below 5%, the variable is significant. However, this study identified a positive and insignificant value of β(1), which implies no LR causality by the independent variables to the dependent one. The VECM system explains the variability of the response data of 45% and 56% around its mean values based on R-square values. The adjusted R-squared represents a 30% and 40% variability of the response, respectively. Statistically, all diagnostic tests are worthless in the VECM model, since it includes an error correction model. Nevertheless, residuals checking in the model imply that, statistically, model 2 (that attains from equation 10) has better fit than model 1 (that attains from equation 09). Both models are individually and jointly free from serial correlation, heteroscedasticity, and normality.

The Wald coefficient test is utilized to diagnose the influences of the independent variables on the dependent ones as to assess short-run (SR) causality. However, the Wald coefficient test with five degrees of freedom shows that the probabilities of the variables in model 1 are 0.02% and 34.44%, and in model 2 are 68.32%, and 61.16%, respectively. Since the p-values of the combined variables are above 5% (except the first test of model 1), the null hypothesis is rejected. A reiteration of model one's first test with three degrees of freedom (i.e. after removing the individually significant variables β2 and β5) shows the p-value is above 5%. This finding designates no SR causality from independent variables to dependent ones, and the variables are significant to describe the models jointly.

3.4.3 Impulse response function (IRF)

A positive impulse of one standard deviation to $\varepsilon_{(1,11)}$ and $\varepsilon_{(2,11)}$ in VECM (5) is estimated for 50 years. The prediction analysis shows that, if a one standard deviation shock is experienced by RE production, the production trend remains always positive, with significant increases and decreases continuing for the following 30 years. Therefore, in the case of mutual shocks between RE and WF, WF yields a negative (decrease) response mainly for years 3–5 and 8–9. Therefore, it becomes negative for the following 50 years. In case of shocks on WF, its relationship with RE represents an upward positive (increase) response. The upward trend becomes steady around the 35th year. Then, in the final stage of the analysis, in response to a positive shock, WF yields a positive but downward response, which becomes negative in the 20th year.

4 DISCUSSION

The worldwide environment, economy, society, and demography are changing and continuously affecting the consumption and production of the Nordic forest products market. This thesis states the changes in the Nordic forest product market based by segmenting the time periods into three states: past, present, and future.

Studying the past periods, the first study identifies the possible structural breaks of the past decades (1964–2012) for two countries, Finland and Sweden. Their domestic consumption and export–import trade data on RW and SW were thus considered. The abundance and significance of export–import shares of forest resources in the past few decades, as well as the implementation of policies against reducing the dependency on fossil fuels in Finland and Sweden, make it interesting to study these countries.

The Chow breakpoint test during 1964–1980 of the Finnish model identified breaks in 1975 and 1976, and no break was noticed for the Swedish model. For the breaks noticed in the Finnish model, the main reason might be the series of MERA programs (1961–1976) (Siiskonen 2007). These programs offered a provision to private forest owners for the selective cutting of trees and support for intensive forestry (Siiskonen 2007; Kotilainen and Rytteri 2011). Additionally, the 1970s are known as a heavy mechanization period for the Finnish forestry as some operations progressed during these periods (Elovirta 1979; Björn 1999). Kotilainen and Rytteri (2011) also indicate that, during 1964–1975, the concepts of logging roads, forest fertilization, drainage systems for peatlands, and industrially constructed pulp mills were introduced. Hence, the extension of the forest industries during 1955–1970 might have helped increase RW demand by approximately 60% (Siiskonen 2007). Furthermore, the increase in wages (because of the Forest Wages Law, 1962), reviews of forest legislation, lumbering technology, the emergence of the multiple uses of forests (late 1970s), and ‘artificially-regenerated’ forests augmented the development of the Finnish forest industry (Tuokko 1992; Elovirta 1979).

In the period during 1981–2012, break years were identified as 1991 and 1992 in the Finnish model. We assumed this could be a consequence of ‘Forest program 2000’, launched in 1984, as it contributed to intensifying RW production by around 15 million m^3 from 1980 to 2010 (Kotilainen and Rytteri 2011). Toppinen and Kuuluvainen (2010) show that during 1990–1995, substantial structural changes were witnessed by the Finnish forest industry. Additionally, in 1991, taxes on energy production, fuel, sulphur dioxide (SO_2), carbon dioxide (CO_2), and electricity in Sweden promoted the use of wood fuel in its domestic market and international trade structure (Johansson et al. 2002; Eurostat 2003). During 1990–2005, the energy tax structure of Finland changed several times (Eurostat 2003). Further, the breakdown of the Soviet Union in 1991 formed new competitive markets that helped Finland expand its RW and SW markets.

The t2 period breakpoints (i.e. 2004, 2005, and 2006) in the Swedish model are validated by empirical studies. One important instance was 2004, when the Swedish forest policy mentioned climate concerns (Bengtsson and Nilsson 2007). The familiarising of climate and energy policies (mainly subsidizing the biofuel sector and imposing a carbon dioxide (CO_2) tax on the fossil fuel sector, and the utilization of woody biomass for combined heat and power (CHP) plants) sped up this process in the area (Lundmark 2010). Therefore, at the beginning of 2005 and 2007, the country experienced two storms, *Gudrun* and *Per*. Comparatively severe damages were caused by *Gudrun*, and it blew down more than 75,000,000 m^3 of trees (KSLA 2009). In 2005, the Swedish policy declared an oil phase-out, initiating a billion-dollar renewable energy and energy efficiency project (Vidal 2006). In 2006, the Swedish Forest Agency (SFA) was launched for coordinating forestry-related environmental laws, regulations, and policies (SFA 2007; KSLA 2009). Another noteworthy incident was cutting the bark beetle-affected trees that had survived

Gudrun (Lindelöw and Schroeder 2008). Thus, domestic bioenergy policies have a substantial influence on the national and global markets (Lamers et al. 2011).

A critical point at this respect concerns the functional structure of the model proposed to analyse the structural breaks. The model assumes a linear relation that is rather convenient from the analysis point of view, as simplifies the statistical treatment of the data. Although this is a common approach, it must be taken into account that the true relationship diverts from the model proposed; the relationships would be better treated using a non-linear function as otherwise would not be fully consistent with the relationships regarding removals. The statistical results are critically dependent of the model assumptions and the final structural form, although arguably this does not necessarily change the main conclusions nor the statistical significance of the variables analysed. Despite the advantages of the approach taken in the study, a more appropriate model structure should have been considered.

In spite of these limitations, the corresponding study weighted all economic, social, political, and environmental factors (that may have an impact on the export–import of forest products). The justification of the cause-and-effect relationship between input (empirical events) and outputs (breakpoint years) is complex and thus, the specific break years indication in the forest sector of the corresponding countries is a significant outcome in the field of forest economics.

The present status of the changing forest market which reflects the turning of the existing economy into a bioeconomy era through the replacement of fossil fuel with biofuel, and the conversion of national policies into regional climate change policies and thus entering in to the bioeconomy era. Therefore, as the first part of present structural changes, the second study of this thesis investigated how external factors support the replacement of forest-based bioenergy products with non-forest-based energy products in the market. The analysis was executed by applying the concavely shaped utility function by Shubik and Levitan (1980). Subsequently, this function was applied to a duopoly and oligopoly market structure by Sing and Vives (1984) and Häckner (2000), respectively. Therefore, in 2012, Liang used this utility function in the analysis of both the duopoly and oligopoly market structures. However, the corresponding model presumes that two different goods could be either substitutes or complements (e.g. Dixit (1979) and Singh and Vives (1984)).

This study considered two external factors, subsidy and tax (two energy promotion tools), and Nordic countries as the study area. For the numerical analysis, it considered mainly the solid form of biofuel that generates electricity and coal as fossil fuel, because presenting the numeric values of different types of fuels as a single figure may not provide a relevant interpretation. Three circumstances were considered to analyse the resulting equations: without tax and subsidy, subsidy on biofuel, and tax and subsidy on biofuel and fossil fuel. Fossil fuel and biofuel were categorized based on their prices and friendly operating environment, under the assumption that a low pricing approach and high friendly operating environment generate positive customer satisfaction levels.

The study assumed that the unit cost of biofuels is higher than that for fossil fuels; on the other hand, biofuels offer a friendlier operating environment than fossil fuels do. Consequently, attaining a friendly operating environment is not currently possible for fossil fuels. Therefore, providing subsidies on biofuels can reduce their unit price and promote the substitution of fossil fuels by biofuels (Löfgren 2008). For illustrating substitution, the study followed the methods and strategy of Liang (2012). However, fossil fuel substitution by biofuel might increase the demand and price of wood utilization in biofuel production (Forsström et al. 2012); hence, these possibilities were incorporated in the results.

The outcome of this study showed that offering subsidies on biofuel shifts the aggregate demand curve upward and, consequently, the possibility of substitution is obvious. The results also demonstrate that a fixed amount of subsidies on biofuel decreases its marginal production cost by around 7.7% and, therefore, biofuel's aggregate demand increases by around 15%. In this situation, imposing tax on fossil fuels decreases their demand. Thus, reducing the price of biofuels by around 15%, the substitutability of fossil fuels by biofuel increases by around 31%. This outcome is directly or indirectly supported by several empirical studies (e.g. Larsson and Rosenqvist (1997), Johansson et al. (2002)) which indicated that, owing to imposition of tax on sulphur, WF demand increased in Sweden during those periods. Therefore, it increased wood biomass demand in the nearby wood biomass-using energy plants and, subsequently, all over Sweden. Timilsina et al. (2011) established that only a carbon tax is not appropriate enough to determine a drastic biofuel market penetration. Additionally, the production cost of biofuels significantly influences the market and, consequently, impacts its consumption level and the GHG reduction level (Chen et al. 2012). Therefore, carbon taxes on fossil fuels along with a biofuel subsidy policy have a significant effect on stimulating biofuel market penetration.

In the second part of the present structural changes study which compared the Nordic expert's perception with other regions' expert perception concerning the current policies undertaken by the EU in light of decreasing CO_2 emissions to prevent current environmental threats. The EU set the targets for RE consumption, GHG emissions reductions, and improvements on EE at 20% for 2020 (EC 2014; EC 2012). To answering the question of achievability or unbelievability of the 20% target for 2020, the RE study showed that half of the experts from all regions perceived that the EU's RE target for 2020 will not be attained. Additionally, 85% experts' perceive that energy savings will help the EU RE target succeed, but the EE target would not. Therefore, the negative response on the insufficiency of EU's GHG emissions policies to fulfil the GHG reduction target (about 60% of experts) are contemptible. Virkki-Hatakka et al. (2013) indicated that different consumer profiles with different behaviours play a substantial role in the EE challenge. Nevertheless, experience is important, as a perception-based study in the UK showed that a person who has experience in climate change expresses more concern on the probable impacts of changing climate and a willingness to mitigate it by saving energy (Spence et al. 2011). A person with proper educational background in the RE sector acquires expertise on it (Karabulut et al. 2011), which helps a higher-level perception than that of non-user experts in times of uncertainty (Evar 2011).

Qin and Brown (2007) showed that, in a study between two types of participants, a 'consequence'-oriented person demonstrates higher-level judgment than a 'perspective'-oriented one. However, the experts' perception study is significant to the technological development of renewables, efficiency, and GHG pollution reduction. A perception-based study of over 131 experts and decision-makers in China concerning carbon capture and storage technologies revealed that experts are concerned about energy penalties (Xi et al. 2011). Moreover, according to Chen et al. (2015), in China, a public perception analysis denotes that the success of an emerging technology depends on economic, societal, and political aspects. Haggett (2011) also indicated the consequence of public perceptions towards offshoring wind power system, especially by those involved in it.

The conclusion of the regional analysis is that 80% of WEC experts' opinions are similar to those of NC experts in that using forest biomass for energy purposes will reduce GHG emissions. As a stable and consistent policy is a determinant for meeting the RE target from forest biomass, NC, SEEC, and EEC experts (82–93%) highly prioritize it. Moreover, except for WEC experts, experts from all other regions perceived that the EU GHG policies are not enough and H2020 targets will not be achieved. NC and CEC experts showed the most confusing results, as they answer *No* to all the individual cases, but *Yes* to the combined cases. There is a contradiction in experts' views, whereas a common outcome is that the majority of experts have pessimistic views regarding the accomplishment of the H2020 targets. At the national level, it is challenging for some countries to achieve the targets, but at the regional level, the EU is close to achieving the target, especially for RE and EE targets (EE targets are already achieved at the regional level).

This contradiction has also been observed in the accomplishments of forest policy and general public perceptions, which are inclined to be more pessimistic (e.g. Fabra-Crespo et al. 2011).

Behavioural changes could be a solution to modifying experts' perceptions. The study by Huebner et al. (2015) on English households found that behavioural change initiatives could be a substantial way to reduce energy consumption levels (especially for shorter heating seasons). Therefore, education could assist to modify human behaviour. Energy literacy enhances the knowledge on the logical usage of energy, which further influences the behavioural characteristics and helps select suitable energy content (DeWaters and Powers 2011).

Nevertheless, the educational backgrounds of different professionals also influence energy perceptions (e.g. it can modify EE perception by delaying its progress) (Virkki-Hatakka et al. 2013). However, EU's H2020 target is ambitious, perhaps causing the experts to draw pessimistic conclusions in its first stages. Hence, despite the current progress of target achievement, experts' opinions are still mixed on the success of the H2020 target.

Finally, the shock study investigated the upcoming unexpected incidence that might structurally change the Nordic forest product market. In reality, forestland covers around 11% to 67% of the land in the Nordic region (Nordic Council of Ministers 2008). A large volume of wood and wood biomass are exploited for fuel purposes, for a substantial share in the RE sector. In 2011, 51% of the total energy supply came from renewable sources in the Nordic countries, where woody biomass and waste materials provided about one-third. Thus, the study investigated the situation of unexpected shocks to the two product markets (i.e. WF or RE production) in terms of how does and for how long the other market reacts. Therefore, data spanning 56 years on RE and WF production were collected for the four Nordic countries: Finland, Sweden, Norway, and Denmark.

The econometric analysis of this study estimates the reaction between variables (from shock or impulse), and a good-fit VECM (5) was proposed. The interaction and future production of RE and WF are estimated using IRF, but the order of variables in the IRF analysis is not determined using econometric methods. We assumed that the first variable RE (e.g. RE, WF) has the potential to instantaneously reflect the consequences on the other variable WF. The IRF analysis considers four situations: reaction or response of WF to RE, of WF to WF, of RE to RE, and of RE to WF.

The analysis showed that an unexpected shock on RE generates positive responses, but negative responses for WF. Therefore, for an unexpected shock on WF, RE also generates positive responses, and WF, negative ones. Accordingly, for shocks on the production of WF or RE, in any situation, the production of RE increases, whereas that of WF decreases. There are numerous causes for this. Climate issues might be one of the significant reasons that have severe influences on RE production and consumption. Hence, the traditional WF utilization process has been changing and increasing the utilization of wood as its secondary form. Scientific and technological improvement in the geothermal, solar, wind sectors, among others, might lead other forms of RE resources that would play a significant role in the total share of RE production. Therefore, any uncertainties might decrease WF production and increase the reliance of RE sources. Additionally, the production and supply of WF is climate sensitive, meaning that its supply cannot be increased immediately based on high demand. Therefore, the product nature of WF is also a limitation for increasing production.

However, the consequence of mitigation can be looked at by several means: (1) through carbon sequestration or stored in forest biomass, (2) transforming wood into resilient woody materials, (3) through substitution by replacing fossil fuels by wood-based fuels, and (4) through wood products that require less fossil fuels compared to their alternatives (Marland et al. 1997). Therefore, the global forest production, consumption, and market patterns are changing rapidly. Uncertain fossil fuel supply sources and increasing prices (as the consequence of increasing environmental concerns) raise the pressures on woody biomass.

Additionally, in Finland and its neighbouring countries, except Norway, the prices of imported fuels increase significantly compared with the case of domestic biofuels (Energiakatsaus 2012; Pelletsatlas 2009a, 2009b). Substantial progress in the logistics sector and EU energy policies are helping reduce the production costs of biofuel, sometimes biofuel prices being lower than fossil fuel ones (Rosenqvist 2008; EMV 2012).

Therefore, this research focused on the substitution of fossil fuels (coal) by the solid form of biofuels and the scope of this analysis can be extended by considering the liquid form of biofuels (e.g. renewable biofuels that produced from lignocellulosic biomass), which can also replace fossil fuels. This broader extension increases the predictability of a corresponding substitution model. An econometric analysis on the growth and pattern of the pellet market is required in future studies, as the production and consumption in this market are experiencing structural changes.

Nowadays, carbon is considered a new forest product, as trees absorb carbon from the environment and a group of people are paying for it under the voluntary cap-and-trade system. Forest owners are currently earning money from carbon storing, with tree growth adjusting their superfluous earnings. Therefore, carbon stocking growth and monetary value in the Nordic forest sector can be analyzed in future studies to represent the changing forest product market.

5 CONCLUSIONS

EU policies are presently encouraging the use of renewable energy and, consequently, impacting European economies. In addition, the expansion of the economy, society, and technological process as a whole affects the exploitation of forest resources, and hence, a structural break analysis in the Nordic forest market perspective was essential. The results and the methods in the structural break analysis can be further utilized to measure the effects of local or global structural changes in the production and consumption of the forest market. The findings of this study ultimately help to provide accurate results for future econometric studies. The substitution analysis mathematically proved that joint actions (i.e. subsidies on biofuels and imposing tax on fossil fuel) have significant impact on increasing the aggregate demand for biofuel and replacing fossil fuel by biofuel. Although this study focused on the Nordic countries and incorporated local data for the analysis, the conclusions have broad economic and policy applications in other regions. The assessment of the present status of EU's H2020 target from the experts' view represents their valuable opinions. These opinions will help EU's policy and decision makers to develop and implement their future projects. Interaction and future estimation analysis on RE and WF production in the Nordic region will not only help policy makers by improving existing policies, but also by developing new policies in these sectors. We presume that, in the forestry sector, these types of prediction and interaction analyses based on the exploitation of econometric tools are essential. These econometrics and mathematical study combine the energy and multi-country forest product market.

However, this study also provides information about the changing forest product market and explains how the EU energy policies have a direct and indirect impact on these changing patterns. Thus the study also helped us to realize that the regional and institutional frequent actions could increase awareness and people's direct participation to mitigate climate change problems and, thus, support EU to achieve the H2020 target. We believe that without proper institutional support, public recognition, and appreciation, RE will not progress. Here, sufficient information provided to the end-user concerning the energy sector could be an additional solution to enhance the public support and lessen the risk perception of the energy sector. The RE-tailored government policies could also encourage public support and participation. Hence, different government, political, and institutional support forms are essential to solve global climate issues. Finally, to mitigate the climate change problem, the three crucial steps to be followed by the EU (i.e. reducing GHG emissions, increasing carbon stocks, and comprising the emissions into the bioenergy production) need to be analyzed in more detail.

REFERENCES

Achard F. (2009). Vital forest graphics. UNEP/FAO/UNFF.75 p.

Baek J. (2006). Price linkages in the North American softwood lumber market. Canadian Journal of Forest Research 36 (6): 1527-1535. https://doi.org/10.1139/x06-043.

Bogner F.X., Wiseman M. (1997). Environmental perception of rural and urban pupils. Journal of Environmental Psychology 17: 111–122. https://doi.org/10.1006/jevp.1997.0046.

Baker M.J. (2003). The marketing book, 5th edition. Butterworth-Heinemann, ISBN 0 7506 5536 4, Oxford. Boston. p. 154-502.

Barr S. (2007). Factors Influencing Environmental Attitudes and Behaviors: A U.K. Case Study of Household Waste Management. Environment and Behavior 39: 435–473. https://doi.org/10.1177/0013916505283421.

Bengtsson A., Nilsson C. (2007). Extreme value modelling of storm damage in Swedish forests. Natural hazards and earth system sciences 7: 515–521. https://doi.org/10.5194/nhess-7-615-2007.

Björn I. (1999). Kaikki irti metsästä: metsän käyttö ja muutos taigan reunalla itäisimmässä Suomessa erätaloudesta vuoteen 2000. (Capitalizing on the forest. Use, users and change in the forest in the wilderness economy on the edge of the Taiga in Eastern Finland through the year 2000). (In Finnish). ISBN: 951-710-121-X. Published: Helsinki: Suomen historiallinen seura, 1999.

Bolkesjø T. F., Trømborg E., Solberg B. (2006). Bioenergy from the forest sector: economic potential and interactions with timber and forest products markets in Norway. Scandinavian Journal of Forest Research 21:175–185. https://doi.org/10.1080/02827580600591216.

Brooks C. (2008). Introductory Econometrics for Finance. Second Edition. Cambridge University Press. p. 290-400.

Carpenter M., Bauer T., Erdogan B. (2010). Principles of Management and Organizational Behavior. Version 1.0.1 Paperback. p. 10-392.

Chen X., Khanna M., Yeh S. (2012). Stimulating learning-by-doing in advanced biofuels: effectiveness of alternative policies. Environmental Research Letters 7(4): 1–13. https://doi.org/10.1088/1748-9326/7/4/045907.

Chen Z.-A., Li Q., Liu L.-C., Zhang X., Kuang L., Jia L. and Liu G. (2015). A large national survey of public perceptions of CCS technology in China. Applied Energy https://doi.org/10.1016/j.apenergy.2015.08.046.

Chow G. C. (1960). Tests of equality between sets of coefficients in two linear regressions. Econometrica 28 (3): 591–605. http://www.jstor.org/stable/1910133.

COM (2006). Commission of the European Communities. Biofuels Progress Report. http://eurlex.europa.eu/LexUriServ/site/en/com/2006/com2006_0845en01.pdf [Cited 28 March 2013].

DCLG. (2006). Department of Communities and Local Government. Code for Sustainable Homes: A Step-Change in Sustainable Home Building Practice. Department of Communities and Local Government: London, UK. http://www.greeninfrastructurenw.co.uk/liverpool/doc.php?docID=104. [Cited 18 Jan 2017].

DeWaters J. E., Powers S. E. (2011). Energy literacy of secondary students in New York State (USA): A measure of knowledge, affect, and behaviour. Energy Policy 39(3):1699-1710. https://doi.org/10.1016/j.enpol.2010.12.049.

Dixit A. (1979). A Model of Duopoly Suggesting a Theory of Entry Barriers. The Bell Journal of Economics 10 (1): 20–32. http://dx.doi.org/10.2307/3003317.

EC (2010). MEMO/10/215. Climate change: Questions and answers on the Communication. Analysis of options to move beyond 20% greenhouse gas emission reductions and assessing the risk of carbon leakage. http://europa.eu/rapid/press-release_MEMO-10-215_en.htm. [Cited 29 July 2015].

EC (2012). Commission staff working paper. Analysis of options beyond 20% GHG emission reductions: Member State results. http://ec.europa.eu/clima/policies/package/docs/swd_2012_5_en.pdf. [Cited 7 March 2015].

EC (2014). The 2020 climate and energy package. http://ec.europa.eu/clima/policies/package/index_en.htm. [Cited 5 March 2015].

EC (2014a). http://ec.europa.eu/clima/policies/brief/eu/ [Cited 5 April 2015].

EC (2014b). A policy framework for climate and energy in the period from 2020 to 2030. http://ec.europa.eu/energy/doc/2030/com_2014_15_en.pdf [Cited 10 March 2016].

EC (2014c). Overview of Europe 2020 targets. http://ec.europa.eu/europe2020/pdf/targets_en.pdf. [Cited 5 Nov 2016].

Elovirta P. (1979). Forestry as an employer in Finland. Silva Fennica 13(3): 227-234. https://doi.org/10.14214/sf.a14896.

EMV (Energiakatsaus) (2012). Ministry of Employment and the economy. http://www.energiakatsaus.fi/digilehti/1-2012/ [Cited 19 May 2012].

Environmental progress. (2017). http://environmentalprogress.org/sweden/ [Cited 21 Sep 2018].

Eurostat (2003). Energy Taxes in the Nordic Countries - Does the polluter pay? National Statistical offices in Norway, Sweden, Finland and Denmark. Final report. http://www.scb.se/statistik/MI/MI1202/2004A01/MI1202_2004A01_BR_MIFT0404.pdf. [Cited 22 Sep 2013].

Eurostat (2012). The contribution of renewable energy up to 12.4% of energy comsumption in the EU27 in 2010. Eurostat Newsrelease 94. http://ec.europa.eu/eurostat/en/web/products-press-releases/-/8-18062012-AP [Cited 19 May 2017].

Ernst M.L. (1978). Some Implications of Current Social, Economic and Technological Trends. A D Little: Copely Plaza, MA, USA.

Evar B. (2011). Conditional inevitability: Expert perceptions of carbon capture and storage uncertainties in the UK context. Energy Policy 39 (6): 3414-3424. https://doi.org/10.1016/j.enpol.2011.03.038.

Fabra-Crespo M., Mola-Yudego B., Gritten D., Rojas-Briales E. (2011). Public perception on forestry issues in the Region of Valencia (Eastern Spain): diverging from policy makers? Forest systems 21(1): 99-110. http://dx.doi.org/10.5424/fs/2112211-11309.

FAO (Food and Agricultural Organization) (2008). The state of food and agriculture, biofuels: prospects, risks and opportunities. Food And Agriculture Organization of the United Nations, Communication division. http://www.fao.org/[Cited 16 Sep 2015].

FAOSTAT (Food and Agriculture Organization Corporate Statistical Database) (2013). http://faostat.fao.org/DesktopDefault.aspx?PageID=628&lang=en. [Cited 16 Sep 2013].

FAOSTAT (2017). Wood fuel. http://faostat3.fao.org. [Cited 29 March 2017].

FFIF (Finnish Forest Industries Federation) (2005). Adjusting to Globalization is Vital for the Finnish Pulp and Paper Industries. Finnish Forest Industries Federation: Helsinki, Finland. http://www.forestindustries.fi/JuuriNyt/Tiedotteet/Pages/Adjustingtoglobalizationisvitalforthefinnishpulpandpaperindustries.aspx. [Cited 29 March 2008].

Finnish Energy (2016). https://energia.fi/en/energy_sector_in_finland/energy_production/electricity_generation [Cited 21 Sep 2018].

Forsström J., Pingoud K., Pohjola J., Vilén T., Valsta L., Verkerk H. (2012). Wood-based biodiesel in Finland: Market-mediated impacts on emissions and costs. VTT Technology 7: 1– 48. https://www.vtt.fi/inf/pdf/technology/2012/T7.pdf [Cited 29 March 2014].

Gujarati D. N. (2004). Basic Econometrics. 4th edition. The McGraw-Hill. p. 273–545.

Häckner J. (2000). A note on price and quantity competition in differentiated oligopolies. Journal of Economic Theory 93: 233–239. https://doi.org/10.1006/jeth.2000.2654.

Haggett C. (2011). Understanding public responses to offshore wind power. Energy Policy 39 (2): 503-510. https://doi.org/10.1016/j.enpol.2010.10.014.

Hetemäki L., Kangas H-L., Laturi J., Lintunen J. and Uusivuori J. (2010). Modeling Energy and Climate Policy in the Finnish Forest Sector. http://www.metla.fi/julkaisut/workingpapers/2010/mwp146.htm. [Cited 29 March 2008].

Hetemäki L. and Hurmekoski E. (2016). Forest Products Markets under Change: Review and Research Implications. Current Forestry Report 2(3): 177-188. https://doi.org/10.1007/s40725-016-0042-z.

Huebner G., Hamilton I., Chalabi Z., Shipworth D., Oreszczyn T. (2015). Explaining domestic energy consumption – the comparative contribution of building factors, socio-demographics, behaviours and attitudes. Applied Energy 159: 589–600. https://doi.org/10.1016/j.apenergy.2015.09.028.

Johansson B., Börjesson P., Ericsson K., Nilsson L. J., Svenningsson P. (2002). The use of biomass for energy in Sweden -critical factors and lessons learned. IMES/EESS Report 35. Lund, Sweden: Energy Environmental System Studies. https://inis.iaea.org/collection/NCLCollectionStore/_Public/42/022/42022188.pdf [Cited 29 March 2016].

Jonsson R. (2011). Trends and Possible Future Developments in Global Forest-Product Markets—Implications for the Swedish Forest Sector. Forests 2 (1): 147–167. https://doi.org/10.3390/f2010147.

Karabulut A., Gedik E., Keçebaş A., Alkan M.A. (2011). An investigation on renewable energy education at the university level in Turkey. Renewable Energy 36 (4): 1293-1297. https://doi.org/10.1016/j.renene.2010.10.006.

Kirilenko, A. P. and Sedjo, R. A. 2007. Climate change impacts on forestry. PNAS 104 (50): 19697–19702. https://doi.org/10.1073/pnas.0701424104.

Kotilainen J., Rytteri T. (2011). Transformation of forest policy regimes in Finland since the 19th century. Journal of Historical Geography 37: 429–439. https://doi.org/10.1016/j.jhg.2011.04.003.

KSLA (Royal Swedish Academy of Agriculture and Forestry) (2009). The Swedish forestry model. http://www.skogsstyrelsen.se/Global/myndigheten/Skog%20och%20miljo/ENGLISH/retrieve_file.pdf. [Cited 22 Oct 2014].

Lamers P., Hamelinck C., Junginger M., Faaij A. (2011). International bioenergy trade—A review of past developments in the liquid biofuel market. Renewable and Sustainable Energy Reviews Vol 15 (6): 2655-2676. https://doi.org/10.1016/j.rser.2011.01.022.

Larsson S., Rosenqvist H. (1997). Willow production in Sweden—politics, cropping development and economy. In: European Energy Crops Conference paper.

Liang J. (2012). Competition between Fixed and Mobile Broadband Access Based on Mobility and Data Volume. International Journal of Management and Network Economics 2 (3): 217–235. https://doi.org/10.1504/IJMNE.2012.048512.

Lindelöw Å., Schroeder M. (2008). The Storm Gudrun and the Spruce Bark Beetle in Sweden. Forstschutz Aktuell 44. http://bfw.ac.at/400/pdf/fsaktuell_44_2.pdf. [Cited 29 March 2008].

Löfgren Å. (2008). Energy systems of the future – the importance of choosing the right regulatory instrument, in: Johansson, B. (Eds.), Bioenergy – for what and how much? Forskningsrådet Formas, Sweden. p. 377–389.

LUKE (Finnish Forest Research Institute) (2012). Finnish statistical yearbook of forestry. p.452. http://www.metla.fi/tiedotteet/2012/2012-12-13-statistical-yearbook.htm [Cited 16 March 2018].

Lundgren T., Marklund P-O., Brännlund R., Kriström B. (2008). The Economics of Biofuels. International Review of Environmental and Resource Economics 2 (3): 237-280. http://dx.doi.org/10.1561/101.00000017.

Lundmark R. (2010). European trade in forest products and fuels. Journal of Forest Economics 16: 235–251. https://doi.org/10.1016/j.jfe.2009.11.007.

Marland G., Schlamadinger B., Canella L. (1997). Forest management for mitigation of CO2 emissions: how much mitigation and who gets the credits? Mitigation and Adaptation Strategies for Global Change 2(2-3): 303-318. https://doi.org/10.1023/B:MITI.0000004484.37564.d5.

Moiseyev A., Solberg B., Kallio A., Maarit I., Lindner M. (2011). An economic analysis of the potential contribution of forest biomass to the EU RES target and its implications for the EU forest industries. Journal of Forest Economics 17: 197–213. https://doi.org/10.1016/j.jfe.2011.02.010.

Nilsson S. (2007). Changing Patterns of Supply- Illegal Logging. http://www.illegallogging.info/uploads/Changing_patterns_of_supply_paper.pdf. [Cited 27 August 2011].

Nordic Council of Ministers. (2008). History of afforestation in the Nordic countries, in AFFORNORD: Effects on Ecosystems. Landscape and Rural Development, Nordic Council of Ministers, Copenhagen. http://dx.doi.org/10.6027/9789289333351-3-en.

Nunnally J. C. (1978). Psychometric theory (2nd ed.). New York, NY: McGraw-Hill.

OECD. (2016). Renewable energy. https://data.oecd.org/energy/renewable-energy.htm. [Cited 20 Dec 2016].

Pelletsatlas (2009a). Development and promotion of a transparent European Pellets Market. Pellet market country report Denmark. http://pelletsatlas.info/pelletsatlas_docs/showdoc.asp?id=090824135512&type=doc&pdf=true. [Cited 12 May 2012].

Pelletsatlas (2009b). Development and promotion of a transparent European Pellets Market Creation of a European real-time Pellets Atlas. Preliminary pellet market country report Sweden.

http://pelletsatlas.info/pelletsatlas_docs/showdoc.asp?id=090810135438&type=doc&pdf=true. [Cited 21 May 2012].

Pelletsatlas (2012). http://www.pelletsatlas.info/cms/site.aspx?p=10089 [Cited 22 June 2012].

Qin W., Brown J. L. (2007). Public reactions to information about genetically engineered foods: effects of information formats and male/female differences. Public Understanding of Science 16(4): 471-488. https://doi.org/10.1177/0963662506065336.

Roberts D., Leithbridge J. and Carreau H. (2004). Changes in the global forest products Industry. Synthesis paper: SP 04-01. http://conservationeconomics.com/pdf_pubs/synth_paper/SP0401_ChangesGlobalForestProd.pdf. [Cited 25 March 2011].

Rosenqvist H. (2008). Energy crops on arable land– who will grow them? in: Johansson, B. (Eds.), Bioenergy – for what and how much? Forskningsrådet Formas, Sweden. p. 285–296.

Saylor. (2015). http://www.saylor.org/site/textbooks/Organizational%20Behavior.pdf. [Cited 25 March 2011].

SFA (Swedish Forest Agency- Skogssstyrelsen) (2007). Forests in Sweden. http://www.svo.se/episerver4templatesSNormalPage.aspx?id=11310. [Cited 16 June 2013].

SFA (Swedish Forest Agency) (2014). Swedish statistical yearbook of forestry. 370 p. http://www.skogsstyrelsen.se/en/AUTHORITY/Statistics/Statistical-Yearbook-/Statistical-Yearbooks-of-Forestry/.

Shubik M., Levitan R. (1980). Market structure and behavior, Nineteenth Dewey ed. Harvard University Press, Cambridge. P. 15-220.

Sijtsma K. 2009. On the use, the misuse, and the very limited usefulness of Cronbach's alpha. Psychometrika 74(1): 107-120. https://doi.org/10.1007/s11336-008-9101-0.

Siiskonen H. (2007). The conflict between traditional and scientific forest management in 20th century Finland. Forest Ecology and Management 249: 125–133. https://doi.org/10.1016/j.foreco.2007.03.018.

Singh N., Vives X. (1984). Price and quantity competition in a differentiated duopoly. Rand Journal of Economics 15 (4): 546–554. http://dx.doi.org/10.2307/2555525.

Sjølie H. K., Trømborg E., Solberg B., Bolkesjø T. F. (2010). Effects and costs of policies to increase bioenergy use and reduce GHG emissions from heating in Norway. Forest Policy and Economics 12: 57–66. https://doi.org/10.1016/j.forpol.2009.08.011.

Spence A., Poortinga W., Butler C., Pidgeon N. F. (2011). Perceptions of climate change and willingness to save energy related to flood experience. Nature Climate Change 1: 46–49. https://doi.org/10.1038/nclimate1059.

Sustainable growth from bioeconomy- The Finnish bioeconomy strategy (2014) http://biotalous.fi/wpcontent/uploads/2014/08/The_Finnish_Bioeconomy_Strategy_110620141.pdf [Cited 19 August 2017].

Timilsina G. R., Csordás S., Mevel S. (2011). When does a carbon tax on fossil fuels stimulate biofuels? Ecological Economics 70: 2400–2415. https://doi.org/10.1016/j.ecolecon.2011.07.022.

Toppinen A., Kuuluvainen J. (2010). Forest sector modelling in Europe—the state of the art and future research directions. Forest Policy and Economics 12: 2–8. https://doi.org/10.1016/j.forpol.2009.09.017.

Toppinen A., Zhang Y., Geng W., Laaksonen-Craig S. Lähtinen K., Li N., Liu C., Majumdar I. and Shen Y. (2010) Changes in Global Markets for Forest Products and Timberlands. P. 137-156. http://orton.catie.ac.cr/repdoc/A5247i/A5247i.pdf [Cited 16 August 2017].

Tuokko K. (1992). Metsänparantajat kansakunnan asialla 1908–1988. Saarijärvi. ISBN: P9529042671.

UNECE (United Nations Economic Commission for Europe) (2013). http://www.unece.org/forests/mis/fp-stats.html [Cited 16 Sep 2013].

van Ree R., Annevelink B. (2007). Status Report Biorefinerie. Report 847; Agro technology and Food Sciences Group: Wageningen, the Netherlands. http://www.biorefinery.nl/fileadmin/biorefinery/docs/publications/StatusDocumentBiorefinery2007final211107.pdf. [Cited 30 Oct 2014].

Vidal J. (8 Feb 2006). Sweden plans to be world's first oil-free economy. The Guardian. http://www.theguardian.com/environment/2006/feb/08/frontpagenews.oilandpetrol [Cited 16 August 2016].

Virkki-Hatakka T., Luoranen M., Ikävalko M. (2013). Differences in perception: How the experts look at energy efficiency (findings from a Finnish survey). Energy Policy 60: 499-508. https://doi.org/10.1016/j.enpol.2013.04.052.

Wooldridge J. M. (2013). Introductory Econometrics: A Modern Approach (5th international ed.). Publisher South-Western Cengage Learning. p. 70–113. ISBN 978-1-111-53439-4.

Worsley A., Skrzypiec G. (1998). Environmental attitudes of senior secondary school students in South Australia. Global Environmental Change 8: 209–225. https://doi.org/10.1016/S0959-3780(98)00016-8.

Xi L., David R., Jia L. (2011). Perceptions of opinion leaders towards CCS demonstration projects in China. Applied Energy 88(5):1873–1885. https://doi.org/10.1016/j.apenergy.2010.10.034.