Developing Biofuel Markets

The importance of standardisation in supply chain management

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ROTTERDAM.CLIMATE.INITIATIVE

Preface

From dozens of metres up, I look down at hundreds of hands waving farewell. With a few big horns the Norwegian Pearl is indicating its urge to leave. Slowly but determined, the immense beast parts with the Wilhelmina wharf and takes position behind a barge filled with coal, following a trail of ships on the crowded waters of the Rotterdam harbour towards open sea. Evidence of the industrial revolution could not be more evident than this one view. In less than 200 years, the access to an abundance of mainly fossil based energy has resulted in an explosion of human activity and initiated the development of metropolises, massive industries and global markets.

During my biology study, I became intrigued by the concept of evolution. The need to survive has been a force towards increased specialisation, driving complexity within natural and social systems. The enormous intricacy observed in social systems, as a consequence of our black gold based global economy, has led to societal imbalance and economic unpredictability. Although the new age of economic growth offered seemingly endless opportunities, it has been at the basis of pollution accumulation, loss of biodiversity, instable financial institutes and increased polarisation of wealth between human populations. Continuation of this path might have a catastrophic effect on humanity. There is a need for sustainable development.

Within a background of rising chimneys, the start of a new evolution is visible. Surrounded by an ocean of fossil based activity, a growing vein of a dozen wind mills represents the growth of a new movement towards more renewable based resources. Rotterdam has proven to be very active in driving this new progress. However, the Darwinism concept explains the observed difficulty in this movement's progression, by favouring short term fossil based economic survival over more expensive but durable renewable resources.

I also became grasped by the multi-dimensional aspects of life itself. Besides being an integral part of its ecosystem, biomass is able to fulfil a dynamic function inside society. The use of biomass as an energy source could be an important element within the renewable movement. Changing our current energy consumption pattern is fundamental. Continuing our path of fossil resource depletion runs dead ended.

There are prerequisites for driving sustainable development. Standardisation might be important in such progress. Standards can facilitate the processes of innovation, economic development and social integration. Standardisation may prove to be an elementary tool for the de-randomisation of existing evolutionary economic forces. By restructuring global economies, standards could actively initiate the needed adaptation of our current society to face and conquer future global bottlenecks. In this sense, standardisation of biofuels might pave a sustainable road towards a biobased economy.

Below me, the glowing climate bowls represent the fragile, but pounding heart of the new sustainable movement. In order to prevent cardiac arrest and stimulate its maturing, it needs social, financial and scientific nutrition. Let us feed.

Executive summary

The transition from a fossil based to a biobased economy has been proposed as a solution towards a sustainable society. Biofuels are expected to become an important pillar in such society. Biofuels can increase energy security, reduce greenhouse gas emissions and stimulate local economies. On national and international level, an increasing number of policies and R&D support is being developed for the promotion and use of biofuels. For several regions, local biomass availability proposes a serious barrier for the production and consumption of biofuels. As a consequence, trade in biofuels will become increasingly important. However, barriers related to governance, supply chain management, market operation and sustainability limit the development of biofuel markets. Standards might be able to reduce biofuel market barriers. Standards can improve sustainable supply chain management and reduce costs associated with production, transportation and consumption of goods. Furthermore, standards can assist in the legitimisation of new technologies and their diffusion into a central position. However, it is unknown how and to what extent standards can influence the development of biofuel markets.

Objectives and approach

In this research, the contribution of standardisation to the development of commoditised markets has been analysed. Also, the value and necessity of standardisation concerning the development of biofuel markets has been assessed. Based on current global market size, a selection of biofuels has been made for inclusion in the analysis. This selection includes the solid biofuels w*ood pellets*, *wood chips* and *agricultural residues*. Concerning liquid biofuels, *biodiesel*, *bioethanol* and *pure plant oil* have been included in the selection.

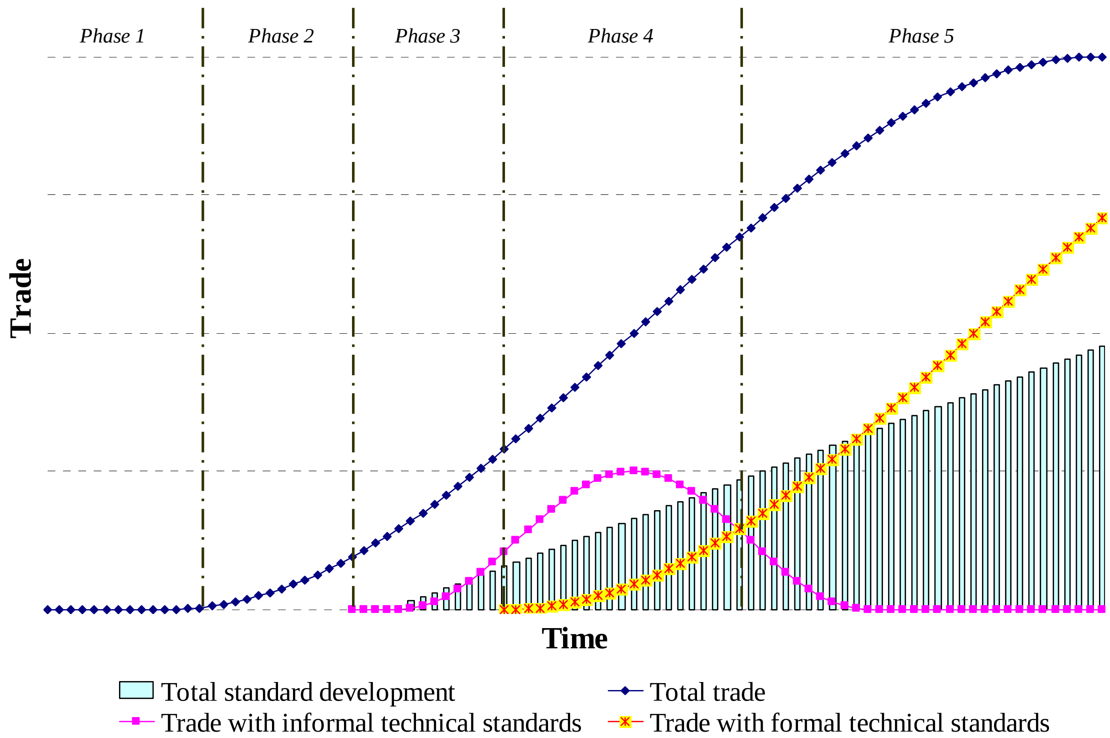

Figure 1 A hypothetical standard diffusion model

Based on technological diffusion theory, a standard diffusion model has been developed (*Figure 1*). The development, integration and implementation of standards in economy show clear parallels with diffusion of innovations. Furthermore, many of the factors that affect the environment of innovations coincide with barriers that have been affecting biofuel market development. In the developed diffusion model, a relation between standardisation and trade volumes is assumed. Within this model, two types of standard differentiations are being distinguished. First of all, the model includes the development of *informal technical standards* and *formal technical standards*. Informal technical standards are standards formulated by market parties or NGOs in a spontaneous process with an initial focus for small scale use. These initial informal technical standards are often succeeded by *formal technical standards* developed by standardisation institutes. Also, standards have been differentiated according to their function in supply chains. In total, 6 differentiated standard types have been included in the standard diffusion model. These standard types relate to supply chain issues of product quality, quality testing, equipment, safety & security, sustainability and air, water & soil quality.

In order to test the hypothetical standard diffusion model, the commoditised markets of coal and palm oil have been analysed. Furthermore, a stakeholder analysis was performed to determine stakeholder influence and the role of standards in the development of biofuel markets. For this stakeholder analysis, an online survey was executed to obtain quantitative data from stakeholders active in the selected biofuel markets. Semi-structured interview were performed to gain in-depth insights.

Results

A large correlation between international standardisation and the development of global production and trade volumes was found. Also in biofuel markets, stakeholders have indicated an important facilitating role for standards in biofuel market development. Biofuel certification is assessed by stakeholders as an important controlling tool for standard validation. Furthermore, a specific pattern in standard development has been detected. For both markets of coal and palm oil, a chronological prioritisation of quality standards has been observed. In biofuel markets, standards related to quality and sustainability are regarded as most important for future market development. Also, these standards were indicated to be prioritised in international standardisation activities.

Concerning the initiation of standards, there is a preference for governmental involvement related to the generic standards of sustainability, environmental quality and safety. Regarding the vertical standards of product quality, logistics and equipment, there is a clear preference for market initiation. Standardisation institutes are considered to have a prime function in standard management. Furthermore, there is a large preference for global scale orientation in the standardisation process. In the past decades, numerous standards for biofuel and biobased feedstock have been developed for local scale use. However, this process of parallel standardisation has hindered the development of required global biofuel markets.

Standardised contracts and the institutionalisation of commoditised markets might have facilitated increased global trading for coal and palm oil. According to stakeholders, current biofuel contracts lack functionality and transparency. Standardised contracts could facilitate increased global biofuel trade and the institutionalisation of biofuel markets. However, a number of barriers have been identified regarding the institutionalisation of biofuel markets. First of all, the current lack of internationally accepted standards negatively impacts the development of standardised contracts. Based on global production or trade volumes of the selected biofuels, it is assumed that the amount of globally accepted biofuel standards is currently insufficient for the development of global markets (*Table 1*).

Table 1 Comparing fuels based on global standardisation and market development

	Global production (MT)	*Global trade (MT)*	*Global standards***
Coal	12.600	1.800	161
Palm oil	48	32	117
Vegetable oils	92	42	27***
Ethanol	59	8	-
Biodiesel	21	22	-
Wood pellets	12*	1*	-

* based on production and inter-trading data between Europe and Northern America; ** based for use as fuel; *** based on standard development from 2005 onwards.

Furthermore, the observed stakeholder relations might impede the realisation of institutionalised biofuel trading. Many of the identified barriers in biofuel markets can be explained in terms of stakeholder connections and relationships. Observations from the online survey show that primary stakeholders endure relatively more negative influence from other stakeholders compared to secondary stakeholders. This finding is remarkable, since most secondary stakeholders have a task to provide services to enhance or facilitate the operational functioning of primary stakeholders.

Conclusions

A relation has been found between standardisation and market development. However, the absence of globally accepted biofuel standards for quality and sustainability might obstruct short term realisation of an institutionalised market. In order to create optimal conditions for global trading, further research is required to investigate possibilities for intra-organisational boundary and value determination for standardised trading. Also, the impact of intended vertical supply chain integration by large corporations on biofuel market development and institutionalisation could be analysed. Furthermore, the expected increase in biofuel demand on biofuel storage management could be assessed. At the moment, storage capacity is still a limiting factor in biofuel supply chains. Finally, it might be analysed to what extent standardisation and institutionalisation could facilitate the development of other biobased goods serving a future biobased economy.

Contents

Appendices

Figures

Tables

Glossary

Biofuel	Biomass used for energy. Includes unrefined and refined liquid and solid biomass.
Biofuel, liquid	Liquid form of biomass used for energy.
Biofuel, solid	Solid form of biomass used for energy.
Brokers	Market independent individuals buying and selling shares securities on behalf of investors. Brokers are regarded are necessary in the education of market participants in risk management technique and provision of reliable pricing data.
Commoditisation	A product or good related transition process from small-scale localised supply and demand towards large-scale global supply and demand.
Commodity	A product or good supplied with qualitative differentiation across a global market.
Economies of scale	Cost advantages that an organisation obtains due to the physical expansion of its operation.
Institutionalisation	The process of embedding something into an organisation.
Institutionalised market	A market defined by set protocols, rules and standards.
Mandated markets	The presence of a mandatory consumption pattern in markets, often defined by legislative tools.
Respondent	A person participating to a survey.
Stakeholder	A person, group or organisation that has a direct or indirect stake in a certain process or development.
Stakeholder, primary	Stakeholders that are directly affected by a certain process or development.
Stakeholder, secondary	Stakeholders that are indirectly affected by a certain process or development.
Standard	An arbitrary solution or best practice, expressing shared interest of compliance and expectations of widespread adoption.
Standard, contract	A contract used for institutionalised trading. It is a variation of a vertical standard, by being a prescription of a document format.
Standard, generic	A standard addressing processes that transcend the more specific activities and processes on supply chain scale or sectoral scale.
Standard, vertical	A standard describing data structures, data definitions, document formats and business processes for specific industries.

Stimulation system	Financial or legislative governmental support.
Supply chain	A system of organizations involved in transforming raw materials into a finished product and moving such products towards the customer.
Supply chain management	The act of managing processes and activities in supply chains, affecting supply chain efficiency and market operation.
Technological change	The expansion of knowledge, such that (1) more output can be produced given the same quantities of the inputs, (2) existing outputs undergo qualitative improvement, or (3) totally new products are produced.
Transesterification	A chemical reaction involving triglycerides and alcohols of lower molecular weights. Homogeneous or heterogeneous substances are used as catalyst to yield fatty acid methyl esters and glycerol.
Vertical integration	The process or activity to gain control over multiple supply chain parts.
Vertical supply chain integration	The control of multiple facets within a supply chain, in order to increase security of supply.

List of acronyms

Institutions

ASTM	American Society for Testing and Materials
BEST	Bioethanol for Sustainable Transport
BSI	Better Sugar Initiative
CBS	Central Bureau of Statistics
CEN	European Committee for Standardisation
DIN	Deutsches Institut für Normung
EC	European Commission
FAO	Food and Agriculture Organisation of the United Nations
FLO	Fair-trade Labelling Organisation
FOSFA	Federation of Oils, Seeds and Fats Associations
FSC	Forest Stewardship Council
GIC	Global Initiative on Commodities
IEA	International Energy Agency
IFOAM	International Federation of Organic Agriculture Movements
ISO	International Organisation for Standardisation
ITTO	International Tropic Timber Organisation
NEN	Dutch Institute for Normalisation
NOFOTA	Netherlands Oils, Fats and Oilseeds Trade Association
OECD	Organisation for Economic Co-Operation and Development
PEFC	Programme for the Endorsement of Forest Certification
PoR	Port of Rotterdam
RBCN	Rotterdam Biomass Commodities Network
RSB	Roundtable of Sustainable Biofuels
RSPO	Roundtable on Sustainable Palm Oil
RTRS	Roundtable on Sustainable Soy
SAN	Sustainable Agriculture Network
SBA	Sustainable Biodiesel Alliance
SCI	Sustainable Commodity Initiative
SEKAB	Svensk Etanolkemi A.B.
SFI	Sustainable Forestry Initiative
UNCTAD	United Nations Conference on Trade and Development
UU	Utrecht University
WUR	Wageningen University & Research centre

Abbreviations

ANOVA	Analysis of variance
AWS-quality	Air, water & soil quality
FAME	Fatty acid methyl esters
FFA	Free fatty acids
GlobalGAP	Global good agricultural practices
ILUC	Indirect land use change
LCFS	Low carbon fuel standard
MSDS	Material safety data sheet
NGO	Non-governmental organisation
NTA	Nederlands technische afspraak (Dutch technical agreement)
PPO	Pure plant oil

R&D	Research and development
RED	Renewable energy directive
S&S	Safety & security
SA	Stakeholder analysis
SCoTA	Standard Coal Trading Agreement
USA	United states of America
VSI	Voluntary sustainability initiative

Conversions

	Notations					
1	Million / Mega	(*M*)	=	10^6		
1	Billion / Giga	(*G*)	=	10^9		
1000	Billion / Terra	(*T*)	=	10^{12}		
	Volume					
1	Litre	(*L*)	=	0,26	Gallons	(*Gal*)
1	Cubic metre	(m^3)	=	1000	Litres	(*L*)
1	Cubic metre	(m^3)	=	264,17	Gallons	(*Gal*)
1	Million Litre	(*ML*)	=	10^6	Litres	(*L*)
	Weight					
1	Kilogram	(*Kg*)	=	2,21	Pounds	(*Lbs*)
1	Tonne	(*T*)	=	1000	Kilograms	(*Kg*)
1	Kilo Tonne	(*kT*)	=	1000	Tonnes	(*T*)
1	Mega Tonne	(*MT*)	=	10^6	Tonnes	(*T*)
	Energy					
1	Mega Joule	(*MJ*)	=	10^6	Joule	(*J*)
1	Giga Joule	(*GJ*)	=	10^9	Joule	(*J*)
1	Tonne of Oil Equivalent	(*TOE*)	=	42	Giga Joule	(*GJ*)
1	Mega Joule	(*MJ*)	=	947,9	British Thermal Units	(*BTU*)
1	kilo Watt hour	(*kWh*)	=	3414	British Thermal Units	(*BTU*)

Physical density[a]			
Ethanol	~	0,79	g/cm^3
Biodiesel	~	0,88	g/cm^3
PPO	~	0,93	g/cm^3
Wood pellet	~	0,65	g/cm^3
Wood chip	~	0,30	g/cm^3
Bituminous coal	~	0,83	g/cm^3
Energy density[a]			
Ethanol	~	26.8	MJ/Kg
Biodiesel	~	32,2	MJ/Kg
PPO	~	32,7	MJ/Kg
Wood pellet	~	17,5	MJ/Kg
Wood chip	~	8,9	MJ/Kg
Bituminous coal	~	24 – 31	MJ/Kg

[a] The represented physical density is an approximate value. This value is to a certain extent variable, due to differences in used feedstock or variations in chemical and physical composition.

1 Introduction

The development of the industrial economy has resulted in increased energy use [1, 2]. During the past century, the extensive consumption of fossil resources has had dramatic impacts on environment, society and economy. The expected increase in future global energy demand is likely to reinforce such negative effects [3, 4]. A transition from a fossil based to a biobased economy has been proposed as a solution towards a sustainable society [5-7]. Biofuel consumption is expected to become an important pillar in such society. Biofuels can increase energy security, reduce greenhouse gas emissions and stimulate local economies of both developed and developing countries [8, 9]. Furthermore, the availability of diverse feedstock sources, the possibility of quality tailored end-products and the presence of existing infrastructure favours the utilisation of biofuels in certain sectors compared to other renewable energy sources [10]. Also, a number of biomass conversion and pre-treatment methods are being developed to increase efficiency, energetic performance and application range of biofuels, of which some are expected to become commercially available on short-term [11, 12].

The financial crisis has cast a shadow over the belief regarding the mobilisation of required assets for meeting the growth in energy needs. The substantial investments needed for a sustainable scenario dominated by renewable sources stress the urge for sound governance. Appropriate policies and regulatory mechanisms are required to encourage the use and competitiveness of biofuels in current energy markets [13, 14]. On national and international level, an increasing number of policies and R&D support is being developed for the promotion and use of biofuels [15-18]. The rise of mandated biofuels markets will have a large effect on future biofuel supply and demand [19-21]. Although the total global potential for biomass production is large [22-24] and able to provide a sustainable and substantial part in projected energy security supply scenarios [25], local biomass availability might propose a serious barrier for the production and consumption of biofuels [26]. It is therefore likely that global trade in biofuels will become increasingly important.

Biofuel standardisation might be able to facilitate increased global trade. Standards are required for the commoditisation of products and the development of institutionalised markets. Commoditisation of products is characterised by the minimisation of qualitative differentiation across a supply base, leading to more efficient supply and increased demand [27]. Institutionalised markets can increase market transparency and decrease trade associated costs of communication [28]. Standardisation is an important intellectual capital in the development of commodities and institutionalisation of markets [29]. Standards can improve sustainable supply chain management and reduce costs associated with production, transportation and consumption of biofuels [30]. Also, standardisation can decrease transaction costs by establishing minimum criteria regarding trade [31].

The advantageous effect of standards on product supply chains has resulted in amplified biofuel and biobased feedstock standardisation activity [32-38]. However, the local focus during this activity has resulted in so called parallel standardisation. The geographical and societal based differentiations between these standards inhibit the range of biofuel trading. In 2009, an European study identified the need for globally accepted standards for stimulating further biofuel market development [39].

Nonetheless, it is still unknown how and to what extent standardisation can support market development of biofuels and initiate institutionalised trade. Standardisation might be especially important in non-matured markets. Furthermore, it is unknown to what extent specific standard types, targeting explicit aspects within biofuel supply chains, need to be prioritised in the overall process of standardisation. In order to assess the value of standardisation in the development of biofuel markets, two research objectives have been formulated. These aims are:

1. *To analyse the contribution of standardisation to the development of commoditised markets.*

2. *To analyse the value and necessity of standardisation concerning the development of biofuel markets, including an assessment of the need for adaptation and creation of current and new standards.*

The biofuels included in this analysis have been chosen based on current market volumes and future potential. The selection constitutes of 3 liquid biofuels and 3 solid biofuels, being:

- *Biodiesel*
- *Bioethanol*
- *Pure plant oil*
- *Wood pellets*
- *Wood chips*
- *Agricultural residues*

From chapter 2 to chapter 4, the developed theoretical framework and the applied methodological approach are elaborated. In *chapter 2*, the current status of biofuel markets is provided, including an historic overview of the production and trade volumes of these biofuels. Also a summery is provided regarding standardisation that has occurred within these markets. In *chapter 3*, a standard diffusion model is developed concerning the fundamental relation between standardisation and market development. Within this model, a differentiation of standards according to their specific function or role within a supply chain is made. In the second part of this chapter, the methodological approach based on the standard diffusion model is presented**.**

From chapter 4 to chapter 7, an overview and discussion of the obtained data and results is provided. In *chapter 4*, case studies are performed to validate the standard diffusion model. Historic trading and standardisation patterns are analysed for coal and palm oil, established commodities that serve as assumed benchmarks for respectively solid and liquid biofuels. In *chapter 5*, the results gathered from a stakeholder analysis is presented. In this analysis, stakeholders of biofuel markets were asked about their influence on market development. Furthermore, data provided by these stakeholders have been utilised to determine how and to what extent standardisation could contribute to further development of biofuel markets. In the last two chapters of this report, the analysed data and results are further elaborated. In *chapter 6*, the context, limitations and implications of the research findings are discussed. Finally, in *chapter 7*, the discussed implications are concluded and summarised. Also, a number of recommendations for practical exploitation or further research are made.

2 Case background

Prior analysing the relation of standardisation and market development of biofuels, there is need for a historic and theoretic background. To understand the possible role standardisation could fulfil in the development of biofuel markets, it is necessary to grasp the fundamental elements of such a relation. In *chapter 3*, the concept of standardisation is elaborated in more detail, including an outline of its origin, characteristics and potential range of influence. In this chapter, a background is provided concerning the use of biomass as a fuel, the growth of biofuel markets and developments in biofuel standard creation.

2.1 Using biomass as fuel

The selected liquid and solid biofuels[a] can be categorised according to their energy providing components. Ethanol is based on starch or sugar, whereas biodiesel and pure plant oil (PPO) are oil-based. Wood chips, wood pellets and agricultural residuals are mainly fibre– and herbaceous-based (*Figure 2*). In the next sections, a brief overview is provided regarding the energetic characteristics of these liquid and solid biofuels.

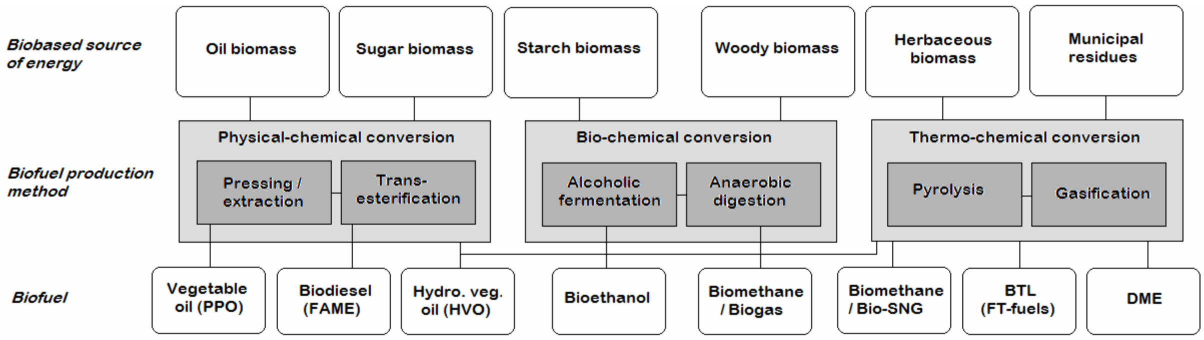

Figure 2 Biobased sources & biofuel production method
A model based depiction of bioenergy routes. There are several potential sources for bioenergy. Bioenergy can be utilised by three types of biomass conversion, which are physical-chemical conversion, bio-chemical conversion and thermo-chemical conversion. Illustration based on [40].

Liquid biofuels

Ethanol

Ethanol can be produced from both fossil and biobased sources. Traditionally, ethanol is produced by the biological fermentation process. A recent trend has been the development of cellulosic-based ethanol production technologies. These technologies are able to break cellulose into glucose by means of slow enzymatic digestive processes. Once released, this glucose can be used in the traditional fermentation process [41]. Although this technology is still in an early developmental phase, its potential to tap into a large supply of globally available cheap cellulosic based feedstock is large. The ability to convert dedicated energy

[a] The selected liquid biofuels for this research are ethanol, pure plant oil and biodiesel. The selected solid biofuels for this research are wood pellets, wood chips and agricultural residues.

crops[a] and all sorts of municipal-, agricultural- and forest residues into ethanol has led to governmental incentives regarding its promotion [42].

The application of ethanol has a long history being an essential element in liquor production. At present time, over 75% of all ethanol produced is used as a fuel and is globally the most consumed biofuel [43]. Due to its relative low amount of particle emissions, it is primarily utilised as an unblended or gasoline-blended transportation fuel. Furthermore, the ability to blend ethanol with diesel for combustion in diesel engines has broadened its range of application [44].

Vegetable oil

Vegetable oil is obtained from plants containing oil-bearing seeds or fruits. It can be extracted physically or chemically, depending on the fruit- or seed-type, available resources and required quality of oil. Like with ethanol, the use of vegetable oils has a long history in traditional food and chemical industries. At the end of the 19th century, the German mechanical engineer Diesel was the first to use vegetable oils as fuel (PPO) in adapted engines [45, 46]. During the oil shocks in the 1970s, there was renewed interest from numerous countries in this source of energy. During this period, numerous research programmes were initiated for optimising the utilisation of vegetable oils as fuel. Since then, this trend has not ceased to exist [47, 48]. The potential high overall performance of vegetable oils remains a strong leverage for the continuation of its use as a fuel.

Biodiesel

However, in present day engine technology, the direct use of chemically untreated vegetable oils can be problematic [49]. There are a number of solutions available to overcome technical barriers related to the use of vegetable oils in modern engines [50]. In the past decade, the transesterification reaction has become one of the most popular solutions to overcome these barriers, by splitting the large triglyceride molecules of vegetable oils into smaller glycerol and ester molecules. Transesterification leads to decreased viscosity and increased volatility [51]. The resulting mix of fatty acid methyl esters (FAME), or biodiesel, resembles to some extent the physicochemical properties of petroleum diesel. Besides the potential conversion of vegetable oil into biodiesel, other lipid bearing sources can be used as feedstock for biodiesel production [52]. Such sources include animal fats and microalgal oil[b].

Solid biofuels

Solid biofuels come in many forms. The woody or herbaceous based feedstock used for their production can originate from a wide variety of sources. Feedstock can be derived from dedicated plantations. However, main sources for woody and herbaceous based feedstock are residual streams, mainly created in the agricultural, municipal and forestry sector. Besides being widely used for soil nutrient recycling and other soil improving purposes, these streams are progressively being utilised as an energy source [53]. Energy production based on residual streams is highly encouraged within a number of countries and regions [54, 55].

Herbaceous biofuels

Depending on the quality of solid biomass, determined by physical and chemical properties, a number of methods can be applied to exploit energy content (*Figure 2*). Recent technological

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[a] Energy crops are plant species that have a high biomass output and the ability to grow in harsh climates and on nutrient poor soils.
[b] Like vegetable oil, algal oil can be used directly as a fuel.

innovations have removed a number of traditional barriers[a] for the use of herbaceous based feedstock, thereby increasing the potential of waste stream utilisation in large scale power plants. Such resources include field crop residues, feed grains, crop milling residues and energy crops [56].

Woody biofuels

Historically, woody biomass is the most widely used renewable energy source. In many developing countries, it is still the prime energy supplier for millions of people. In comparison with herbaceous based feedstock, quality of wood is more homogeneous. Two types of woody biofuels include wood chips and wood pellets. Although wood chips are intensely used in paper and packaging industries, its traditional use relates to internal building heating and the generation of electricity in power plants. Wood pellets, generally made from compacted sawdust originating from wood transformation activities, can be used as efficient combustibles in small and large scale power and heat generation facilities.

2.2 Market development of biofuels

Of all biofuels, ethanol, vegetable oils, biodiesel and woody based biofuels are at present most dominant in international markets [57]. In the following section, a closer look is taken at historic production and trade patterns of these products.

Liquid biofuels

Ethanol

The increased use of ethanol as a fuel has contributed significantly to the increase in global ethanol production, which has grown from less than 10.000 million litres (ML) in 1975 to over 70.000 ML in 2009 (*Figure 3*).

Currently, the three largest ethanol producers are Brazil, the United States of America (USA) and Europe [58]. USA produced in 2008 around 34.000 ML of mainly maize based fuel ethanol [42]. A large share of USA's ethanol production is used domestically and supplemented by imports from other countries [59]. Before USA became the largest producer of ethanol, Brazil has been dominating global production as a result of historically based governmental incentives. This promotion has resulted in a current 40% ethanol share in the total fuel used by Brazilian passenger cars [60]. In 2008, the annual production of mainly sugarcane based fuel ethanol was approximately 25.000 ML. Annual production is expected to increase to about 31.000 ML in 2015. Although much of the produced ethanol is consumed domestically, Brazil is also the world's largest exporter.

Europe is currently the third largest global ethanol producer, although the production of approximately 3.000 ML in 2008 is in sharp contrasts with the amounts produced in USA and Brazil. Although Europe's main focus regarding liquid biofuels is still on biodiesel, a number of countries have developed substantial ethanol production facilities. Germany and Spain are leading in this development. Various types of feedstock are used, including sugar beet, wheat, cassava and other related crops [61]. A number of African and Asian countries are also investing in ethanol production. China, Thailand and India belong to the top ten of ethanol

[a] Traditional barriers for the use of herbaceous feedstock are mainly related to its chemical properties. Presence of potassium and chlorine can create salt and clinker formation during combustion, reducing the performance of boilers. The development of staged-combustion methods has minimised such impacts.

producing countries. In Africa, ethanol production is growing due to several governmental mandates and incentives [62].

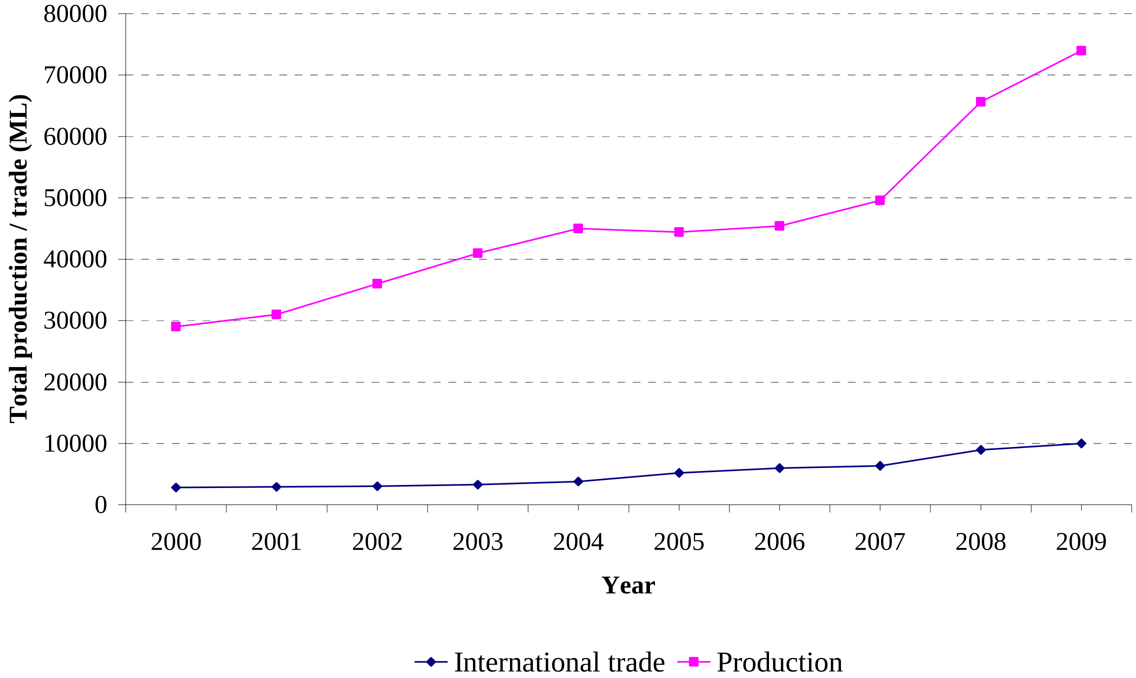

Figure 3 Global production and trade in ethanol
Global ethanol market has expanded considerably during the past decade. There is a clear increase in global production and trade volumes. Sources: [43, 63-68].

Vegetable oil

The increased use of vegetable oils as an energy source has resulted in increased global production (*Figure 4*). Production of palm, rapeseed and soy oil has increased substantially over the last 20 years. Also, trade has increased notably in this period (*Figure 5*). This trend can partly be explained by initiated biodiesel production in Europe.

Biodiesel

When the market for biodiesel started growing in the first decade of the 21st century, Europe became global leader in its production (*Figure 6*). In 2002, Germany, France and Italy contributed together for approximately 80% of the total global biodiesel production [69]. In 2008, European biodiesel production was around 9.000 ML, with a production capacity of almost 24.000 ML [70]. The main feedstock used for European biodiesel production is rapeseed, of which a large part of European crops are used. The European target of 10% biofuels in road transport fuels in 2020 represents a total estimated energy requirement of 36 million tonnes of oil equivalent (MTOE), or approximately 1,5 EJ. This energy supply by biofuels is expected to result in a potential shortage of approximately 1.200 ML rapeseed oil [71]. This shortage needs to be compensated with biofuel import or substitution by other feedstock types.

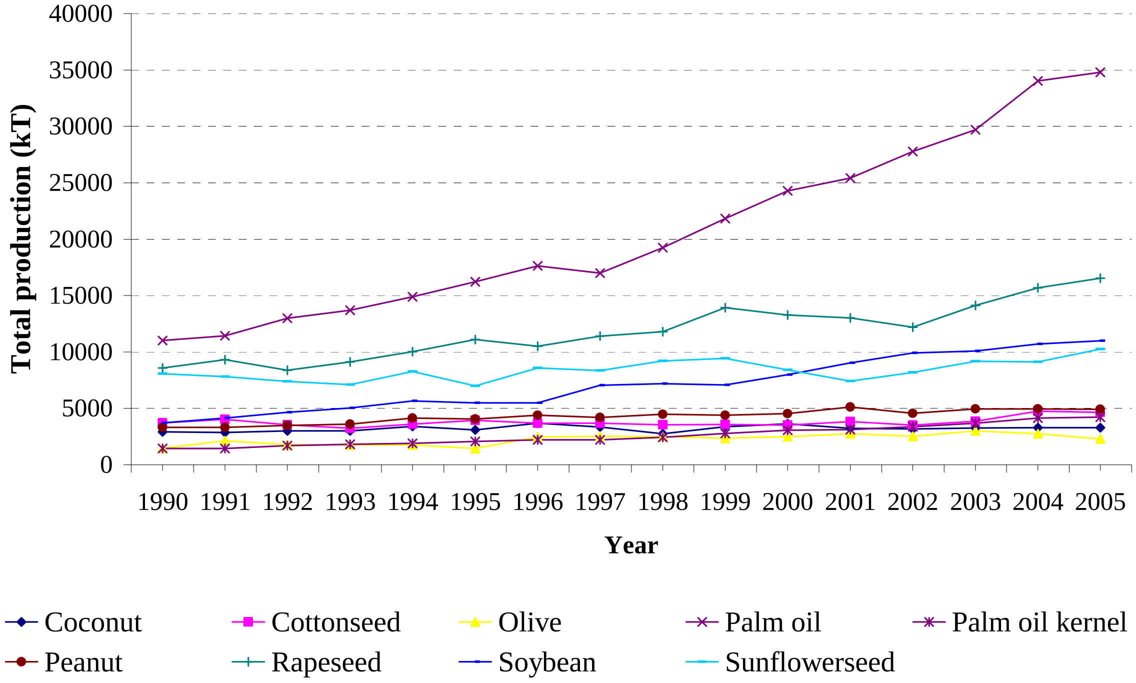

Figure 4 Global productions of vegetable oils with large market shares
Global vegetable oil production has expanded considerably since 1990. This increase is especially relevant regarding palm oil and rapeseed production volumes. Sources: [72]

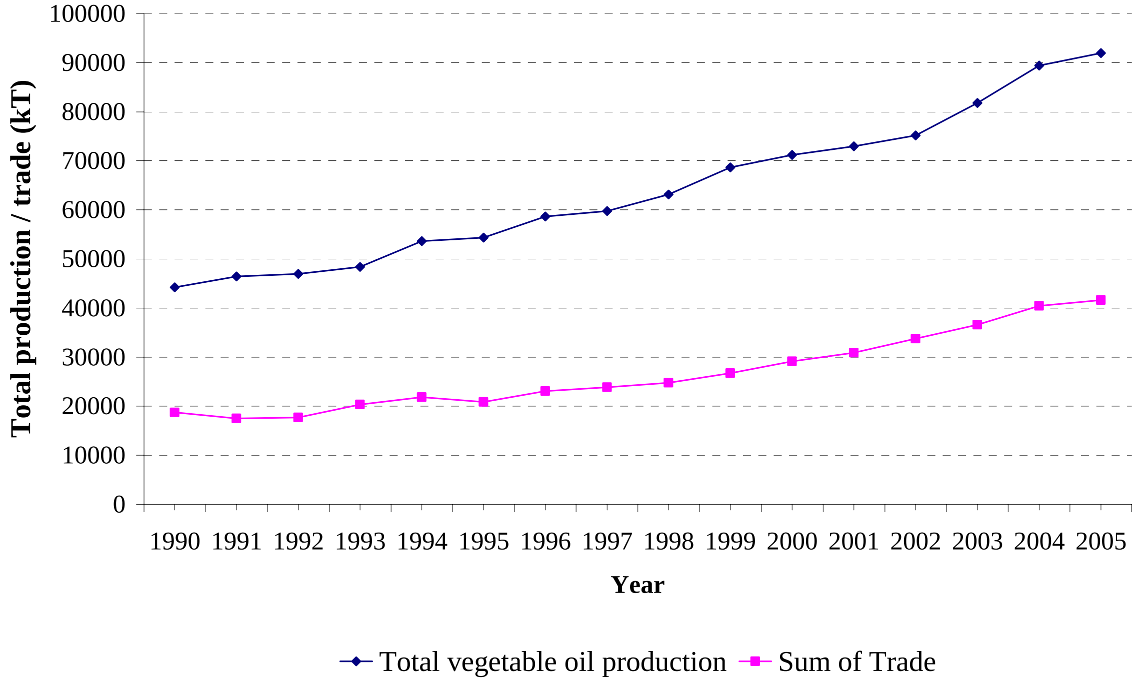

Figure 5 Global production and trading volumes of vegetable oil
Total global vegetable oil production and trade have expanded considerably since 1990. Sources: [72]

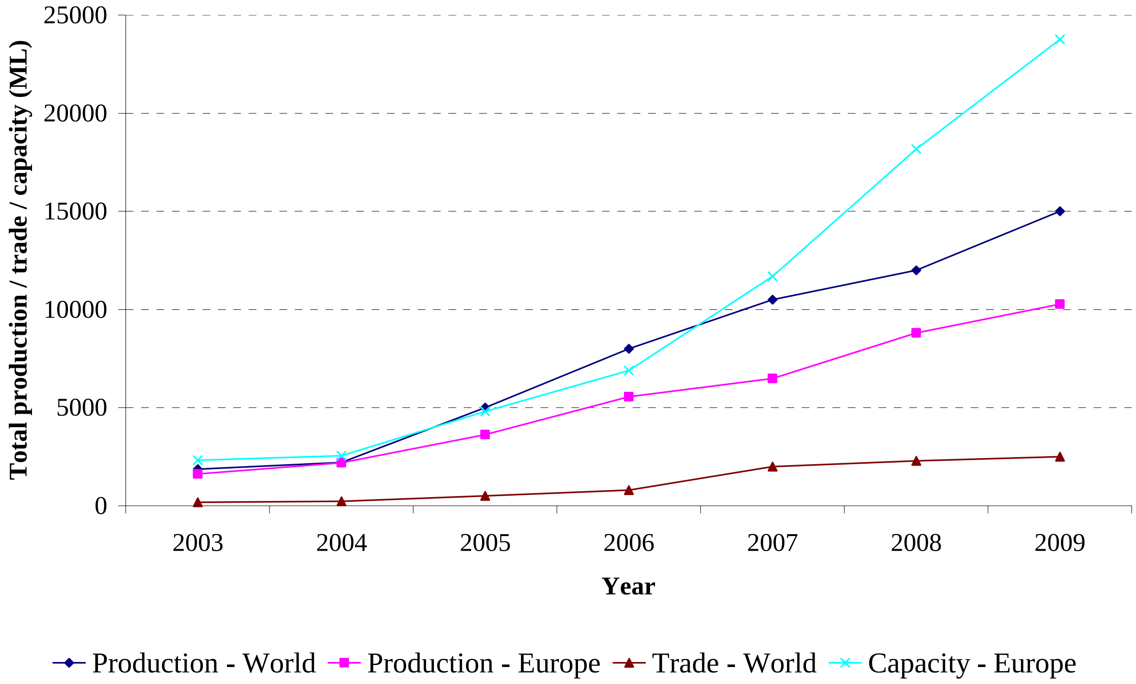

Figure 6 Production, production capacity and trade in biodiesel
Since the initiation of the European biodiesel market, production, production capacity has increased considerably. Global trade in biodiesel is relatively still limited. Sources: [73-76]

Outside Europe, the United States, Australia, Brazil, several Asian countries[a] and an increasing number of African countries are investing in biodiesel. These investments are often stimulated by governmental incentives and mandates [42, 77, 78]. However, it is expected that a large share of the substantial growth in production capacity outside Europe will be consumed on domestic markets and therefore excluded from global trade [71].

Solid biofuels

Wood pellets

The global wood pellet industry has developed significantly in the past decades. In approximately 15 years, it has evolved remarkably fast from practically non-existing to an important consumer of fibre (*Figure* 7). As a consequence, the energy sector is increasingly competing with the traditional pulp and wood-panel industry for residual wood streams [79]. The amount of dedicated plantations is growing, in order to meet the expected increase in wood demand.

In 2008, around 25% of the global pellet production was traded on intra- and intercontinental scale [79]. Currently, high trade intensity exists between European countries. Germany is a large exporter towards its neighbouring countries of Austria, the Netherlands, Belgium and Italy. Also, significant wood pellet volumes are traded between Baltic and Scandinavian countries [78].

Import of wood pellets from outside Europe mainly originates from Canada. Canadian wood pellets are in general transhipped towards Belgium, the Netherlands and Sweden.

[a] These Asian countries include India, Malaysia, Indonesia, China and the Philippines.

Intercontinental trade is mainly caused by feedstock price for wood pellet production. Due to a relative large scarcity of European feedstock, Canadian wood pellets can compete with the expensive European wood pellets. Wood pellet production is expected to continue to grow in the next years, with some experts forecasting a global annual growth of 25-30% over the next decade. Increased interest outside Europe for wood pellets might have a considerable effect on current trade patterns, diminishing wood pellet flows from Northern America towards Europe.

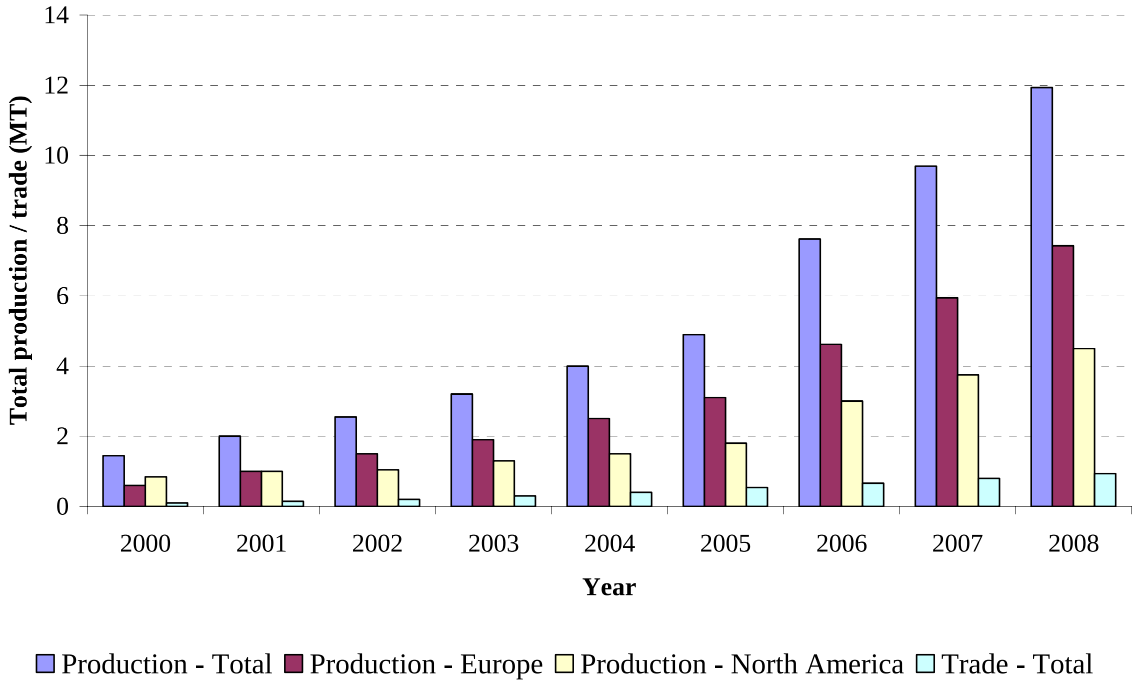

Figure 7 Production and trade of wood pellets in Europe and North America
Like the biodiesel market, production of wood pellets has increased substantial in the past decade. Mainly Europe and North America are active in this developing market. In this figure, trade represents flows between Europe and North America and excludes intra-continental trade. Source: [80]

Wood chips

The market of wood chips has developed considerable. Global trade in wood chips has more than doubled in 20 years. This increase is mainly caused by decreasing supply in close proximity of pulp mills in the Northern Hemisphere, leading to increased sourcing of cheap wood from fast-growing plantations abroad [79]. Most trade in wood chips is still initiated by demand from the pulp- and paper industry. However, many energy companies in Europe are searching for new sources of biomass which could further expand the overseas trade of wood chips. Trade of wood chips is still highest in the Pacific Rim, where imports to Japan, Taiwan, South Korea and China account for about 55% of the total global trade and over 95% of water-born trade. In 2007, the major supplying regions to Asia were Australia, South Africa, Chile and Vietnam.

2.3 Standardisation of biofuels

Biofuel standards might be an important prerequisite for the development of their markets. The importance of biofuel standards has not gone unnoticed [81, 82]. On national and international scale, numerous standards and standardisation initiatives are or are being developed. In the first part of *chapter 4*, the fundamental concept of standardisation is elaborated. Also, the importance of harmonised or globally accepted standards is explained. In the following section, we take a look at quality and sustainability standards that have been developed for biofuels.

2.3.1 Quality standards

Quality standardisation of biobased goods is not new. On the contrary, the historic use of ethanol, vegetable oils and wood chips in several industrial sectors has led to extensive standard development. However, the increased interest for using these products as a biofuel has created a new perspective on their quality. During the past decades, a significant amount of quality standards have been developed for several types of biofuels (*Table 2*). In the following section, the development of these standards for both liquid and solid biofuels is further discussed.

Liquid biofuels

Vegetable oils

There are a number of distinctive quality parameters that are important for the use of vegetable oils as a fuel. These parameters include fatty acid composition, water content and presence of insoluble components. Nevertheless, compared to biodiesel, the amount of crucial variables that need to be validated is relatively small. The trend of increased use of vegetable oils as an energy source has led to the development of several quality standards for their use as a transportation fuel. However, much of these standards have focussed on regional application, limiting its applicability on larger scale. The rapeseed-oriented German DIN standard has recently evoked the initiation of a workgroup by the European Committee for Standardisation (CEN), in order to formulate a European feedstock independent quality standard for the use of vegetable oils in modern diesel engines ([83]).

Biodiesel

In contrast to vegetable oils, there are considerable more parameters that can influence quality of biodiesel (*Table B-I*). The transesterification reaction of vegetable oil into fatty acid methyl esters (FAME) has several drawbacks, including its energy intensity, difficult glycerol recovery, difficult catalyst separation, the need for waste water treatment, interference of free fatty acids (FFA) and interference of water with the reaction [84]. Ineffective biodiesel separation and purification can cause severe diesel engines problems, including filter plugging, coking on injectors, carbon deposits, excessive engine wear, oil ring sticking, engine knocking and thickening and gelling of lubricating oil [85].

To eliminate these negative effects, a number of international technical standards have been developed. Main standards used are from CEN and the American Society for Testing and Materials (ASTM). These standardisation institutes have developed standards for a number of different biodiesel grades. In 2009, the EU-funded Bioscopes-project investigated the need for a revision of the European biodiesel standard. Like the DIN standard for using vegetable oil as a fuel, the current European biodiesel standard is rapeseed focused. Based on future need of supply source diversification and prevent decreased fuel quality and engine performance, the European biodiesel standard is currently being revised [86].

Furthermore, there is increased interest in the use of biodiesel in South America, reflected in a series of standards and resolutions created related to its consumption in a number of countries. Also in Asia and Australia, the consumption of biodiesel has gained importance in the past decade.

Table 2 Overview quality standards for biofuels

Biofuel	Region	Standard
Liquid biofuels – Biodiesel		
Continental	Europe	EN 14214
		EN 590
Country	Argentina	Resolution 1283/2006
	Australia	Fuel Quality Standards Act 2000
		Fuel Standard (Biodiesel) Determination 2003
	Austria	ON C1191
	Brazil	ANP Resolution 15/2006 / ANP 42
	Canada	CAN/CGSB-3.520
	India	IS 15607
	Malaysia	B5 Palm Biofuel Blend-Specification
	Peru	Decree D.S. N - 021-2007
	USA	ASTM 975
		ASTM D6751
		ASTM D7467
Liquid biofuels - Bioethanol		
Continental	Europe	CWA 15293
		EN 15376
Country	Brazil	DNC - 01/91
	Canada	CAN/CGSB 3.511-93
	Denmark	DS DSF/PREN 15492
	Poland	PN - 91/A-79521
	Sweden	SEKAB standard
	Ukraine	Ukrspirt
	USA	ASTM D4806 – 09
		ASTM D5798-98a
Liquid biofuels - Vegetable oil		
Country	Czech Republic	CSN 65 6507
	Germany	DIN V51605
		RK-Qualitätsstandard
	Italy	UNI 10635
	Sweden	SS 155436
Solid biofuels – Wood pellet		
Country	Austria	ÖNORM M 7135
	Germany	DIN 51731
Solid biofuels - General		
Global		ISO/TC 238
Continental	Europe	CEN/TC 343
Continental		CEN/TC 335, TS 14961:2005
		CEN/TC 335, TS 15234:2006

Derived from [87]

Ethanol

For the use of ethanol as fuel, there are a number of distinctive parameters that need to be controlled for optimal performance (*Table B-II*). These parameters include presence of other alcohol types, water content and chemical contamination. The trend of increased use of ethanol as a transportation fuel has resulted in the development of several fuel ethanol standards. In the important ethanol producing and consuming regions, including USA, Brazil and Europe, such standards have been created. In Europe, the absence of a quality standard for neat ethanol[a] is claimed to limit the full potential of European ethanol consumption. In order to address the need for such a standard, CEN has set up a workshop agreement using the national Swedish ethanol standards as a basis [88].

Solid biofuels

Also for solid biofuels, there are several important parameters that can influence the process of combustion in heat and power production (*Table B-III*). Influencing variables include moisture, ash, nitrogen, chlorine, sulphur and distribution of particle size. Most standards for solid biofuels have been developed in Europe. CEN has been working on a number of quality standards for solid biofuels, including the standardisation of physical properties, chemical properties and the source of feedstock material. Prior the development of CEN standards, several countries have created such standards for their use smaller scale. On global level, the International Organisation of Standardisation (ISO) has recently started a solid biofuel program. This program includes biofuels based on residual streams from agriculture and forestry. However, no standards have been published yet.

Wood pellets

Concerning quality standardisation of specific solid biofuels, such activities have focussed primarily on wood pellets. Most wood pellet standards have been developed on national level. The national orientation of many wood pellet standards is believed to limit their international application, constituting a potential barrier for wood pellet market development.

2.3.2 Sustainability standards

Potential negative side effects related to mass industries has increased the importance of sustainability standards. Governmental bodies, market parties and civil society organisations have set up initiatives to address such critical issues. A growing number of stakeholders are forming multi-stakeholder alliances in order to establish best sustainable practices. These voluntary sustainability initiatives (VSIs) have resulted in the development of several standards concerning sustainable production, trade and consumption. Also for biofuels and biofuel feedstock, a number of sustainability standards have been developed.

Feedstock production

Feedstock production practices might become crucial in assessing the sustainability performance of biofuels. Although a growing share of biofuels is based on residual streams, most feedstock is still derived from either forests or agricultural lands. Feedstock used for the production and consumption of biofuels need to comply with environmental requirements for agriculture and forestry, including the protection of biodiversity, water quality and social conditions.

[a] An ethanol blend higher than 95%.

Table 3 Overview of sustainability standards and agreements for biofuels

Scale	Scale specific	Standard
Feedstock production - Agriculture		
Global		BSI standard
		FLO standard
		GIC standard
		GlobalGAP standard
		IFOAM standard
		OECD standard
		SAN standard
		SCI standard
		SCS Sustainable Agriculture Practice
Feedstock production - Forestry		
Global		American Forest Foundation's Standards of Sustainability
		FAO sustainable forests standard
		FSC standard *
		ISO 14000
		ITTO standard
		Pan-European Process
		PEFC standard*
		SFI standard
		the Montréal Process standard
Liquid biofuels - Vegetable oils		
Global		RSPO standard
		RTRS standard
Continental	Europe	FLO-ev
Country	Switzerland	The Basel Criteria for Responsible Soy Production.
	Netherlands	SMK standard (rapeseed).
Liquid biofuels - Biodiesel		
Country	USA	SBA standard
Liquid biofuels - Ethanol		
Continental	Europe	BEST standard
Country	Brazil	The Social Fuel seal
	Sweden	SEKAB
Liquid biofuels - General		
Continental	Europe	RSB standard
Country	Netherlands	NTA 8080
	Switzerland	Swiss mineral oil tax redemption for sustainable biofuels
	United Kingdom	Renewable Transport Fuel Obligation
	Germany	Biofuel Quota Law
State	British Colombia (Canada)	LCFS
	California (USA)	LCFS

* = includes certification. Derived from [87]

The European Commissions already stressed the need to regard primary forest in accordance with the definition used by the Food and Agriculture Organisation of the United Nations (FAO) in its Global Forest Resource Assessment[a]. A number of system based standards, criteria and indicators have been developed concerning the sustainable management of forests and agricultural lands (*Table 3*). However, concern exists that certain countries might not

[a] The Global Forest Resource Assessment is an assessment used worldwide to report on the extent of primary forest and its protection by national environmental protection law.

respect the proposed environmental and social requirements concerning the production of biofuels. In this sense, the European Renewable Energy Directive (RED) stressed the need developing multilateral and bilateral agreements to promote sustainable global production of biofuels.

Biofuels

Many sustainability initiatives and standards for biofuels have been formulated on meta-level due to the transcending nature of such criteria (*Table 3*). Nevertheless, there have been a number of standardisation initiatives regarding the sustainable production of specific biofuels.

Liquid biofuels

Of all biofuels, the usage of vegetable oils as fuel is probably mostly debated. Publicly discussed impacts on land conversion, food availability and food prices due to imbalanced production and allocation of vegetable oil have resulted in a number of specific sustainable orientated initiatives. Similar discussions regarding the increased demand for ethanol as a fuel have led to several initiatives dedicated to the production of sustainable ethanol. However, the effectiveness and legitimacy of such initiatives is seriously doubted, as it is not always clear whether all stakeholders of all relevant sectors are sufficiently represented [69].

Solid biofuels

Sustainability standards for the production and consumption of solid biofuels are underdeveloped. On European level, there is currently no uniform sustainability standard for solid biofuels. Only a number of sustainability parameters and criteria have been described for solid biofuels [89]. Also on global level, a sustainability standard for solid biofuels is lacking.

3 Theory & Methodological approach

In the previous chapter, it was shown that biofuel markets have clearly expanded over the past decades. Also, a number of standards have been developed that are directly or indirectly related to biofuel markets and supply chains. However, several barriers are limiting further development of biofuel markets. Barriers related to policy, supply chain management, market operation and sustainability are negatively affecting production and consumption patterns of biofuels (*Table 4*). As a consequence, growth in trade has considerable lacked behind the increase in biofuel production capacity. Furthermore, a large share of this production capacity is unused [12]. The developmental freeze of the European biodiesel industry is a pronounced example of how non-harmonised governance can negatively impact markets (see *chapter 2*, *Figure 6*). Also, the unpredictability and insecurity regarding wood pellet supply have stimulated large companies to invest in vertical supply chain integration [90-92]. It is unknown to what extent such activities might affect the development of wood markets.

This chapter is divided in two parts. In the first part, a theoretical based investigation is made regarding the value and function of standards in removing existing barriers within biofuel markets. An examination has been made concerning the ability of standardisation to improve supply chain management, enhance communication and create more transparent markets. Also, a hypothetical model is introduced regarding the relation between market development and standard diffusion into an economy. Within this model, different types of standards are being distinguished.

In the second part of this chapter, the used methodological approach for addressing the research aims is elaborated. Regarding the first research aim, which was concerned with analysing the contribution of standardisation to the development of commoditised markets, the executed comparative-correlation analysis is elaborated. Related to the second research aim, being concerned with analysing the value and necessity of standardisation in biofuel markets, the applied stakeholder analysis is discussed in more detail.

3.1 Theory

3.1.1 The role of standardisation in supply chain development

In order to improve market development of biofuels, it is necessary to identify key variables in such process. Most of these variables are directly or indirectly related to the supply chain, a system of organisations, activities and resources acting at the core of a certain market [27, 93, 94] (*Figure* 8). The ability of a supply chain to influence production, transportation, trade and consumption can be explained with the economic supply-demand model (see *text box*). An expanding market is the direct result of a positive induced supply-demand equilibrium, which occurs due to 1) an increase in supply, or 2) an increase in demand. There are a number of drivers that influence the supply-demand equilibrium (*Table 5*).

Standards can influence drivers that affect the supply-demand equilibrium. In the next section, an explanation is provided regarding the fundamental emergence and use of standards in economies. Furthermore, the function of different standard types is elaborated. Also, the most important aspects related to the development of standards are being mentioned.

Table 4 Overview of identified barriers for market development of biofuels

Barrier for market development	Specification of barrier
Policy & society	
Non-harmonised governance	▪ Uncertain and inappropriate stimulating systems ▪ Tariffs
Lack of public support	▪ Complicated commercialisation of biofuel technologies ▪ Biased or ill founded education of the general public
Sustainability	
Concerns regarding sustainable production	▪ Effect on socio-related variables (labour conditions, destruction of communities) ▪ Forest and land management ▪ Carbon footprint of biofuel supply chains ▪ Balancing ecosystem thresholds and carrying capacities ▪ Preservation of biodiversity and carbon stocks, especially in developing countries
Traceability of origin	▪ Insufficient methods to determine geographical origin and age of carbon
Supply chain level	
Unprofessional supply chain management	▪ Lack of biofuel integration into organisational processes ▪ Lack of knowledge within biofuel supply chains ▪ Quality issues related to biofuels and biobased feedstock ▪ Lack of dedicated equipment and biofuel malfunctioning with available technology ▪ Abundance of interfaces reducing supply chain efficiency ▪ Poor data collection and availability ▪ Poor communication between stakeholders
Limited availability and high price of feedstock	▪ Competition within biofuel markets and between other sectors for feedstock ▪ Limited period for harvesting ▪ Complicated supply and scattered sources ▪ Lack of cost-effective feedstock extraction methods ▪ Price of feedstock
High logistic costs	▪ Lack of decentralised biomass densification facilities ▪ Lack of dedicated shipping- and storage capacities ▪ Lack of storing concepts to improve cost-effectiveness of biofuel storage
Market operation	
Non-transparent market	▪ Limited price transparency ▪ High market volatility ▪ Unsecure and unreliable supply concerning both biofuel quantity and quality ▪ Limited scalability of power plants due to uncertain feedstock availability ▪ Insufficient price hedging opportunities for biofuels and biobased feedstock ▪ Unclear price indexation ▪ Limited availability of general contractors, due to oligopolistic market structure ▪ Unstable biomass price development
Hurdle of high initial investment cost and the risk perception of financers	▪ Net invested costs are often larger than net benefits ▪ Risk of investment high with new biofuel production technologies ▪ Conservative capital expenditure (CAPEX) reserve as percentage of total investment ▪ Decreasing prices for fossil fuels
Insufficient long- & short-term contracting	▪ Limited standardised contracts ▪ Structure of natural resources ownership complicates long term supply contracts

Sources: [69, 80, 90, 95-118]

Supply and demand

In competitive markets, the driving forces of supply and demand determine the economic market equilibrium, due to negative feedback between product price and quantities sold. The supply is a function of the production level of an economy at a specific time, representing the amount of some good that producers are willing and able to sell at variable prices. The demand is a function of the consumption level of an economy at a specific time, representing the amount of some good that buyers are willing and able to purchase at variable prices. A number of factors influence the functions of supply and demand. In a static situation in which these factors remain constant, the supply-demand equilibrium remains unchanged. However, the time-dependent dynamic character of most variables affects the supply-demand equilibrium.

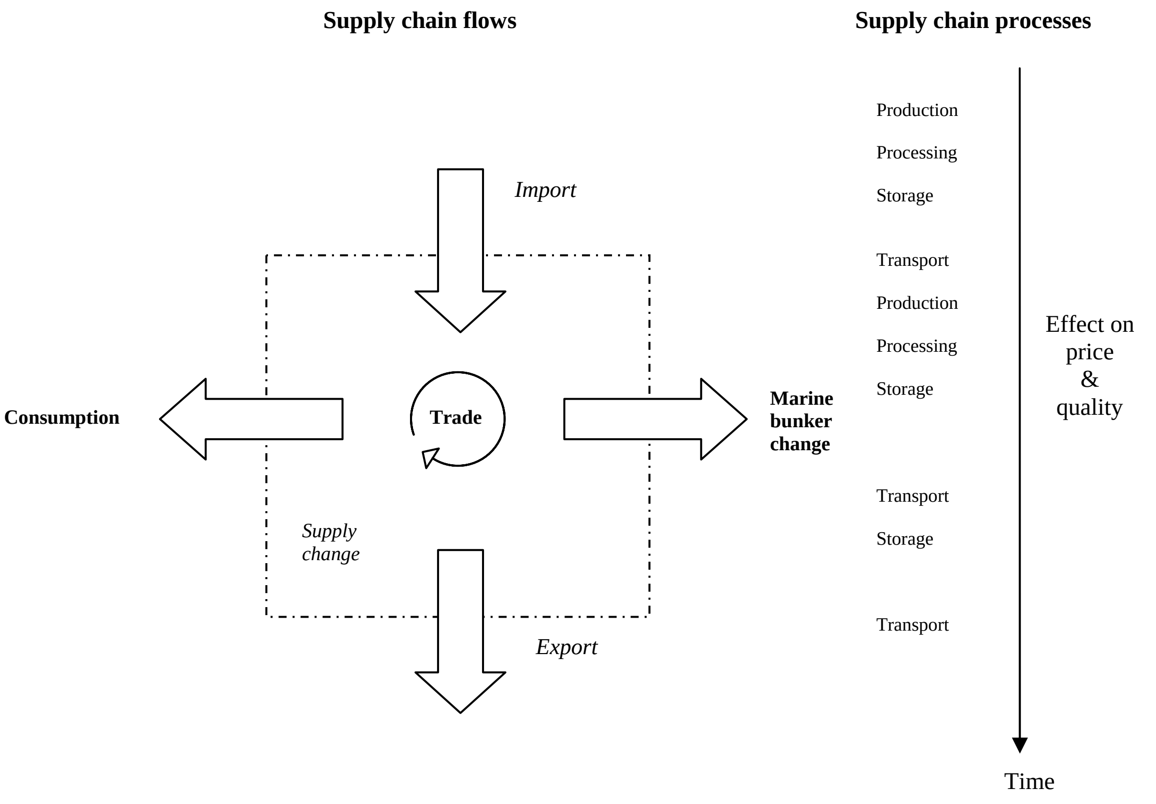

Figure 8 Schematic representation of a supply chain

General flows and processes within a region are depicted. Explanation of terms: *supply change* = determined by time-dependent variables of consumption, import, export and marine bunker change; *marine bunker change* = the amount of fuel that is consumed on international waters or airspace, measured independently from regional consumption; *trade* = (physical) exchange of goods that can lead to a movement of such goods inside a region (internal trade) or across a region's border (external trade); *transport* = occurs as well internally (inside a predefined region) as externally (import and export); *production* = production of feedstock; *processing* = production of end-product from feedstock; *storage* = can refer to short-term or long-term storage. In case of long-term storage, the unused amount of a certain product will be available for a next period. Furthermore, there are different locality types of storage, ranging from storage at production to storage at end-users.

Table 5 Variables influencing supply and demand within the supply chain

Drivers of supply and demand	**Description of driver**
Drivers of demand	
Economic expansion	▪ Increases the average consumer purchasing power
Mandated markets	▪ Influence of consumption pattern by legislative tools
Substitution	▪ Increase of market penetration due to advantageous fulfilment of a similar function of a substitute
Technological improvement	▪ Improved qualitative output of a certain entity, being the result of knowledge increment due to experience and competition
Drivers of supply	
Technological improvement (competition & experience)	▪ Improved quantitative output of a certain entity, being the result of knowledge increment due to experience and competition ▪ Competition is driven by the phenomenon of globalisation. There are a number of factors that counteract the effect of competition, including: o Ad valorem tariffs: artificially decreasing or eradicating prices within a product group or between substitutes o Subsidies: artificially decreasing or eradicating prices within a product group or between substitutes o Monopolistic tendencies
Energy price	▪ Influencing investments made within the supply chain ▪ Can offset imposed tariffs ▪ Large influence on transport costs: o Transport costs affect the availability and range of goods and services across national borders. o Reduction in transport costs can increase productivity by allowing more specialization.
Supply chain management	▪ Reduction of obsolete linkages can reduce the total added value of a product, resulting in overall lower consumer entity price. Communication plays a prominent role in such process.

Sources: [4, 94, 119-123]

Description of a standard

Standards emerged as a necessity for the public good. Initially, the development of standards was aimed at plain regulation of quantity and quality related aspects. However, the process of standardisation evolved in time into a fundamental part of general management theory, in which standards target constraints of a purely individualistic system.

Standards are considered arbitrary solutions or best practice by expressing a shared interest of compliance and expectations of widespread adoption [124]. The concept of a standard resembles a modelling activity and improves exchange of information in business processes [125]. In practice, standards contain technical specifications or other determined criteria and manifest themselves in protocols, prescriptions and rules within documents open for public access [126, 127]. Standards can be said to have a conceptual resemblance with a recipe or an advice [128].

The difference between standards, norms and legislative acts

The initial movement toward market standards has been tied up with increased governmental control in multiple directions [129]. In this sense, standards are akin to norms and legislative acts. However, there are a number of fundamental differences that distinguish standards from the other two. Norms miss the explicitness of standards. The absence of explicitness is caused due to a norm's unavailability in formal authorities, consortia or de facto conditions. They often lack a clear source. As a consequence, norms have more difficulty in reaching a critical mass of installed base.

Legislative acts are issued by an authority and therefore mandatory by nature. While standard leadership is based on voluntariness and desire for group membership, legislative acts carry the authorization of organizational leaders [125]. They target a specific group of members and can be supported by sanctions. Standards can be adapted by local or regional governing authorities and integrated into legislative structures. Such standards have been entitled *de jure standards*, meaning literally standards concerning law. De jure standards oppose *de facto standards*, which are standards concerned with facts [130]. The transformation of de facto standards into de jure standards implicates the abandonment of the fundamental pre-requisite of voluntariness. As a result of legal embedding, de jure standards lose their identity as a standard.

Function of standards

Standards have historically been developed with the aim of increased control. Increased control can have a number of effects on as well emerging markets as developing markets. Such effects include increased stability and niche creation in emerging markets. In developing markets, increased control induced by standards can improve supply chain management.

Create stability or niche positions in emerging markets

The incentive of standardisation is to gain stability, which can lead to increased benefit and greater growth. Especially in an emerging field, the risks of instability and loss of control may be extremely high. In such situation, firms may share their knowledge selectively to stimulate the market or discover unanticipated applications [131]. Besides stability, standardization can be a competitive strategy for new entrants to oppose dominant firms [132]. It can assist the legitimisation of new technologies and their diffusion into a central position [30].

Improve supply chain management in developing markets

The effect of standardisation on market expansion is also explained by the interaction between supply dynamics and produces price. Standards can improve supply chain management by diffusion of knowledge (*Figure 9*). Improved supply chain management might eradicate superfluous links in the supply chain, leading in overall to less 'value-added' and impacting the final accumulated value of a certain good [94]. Decreasing prices increase demand, as a result of improved pay-back period, increased net present value and a more positive internal rate of return [133].

Classes of standards

There are different classes of standards. On aggregate scale, three different classes of standardisation are being distinguished. These classes are vertical standardisation, contract standardisation and generic standardisation [126, 127].

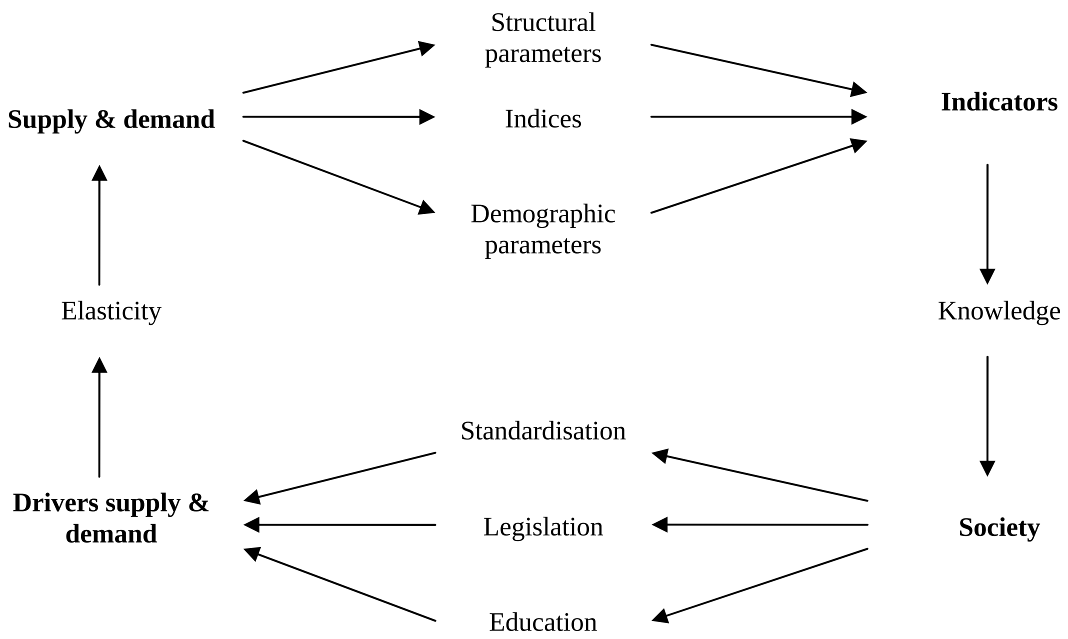

Figure 9 Interaction between energy demand, drivers, indicators and energy policy
There are several inter-related variables steering supply and demand dynamics. These variables are present on both and small scale in society. Flow chart based on [133].

Vertical standardisation

A vertical standard is a prescription of data structures, data definitions, document formats and business processes for specific industries [125]. Most of these standards are often directly or indirectly related to a quality[a] related goal [134, 135]. Such goal can be obtained by defining limits of discussed quality, but can also be addressed by improving or harmonising procedures, processes or functions within the supply chain. Vertical standards are often linked to the commoditisation of goods due to their ability to minimise qualitative differentiation across the supply base, which can lead to more efficient production of goods.

Contract standardisation

Standardised contracts show parallelism with vertical standards. In general, the development of contracts can take place on two different levels of collectivisation. On the first level, a contract is determined by standard business conditions on company level. At the second level of collectivisation this determination takes plays on sector level, induced by the establishment of trade association networks with pooled interests. In the latter case, we can speak of true market based standardised contracts. Standardised contracts are industry specific, serving the explicit goals of security of supply, price and quality. They are used to improve communication in a market dominated by individual and isolated developed contracts[b] [136]. Technical harmonisation within standardised contracts can have an impact on competition [136]. Standardised contracting goes hand in hand with the requirement of standardisation in industrialised mass production. In markets dominated by standardised contracts, product

[a] Quality is a state of something being subject to negotiation.
[b] Between contracts developed in isolation, different perceptions of product quality can exist.

quality is no longer the result of an individual agreement, but more an outcome of pre-defined objective standards.

Generic standardisation

Generic standards address fundamental processes. Such fundamental processes transcend the more specific activities and processes on supply chain or sectoral scale targeted by vertical standards. Generic standards are aimed at basic but important principles within society, in order to control fundamental economic and environmental variables. Sustainable development has received increased attention over the years within such standardisation practices [137, 138]. The natural process of environmental volatility, a result of increased pressure on ecosystems, is being addressed on meta-level by means of formal language [125]. The formation of partnerships between market parties, governments and non-governmental organisations (NGOs) has proven to be an important driver in the development of sustainability standards [139].

Development of standards – Scope, timing and stakeholder involvement

There are a number of variables that influence the development of standards (*Figure 10*). When creating new standards, several aspects should be controlled for successful standard development. These aspects are related to the scope of developed standards. The scope of a standard defines by whom and for what purpose a standard will be used. The scope is influenced by time and involvement of stakeholders.

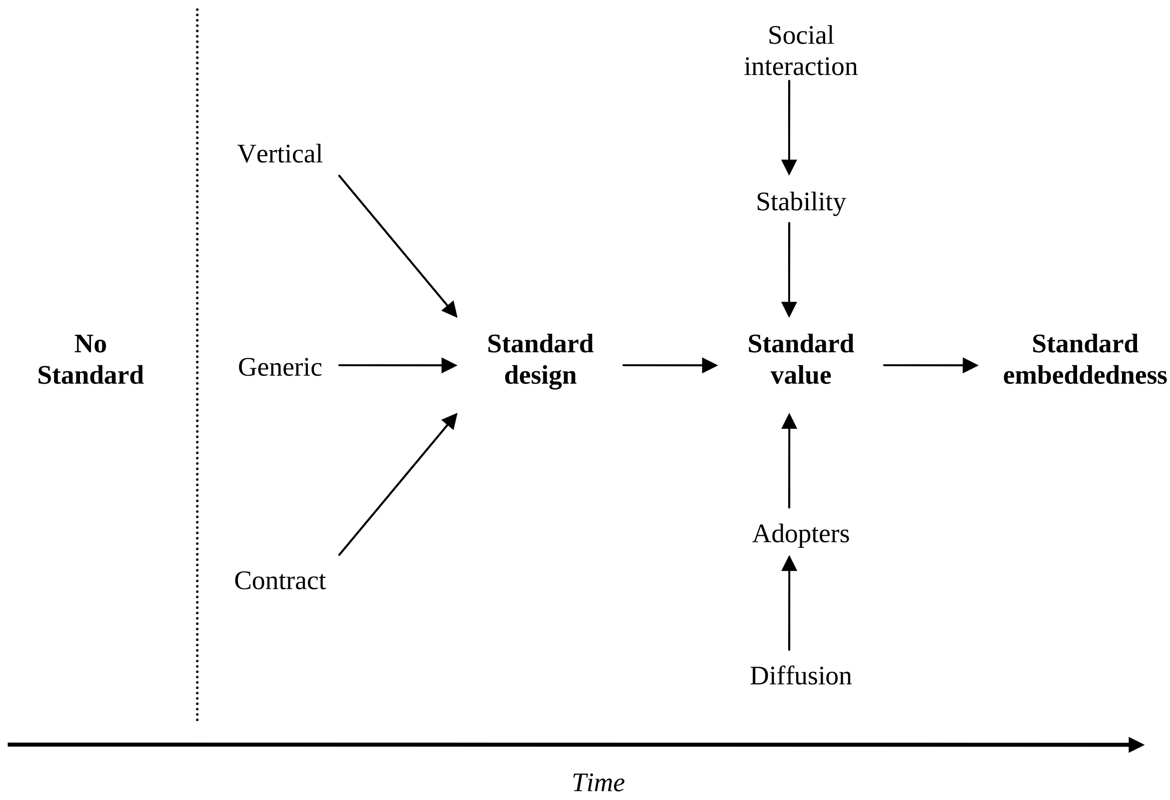

Figure 10 A fundamental representation of the standardisation process
Time and stakeholder participation are important factors in the standardisation process. Time concerns both the timing of standard development and stability of standards over time. Stakeholder participation concerns both the quantitative amount of adopters and the qualitative party inclusion of relevant stakeholder groups. Flow chart based on [125].

Stakeholder involvement

The value of standardisation is affected by the number of adopters and stability over time [125]. Standards are developed to be used by different parties. The need for reached consensus within the standardisation process requires cooperation. Although participation is driven by positive self-interest, the inclusion of all relevant stakeholders has proven difficult in history. In most cases, stakeholder absence is explained by fear of organisational confidentialities exposure.

The nature of an agreement depends on the activities of those participating in the consensus [131]. The standardisation process is affected by both quantitative and qualitative party inclusion. Quantitative party inclusion refers to the amount of adopters and scale of geographical orientation during standard creation. Qualitative party inclusion concerns the involvement of specific stakeholder groups. Imbalance between stakeholder interests, or limited reflection of opinions within standards, can hamper their widespread adoption and use [140-142].

Timing of standardisation

Development of standards can be anticipatory, participatory or responsive [131]. However, it has been observed that standards might be especially instrumental, or even a prerequisite, for the emergence and formation of new markets [125]. It has been observed that a lack of standards can create barriers to commercialization, due to the absence of useful rules governing the application of a certain technology [140].

3.1.2 Global standards, institutionalised markets & innovation diffusion

Standards can have a fundamental role in supply chain management and creating stability in developing markets. In the standardisation process, timing and stakeholder involvement are important in successful implementation of standards in an economy. Also, stability of standards over time determines the value of standards.

In the previous chapter, an overview of biofuel standards was provided. These standards might have contributed to the initial development of biofuel markets. However, a number of barriers are limiting further development of biofuel markets (*Table 4*). The unsynchronised process of parallel standardisation has resulted in large variability between developed biofuel quality and sustainability standards. Regarding biofuel quality standards, variation in local and sector dependent stakeholder contribution has been a main drivers towards regional qualitative and quantitative differentiation within standards [143, 144]. For sustainability standards, the implementation of indirect land use change (ILUC), greenhouse gas-allocation methodologies and inclusion of social variables is still heavily debated [145].

Global markets have proven to be significantly more economically productive compared to protected markets [146]. The lack of internationally accepted and implemented biofuel standards might hinder the development of a global market. There have been a number of initiatives trying to identify opportunities and hurdles for the development of global standards and meta-standards for biofuels [32-38]. Also, there have been initiatives to assess differences between quality standards for biofuels and to what extent these could be eliminated [143]. However, so far these initiatives have not resulted in the development of such standards. In the next section, the importance of globally accepted and implemented standards is discussed for further market development. Also, the function of standardisation for institutionalisation of markets is explained. In the final part of this section, a link is made between standardisation and innovation theory. This parallel will be used as a basis for the creation of a hypothetical standard diffusion model.

The need of global standards in institutionalised markets

Standardisation facilitating globalisation

Standardisation might have had a supporting role in the globalisation process. Global markets are a consequence of liberalisation of trading regulations, which have initiated the border-transcending corporation expansion and stimulated international competition [147]. Globalisation requires the formation of extensive linkages and global interdependence in order to develop potential for exchange, commercial expansion and overall growth [4]. The standardization of interfaces is necessary for the management and control of connectivity. Also, the decreasing influence of individual governments on transnational markets stresses the importance of globally accepted standards [131]. Non-harmonised standards for similar technologies can contribute to technical barriers in trade [148].

Globalisation facilitating standardisation

Like standards have facilitated globalisation, globalisation has opened the way for international cooperation in the standardisation process. In this sense, standardisation is a typical product of the industrial age [149]. The development of a high density network structure has facilitated increased access to knowledge, goods and services [94]. Export-minded industries have long sensed the need to agree on supranational standards in order to rationalise international trading processes. Harmonisation diminishes trade barriers, promotes safety and allows interoperability of products, systems and services. Also, harmonisation promotes common technical understanding [126, 150]. International standards can provide a common global lexicon for market specific requirements (vertical standards), determination of global trading mechanisms (standardised contracts) and the interconnected transcending challenges (generic standards) [127, 136].

Institutionalisation

Institutionalisation of markets can be an important tool in facilitating global trade. The function of an institutionalised market is to increase price transparency and security of supply [28]. Institutionalisation can result in fair competition, lower prices and improved product development [28, 31].

Standards have an important function in the formation of institutionalised markets. Institutionalisation of markets is not an autonomous process. According to institutionalisation and structuration theories, there are a number of pre-requisites to develop an institutionalised market. These pre-requisites include resources of power, norms to sanction and minimal transaction costs of communication (*Table 6*). Especially concerning the cost-optimisation of communication, standards fulfil an important function.

Technological diffusion, innovations and similarities with the standardisation process

The importance of technological change, based on the expansion of knowledge, is a driving factor in supply-demand dynamics (*Table 5*) [94]. Technological inventions are able to diffuse as innovations into the commercial domain of an economy. The technology diffusion theory describes how, why and at what rate new ideas or technology spread through cultures [151].

Table 6 Prerequisites for the development of an institutionalised market

Prerequisites	*Description of prerequisites*
Resources of power	Power of the exchange market and its participants to set a market price that is used and perceived by all market participants acting on or outside the market.
Norms to sanction	Enforcement of market rules that are embraced by its members.
Minimal transaction costs of communication	Achieved by: ▪ standardising product specifications at the physical market ▪ creating standardised contracts ▪ setting up rules for fair trade (code of conduct) ▪ create rules about pricing, balancing and delivery arrangements

Source: [29]

Elements within technological diffusion theory

There are four key elements that have been identified within technology diffusion theory (*Table 7*). The main key element within this theory is innovation, whereas the other three elements constitute or determine the innovation environment. The environment in which an innovation is placed influences the rate of diffusion. Factors affecting such environment include (1) economic structures, (2) networks structures along which innovations diffuse, (3) legislation, and (4) uncertainty on social level [152-155].

Within this innovation environment, both demand- and supply side play a major role in shaping diffusion patterns [152]. The adoption step may be seen as the demand side for innovations [156]. However, the ability of a consumer to adopt an innovation in the first place depends on previous stages within the diffusion process, including actors that control the spread of innovation towards potential adopters. These previous stages within the diffusion process can be seen as the supply side of innovations.

Table 7 Key elements within technology diffusion theory

Element	*Description of element*
Innovation	An idea, practice, or object that is perceived as new by an individual or other unit of adoption.
Communication channels	The means by which messages get from one individual to another.
Time	Includes innovation decision period & rate of adoption: ▪ Innovation-decision period: Time required to pass through the innovation-decision process ▪ Rate of adoption: Relative speed with which an innovation is adopted by members of a social system
Social system	A set of interrelated units that are engaged in joint problem solving to accomplish a common goal.

Source: [151]

Parallels between technological diffusion theory and standardisation

The development, integration and implementation of standards in economy show clear parallels with technological diffusion theory [146]. Innovations are often regarded as being novel products or original methods of thinking. However, innovations may also refer to emergent, radical and revolutionary changes in processes or organizations [146].

It might be assumed that the development of standards can be such innovation. Standards are expectations of widespread adoption and able to improve the exchange of information. Furthermore, regarding the key elements of communication channels and time, diffusion of knowledge steers the development of a standard. The design of a standard impacts its rate of diffusion into society, which influences the spread of its contained knowledge [125]. Concerning the key element of social system, the obliged set of interrelated units engaged in joint problem solving is equivalent to the required presence of reached consensus in the standardisation process.

Regarding the importance of demand- and supply side of innovations, such pattern is also observed in standardisation (*Figure 10*). In the standardisation process, the standard design and standard value, determined by the amount of adopters and social interaction, determines the extent of standard embeddedness in an economy.

Standard diffusion in biofuel markets

Many of the factors that affect the environment of innovations coincide with barriers that have been affecting biofuel market development (*Table 4*). Concerning the effect of economic structures, there is a clear lack of transparent biofuel markets and trading tools to increase security of supply. Lack of network structures in biofuel markets is characterised by unprofessional supply chain management and difficult feedstock sourcing. The effect of legislation and national governments on biofuel market development is represented in non-harmonised biofuel stimulation systems and the presence of region based tariffs. Finally, uncertainty on social level is indicated by lack of sufficient public support related to sustainable production of biofuels.

In second part of this chapter, a model is presented explaining a relation between market development and the process of standard creation. Also, the methodological approach is elaborated that has been used for addressing the research objectives.

3.2 Methodological approach

In the previous section, a link has been made between innovation diffusion and the diffusion of standards in an economy. According to innovation-diffusion theory, diffusion happens based on an S-shaped curve. A similar pattern might be present regarding the development and adoption of standards by a market. In general, market parties or NGOs are responsible for the initial development of standards. These *informal technical standards* are often formulated on local level in a spontaneous process. Informal technical standards are often succeeded by *formal technical standards* developed by standardisation institutes to provide large scale harmonisation [157].

Based on the resemblance of innovation diffusion with standard progression in an economy, a hypothetical standard diffusion model is developed. In this standard diffusion model, a potential correlation between standardisation and global trade patterns is assumed (*Figure*

11). Within the model, a number of distinguishable phases have been identified (*Table 8*). Furthermore, based on the concepts of generic, vertical and contract standardisation, a differentiation within the total domain of standardisation has been developed for inclusion in the standard diffusion model (*Table 9*). In developing markets, certain standard types might prove more important for a certain developmental phase compared to other standard types.

Based on the suggested standard diffusion model, the relation between standardisation and market development has been tested. In the remainder of this chapter, the methodological approach based on this model is further elaborated.

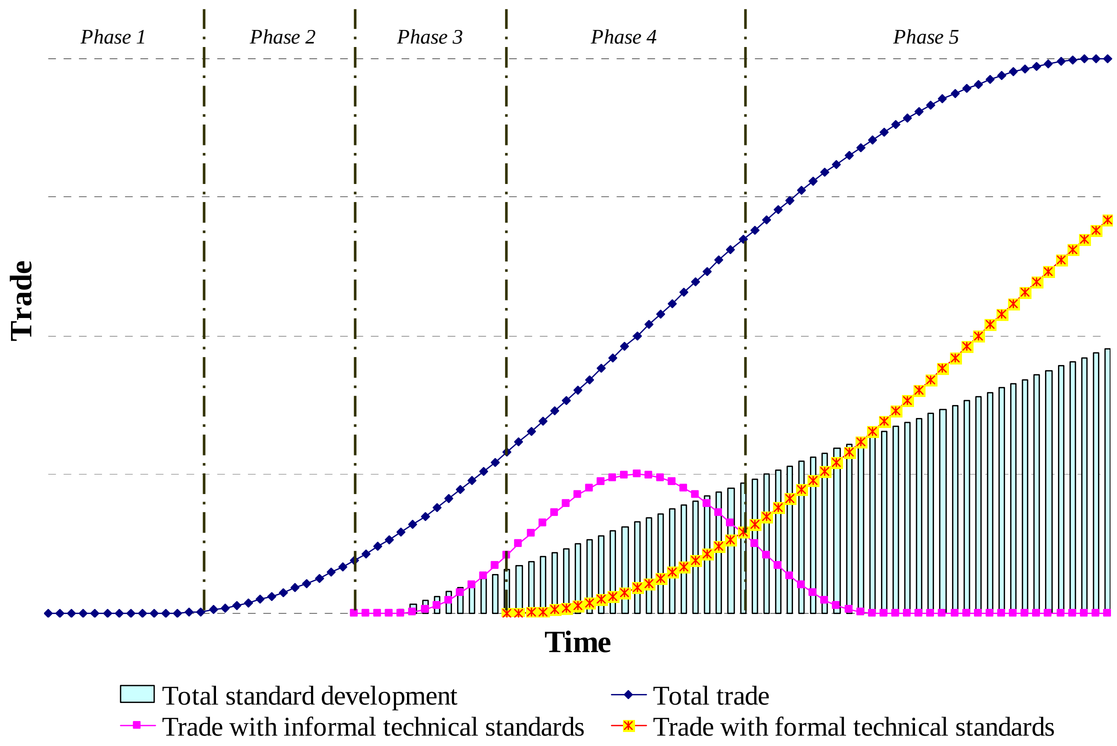

Figure 11 Standard diffusion model
A hypothetical model of standardisation and market development is developed. This model incorporates the development of *informal technical standards* and *formal technical standards*. Furthermore, a number of phases are distinguishes (see table below). Also, a differentiation of standard types has been developed for model integration (see table below).

Table 8 Hypothetical development of standardised trade

Phase	*Phase description*
1	Initial product and supply chain development
2	Initiation of small scale trade
3	Spontaneous development of standards by market parties (*informal technical standards*)
4	Initiation of standard development by standardisation institutes (*formal technical standards*)
5	Trade with formal technical standards dominates trade with informal technical standards

Table 9 Overview of different standard classes and types used for analysis

Type	Description
Generic standards	
Air, water and soil quality	▪ Determination of waste streams ▪ Measurement of waste streams amounts
Sustainability standards	▪ Measurement of direct and indirect effect on environmental and socio-economic variables, including: o Biodiversity o Direct / indirect land use o Human welfare o Includes also air, water and soil quality
Safety & security	▪ Safety during handling of product ▪ Management and security monitoring systems, related to: o Mixture o Storage o Transportation o Distribution
Vertical standards	
Quality	▪ Determination of product properties, including: o Chemical properties o Physical properties o Biological parameters
Quality testing	▪ Determination of consistency in different application equipment ▪ Determination of sampling methods ▪ Determination of reference products
Equipment	▪ Technical specifications of equipment used in supply chain, including phased of: o Production o Transport o Storage o Consumption
Logistics	▪ Product or feedstock collection ▪ Product transport, (un)loading & storage ▪ Disposal of waste products
Standard contracts	
Contract	▪ Specification of contract design ▪ Specification of contract content & standard references

3.2.1 Testing the relation between standardisation and the commoditisation of markets

In order to test the standard diffusion model, an analysis of commoditised markets has been executed. The non-commoditised status of biofuel markets is not suitable for the validation the model. Therefore, a historic market analysis of the established commodities coal and palm oil has been conducted (see *chapter 4*). Based on the functions these products fulfil, it is assumed that these goods can serve as benchmarks for respectively solid and liquid biofuels.

Coal

Coal is and important commodity for power generation, liquefaction and a number of other industrial processes. Coal can be substituted by a number of solid biofuels. Comparing global production and trade patterns of coal with global standard development, the need or value of specific standard types for developing markets of solid biofuels has been identified.

Palm oil

Palm oil, being traded for a long period for nutritional purposes, personal care products and soap, is increasingly being used as an energy source in the transportation sector. The effect of this new function of palm oil had on historic production volumes, trade volumes and standard development has been analysed. Such analysis provides valuable information regarding specific requirements or needed standard types for using liquid biomass as an energy source.

Data collection

Included standards

These case studies focus on global market development and international standardisation. Therefore, only standards focussed on global embeddedness have been used. Furthermore, this analysis has focussed on formal technical standards developed by standardisation institutes. Due to limited enclosure and difficult tracing of informal technical standardisation data, informal technical standards have not been included in the analysis.

The analysed formal technical standards have been developed by the International Organisation for Standardisation (ISO). All specific standards developed by ISO related to coal- and palm oil supply chains have been included. ISO standards have been abstracted from the ISO-website. Once acquired, these standards were labelled according to the applied standard categorisation (*Table 9*). Standards were also labelled as being (1) new standards or (2) revisions of previously developed standards. New standards are standards that were not prior developed by ISO. New standards differ from standards that have been revised due to altered market conditions or stakeholder requirement for specific standard modification. Within these revisions, the standard scope is unchanged.

Global trade- and production data

Global trade- and production data are used as indicators for market development. Global production data represents the amount of a certain good produced globally. Global trade data represents the total physical import or export of physical goods from or towards all global countries. Trade statistics are extracted from databases of the International Energy Agency (IEA), the United Nations Commodity Trade and Development (UNCTAD), Central Bureau of Statistics (CBS) and the Eurostat division of the European Commission (EC). Since ISO has been founded in the second half of the 20th century, the historical time span of the case studies is from 1960 to 2009.

Data analysis

Quantitative analysis

In the standard diffusion model, there is a relation between formal technical standard development and trade volumes. In this analysis, the relation between standardisation and development of trading and production volumes for both coal and palm oil has been assessed. This relation has been determined by means of ‘product moment correlation’. Product moment correlation, or Pearson's correlation, is a measure of linear dependence between two variables.

New and total developed standards have been plotted against production and trade volumes. Both correlations between (1) global formal technical standardisation and the development of global production volumes, and (2) global formal technical standardisation and the development of global trade volumes were tested.

Concerning time-dependent initiation of globally formal technical standards, the duration of the second and third phase in the standard diffusion model has been estimated. In other words, the interval between globally formal technical standardisation and trade development for both coal and palm oil is determined.

Qualitative analysis

In our standard diffusion model, a differentiation within the total domain of standardisation is developed. Abstracted ISO standards have been labelled according to this standard differentiation. These labelled ISO standards have been used to identify prioritisation of standard types in the overall standardisation process. Based on such prioritisation, a time-dependent pattern concerning the development of markets and the occurrence of globally accepted standard types has been determined.

3.2.2 A review of biofuel standardisation and the development of biofuel markets

Besides validating the standard diffusion model based on commoditised markets, a review of standardisation and market development of biofuels has been performed. For this assessment, a stakeholder analysis (SA) was executed. An SA is an approach for the identification of actors affected by or affecting a certain process. An SA can be utilised for generating knowledge about such actors, in order to understand their behaviour, intentions, interrelations and interests [158-162]. It is a frequently used tool to assess the attitudes of stakeholders regarding incoming changes.

Construction of the stakeholder analysis

Approach & Phases

The SA has an instrumental, normative and descriptive utility. Furthermore, the SA has been constructed according to three distinctive phases (*Table 10*). The first phase is based on prior literature research and formed the fundament of this research. Market development of biofuels is the research prime subject and represents therefore an aspect of a social phenomenon. The ability of standardisation to influence market development of biofuels can be assessed as an action affecting such social phenomenon.

In the second phase, the scope has been determined for execution of the third phase. The scope of the SA has been determined by the scale of execution, selection of stakeholders, selection of biofuels and differentiation of standardisation. The selected biofuels chosen for the SA has been based on the selection of biofuels used for this research. The liquid biofuels included are biodiesel, bio-ethanol and pure plant oil, whereas the selected solid biofuels are wood pellets, wood chips and agricultural residues. Differentiation of standardisation has been based on the developed standard diffusion framework (*Table 9*). The selected stakeholder groups contains organisation types that are directly (primary stakeholders) or indirectly (secondary stakeholders) affected [163] (*Table 11*).

Table 10 Utility and construction of a stakeholder analysis

SA approaches & phases	Description
Utilities of a stakeholder analysis	
Instrumental approach	Concerned with the hypothetical relation between objectives and possible ways to reach them (descriptive)
Normative approach	Concerned with how something ought to be (normative)
Descriptive approach	Concerned with how something actually is (instrumental)
Phases in stakeholder analysis	
Phase 1	Define aspects of a social and natural phenomenon affected by a decision or action
Phase 2	Identify individuals, groups and organisations (stakeholders) who are affected by or can affect those parts of the phenomenon & Prioritise stakeholders for involvement in the decision-making process
Phase 3	Investigating relationships between stakeholders & defining the effect of the decision or action on the social and natural phenomenon

Based on [164] [158]

Table 11 Overview of stakeholder groups used in the stakeholder analysis

Stakeholder group	Description stakeholder
Primary stakeholders	
Producer	Individual or organisations producing biofuels
Consumer	Individual or organisation consuming biofuels, including power companies and transport industry
Logistic service provider	Individual or organisation facilitating transport and storage
Trader	Individual or organisation active in buying and selling biofuel (derivatives)
Secondary stakeholders	
Quality assurance company	Organisation active in systematic product monitoring and evaluation related to standards of quality.
Trade facilitator	Individual or organisation intending to improve market conditions, including consultancy & research organisation
Standardisation institute	Organisation developing standards and certification schemes
NGO	Organisations operating independent from governments
Policy maker	Individual active within governments regarding the development of policy and legislation

The selection is based on a focus group that has been identified with literature research and has been expanded in an iterative process based on qualitative data from semi-structured interviews during the third phase. On both national and international level, individuals and organisations were addressed for participation.

The third phase entailed the collection of data. The approach applied for data collection is addressed in the next section.

Data collection

For addressing the third phase of the SA, data has been collected with two different approaches. Qualitative data was gathered using an online survey, whereas qualitative data was assembled by means of semi-structured interviews. For both methods, 5 different themes have been formulated that were used during the execution of the online survey and semi-structured interviews (*Table 12*). These themes address current relations between stakeholders active in biofuel markets, the need for adaption of current standards and development of new standards. Also, the current and future role of certification[a] in market development of biofuels was reviewed.

Online survey

An online survey was executed to obtain quantitative data from stakeholders active in the selected biofuel markets. Based on the formulated themes, a total of 17 nominal and ordinal questions were composed to be answered by respondents (*Appendix C*). Ordinal questions have been based on a Likert scale structure[b]. Furthermore, respondents were asked about (1) their geographical origin, (2) in which biofuel market they are active, and (3) to which stakeholder group they belong. The online survey has been executed using the web-based program SurveyMonkey [165].

Semi-structured interviews

Semi-structured interviews were performed to gain in-depth insights regarding the themes addressed in the stakeholder analysis [158]. Interviewees were chosen based on the biofuel market they are active in and the stakeholder group they represent.

Data analysis

Online survey

Data obtained from the online survey has been transformed and normalised according to two different scales. For questions were a positive or negative respondent rewarding was acquired, data was transformed and normalised according to a scale ranging from $-1 < x < 1$. For all other questions, data was transformed and normalised according to a scale ranging from $0 < x < 1$.

[a] Standardisation often operates in combination with certification. Certificates are necessary in order to identify products that are based on formulated standards. Like standards, certification systems can focus on a specific aspect of a good, process or activity. There are a number of reasons for organisations to demonstrate compliance with standards and norms, including regulations put down by the state, social pressure from civil society or expectations from the consumer.

[b] Likert scale is a variation of a rating scale. In Likert scales, respondents are asked to specify their level of agreement to a certain statement.

Table 12 Overview of different themes used in the stakeholder analysis

<table>
<tr><th>Theme</th><th>Questions within theme</th></tr>
<tr><td>Market development</td><td>In your opinion, to what extent does your market segment influence the overall market development of biobased products?
In what manner and to what extent is your market segment affected by other stakeholders?</td></tr>
<tr><td>Effect of standardisation & certification</td><td>To what extent can standards effect:
The supply chain
Competition
Free trade
Product pricing
The social performance of your organisation
The financial performance of your organisation
Market transparency
To what extent can certification schemes effect:
The supply chain
Competition
Free trade
Product pricing
The social performance of your organisation
The financial performance of your organisation
Market transparency</td></tr>
<tr><td>Importance, use and prioritisation of specific standard types</td><td>In relation to the number of transactions dealt with by your company, how often are these standard types currently used by your organisation (possible answers: no, little, medium, often, all the time)? And by whom have these standards been developed?
In your opinion, how important are each of these standard types for the development of your market segment?
In your opinion, to what extend need the following standard types to be enhanced or prioritised to achieve improved market conditions?</td></tr>
<tr><td>Development of standards and certification schemes</td><td>Depending on the indicated standard types for biobased products, by who should standardisation be initiated & managed?
Which of the indicated standard types should be voluntary or mandatory?</td></tr>
<tr><td>Standardised contracts</td><td>How do you judge functionality and transparency of current contracts used for trade in biobased products?
To what extent need the following standard types to be included or prioritised within standardised contracts used for trade in biobased products?</td></tr>
</table>

The analysis of variance (ANOVA) model was exploited for statistical determination of mean equality between (1) standard types, (2) biofuels markets, and (3) stakeholder groups. When analysing data influenced by two factors, a factorial analysis of variance was applied [166].

Semi-structured interviews

Obtained data from semi-structured interviews has been filtered based on theme relevance. The attained information has been used to support, explain or contradict the quantitative data required from the online survey.

4 Standardisation and the commoditisation of markets

In the previous chapters, an overview of biofuel markets, the proposal of a hypothetical standard diffusion model and the methodological approach used for the validation of this model have been elaborated. In this chapter, the results of the first part of the methodological approach are provided. Two case studies have been performed to test the relation between standardisation and the commoditisation of markets. The commodities coal and palm oil have been chosen based on their functional relatedness to solid and liquid biofuels. In the first part of this chapter, the case study of coal is presented. The case study of palm oil is given in the second part.

4.1 Case study 1: The development of the coal market and global coal standards

4.1.1 Introduction – Coal classification, supply and quality management

Classification

There are numerous varieties of coal [167]. Variation in chemical and physical variables are important in the determination of coal quality [168]. The main primary functions of coal are (1) electricity and heat production, (2) feedstock for iron production (cokes), and (3) feedstock for petrochemical processes. For most functions of coal, its quality is determined by carbon and moisture content (*Table 13*). However, other quality-variables used by geologists include density of macerals and presence of minerals[a] [169].

Table 13 Classification of coal types

Coal type	*Abundance*	*Carbon & energy content*	*Moisture content*	*Main application*
Peat & lignite	20 %	Low	High	Power generation
Sub-bituminous	28 %	Medium	Medium	Power generation, cement manufacture
Bituminous	51%	High	Low	Power generation; cement, iron & steel manufacture
Anthracite	1 %	Very high	Very low	Domestic use, smokeless fuels

Based on [170].

Supply

There are three variables that have a significant effect on coal supply, being extraction of coal, storage of coal and coal transport [171]. Coal extraction from coal seams can occur at the surface or underground, in which the choice of mining method depends mainly on seam depth, seam thickness and seam quality [172]. Many coals extracted from both surface and underground mines require washing in a coal preparation plant. Since it is expected that coal export will continue to increase over the next decades, substantial capital costs will be

[a] Macerals are organic debris, whereas minerals are inorganic content. Both variables affect the ash content of coal.

involved in developing the necessary facilities and in maintaining sizable stockpiles at the exporting ports [173]. These facilities are important in determining the competitiveness of various coals in world markets.

Quality management

Regarding coal quality management, coals are liable to spontaneous combustion. Also, coals can be prone to deterioration of both calorific values and coking properties. This process is especially relevant for coals having low carbon content and is mainly caused by heat generation through the process of oxygen absorption [174]. Higher ranks are less susceptible, since the coalification process converts instable reactive elements into more stable ones[a]. As a consequence, temperature and ventilation are important variables that need to be controlled and secured during storage of lower rank coals. Moisture content can also affect coal quality.

Controlling the variables of temperature and ventilation is also relevant during coal transportation. Transportation of coal can occur by ship, train, truck, conveyors and pipeline. The mode of transportation applied depends on a number of factors, including distance, geological location and present logistic infrastructure. Transportation can account for a large fraction of the total consumer price [175].

4.1.2 Market development of coal – Production, trade and standard development

Production and trade

Production

Global production of coal has grown steadily over the last 50 years (*Figure 12*). Total global production has increased from less than 2.000 million tonnes (MT) in 1950 to over 10.000 MT in 2003. Bituminous coals show highest production rates of approximately 7.500 MT.

Trade

There is a clear increase in global trade (*Figure 12*). Global trade had grown from around 170 MT in 1970 to almost 1.450 MT in 2003. A large share of traded coal consists of bituminous coal. Approximately 1.200 MT of bituminous coal is traded globally, which consists about 80% of the total global coal trade. Around 200 MT, or approximately 15% of the total global coal trade, has been traded for iron and steel manufacturing. Trade in lignite has also increased over the past decades, although in absolute amounts at much smaller scale compared to bituminous coal.

Standard development

Amount of developed standards & the relation with production and trade volumes

The first coal standards developed by ISO are over 50 years old. In the period 1959-2010, the 161 standards developed include 107 new standards[b] and 54 revisions of standards[c]. The

[a] The coalification process is a geological process of material formation with increasing content of organic carbon. The process contains both a biological stage and a high pressure geochemical stage. It affects chemical and physical properties due to the response of coal on cumulative pressure and heat over time. It is also a dehydrogenation process.

[b] New standards are standards containing an original scope not addressed in prior standards. These standards obtain a unique standard-code.

[c] Revisions of standards are standards that have been modified but with an unchanged scope.

yearly average of total developed coal standards has grown over the years, although this increase is relatively small.

There is a strong correlation between coal market development and coal standardisation (*Figure 12*). The correlation between global coal production and ISO coal standard development is in the range of 0,943 — 0,963. The correlation between global coal trade and global standard development is in the range of 0,987 — 0,990.

Concerning the time interval between standardisation and global trade, it can be observed that global production has occurred in the absence of global formal technical standards. However, global trade in coal has been relatively limited in the absence of such standards.

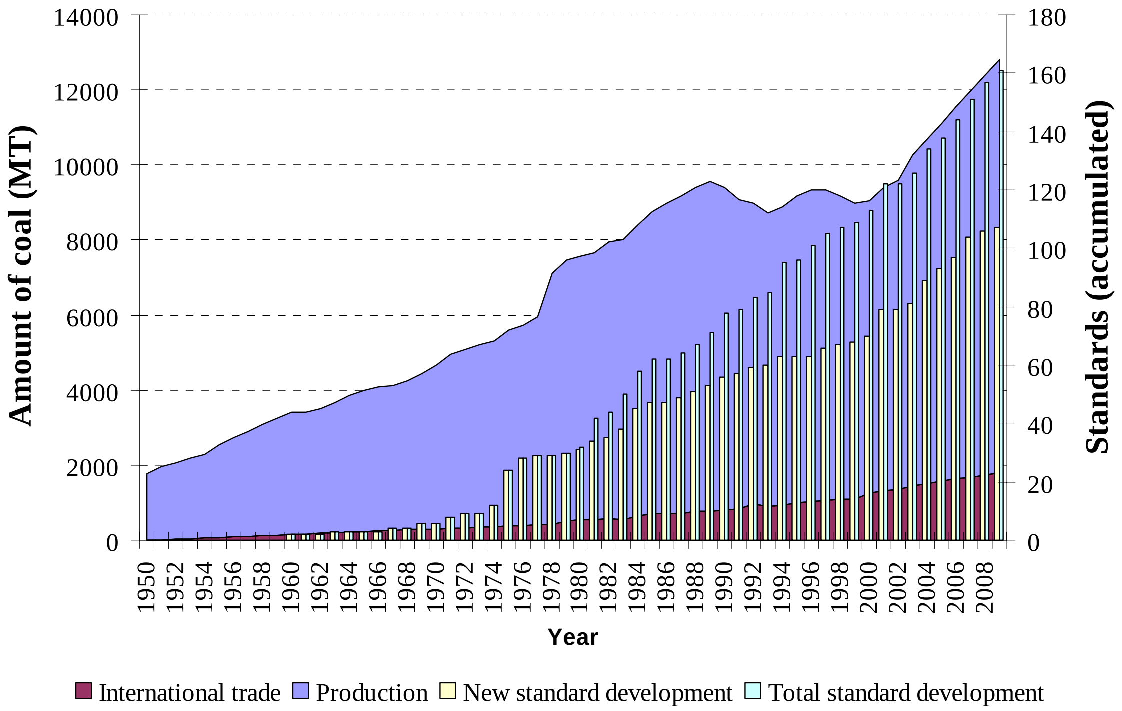

Figure 12 Development of the global coal market and standardisation of coal
Correlation of coal production with new / total coal standard development: 0,963 / 0,943; Correlation of international coal trade with new / total coal standard development: 0,987 / 0,990. The sudden rise in the data between the year 1977 and 1978 is explained by additional monitoring of anthracite and sub-bituminous coal by IEA. Trade in these products is likely to have followed a similar trend prior 1978. Production and import data prior 1978 and from 2003 onwards are partly based on extra- and interpolation of data. International trade is based on import and export data. Sources: [176, 177]

Prioritisation of standard types

There seems to be a clear pattern in standard development (*Figure 13*). During the first 15 years of coal standard development, there is a clear focus on quality standards. Also, the first revisions made in 1980 concern coal standards that are related to the measurement of coal quality. After this initial development of quality standards, equipment standards and quality sampling & analysis standards are being created. After a period of equipment standardisation, standards related to logistics and safety issues have been development.

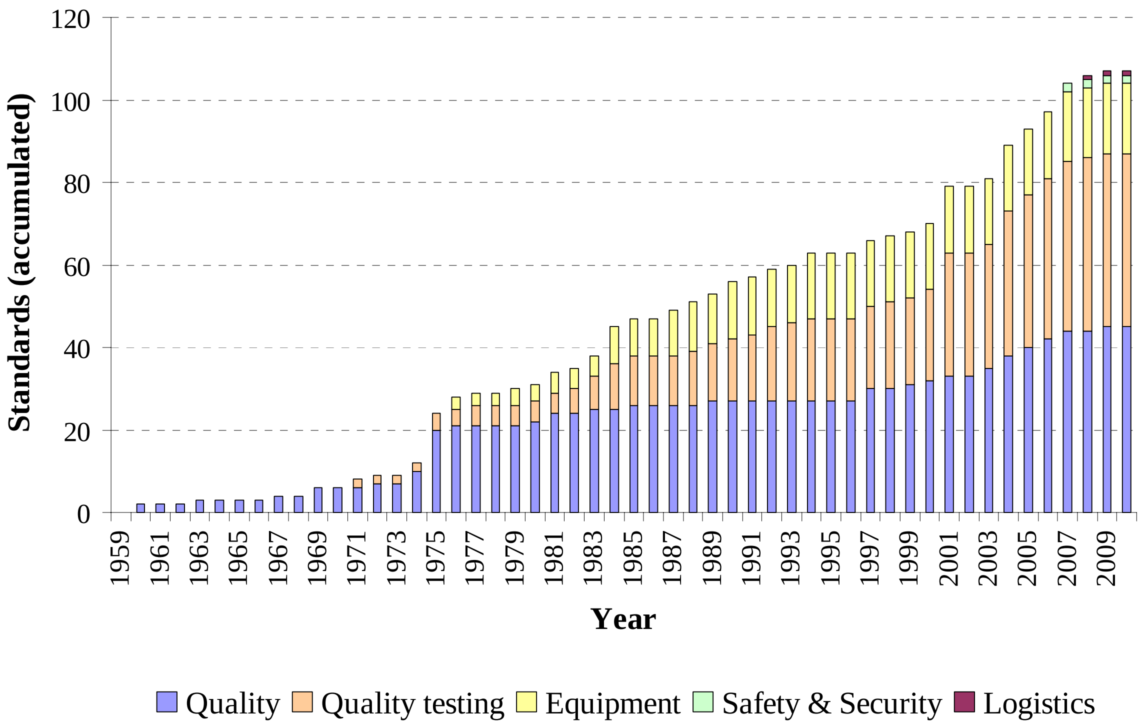

Figure 13 Development of new ISO coal standards
A chronological prioritisation of specific standard types is observed. Standards related to quality are prioritised in initial global market development. Following quality, standards related to equipment are developed. Only recently, standards related to safety and logistics have been created. Sources: [178]

The chronological prioritisation of specific standard types has impacted the distribution of total coal standards over the differentiated standard types. Most coal standards developed are related to coal quality, coal sampling and sample analysis. Also, there has also been considerable development of equipment standards, of which a large share focuses on mining procedures.

Standard development related to logistics and safety issues has been almost non-existing. At the end of the 20th century such standards started to become developed, although their relative share is in sharp contrast with standards that focus on coal quality, coal sampling and sample analysis. Standards concerning environmental issues and sustainability have not been made exclusively for the coal market. A number of such standards have been developed for products and processes in general. However, the examination of such product generic standards falls outside the scope of this case study and will therefore not be discussed in more detail.

Periods of increased standardisation intensity

Two periods of increased global coal standardisation intensity are observed. In both cases, there was a considerable growth in trading and production volumes in years following increased standardisation intensity (*Figure 12*).

In 1975, a large increase in developed coal standards is due to the development of quality standards for numerous coal types. These coal types include lignite, sub-bituminous, bituminous and anthracite coal. Also, a number of standards focussed on steel manufacturing were developed in this period. All these standards include basic property determination methods for water, carbon and sulphur. Furthermore, a number of testing and sampling methods have been formulated in this period. The second large increase in 2001 is explained by the development of a series of standards related to mechanical sampling of hard coal and coke.

Standardised contracts

Standardised coal contracts might have had a considerable impact on global production and both quantitative and qualitative trade. Standardised contracts emerged in the second half of the 20th century, in a period characterised by increased liberalisation and institutionalisation of markets. These contracts provided a single set of legal terms and conditions for coal trading, containing predefined quality specifications and fixed contractual terms. As a consequence, spot trade increased from 14% to 80% in approximately twenty years [179, 180].

4.1.3 Conclusion

To conclude this case study, a summarised overview of the main findings is given. First of all, there is a strong relation between global standardisation and international production and trade volumes. Although global coal production has been considerable in the absence of global formal technical standards, global trade has been very limited. Also, there is a clear pattern concerning the chronological prioritisation of specific standard types. Concerning the standard diffusion model, standardisation related to coal quality has dominated the beginning of *phase 4* (*Figure 11*). Following the development of quality related standards, there has been considerable attention for equipment standardisation. Most equipment standards developed are related to coal mining and coal preparation. There has been limited or insufficient interest for coal specific standards for logistic, safety, environmental and sustainability issues.

There are a number of similarities between coal and solid biofuels. Like for coal, there are a number of specific variables that determine solid biofuel quality. In the past decades, there has been considerable attention for solid biofuels quality standardisation (see *chapter 2*). Based on the coal case study, it might be expected that the development of global formal technical standards concerning solid biofuel quality will be followed by equipment standardisation. The prime focus of coal equipment standardisation has been on the mining phase, which might be regarded as comparable to biobased feedstock collection and solid biofuel production. Furthermore, it is generally assumed that solid biofuel quality is more liable to time-dependent quality deterioration compared to most coal grades. Therefore, there might be more attention for standardisation of solid biofuel logistic issues than observed in coal markets.

Standardised contracts have facilitated trading in coal. The general trend of increased growth in derivatives and options trade, due to greater demand in risk management and low volatility, is likely to continue. Based on the quality deterioration potential and complex feedstock sourcing of solid biofuels, standardised contracts might become crucial in future solid biofuel trading.

4.2 Case study 2: The development of the palm oil market and global palm oil standards

4.2.1 Introduction – Palm oil classification and palm oil supply

Classification

Palm oil is produced by the species *Elaeis guineensis* [181, 182]. *E. guineensis* produces two types of oil. The traditional palm oil is derived from the fruit, whereas palm kernel oil originates from the kernel. Although the chemical content of palm oil and palm kernel oil is different, they both have a relatively high saturation of fats [182]. They are used as an ingredient for food, personal care products, lubricants and are used as feedstock in several industrial processes [181]. Like other vegetable oils, they can be used as a fossil fuel substitute. In energy utilisation, vegetable oils have an indirect function by providing carbohydrates for conversion into alcohol. They can also have a direct function as a fossil diesel substitute.

Supply

Within the supply chain of palm oil, production, extraction, storage and transport are most important. The oil winning process involves the reception of fresh fruit bunches from the plantations, sterilizing and threshing of the bunches to free the palm fruit, mashing the fruit, pressing out the crude palm oil and further treatment to purify and dry the oil for storage and export [182-184]. The conversion from crude to refined oil involves three main processes. These processes are thermo-mechanical fractionation into liquid and solid phases, removal of impurities by degumming or melting and physical or chemical filtering for colour and flavour removal.

Palm kernel oil extraction is generally separated from palm oil extraction. In general, palm kernel oil extraction is carried out in mills processing other oilseeds due to a similarity in the extraction procedure[a] [182]. The ratio between palm oil and palm kernel oil yield is approximately 4:1.

Quality management

Concerning crude vegetable oil quality, there are five main criteria. These criteria are a low content of free fatty acids, low content of oxidised elements, low contamination with water or other impurities, a readily removed colour and good bleachability potential [182]. The extent in which these criteria are not met affects the effectiveness of the refining process, decreasing the overall cost-efficiency of the final product. Minimal bruising during harvest, minimised harvest-bunch sterilisation interval and effective drying of the crude oil are regarded as most critical processes for maintaining high quality of palm oil [181]. When fruit is bruised, the autocatalytic hydrolysis process[b] can commence, which causes decreased overall oil quality.

There are three general principles during storage of palm oil. First of all, elimination of water is necessary to prevent microbial growth. Initiation or further progression of lipolytic micro-organism activity in stored oil can affect its quality [181]. The autocatalytic hydrolysis stops almost completely when moisture concentration is kept below 0.1%. Secondly, it is necessary

[a] The extraction procedure consists of kernel grinding, kernel heating, oil extraction and oil filtering.
[b] The autocatalytic hydrolysis process is induced by micro-organisms. Certain micro-organisms are able to decompose vegetable and animal fats. This decomposition is initiated through lipase enzymes, converting fats and oils into glycerol, fatty acids, and water.

to maintain temperature above the melting point. Storage below the recommended temperature can lead to crystallisation, affecting oil quality and causing increased pressure when reheated. Finally, the construction material used for oil containers is essential to prevent oxidation or chemical deterioration.

Palm oil can be moved by any means of transportation. Since most palm oil is produced in only a limited amount of countries, large quantities are being exported by ship. For long distance transportation, shipping palm oil is most cost-effective. The main variables that need to be controlled during transport are temperature, moisture content and the oil container construction material.

4.2.2 Market development of palm oil – production, trade and standard development

Production and trade

Production

Global palm oil production has increased considerable in the period 1964-2005. There seems to be an exponential growth from 1995 onwards. This trend might be explained due to increased utilisation of palm oil for biodiesel production. In 2007, Indonesia and Malaysia were the two largest palm oil producers. Both countries have invested considerably in biodiesel production [185, 186].

Trade

The global growth in palm oil trade has been stimulated by the European industrial revolution, which led to increased demand for tropical commodities [181]. Since then, trade in palm oil has become increasingly important over the years (*Figure 14*). In the period 1961-2005, trade in palm oil and palm kernel oil increased from less than 1.000 kilo tonnes (kT) in 1964 to over 26.000 kT in 2003. The development of the European biodiesel industry in the beginning of the 21st century is partly responsible for the exponential increase of both production and trade of vegetable oils. Currently, Malaysia is the largest exporter of palm oil in the world.

Standard development

Amount of developed standards & the relation with production and trade volumes

Most standards published for palm oil fall under the umbrella of vegetable and animal oil standards. Only few standards have been developed specifically for palm oil. The first vegetable standards developed by standardisation organisation are over 45 years old. In the period 1961-2010, ISO developed 117 vegetable and animal oil related standards. These 117 standards include 71 new standards[a] and 46 revisions of standards[b]. There seems to be an increasing trend in the amount of developed standards per year.

A strong correlation between the market development of palm oil and the development in standards has been determined. The correlation between production and new standard development is in the range of 0,961 — 0,982. The correlation between international trade and new standard development is even higher, being in the range of 0,970 — 0,991 (*Figure 14*).

[a] New standards are standards containing an original scope not addressed in prior standards. These standards obtain a unique standard-code.
[b] Revisions of standards are standards that have been modified but not changed fundamentally.

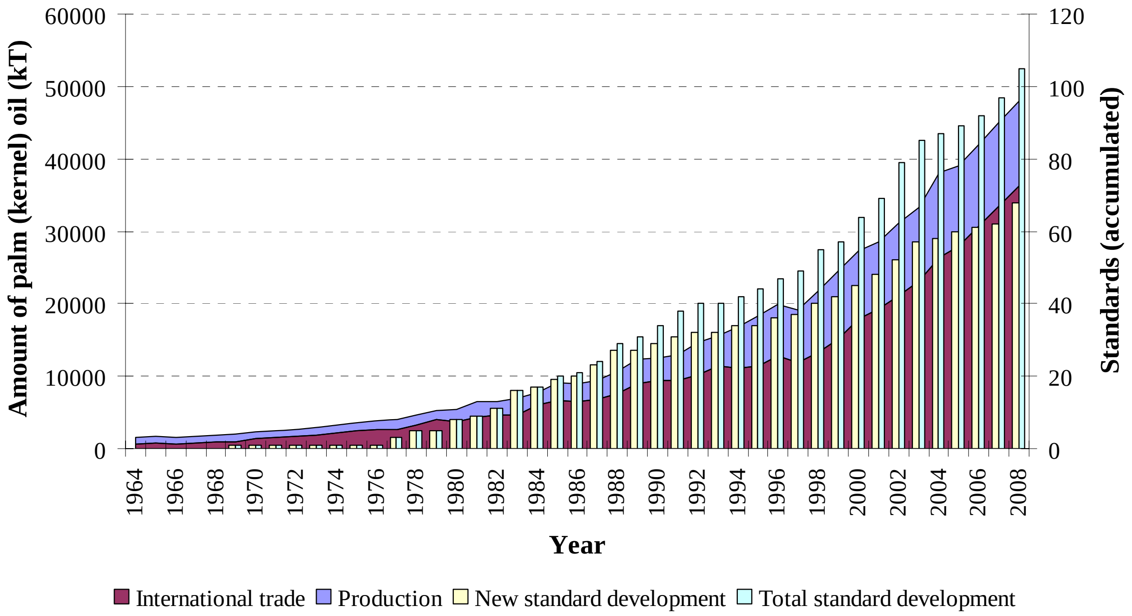

Figure 14 Development of global market and standardisation of palm (kernel) oil
Correlation palm oil production with new / total standard development: 0,961 / 0,982; Correlation international palm oil trade with new / total standard development: 0,970 / 0,991. Production and import data from 2005 onwards partly based on interpolation. International trade based on import and export data. Sources: [72, 187, 188]

Both production and trade has increased significantly after the first global formal technical standards were being developed. However, prior the development of global formal technical standards for vegetable oils, both production and trade volumes of palm oil were relatively small compared to present day quantities.

Prioritisation of standard types

Compared to coal, a somewhat different pattern is observed regarding chronological standard type prioritisation for vegetable oils (*Figure 15*). During the first phase of formal technical standardisation, aspects and variables related to vegetable oil quality have been prioritised. This finding is comparable with the chronological standard type prioritisation observed for coal.

In global coal standardisation, this phase related to quality was followed by the development of equipment standards. This has not been the case for vegetable oils in general. This finding is remarkable, as quality of vegetable oils is very dependent on procedures used during harvesting and treatment of obtained oil. Related to this, it is notable that no international standards related to vegetable oil logistics have been formulated. The absence of these standard types is not clear. Crucial variables influencing the production and storage of vegetable oils might be described in standards developed for other biological goods or fossil oils. However, such postulation can not be validated with the results gathered in this case study.

Also, standards concerning environmental quality or sustainability have not been developed specifically for palm oil or vegetable oils. Such standards have only been developed for products or processes in general.

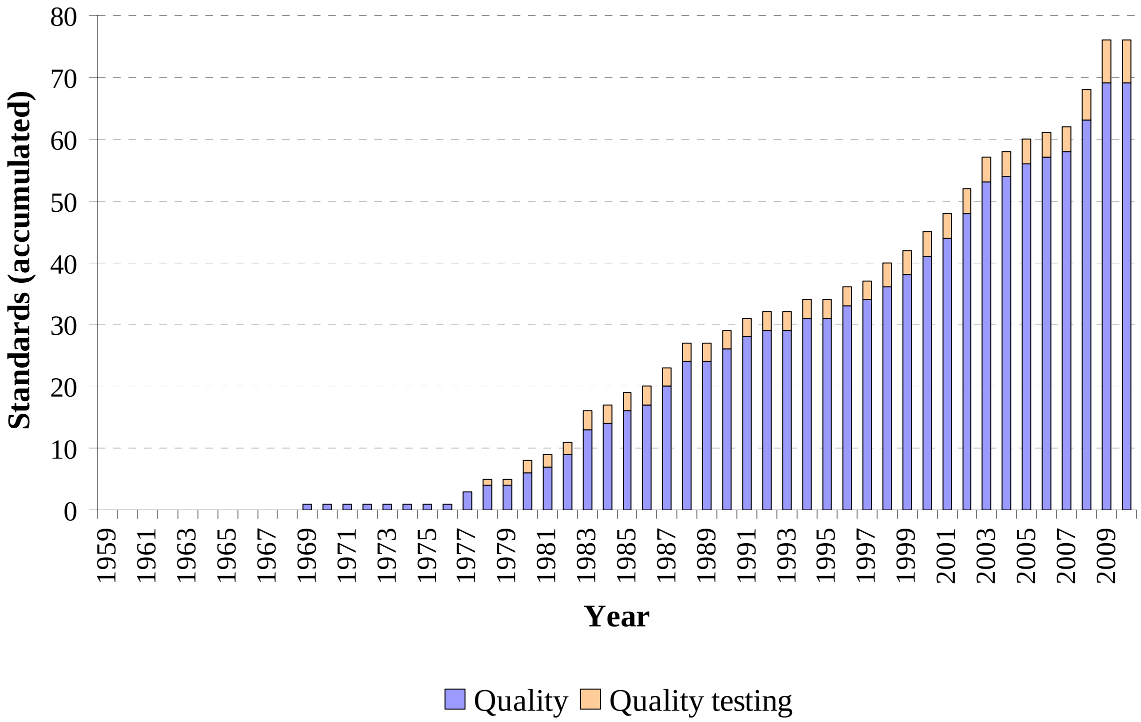

Figure 15 Development of new ISO palm (kernel) oil standards
A chronological prioritisation of specific standard types is observed. Standards related to quality are prioritised in initial global market development. In contrasts with the global coal markets, these quality standards have not been followed by development of other type standards. Sources: [178]

Period of increased standardisation intensity

Especially at the beginning of the 21st century, there is a large increase in developed quality standards (*Figure 15*). It is likely that many of these standards are related to the establishment of joint working groups regarding quality assurance of FAME used in biodiesel production. The big increase in standard development in 2008 and 2009 includes a large increase in determination methods for a number of qualitative parameters[a]. Many of these tests are dedicated towards FAME quality testing.

Standardised contracts

Like in coal markets, standardised contracts have also facilitated institutionalisation of agricultural markets. In the past decades, a number of standardised contracts have been created for trading vegetable oils, seeds and fats. It is likely that liberalisation of markets have had a large impact on the global palm oil supply and demand dynamics. Since 1980, there seems to be a considerable increase in both production and trade volumes of palm oil.

4.2.3 Conclusion

Also for this case study, a summarised overview is given of the foremost observations. First of all, most standards have been developed for vegetable oils in general. Nevertheless, a strong correlation was found between international vegetable oil standardisation and global production and trade volumes of palm oil. Compared to current quantitative volumes, both

[a] Such qualitative aspects include: Water content, solid fat, ash, peroxide value, acid value and acidity, chlorophylls, glycerol content, insoluble matter, hydrocarbons, phospholipids and sterols.

global production and trading rates of palm oil have been relatively small prior the development of formal technical international standardisation. Concerning the chronological prioritisation of specific standard types, only issues and parameters related to oil quality have been subjected to ISO standardisation. Other specific standard types, including standards related to equipment, logistics, safety, environmental quality and sustainability, have not been addressed specifically for palm oil or vegetable oils in general.

The absence of ISO standards concerning sustainability issues seems remarkable. When markets were liberalised at the end of the 20th century, the movement of sustainable development increased strength as a likely result of the commoditisation of several fossil and agricultural based products. It can therefore be argued that the timing of biodiesel market creation during this wave of globalisation has initiated increased awareness concerning sustainable production of biofuels. However, although the growing biodiesel sector has increased total demand for vegetable oils in the past 15 years, the biodiesel sector is only partly responsible for the observed increase in global palm oil production[a].

Another comparison between palm oil and liquid biofuels relates to quality and quality management during storage or transport. In contrast to vegetable oils, there are considerable more parameters that can influence biodiesel quality (*Table B-I*). Quality deterioration of biodiesel, as a result of biological activity, can be both process and time-dependent. Also for ethanol, there are also several parameters that are crucial for its quality. However, these parameters are less likely to be time-dependent compared to parameters affecting biodiesel quality. It is therefore not remarkable that numerous national or continental based quality standards have been developed for liquid biofuels. It is likely that such standards will be prioritised in global formal technical standardisation.

For both case studies, the inability to estimate standardised trade volumes seems to limit the interpretation of these case studies concerning the developed standard diffusion model. However, formal technical standards are only developed by standardisation institutes if there is sufficient demand from the market. Therefore, it could be assumed that there is a positive relation between the amount of formal technical standards developed and volumes of standardised trade. Based on total standard development, standard type prioritisation and market size, it might be concluded that development of the global coal market is in a more matured phase compared to the global market of palm oil.

[a] In 2009, approximately 15.000 ML, or 13.500 kT, of biodiesel was produced globally. In the hypothetical case all produced biodiesel is palm oil based, less than half of the total increase in palm oil production is explained. Palm oil production increased between 1996 en 2008 with approximately 30.000 kT.

5 Biofuel standardisation and the development of biofuel markets

In this chapter, the results of the executed stakeholder analysis (SA) are given. The SA was executed in order to address the second aim of this research. This aim focussed on the value and necessity of standardisation in developing biofuel markets. In this analysis, an assessment of the need for adaptation and creation of current and new standards is made. Furthermore, relations between stakeholders active in biofuel markets are identified and rated based on stakeholder perceptions and impressions.

The chapter is divided in six parts. In the first part, an aggregated overview of the obtained data is provided. In the remaining five parts, the results are discussed based on the formulated 5 themes used for the execution of the SA (*Table 12*). All parts are divided in results gathered by the online survey or obtained from semi-structured interviews. At the end of each part, summarised conclusions and implications of the data are given. These conclusions and implications are further elaborated and discussed in *chapter 6*.

5.1 Data collection

5.1.1 Data from the online survey

The online survey was executed from July 2010 until September 2010. In total 114 respondents have participated in the online survey. Of the 114 respondents, data provided by 77 respondents has been included for further analysis. Data provided by the other 37 respondents was excluded due to wrong or incomplete survey participation. In *Table 14* and *Figure 16*, the distribution of these respondents according to origin, stakeholder group and biofuel market is given.

Table 14 Stakeholder properties of respondents participated in online survey

	Agri-residues		*Biodiesel*		*Bioethanol*		*Pure plant oil*		*Wood chips*		*Wood pellets*		**Total**	
Consumer	5	(4)	1	(1)	-	(-)	1	(-)	2	(1)	2	(1)	11	(7)
Logistic service provider	-	(-)	1	(-)	1	(-)	-	(-)	-		2	(1)	4	(1)
NGO	2	(-)	1	(-)	1	(1)	-	(-)	2	(1)	3	(2)	9	(4)
Policy maker	2	(1)	2	(2)	2	(1)	2	(-)	2	(-)	2	(1)	10	(5)
Producer	3	(2)	1	(-)	1	(-)	3	(3)	3	(-)	6	(5)	17	(10)
Quality assurance company	1	(-)	2	(1)	-	(-)	-	(-)	-		4	(3)	7	(4)
Standardisation institute	-		1		-	(-)	-	(-)	1		-		2	(-)
Trade facilitator	1	(-)	1	(-)	-	(-)	-	(-)	2	(-)	3	(2)	7	(2)
Trader	1	(1)	2	(1)	1	(-)	-	(-)	-		6	(6)	10	(8)
Total	15	(8)	12	(5)	6	(2)	6	(3)	11	(2)	27	(21)	77	(41)

Stakeholders are differentiated according to stakeholder group and biofuel market. Within brackets are the amounts of respondents that indicated to have high expertise.

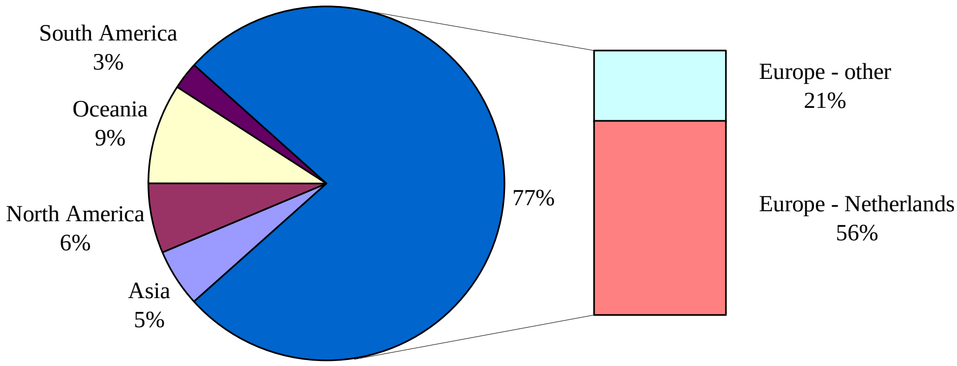

Figure 16 Geographical distribution of 77 respondents included in data analysis
Most respondents originate from Europe. Of all respondents, more than half originates from the Netherlands.

5.1.2 Insights from semi-structured interviews

In total 15 interviews were performed with different stakeholders active in different biofuel markets (*Table 15*).

Table 15 Overview of conducted semi-structured interviews

Stakeholder	*Organisation*
Certification system developer (1)	SMK [189]
Certification system developer (2)	UTZ Certified [190]
Consumer - solid biomass (1)	E-On Benelux [191]
Consumer - solid biomass (2)	Eneco [192]
Logistic service provider – storage liquid biofuels	VOPAK [193]
Logistic service provider & trader – liquid biofuels	Van der Sluijs Groep [194]
Producer - wood pellets	GF Energy [195]
Quality assurance company – solid & liquid biofuels	Control Union [196]
Standardisation institute (1)	NEN [197]
Standardisation institute (2)	NEN [198]
Trade facilitator – consultancy (1)	KEMA [199]
Trade facilitator – consultancy (2)	KEMA [200]
Trade facilitator – consultancy (3)	RBCN [201]
Trade facilitator – research organisation	WUR [202]
Trader	NIDERA [203]

5.2 Market development of biofuels and the influence of stakeholders

The first theme of the stakeholder analysis concerns the development of biofuel markets in general. Both the impact of stakeholders on biofuel market development and the influence of stakeholders on one another have been determined. Stakeholders were posed the following two questions:

- *In your opinion, to what extent does your market segment influence the overall market development of biofuels?*

- *In what manner and to what extent is your market segment affected by other stakeholders?*

5.2.1 Data from the online survey

Influence of specific stakeholders on the development of the biofuel sector

There exists a perceived difference between respondents active in different biofuel markets regarding their influence on the development of the biofuel sector in general. Respondents active in PPO and wood chips perceive a low influence in the overall development of the biofuel sector, whereas stakeholders active in wood pellets and agricultural residues perceive a high influence on such development (*Table 16*).

Table 16 Influence of stakeholders on the biofuel sector in general

Respondent differentiation	Relative influence on biofuel sector		
Biofuel market			
Wood pellets	0,78	(0,82)	High
Agricultural residues	0,77	(0,76)	High
Biodiesel	0,67	(0,78)	High medium
Bioethanol	0,67	(0,50)	Medium
Wood chips	0,48	(0,33)	Low
Pure plant oil	0,33	(0,22)	Low
Stakeholder group			
Standardisation institutes	1,0	(-)	High
Traders	0,83	(0,83)	High
Logistic service providers	0,78	(1,0)	High
Consumers	0,81	(0,78)	High
Quality assurance companies	0,71	(0,92)	High medium
Trade facilitators	0,58	(1,0)	Medium
NGOs	0,63	(0,58)	Low
Policy makers	0,67	(0,58)	Low
Producers	0,55	(0,59)	Low

Scoring is based on a range from 0<x<1, in which 0 means no influence and 1 means high influence. Within brackets are the scores from respondents that indicated to have high expertise. Complete dataset is presented in *Appendix D.*

Table 17 Perceived influence from or imposed influence on other stakeholder groups

Stakeholder group	*Relative perceived influence from other stakeholder groups*			*Relative imposed influence on other stakeholder groups*		
Trade facilitators	0,48	(0,78)	Positive	0,12	(0,10)	Medium
Standardisation institutes	0,44	(-)	Positive	0,14	(0,22)	Medium
NGOs	0,31	(0,39)	Medium	0,03	(0,04)	Negative
Logistic service providers	0,25	(0,33)	Medium	0,19	(0,23)	Medium
Policy makers	0,20	(0,35)	Medium	0,02	(-0,04)	Negative
Quality assurance companies	0,20	(0,24)	Medium	0,14	(0,16)	Medium
Consumers	0,08	(0,06)	Negative	0,25	(0,25)	Positive
Traders	0,03	(0,04)	Negative	0,10	(0,16)	Medium
Producers	0,00	(0,01)	Negative	0,35	(0,32)	Positive

From a scale from -1<x<1, in which -1 means a very negative influence and 1 means a very positive influence, the quality of all possible relations has been assessed. Within brackets are the scores from respondents that indicated to have high expertise. Complete dataset is presented in *Appendix D.*

Respondents active in biodiesel markets regard their influence on the biofuel sector lower compared to stakeholders active in markets of wood pellets and agricultural residues.

Respondents active in the bioethanol market observe having a medium influence on biofuel sector.

Concerning the different stakeholder groups, mainly consumers, logistic service providers, traders and standardisation institutes perceive a high influence on market development of biofuels. Trade facilitators and quality assurance companies score somewhat lower. NGOs, policy makers and producers observe a relatively low influence on market development.

Perceived influence from and imposed influence on other stakeholder groups

Besides the extent of influence, respondents were also asked regarding the quality of observed or endured influence. Regarding the perceived influence of specific stakeholder groups from others, none of the stakeholders are overall negatively influenced (*Table 17*). However, it is remarkable that primary stakeholders[a] perceive relatively more negative influence compared to secondary stakeholders[b] (*Figure 18*). Consumers, producers and traders bear a relative high amount of negative influence from the combined total of other stakeholder groups. Logistic service providers perceive a somewhat less negative influence.

Regarding the imposed influence of specific stakeholder groups on others, consumers and producers are perceived as having a relative positive influence on other stakeholder groups. Concerning standardisation institutes and trade facilitators, this influence is regarded as relatively medium. NGOs and policy makers are found to have a relatively negative influence on other stakeholder groups.

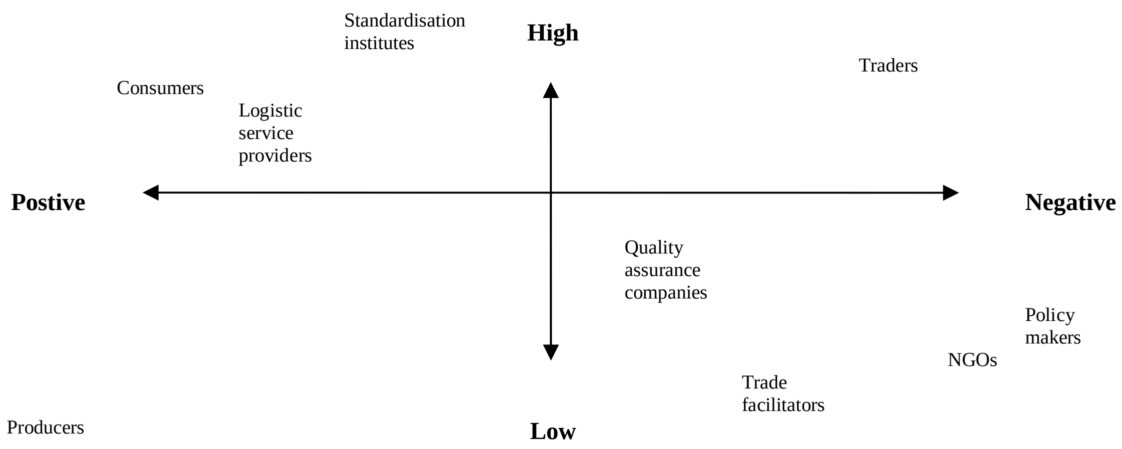

Figure 17 Stakeholder influence on market development
A graphical representation is depicted of the combined data of perceived stakeholder group market influence with their imposed influence on other stakeholder groups. Combination of perceived stakeholder specific influence on biofuel markets as a whole with perceived influence from other stakeholder. Based on data of all respondents. Complete dataset is presented in *Appendix D.*

[a] Primary stakeholders include consumers, producers, traders and logistic service providers.
[b] Secondary stakeholders include NGOs, policy makers, quality assurance companies, standardisation institutes and trade facilitators

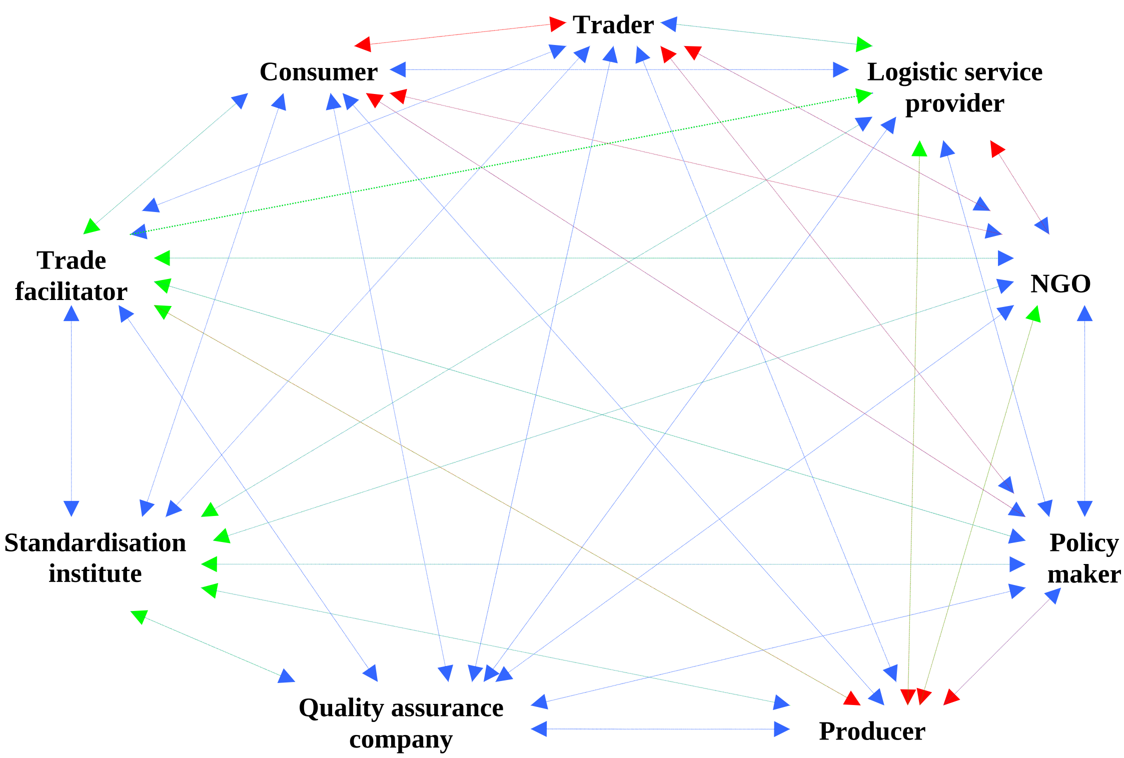

Figure 18 Influence of stakeholders groups
A graphical representation concerning the described perceived and imposed influence of stakeholders on one another. From a scale from -1<x<1, in which -1 means a very negative influence and 1 means a very positive influence, the quality of all possible relations has been assessed. All values of all possible relations are in the range from -0,29 – 1,0. The different colours of the lines represent the quality and amount of influence. The colour of the arrow pointing to a stakeholder represents the influence perceived. Colour explanation: -0,5<x<0 = red; 0<x<0,5 = blue; 0,5<x<1 = green. All values are based on *Appendix D.*

Perceived influence from stakeholder groups by specific biofuel markets

When looking at the different biofuel markets, mainly stakeholders active in PPO and agricultural residues perceive large resistance by other stakeholders. Other biofuel markets perceive less resistance. Biofuel markets of wood chips, biodiesel, bio-ethanol and wood pellets endure in general more positive influence from other stakeholders in their functioning. In *Figure 19*, the influence from different stakeholder groups on market development of different biofuels is depicted.

5.2.2 Insights from semi-structured interviews

A number of limiting factors were mentioned by interviewees as influencing current biofuel markets. These factors are related to governance, price of biofuels, development of other feedstock dependent sectors and the spread of information.

National & International governance

Interviewees identified policy makers as an influential stakeholder group by creating potential barriers to trade. This observation is in line with findings of the online survey (*Figure 17*). The current status of biofuel markets can for a large part be explained with policy, legislation and governmental stimulation systems [191, 192, 203].

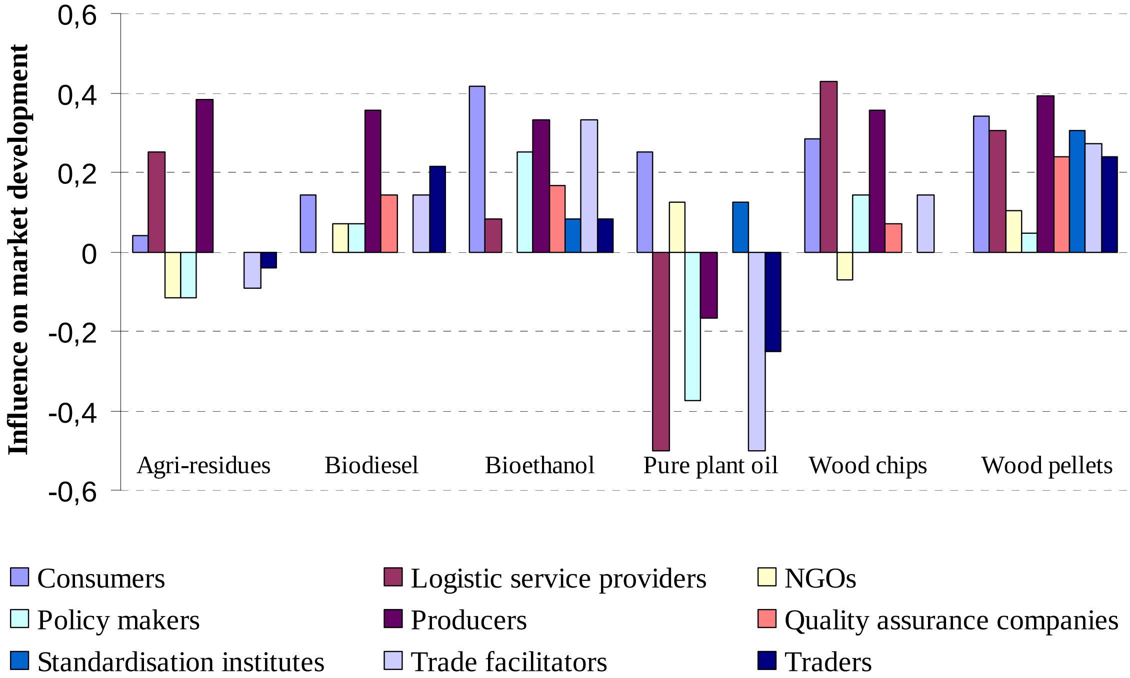

Figure 19 Influence of stakeholders on the market development of the different biofuels
The perceived influence from stakeholder groups by specific biofuel markets was determined. Range from -1<x<1, in which-1 = very negative influence, 1 very positive influence. All respondents are included. Within brackets are the scores from respondents that indicated to have high expertise. Average scores per biofuel: PPO = -0,14 (-0,17); agricultural residues = 0,04 (0,01); wood chips = 0,15 (0,00); biodiesel = 0,13 (0,24); bioethanol = 0,20 (0,36); wood pellets = 0,25 (0,24). Complete dataset is presented in *Appendix D.*

Main explanatory variables controlled by governments include mandates for production and consumption, governing the price difference with fossil substitutes and the imposition of tariffs. The absence of an European mandated market for solid biofuels, in contrast with the existing mandated market for liquid biofuels, is seen as a barrier regarding market development [195]. Also, the lack of an international obligation system regarding the off-take of renewable produced electricity, comparable to systems introduced in Germany and Belgium, hamper further development of solid biofuel markets [195].

Furthermore, solid and liquid biofuel stimulation systems are targeted at national scale [196]. The current high price of biofuels compared to fossil substitutes leads to a situation in which biofuel trade-flows can be explained by national differences in subsidy systems [194]. At the consumption side, subsidising biofuels will decrease the price gap with substitutes, leading to an increase in their demand. At the production side, subsidising biofuels can artificially decrease production costs and increase supply. Such phenomenon was recently experienced with biodiesel imports from the USA, also known by the splash-and-dash phenomenon.

For more balanced trade, there is need for identical starting points across biofuel markets [192]. An internationally organised stimulation system might reduce such practices. However, the development of a centralised stimulation system might be difficult to develop for biofuels. The global character of biofuel supply chains complicates fair subsidising of biofuel production or consumption when these activities are geographically dispersed [196].

Price of biofuels

There are other price related developments affecting biofuel markets. Variables mentioned by interviewees include currency imbalance and artificial pricing [192, 194, 203]. Currency imbalance has an effect on trade due to its impact on import costs [192]. The artificial lowering of biofuel prices[a] disturbs the supply-demand equilibrium and creates market distortion [195].

Development of other energy markets and feedstock dependent sectors

Other energy markets or industry sectors can also reduce the development of biofuel markets. The share of current existing infrastructures of nuclear- and hydropower negatively influences the demand for large-scale utilisation of solid biofuels. This has caused a focus for small-scale solid biofuel consumption in certain countries, including Germany, Austria and France [196]. Furthermore, regional economic activity has been mentioned as having an influence on the supply of waste residues used for wood pellet production, thereby increasing the dependency on plantations [195].

Spread of information

Flawed education of biofuel consumers can have severe consequences for future biofuel market development. This education or informational provision concerns both quality and sustainability issues related to biofuel production, trade and consumption. In some cases, such practices are driven by interest, misjudgement or incomplete information [194].

5.2.3 Conclusion

There are a number of barriers that inhibit further development of biofuel markets. Many of the identified barriers limiting the demand and supply of biofuels are explained in terms of connections and relationships. Especially the influence of national and international governance is in general perceived as relatively negative. NGOs are also regarded as limiting the development of the biofuel sector. However, it is remarkable that these stakeholder groups perceive having a relative limited influence on market development of biofuels. Of all stakeholder groups, standardisation institutes regard their influence on biofuel markets highest. In the next section, the general effect of standardisation and certification on biofuel market development is analysed.

5.3 Effect of standardisation & certification on biofuel market development

In this second theme of the stakeholder analysis, the extent in which standardisation and certification influence certain market related parameters is analysed. Stakeholders were posed the following two questions:

- *To what extent can standards effect a) the supply chain, b) competition, c) free trade, d) product pricing, e) the social performance of your organisation, f) the financial performance of your organisation, and g) market transparency?*

[a] In static or unfavourable market conditions, primary stakeholders can artificially lower biofuel prices in order to maintain cash flow.

- *To what extent can certification schemes effect a) the supply chain, b) competition, c) free trade, d) product pricing, e) the social performance of your organisation, f) the financial performance of your organisation, and g) market transparency?*

5.3.1 Data from the online survey

Effect of standardisation

In general, for all stakeholder groups and biofuel markets, respondents assessed standards as having a positive influence on market development (*Figure 20*). Although there are quantitative difference between the different market development indicators, this difference is not significant. Regarding the different biofuels, no significant difference was detected between the market development indicators.

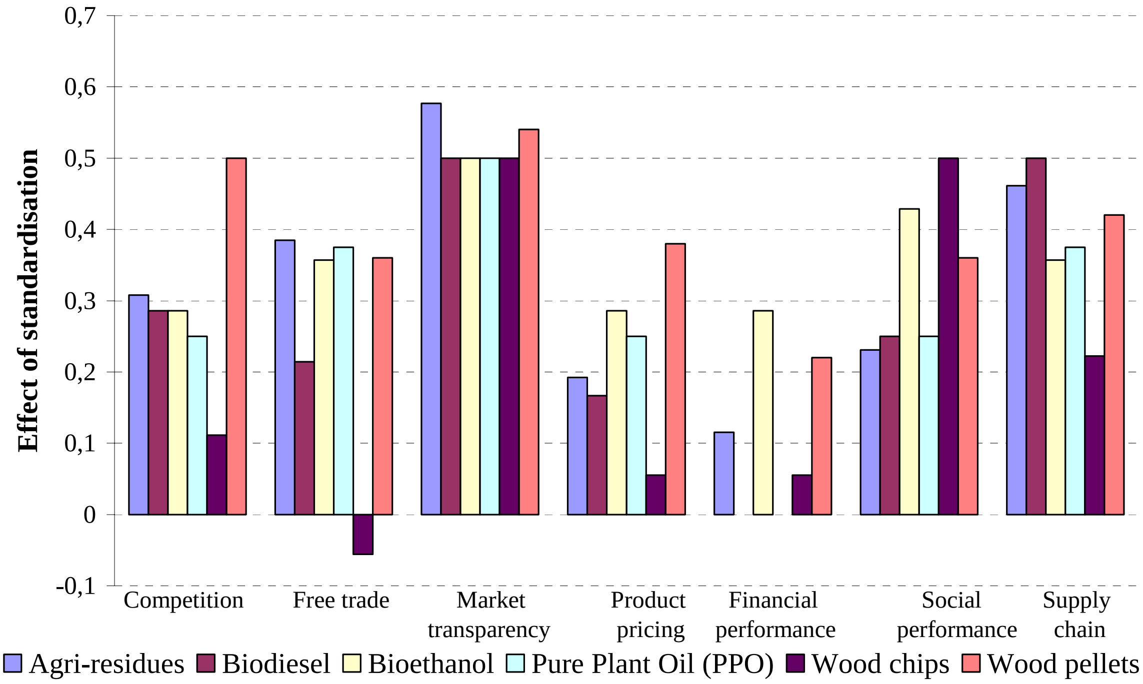

Figure 20 Perceived effect of standardisation on several market parameters
Stakeholders were asked what effect standardisation might have on market parameters of (1) competition, (2) free trade, (3) market transparency, (4) product pricing, (5) a company's financial performance, (6) a company's social performance and (7) biofuel supply chain development. Range from -1<x<1, in which-1 = very negative influence, 1 very positive influence. All respondents are included. Average effect of certification on market parameters: Complete dataset is presented in *Appendix D.*

Effect of certification

The effect of certification was also perceived as being positive for market development of biofuels. However, a significant difference was observed between the different market parameters (*Figure 21*). Certification has a relative more negative impact on free trade, product pricing and financial performance compared to the effect of certification on competition, market transparency, social performance and supply chain management quality. Concerning the different biofuel markets, stakeholders active in PPO and wood chip markets indicate a negative influence of certification on market development. Stakeholders active in agricultural residues, biodiesel, bioethanol and wood pellets regard the influence of certification more positive.

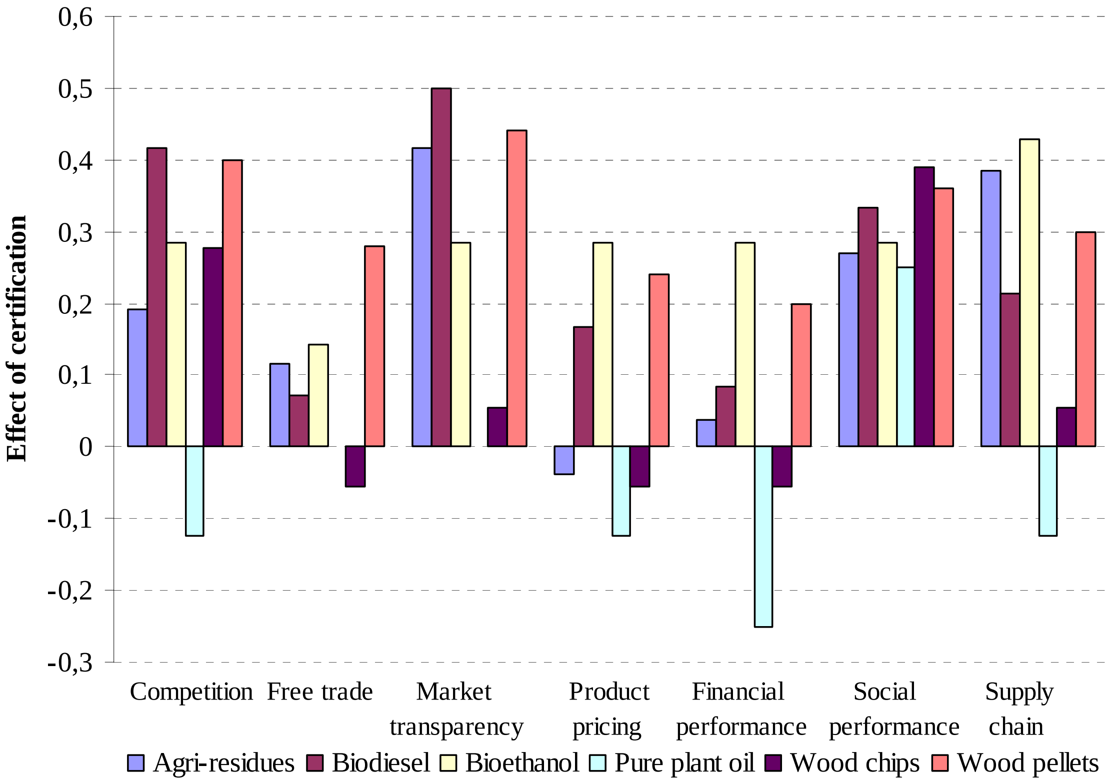

Figure 21 Perceived effect of certification on several market parameters
Stakeholders were asked what effect certification might have on market parameters of (1) competition, (2) free trade, (3) market transparency, (4) product pricing, (5) a company's financial performance, (6) a company's social performance and (7) biofuel supply chain development. Range from -1<x<1, in which-1 = very negative influence, 1 very positive influence. All respondents are included. Within brackets are the scores from respondents that indicated to have high expertise. Average effect of certification on market parameters: competition = 0,30; free trade = 0,15; product pricing = 0,12; financial performance = 0,10; market transparency = 0,34; social performance = 0,33; quality of supply chain management = 0,26. Average effect of certification on market development in general, according to different biofuel markets: PPO = -0,05 (-0,07); wood chips = 0,09 (-0,86); agricultural residues = 0,19 (0,08); biodiesel = 0,24 (0,09); bioethanol = 0,29 (0,36); wood pellets = 0,32 (0,34). Complete dataset is presented in *Appendix D.*

5.3.2 Insights from semi-structured interviews

Standardisation

Comparable to the results of the online survey, most interviewees indicated a positive effect of standardisation on the development of international biofuel markets. Positive effects mentioned include the shaping of a transparent, uniform and stable market climate [196], improving market access of smaller producers [192] and increasing quality of supply chain management [191, 192]. Furthermore, standards can be used in mandated markets by functioning as an extension of regulation. This function is especially relevant in the absence of quantitative indicators for performance measurement [197]. Moreover, standards setting higher requirements compared to legislation could be used by organisations as a tool to gain a niche market [197].

However, not everyone confirmed the necessity of standardisation in biofuel markets. In non-institutionalised markets, some organisations judge standards as not crucial for their operation

[203]. Furthermore, standardisation might have a negative impact on biofuel price due to required investments for the development and implementation of standards [192]. This negative effect was also indicated by respondents of the online survey (*Figure 20*). Also, standardisation could have a negative impact on competition. This observation is related to non-harmonised biofuel markets, due to global differences concerning biofuel standardisation and regulation [191, 192].

Certification

Interviewees also indicated a positive effect of certification on biofuel markets. In current commoditised markets, certification is a common tool in trading [197]. Certification has proven to be important for the insurance of large investments. These investments include both supply of biofuels and construction of supply chain related facilities [192]. Furthermore, certification is perceived important to trace and assess supply chain processes impacting the sustainable performance of biofuels [191].

However, certification might have a considerable effect on the overall price of biofuels [191]. This issue was also indicated in the online survey (*Figure 21*). The relative costs of certification depend on the scale of operation. For large companies, these costs represent a small share of total investments. For small producers, such share could be much more substantial [201]. Therefore, it might be crucial to allocate certification costs to large scale end-consumers active in the energy and transportation sector [196]. It has been stressed by interviewees that such an approach should be implemented on international scale. Implementation on international scale is necessary to prevent differences in compliance regarding such certification approaches, which might introduce distortion of global competition [196].

Other limiting effects of certification on market development of biofuels relate to market transparency and free trade. The negative effect of certification on market transparency was not observed in the online survey (*Figure 21*). A multitude of certification systems could reduce transparency for consumers regarding what standard-based values they represent [191]. In a hypothetical situation of multiple available certification systems, such schemes should be based on same internationally agreed standards [196]. Furthermore, certification might reduce the amount of freedom and flexibility needed for innovation and market adaptation [195].

5.3.3 Conclusion

Stakeholders active in different biofuel markets and different market segments assessed standards as having a positive influence on market development. In the case studies discussed in the previous chapter, it was observed that for both coal and palm oil global trade was very limited in the absence of globally accepted formal technical standards. In combination with the institutionalisation of markets, global production and trade volumes for both coal and palm oil increased significantly. The reluctance observed among traders concerning the importance of standardisation might be related to a decrease of their necessity in future institutionalised biofuel markets with increased liquidity[a].

Certification was also found to have a general positive influence on market development. There is a strong resemblance of stakeholder perception of certification with standardisation. Although the connection and relation between certification and standardisation is apparent,

[a] Liquidity is a trading concept based on the ratio of paper trading with total physical trading.

there are also fundamental differences that might provoke different effects on biofuel market development. In the next section, the importance of standardisation and certification is further elaborated.

5.4 Importance, use and prioritisation of specific standard types

In the third theme of the stakeholder analysis, the distinguished standard types have been tested on current usage and importance in biofuel markets. Also, the need for development, enhancement or prioritisation of specific standard types has been investigated. Stakeholders were posed the following three questions:

- *In relation to the number of transactions dealt with by your company, how often are these standard types currently used by your organisation? And by whom have these standards been developed?*

- *In your opinion, how important are each of these standard types for the development of your market segment?*

- *In your opinion, to what extend need the following standard types to be enhanced or prioritised to achieve improved market conditions?*

5.4.1 Data from the online survey

Importance of specific standard types

Of the distinguished standard types, quality, quality testing and sustainability standards are perceived as most important for market development of biofuels (*Figure 22*). Standard types concerning air, water and soil quality (AWS-quality), equipment, safety and security (S&S) and logistics score significantly lower. For certification, a similar pattern has been observed.

Usage of specific standard types

Compared to the importance of specific standard types, a similar pattern is observed regarding their usage (*Figure 23*). The perceived important quality and quality testing standards are also most used by stakeholders. However, the indicated important sustainability standards are significantly less used by stakeholders. Standards of the standard types of AWS-quality, equipment, logistic and S&S are also significantly less used by stakeholders compared to quality and quality testing standards.

Furthermore, there is a significant difference in standard type usage between different biofuel markets. Stakeholders active in the PPO market make most use of standards. Stakeholders related to the markets of wood pellets and agricultural residues make less use of standards. Stakeholders active in the markets of biodiesel, bioethanol and wood chips score relatively low regarding standard usage. Remarkable is the relative low usage of sustainability standards in the biodiesel market and relative low use of quality standards in the ethanol market.

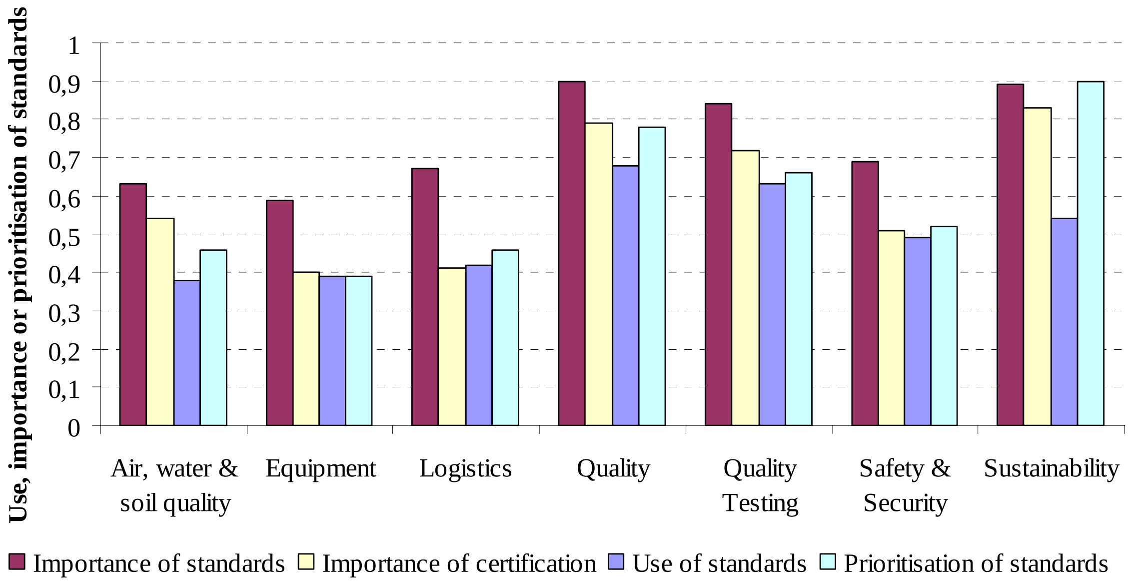

Figure 22 Use, importance & prioritisation of standard types within biofuel markets
The use, importance and prioritisation of specific standard types based on all stakeholders have been determined. Scoring is based on a range from 0<x<1, in which 0 means no use / importance / priority and 1 means high use / importance / priority. All respondents are included. Complete dataset is presented in *Appendix D.*

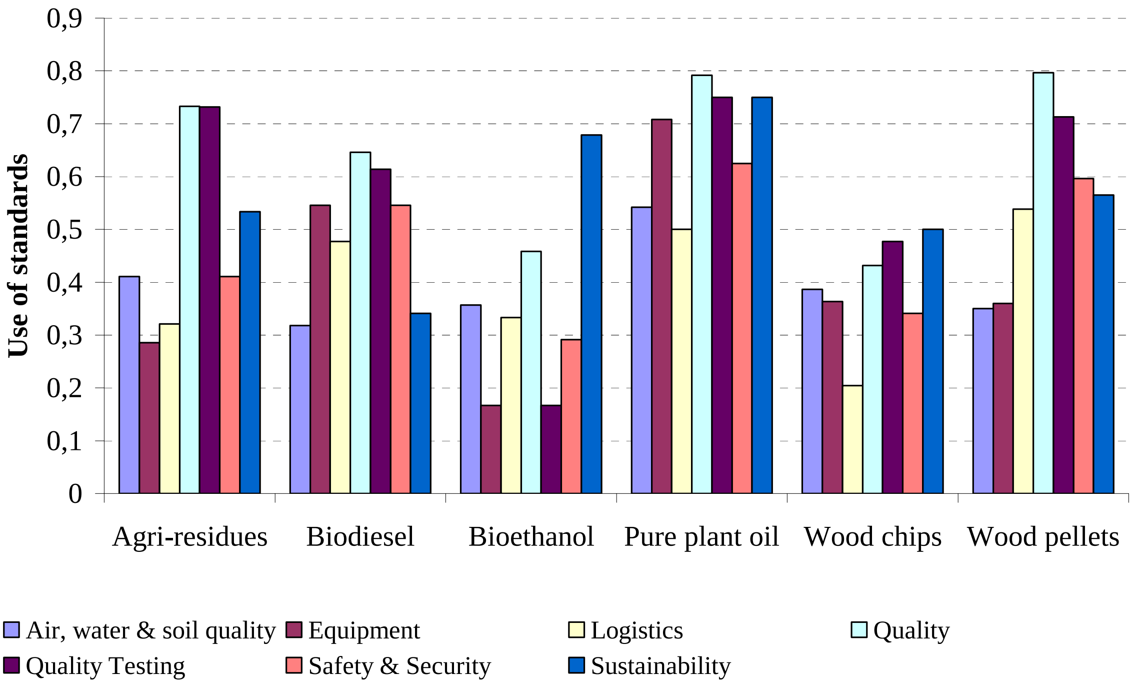

Figure 23 Use of specific standard types in different biofuel markets
The use of specific standard types by different biofuel markets was investigated. Scoring is based on a range from 0<x<1, in which 0 means no use and 1 means high use. All respondents are included. Within brackets are the scores from respondents that indicated to have high expertise. Average use of standards by different biofuel markets: PPO = 0,67 (0,86); wood pellets = 0,56 (0,59); agricultural residues = 0,49 (0,53); biodiesel = 0,50 (0,36); bioethanol = 0,36 (0,14); wood chips = 0,39 (0,34). Complete dataset is presented in *Appendix D.*.

Prioritisation of specific standard types

Mainly sustainability and quality standards have the highest level of prioritisation according to the stakeholders (*Figure 22*). Concerning this prioritisation of standard types, there are no significant differences between stakeholders active in different biofuel markets.

5.4.2 Insights from semi-structured interviews

Use of specific standards types

According to the interviewees, mainly standards related to biofuel quality are being used. This finding is in line with results gathered from the online survey (*Figure 23*). Currently, energy companies maintain individual and heterogeneous informal technical standards regarding the quality of solid biofuels [191, 192]. However, differences in quality demand at the consumer site of the biofuel supply chain provoke additional investments needed at the production site, leading to loss in capital- and time-efficiency [195]. Such developments have created a need for quality regulation by some parties. At the moment, technical quality standards for large scale heat and power generation are lacking [199]; the current European quality standard (DINplus) is focused on small scale production [192, 196].

Importance of specific standards types

Quality and sustainability standards

Standards related to quality are regarded as very important [191, 192, 195]. All interviewees also stressed the importance of sustainability standards. This finding correlates with the results of the online survey (*Figure 22*). However, the plurality of sustainability standards hinder biofuel market operation, stressing the need for uniformity [194, 199]. At the moment, sustainability criteria concerning solid and liquid biofuels are unclear in international trade [199].

Logistics, equipment and safety & security standards

The importance of other vertical standards[a] is stakeholder specific [192]. This observation has been mentioned especially for the more supply chain specific standard types of logistics and equipment [194]. Products, procedures or activities that are addressed by such standards are often covered in insurance practices or contractual agreements between third parties. The occurrence of such practices and agreements limits the need for certain stakeholders to use such standards [191, 192, 194]. Furthermore, the similarity of logistic requirements with existing commodities, including fossil fuels and agricultural bulk, eradicates the urgency for additional standards [194]. Regarding safety and security, the existing MSDS format (Material Safety Data Sheet) might be implemented for biofuel markets [194].

Prioritisation of standard types

Sustainability

The development of an international sustainability standard is regarded crucial [199]. In general, interviewees prefer for strictness within such standard. Certain interviewees consider

[a] A standard describing data structures, data definitions, document formats and business processes for specific industries. See *chapter 3* for further elaboration.

RED[a] to be not strict enough for complete coverage of sustainability issues [194, 196, 197]. Current developments within the ISO sustainability working group are considered as more thorough, since this working group is based on the triple-P approach[b] [197, 199].

Quality

Concerning existing conflicting biofuel quality definitions, certain interviewees stressed the need for uniform and internationally oriented quality standards. For solid biofuels, such accepted standard could facilitate in large scale biobased electricity and heat production. The need for uniform quality definitions for solid biofuels has led to cooperation between European energy companies[c], in order to influence the adaption of the DINplus standard [196][192]. Also, both CEN and ISO are active in the development of quality and quality determination standards. CEN has created six working groups. Within ISO, one working group (TC 238) has been set up. First public proceedings are expected at the end of 2010 [197].

Concerning liquid biofuels, the need for further standardisation might not be necessary [194]. Developed quality standards for vegetable- and fossil oil might prove sufficient, due to certain similarities with liquid biofuels [194]. However, there is a considerable difference in the amount of variables influencing vegetable oils, biodiesel or bioethanol. Furthermore, geographically determining differences in feedstock and operational processing methods can influence quality of liquid biofuels [194].

Logistics and safety & security

Related to quality management of biofuels, improving storage of solid and liquid biofuels is considered important for biofuel market development [191, 192]. Compared to coal (see *chapter 4*), there are considerably more variables that could affect solid biofuel quality during storage [192]. Concerning safety, there is a need to minimise risks related to decomposition of biomass [191, 192]. Therefore, the necessity for a controlled environment for solid biofuels requires prioritisation of logistic standards [191, 192]. Also, storage conditions of liquid biofuels might be different compared to fossil diesel, stressing the need for standardisation [194].

5.4.3 Conclusion

In general, the results of the online survey and semi-structured interviews are in line. Standardisation related to biofuel quality and sustainability issues is regarded as most important for market development. Furthermore, these standard types need to be prioritised in the standardisation process in order to facilitate increased trading on international scale. Between stakeholder groups or biofuel markets, no significant difference was observed related to the remarked importance and prioritisation of specific standard types. Importance of managing biofuel logistics was mentioned by interviewees as an important prerequisite for smooth trading and sound quality management. Such importance was not observed in the results of the online survey.

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[a] RED, or the Renewable Energy Directive, contains European regulation for liquid biofuels. In this directive, a number of sustainability requirements are posed for liquid biofuels. In case liquid biofuels do not meet these requirements, these biofuels can not be used in meeting mandatory targets set for renewable transportation fuels.
[b] Triple-P approach indicates consideration regarding the global spheres of people, planet and profit.
[c] Including large European companies of RWE, Electrabel (Suez), E.ON, Dong energy, Vattenfall (Nuon), Drax Power limited and Scottish & Southern Energy.

5.5 *Development of standards and certification schemes*

In the fourth theme of the stakeholder analysis, the role of stakeholders in developing and managing biofuel standards and biofuel certification schemes was addressed. Stakeholders were posed the following two questions:

- *Depending on the indicated standard types for biofuels, by who should standardisation be initiated & managed?*

- *Which of the indicated standard types should be voluntary or mandatory?*

5.5.1 Data from the online survey

Standardisation

General initiation & management

Regarding the geographical level at which standardisation should occur, an international scale is preferred (*Table 18*). In general, the market (primary stakeholders) should initiate the development of standards. Once developed, standardisation institutes are preferred for the management of such standards.

Table 18 Initiation and management of standardisation

	International		National		Total	
Initiation						
Government	18	(21) %	17	(12) %	35	(33) %
Market	30	(26) %	14	(11) %	44	(37) %
Standardisation institute	20	(28) %	1	(2) %	21	(30) %
Total	**68**	**(75) %**	**32**	**(25) %**	**100**	**(100) %**
Management						
Government	12	(13) %	11	(9) %	23	(22) %
Market	16	(14) %	14	(8) %	30	(22) %
Standardisation institute	37	(47) %	10	(9) %	47	(56) %
Total	**65**	**(74) %**	**35**	**(26) %**	**100**	**(100) %**

Concerning by who and what aggregate scale standardisation should occur. Numbers are based on the percentage of total respondents. Within brackets are the scores from respondents that indicated to have high expertise. Complete dataset is presented in *Appendix D.*

Scale of initiation & involved stakeholder groups

Concerning the different standard types, there are differences regarding by whom and at what scale standards should be initiated and managed (*Figure 25* & *Figure 26*). For the generic standards of AWS-quality, S&S and sustainability, there is a large preference for government initiation. For the more supply chain specific standard types of equipment, logistics and quality, there is a large preference for market initiation. Concerning quality testing standards, standardisation institutes might have an important role.

These findings reflect to some extent the opinions of respondents regarding the need for regulation. Although there are some perceived differences between the different biofuels, the generic standards of AWS-quality, S&S and sustainability score relatively high regarding the need for legal regulation (*Figure 24*).

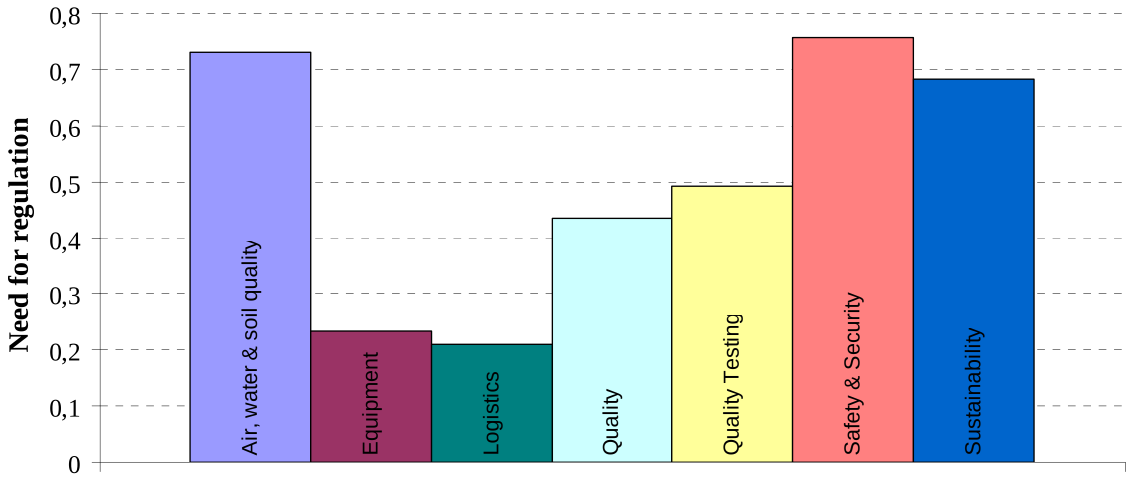

Figure 24 Need for regulation of the different standard types
For all distinguished standard types, the need for regulation was determined. Scoring is based on a range from 0<x<1, in which 0 means no regulation and 1 means regulation. Scores: AWS-quality = 0,73 (0,70); equipment = 0,23 (0,27); logistics = 0,21 (0,28); quality = 0,43 (0,43); quality testing = 0,49 (0,51); S&S = 0,76 (0,71); sustainability = 0,68 (0,65). Complete dataset is presented in *Appendix D.*

Regarding the scale of initiation, all standard types are preferred to be developed on international level (*Figure 25*). However, for the generic standards of AWS-quality and S&S, there is a tendency for national based standard initiation. Concerning the generic sustainability standards, there is a clear preference for international initiation of standards.

Scale of management & involved stakeholder groups

Concerning the management of standards, a similar trend is observed (*Figure 26 & Table 18*). Furthermore, there is a clear preference for international standardisation for almost al standard types. However, for AWS-quality and S&S, stakeholders show a tendency towards national management. Regarding equipment standards, there is no clear preference for national or international based management of standards.

Regarding the involved stakeholder groups, respondents have indicated a preference for standard management by standardisation institutes for the vertical standards of equipment, quality, quality testing and logistics. Management of generic standard types is not clear cut. Respondents show no real preference concerning standard management related to AWS-quality, S&S and sustainability.

Figure 25 Initiation of standards
Stakeholders were asked by what organisation and on what scale standard creation should be initiated. This assessment has been differentiated according to specific standard types. Scoring based on percentage of all respondents. Complete dataset is presented in *Appendix D.*

Figure 26 Management of standards.
Stakeholders were asked by what organisation and on what scale standards should be managed. This assessment has been differentiated according to specific standard types. Based on percentage of all respondents. Complete dataset is presented in *Appendix D.*

Certification

General initiation & management

There is a clear preference for international initiation and management of certification (*Table 19*). This finding is comparable with the preference found for international standardisation. Furthermore, the market should be prime responsible for the initiation of certification.

Table 19 Initiation and management of certification.

	International		National		Total	
Initiation						
Government	16	(19) %	16	(10) %	31	(29) %
Market	33	(32) %	19	(12) %	52	(44) %
Standardisation institute	15	(25) %	2	(2) %	17	(27) %
Total	**63**	**(76) %**	**37**	**(24) %**	**100**	**(100) %**
Management						
Government	9	(10) %	11	(7) %	20	(18) %
Market	19	(22) %	16	(9) %	35	(31) %
Standardisation institute	31	(39) %	14	(12) %	45	(51) %
Total	**59**	**(72) %**	**41**	**(28) %**	**100**	**(100) %**

Concerning by who and what aggregate scale standardisation should occur. Within brackets are the scores from respondents that indicated to have high expertise. Complete dataset is presented in *Appendix D.*

Scale of initiation & involved stakeholder groups

When results are differentiated according to specific standard types, the preference for international certification is especially obvious for the standard types of quality, quality testing and sustainability (*Figure 27*). Furthermore, a governance based initiation is favoured for certification schemes based on the generic standards of AWS-quality, S&S and sustainability. Certification schemes that are based on the vertical standards of equipment, logistics, quality and quality testing are preferred to be developed by the market.

Scale of management & involved stakeholder groups

A clear preference exists for international management for the standard types of quality, quality testing and sustainability (*Figure 28*). Certification schemes related to these standard types are preferred to be managed by standardisation institutes. This finding is comparable with the expressed preference for standard management (*Figure 28*). Also, certification systems related to the standard types of equipment and S&S are preferred to be managed by standardisation institutes.

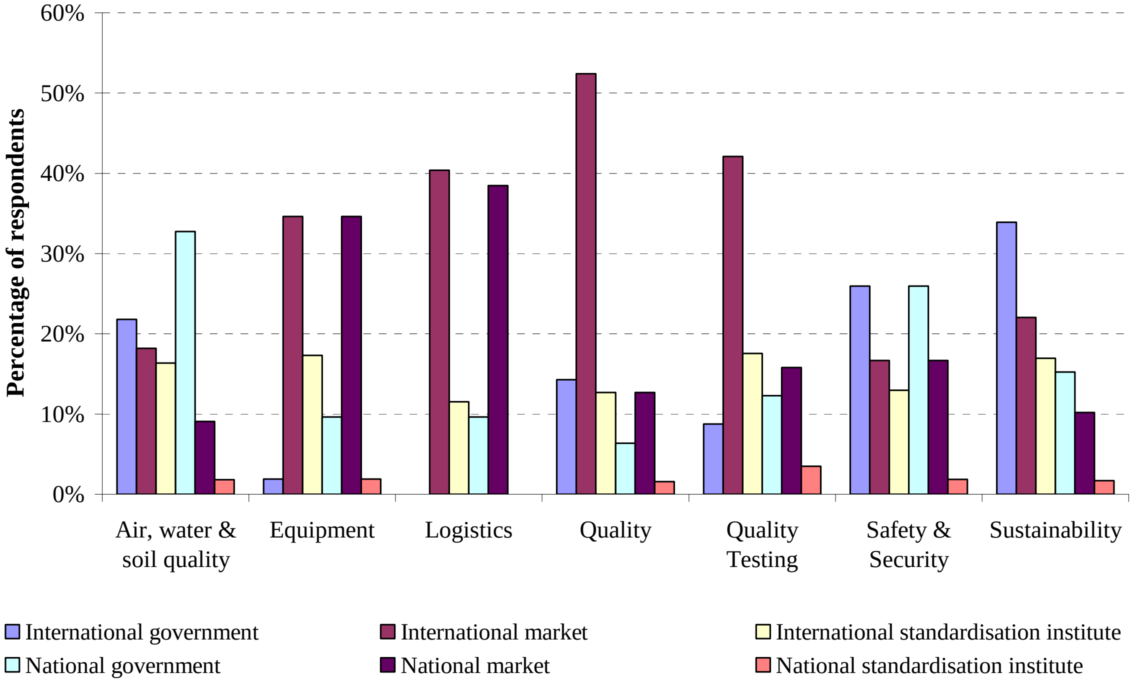

Figure 27 Initiation of certification
Stakeholders were asked by what organisation and on what scale certification should be initiated. This assessment has been differentiated according to specific standard types. Based on percentage of all respondents. Complete dataset is presented in *Appendix D.*

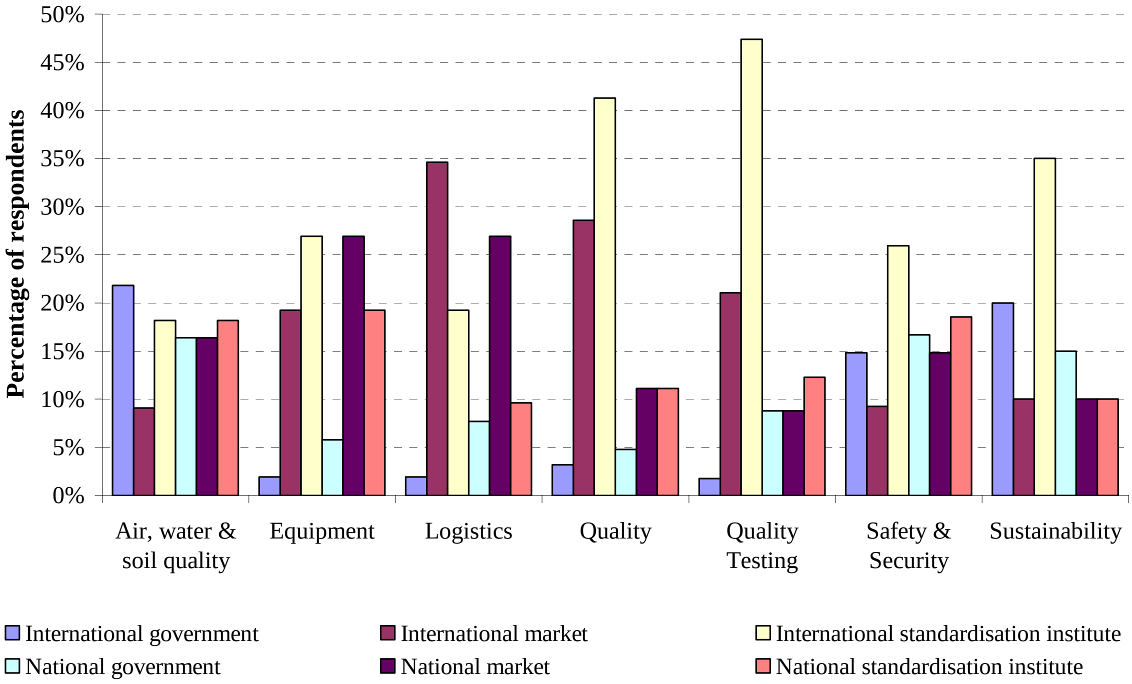

Figure 28 Management of certification.
Stakeholders were asked by what organisation and on what scale certification should be managed. This assessment has been differentiated according to specific standard types. Based on percentage of all respondents. Complete dataset is presented in *Appendix D.*

5.5.2 Insights from semi-structured interviews

Development of standardisation

Market initiation & management by standardisation institutes

Interviewees showed a preference for standard development by market parties [191]. This finding is in line with data of the online survey (*Table 19*). Development of generic standardisation should be based on interaction between state and market [191]. Standardisation institutes can have an important informative role in the initiation of standardisation by demonstrating market barriers and catalyse standard development [197]. Once developed, standards can be managed by standardisation institutes. However, market parties should always be involved to provide input needed for standard adaptation in dynamic markets [194].

Regulation of sustainability issues

Stakeholders active in solid biofuel markets indicate a preference for regulation of sustainability issues, as comparable to the European situation concerning liquid biofuels. Such approach is founded on avoiding potential discussions questioning the sustainability performance of organisations [191]. The absence of legal sustainability requirements could have a paralysing effect on solid biofuel markets [189, 196]. However, not all stakeholders support sustainability regulation. The potential formation of trade barrier, related to varied global sustainability regulation, could distort global competition. Such distortion could negatively impact the supply-demand equilibrium and hamper proper and transparent functioning of biofuel markets (see *chapter 3*, *Table 5*).

Regulation of issues related to vertical standardisation

According to interviewees, vertical standards should remain in the voluntary sphere. This is necessary in order to create space for product innovation and flexibility in process improvement [191, 192]. However, biofuel logistic standards might require a certain degree of localised regulation, due to potential safety hazards of biomass decomposition during storage [197].

Development of quality and sustainability certification

Based on current quality standards, shipment quality certificates for their use in trade have been developed [196]. Concerning sustainability, such certificates have not been developed yet [196]. Certain European sustainability certification systems for liquid biofuels have been developed for showing compliance with RED, although so far none have been approved by the EC. Also, it has been questioned whether current developed certification systems for liquid biofuels will not create barriers of trade due to global scale differences in sustainability perception [192].

5.5.3 Conclusion

International standardisation is in general preferred above national standardisation. International standardisation preference is caused due to its ability to improve market development, expend business over national borders and increase turnover. This observation is in line with the high correlation between global standardisation and production and trade volumes of both coal and palm oil (see *chapter 4*). Concerning generic standards, there is a preference for governmental involvement. For vertical standards, there is a clear preference for market initiation of vertical standards. Standardisation institutes are considered important in the management of standards in general. The initiation and management of related certification schemes shows a similar trend.

5.6 *Biofuel contracts*

In the last theme of the stakeholder analysis, the functionality[a] and transparency[b] of current contracts used in biofuel trading has been assessed. Also, stakeholders were asked what elements or issues should be addressed in standardised biofuel contracts. Stakeholders were posed the following two questions:

- *How do you judge functionality and transparency of current contracts used in trading biofuels?*

- *To what extent need the following standard types to be included or prioritised within standardised contracts used for trading biofuels?*

5.6.1 Data from the online survey

Current biofuel contracts

Both functionality and transparency of biofuel contracts are perceived being negative. In general, transparency is perceived to be more negative compared to functionality (*Figure 29*). When differentiating contracts according to biofuel market, contracts used in PPO trade score most negative. Contracts used in trading wood chip are considered most positive. Contracts used in markets of agricultural residues, biodiesel, bio-ethanol and wood pellets score in between.

Development of standardised biofuel contracts

Standardised contracts can be a tool to simplify trade and create more transparency (see *chapter 3*). Concerning the inclusion of specific issues in biofuel standard contracts, there is a significant difference between the prioritisation of distinguished standard types (*Figure 30*). The most crucial standard types for inclusion in standardised contracts are quality, sustainability and, to a certain extent, quality testing. According to respondents indicated having high expertise, logistics and S&S should also be covered within biofuel contracts. AWS-quality and equipment standards are considered having low priority for implementation into standardised biofuel contracts.

Standardised contract development according to biofuel markets and stakeholder groups

Between biofuel markets, no significant difference was found regarding perceived prioritisation or inclusion of specific standard types within standardised biofuel contracts. However, between stakeholder groups a significant difference between prioritisation of standard types has been measured. This difference was especially clear between primary stakeholders (*Figure 31*).

[a] Functionality of contracts indicates the usability of these contracts in biofuel trading. Functionality is also related to the exchangeability of contracts.
[b] Transparency of contracts indicates the unambiguousness, clarity and simplicity of contracts.

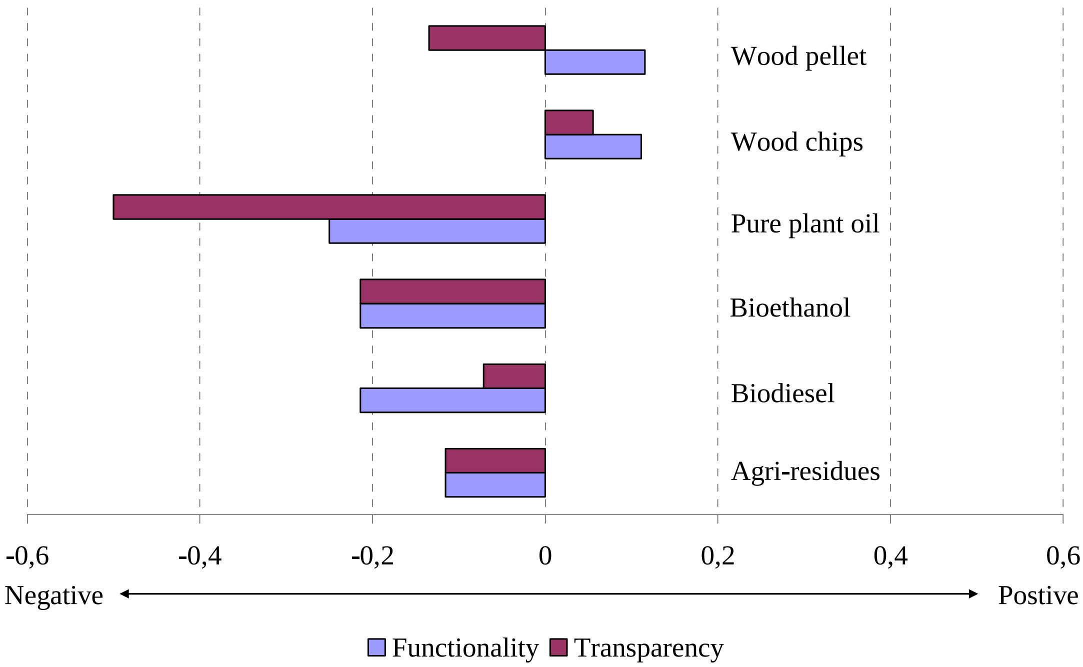

Figure 29 Contracts used in the market of biofuels.
Stakeholders active in different biofuel markets were asked regarding the functionality and transparency of biofuel contracts used in trading. All respondents are included. A scale ranging from -1 (very negative) to 1 (very positive) is applied. Complete dataset is presented in *Appendix D.*

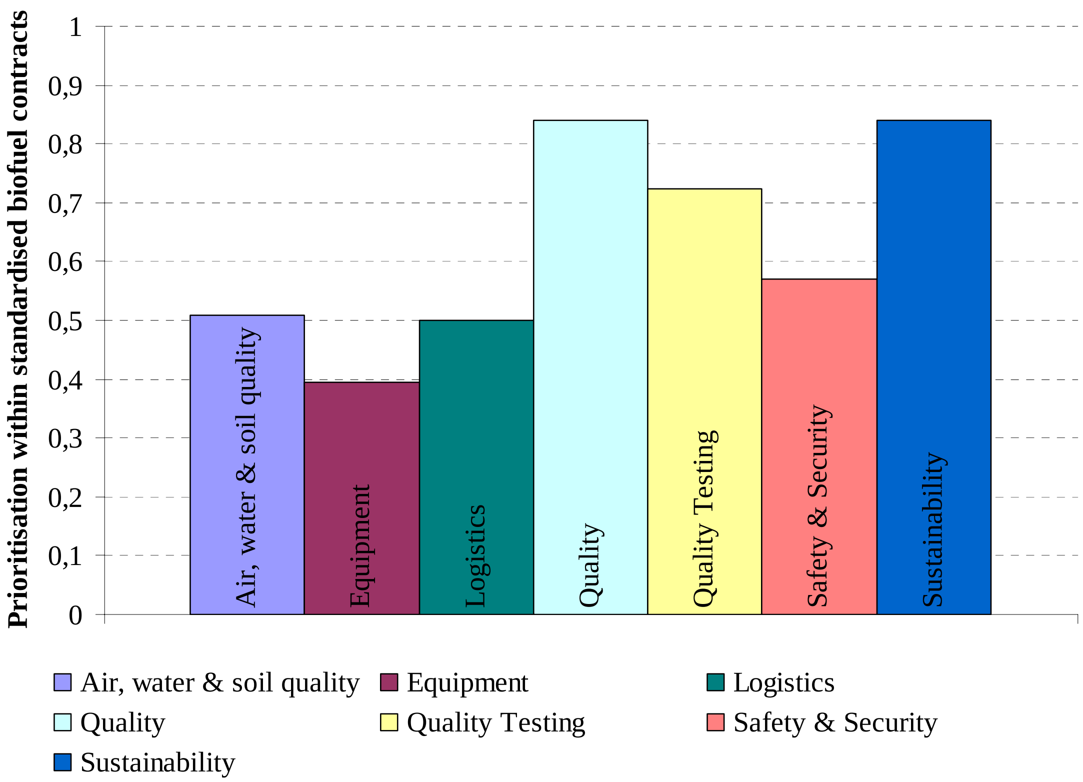

Figure 30 Need for inclusion of standard types in standardised contracts (1).
Perceived need by different biofuel markets to prioritise or include specific standard types in standardised biofuel contracts. Based on a range from 0<x<1, in which 0 means low priority and 1 means high priority. Within brackets are the scores from respondents that indicated to have high expertise. AWS quality = 0,51 (0,39); equipment = 0,39 (0,47); logistics = 0,50 (0,58); quality = 0,84 (0,79); quality testing = 0,72 (0,68)); S&S = 0,57 (0,55); sustainability = 0,84 (0,79). Complete dataset is presented in *Appendix D.*

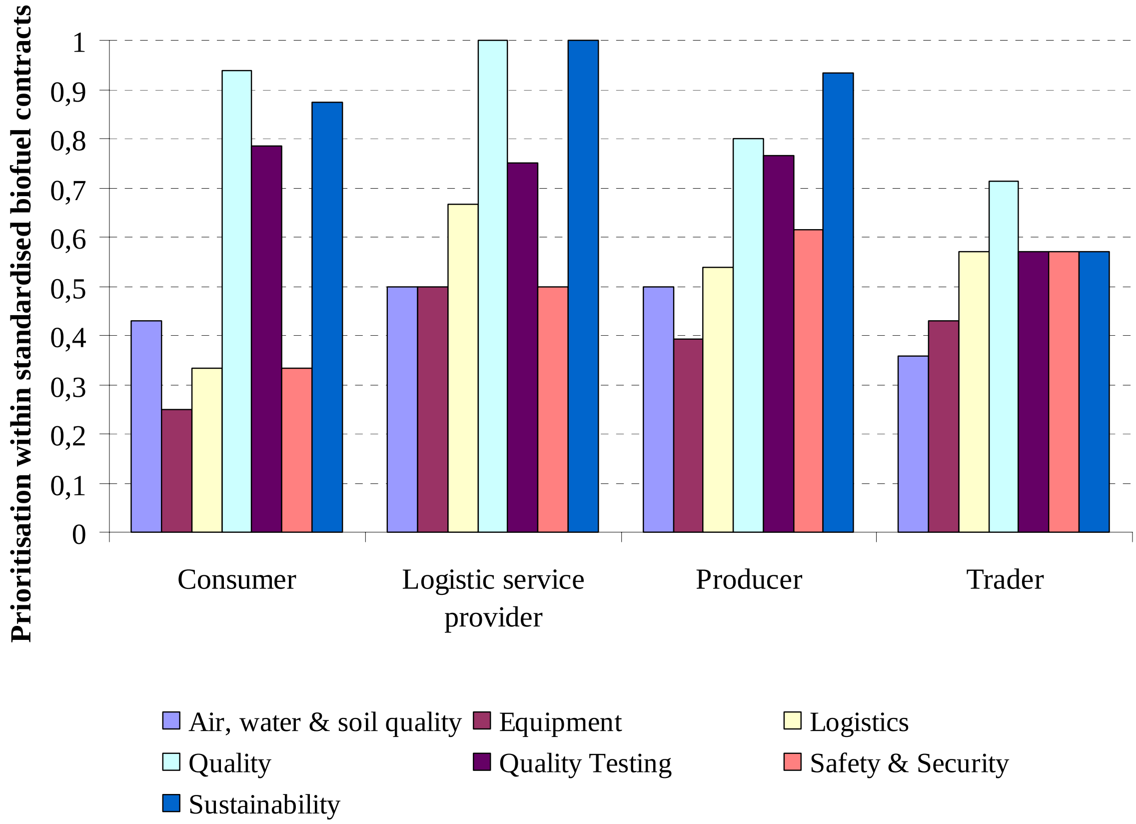

Figure 31 Need for inclusion of standard types in standardised contracts (2).
Perceived need by different biofuel markets to prioritise or include specific standard types in standardised biofuel contracts. Based on a range from 0<x<1, in which 0 means low priority and 1 means high priority. Complete dataset is presented in *Appendix D.*

Especially between traders and other primary stakeholders, a different perception was measured regarding the prioritisation of sustainability and quality standard inclusion in standardised contracts.

5.6.2 Insights from semi-structured interviews

Current biofuel contracts

Many of the contracts used in current solid and liquid biofuel trade have not changed fundamentally over the past decade [196]. A number of issues are yet broadly addressed in these contracts. These issues relate to quality, quality testing methods and shipping requirements [196]. Most differences in contracts are explained by different demands related to security of biofuel supply [196]. However, such extensiveness increases complexity, complicates contract reviewing and hinders the tradability of contracts [197]. The use of pre-defined standards within biofuel contracts can decrease this extensiveness and complexity of contracts. Using standards within biofuel contracts could initiate the development of standardised contracts [196].

Standardised biofuel contracts

The results obtained from the online survey are comparable with insights acquired from interviewees. Within standardised biofuel contracts, issues related to quality, quality testing, logistics and sustainability should be addressed [192] (*Figure 30*). However, it has been stressed that prior the development of standardised biofuel contracts, all standards needed for market development are present [197]. Based on required data, these standards include quality standards, quality testing standards and sustainability standards (*Figure 30*). However, addressing sustainability or using sustainability standards in contracts is considered an obstacle [196]. International non-harmonisation related to sustainability requirements and indicators complicates the inclusion of sustainability within standardised contracts appropriate for global trade [196].

5.6.3 Conclusion

According to stakeholders, current biofuel contracts could be improved considerably. Although biofuel contracts have not drastically changed over the past decade, their functionality and transparency is still limited. According to theory, standardised contracts can be an important financial vehicle to accomplish transparency and stability in trading [28]. Within standardised contracts, sustainability, quality and quality testing standards require high priority. However, addressing sustainability within standardised biofuel contracts might be hard, due to difficult international harmonisation of sustainability requirements and related indicators. This non-harmonisation might complicate the development of standardised biofuel contracts.

6 Discussion

This research was initiated in order to identify the role of standardisation in market development of biofuels (*chapter 1*). Based on this prime aim, an overview has been provided regarding the history and present status of using biofuels in the global economy (*chapter 2*). Furthermore, the fundamental role of standardisation was studied in order to assess its function in facilitating further development of biofuel markets (*chapter 3*). Based on an elaborated methodological approach, two analyses were executed to determine how standards could be developed and used to improve biofuel supply chains and advance biofuel trade (*chapter 4 & 5*). In these last two chapters, these chapters will be linked by connecting the acquired research data to the current status of biofuel markets. In the final chapter, final conclusions and future recommendations are made.

This chapter is divided in three parts. In the first part, the main findings of the executed analyses are summarised and framed in the current status of biofuel markets. In the second part, the limitations of the applied methodological approach are discussed. Based on these limitations, implications of the analyses outcomes are given. In this last section of the chapter, the findings of the executed analyses are used to draw conclusions related to the developed standard diffusion model explaining the connection between standardisation and market development.

6.1 Context of the results

Stakeholder influence on the development of biofuel markets

Increased attention for biofuels as a new source for renewable energy has had a large impact on the development of their markets. For both solid and liquid biofuels, there has been a drastic increase in global production capacity. However, this increased attention and development of capacity building has yet to result in a matured global biofuel markets. For certain biofuels, a large part of available production capacity is unused. Furthermore, global trade is still relatively limited for all biofuels discussed. A large share of both liquid and solid biofuels remains in the region of production.

In *chapter 3*, an overview was listed including barrier limiting the demand and supply of biofuels (*Table 4*). Many of the identified barriers are explained in terms of stakeholder connections and relationships. Observations from the online survey show that primary stakeholders endure more negative influence from other stakeholders compared to secondary stakeholders. This finding is noteworthy, since most secondary stakeholders have a task to provide services to enhance or facilitate the operational functioning of primary stakeholders.

Influence of governments & NGOs

Respondents of the online survey perceived the influence of governments on biofuel markets most negative compared to other distinguished stakeholder groups (see *chapter 5, Figure 17*). This finding was confirmed during the execution of semi-structured interviews. However, policy makers and NGOs perceive having a relative low influence on market development of biofuels (see *chapter 5, Figure 17*). This finding is in sharp contrast with the above mentioned perception of other stakeholder groups.

Almost all interviewees regarded the role of governance as most influential in the development of biofuel markets. National and global governance are hold prime responsible for the current inconsistent and ineffective operation of biofuel markets. Stimulation mechanisms for biofuel production and consumption seem to distort global market processes.

Furthermore, flawed or incomplete information distribution regarding biofuel production and consumption might have had large negative influence on biofuel market performance. This educational role of biofuel knowledge transmission concerns all secondary stakeholders. Based on this role, NGOs were assessed by the online survey respondents as having a relative negative influence on market development of biofuels (see *chapter 5*, *Figure 17*). This finding might be explained by activities undertaken by certain NGOs to limit biofuel market development. A number of NGOs have been questioning the impact of biofuel production and consumption on sustainability. This could have had a direct or indirect negative impact on public and governmental biofuel perception.

Influence of producers and consumers

Also, the perceived low influence by producers is remarkable, as producers are together with consumers regarded as having a positive effect on biofuel market development. Especially consumers seem to have a considerable positive influence on market development. These biofuel consumers include large scale power companies for solid biofuels and the transportation sector as a whole for liquid biofuels.

Importance and use of standards and certification schemes

In the developed standard diffusion model, it was hypothesised that standard development is correlated with increased trade volumes (see *chapter 3*, *Figure 11*). Stakeholder groups active in all analysed biofuel markets assessed standards as having a positive influence on market development (see *chapter 5*, *Figure 20*).

Use of standards

Stakeholders active in the markets of PPO and agricultural residues make most extensive use of standardisation. Stakeholders active in the biodiesel and ethanol market make relatively least use of standards (see *chapter 5*, *Figure 23*). Especially the low use of sustainability standards in the biodiesel market seems surprising, since liquid biofuel markets will become subject of mandatory sustainability requirements from 2011 onwards. Also, the relative low use of quality standards in the ethanol market is remarkable.

The high usage of mainly quality and quality testing standards in the agricultural residue market might be related to there extensive use by several large power companies. In such organisations, a high level of control is required to maintain process stability.

Although the total global market of vegetable oils is very large (*chapter 2*, *Figure 4*), the amount of consumers of pure plant oil as a transportation fuel is still limited. On the other hand, consumption of ethanol as a fuel has a relatively long history. About 75% of global ethanol production is used as a source for energy (see *chapter 2*, *Figure 3*)

However, this finding might be partly explained by the size of these markets. According to technological innovation theory, small markets are in general characterised by a low degree of specialisation in supply chain related functions (*chapter 3*). Such low degree of specialisation might result in the need for controlling multiple supply chain facets by individual stakeholders. Controlling larger parts of a product-supply chain might increase the need and absolute usage of standard.

Geographical scale of standardisation

In the developed standard diffusion model, a relation between international formal technical standards and market development was suggested. This relation has been partly confirmed by the performed analyses of commoditised markets. A high correlation between global standardisation and production and trade volumes of coal and palm oil were measured (see chapter 4, *Figure 12* & *Figure 14*). For both coal and palm oil, international trade has been very limited in the absence of international formal technical standards. Development of international accepted standards, in combination with (or facilitating) the globalisation and liberalisation of markets, might have facilitated the enormous increase in supply and demand of goods.

Based on global production and trade volumes of biofuels discussed in this research, it might be assumed that the amount of globally accepted biofuel standards has been insufficient for the development of global markets. Such assumption is also in line with results required from the stakeholder analysis. According to interviewees, international standardisation has the ability to improve market development, expend business over national borders and increase turnover. As a consequence, international biofuel standardisation is preferred over national standardisation (see *chapter 5, Figure 25*).

Advantages and disadvantages of certification

The assessed value of biofuel certification as a tool to facilitate the operation of standards shows similarity with the value of standardisation. In general, certification is assessed by stakeholders as having a positive influence on market development.

The resemblance of stakeholder perception between standardisation and certification is remarkable. Besides the obvious comparatives, there are also a number of distinct differences between standardisation and certification that might have distinct impacts on market development. Such differences are mainly caused by a practice based disparity in voluntariness. The principle of equivalence forms the basis of the voluntary nature of standards and certification schemes, by not inhibiting the option for individual proof of commitment. However, certain interviewees indicated certification as a prerequisite in commodity trading. Certification can be a necessity in insuring investments related to biofuel supply or facilities needed for supply chain development. Such necessity decreases the voluntary nature of certification in practice.

This aspect might relate to the observed negative effect of certification on free trade, product pricing and financial performance (see *chapter 5, Figure 21*). Fear exists that certification could decrease space needed for technological improvement and supply chain optimisation. Furthermore, stakeholders stressed the importance for global conformance towards certification schemes to minimise unfair competition. Finally, product certification can be costly due to large static costs of the certifying procedure. Related to these certification costs, certain small organisations fear for market exclusion.

Prioritisation of specific standard types

Standards related to sustainability

The rapid rise of sustainability in society has led to a remarkable importance of sustainability standards. In biofuel markets, sustainability standardisation has become equally important with quality standards. However, non-harmonisation of sustainability criteria has proven to be an important barrier regarding market development of biofuels. The current absence of global sustainability standards stresses the need for their prioritisation in international biofuel standardisation.

Standard related to quality

The vertical standard types of biofuel quality and quality testing are currently most used and are together with sustainability standards regarded as most important by all stakeholders. This observation is in line with observations drawn from the coal and palm oil market, in which also quality and quality testing standards have been prioritised in historic market development. However, stakeholders indicated the need for improved and prioritisation of biofuel quality standards. This need is based on local differences regarding biofuel quality as a result of parallel standardisation. Globally accepted standards could reduce biofuel quality variability and increase the geographical exchangeability of biofuels. Only for using vegetable oils as fuel feedstock, a number of global formal technical standards concerning quality determination have been developed or improved so far.

Standards related to equipment

Within the coal market there has been considerable development of equipment standards (see *chapter 4*, *Figure 13*). Most of these standards focus on the coal production or mining process. However, according to stakeholders active in biofuel markets, the development of equipment standards has low priority. This is noteworthy, since many issues affecting efficiency and quality of biofuel supply are comparable with those studied for coal and palm oil supply chains. These affecting issues are mainly related to the importance of quality management in stages of production and storage.

Decreased prioritisation of equipment standards in biofuel markets is comparable with the standardisation pattern as observed within the palm oil market. In the palm oil market, standardisation has mainly been focussing on the determination of oil quality and related testing and sampling procedures, lacking standards related to equipment needed in supply chain processes. This low prioritisation might be explained by the required freedom and space for system innovation, eradicating the need for such standards in first instance. However, as indicated in *chapter 3*, standards can guide technical innovations and facilitate increased market specialisation. Standards could fulfil a role in the emergence of niches for specialised system development. Furthermore, the development of equipment standards could decrease the emergence of non compatible techniques.

Standards related to logistics

The importance of logistics in biofuel supply chains is in contrast with the observed lack for prioritisation of such standards. Also in the coal and palm oil market, almost no standards have been found targeting logistic processes. Concerning transportation of biofuels, it remains questionable to what extent standardisation could improve its cost-efficiency, since energy price has proven to be a main determinant for total transport costs (see *chapter 3*). This might be different for biofuel storage. The potential negative effect of biofuel storage on quality and safety issues, dilemmas related to biological activity and biomass decomposition, stresses the need for attention. This is especially relevant for solid biofuels.

The observed limited need for prioritisation of standards related to storage might be explained by the extent in which existing standards could be used. The similarity in composition and characteristics between biofuels and other goods of biobased or carbon-hydrogen content might facilitate the adaptation of existing standards related to storage and safety in biofuel markets.

Standardised contracts

According to certain interviewees, biofuel contracts have not drastically changed over the last decade. However, respondents of the online survey regarded the functionality and transparency of biofuel contracts as being insufficient (see *chapter 5, Figure 29*).. Standardised contracts can increase transparency and stability in trading (see *chapter 3*). Within standardised contracts for biofuels, sustainability, quality and quality testing standards should be included (see *chapter 5, Figure 31*).

Initiation and management of standards

Generic standards

Concerning generic standards, there is a preference for governmental involvement (see *chapter 5, Figure 25*). This finding indicates some form of regulation for issues associated with sustainability and security. Standards related to quality of air, water and soil, having a direct tie with the concept of sustainability, were also considered important. However, most of these issues are perceived to be covered sufficiently within national and international regulation. Standards needed for compliance are regarded sufficient. The majority of stakeholders expressed the need for sustainability regulation due to its perceived fundamental importance for long term societal stability. In such regulation, sustainability standards could act as a tool for meeting legislative mandates. Also, standards could be utilised as de jure standard (see *chapter 3*).

Vertical standards

There is a clear preference for market initiation of vertical standards, implicating the need for market input needed in shaping standards according to determined conditions by their primary users. Management of vertical standards is preferred by standardisation institutes. Standardisation institutes, having no stake in standard content, can facilitate effective progression by functioning as a central point in an interconnected stakeholder network.

6.2 Data quality and limitations

In this section, the limitations of the developed standard diffusion model and the data quality of the executed analyses are discussed.

Standard diffusion model

The developed standard diffusion model was based on the similarity between standardisation and technological diffusion theory. The parallel between standards and innovations was made founded on resemblances of key elements and time-dependent developmental phases.

However, due to the mere inclusion of global formal technical standards in the performed case studies, not all distinguished phases of the standard diffusion model could be validated (see *chapter 3*, *Figure 11*). Only conclusions concerning the last two phases of the model could be drawn. Although it is expected that the relative small scale production and trade prior the development of global formal technical standards has been based on informal standards, this assumption could not be tested.

Also, data concerning standardised trading and production volumes was difficult to obtain. For the case studies, only total global production and trade volumes was obtained. The absence of standardised trading data limits the interpretation of the standard diffusion model.

Method 1: Testing the relation between standardisation and the commoditisation of markets

The developed standard diffusion model was tested by two case studies. For the commodities of coal and palm oil, the relation between standardisation and market development was analysed. Coal and palm oil were used to serve as benchmarks for respectively solid and liquid biofuel markets. However, a number of methodological limitations might reduce conclusions derived from the outcomes and the comparability with biofuel markets. These limitations are mainly related to complexity of markets, the exclusion of informal standards, absence of standardised trade data and indicators used for market development.

Complexity of markets

The economical and societal structures in which the coal and palm oil markets developed have drastically changed over the last century. Halfway the 20th century, when the global markets of coal and palm oil started to blossom, the scarcity of substitutes might have made the development of these markets less constrained. Also, the demanded level of quality by consumers has increased significantly over time. The increased complexity of the current global economy might affect the development of new markets. The large availability of energy substitutes increases the extent of competition. This difference in economy complexity might reduce the extent in which the observed correlation between standardisation and trade volumes can be applied to biofuel market development.

Exclusion of informal standards

Furthermore, the mere inclusion of formal technical standards in this research might not sufficiently represent the total effect standards had on market development of coal and palm oil. Informal technical standards, in general preceding the development of formal technical standards, might have influenced initial small scale global trading and production patterns. The difficult enclosure of knowledge related to informal standards has resulted in their exclusion for this research.

Absence of standardised trade data

Also, the difficulty in assessing standardised trade volumes has hindered studying the relation between standardised trade and standard development. Interpretation of the observed high correlation between trade and standardisation might be difficult due to the inability to compare standardisation with standardised trade. It can not be proven that increasing trade volumes were based on standardised products or procedures.

Indicators for market development

Production and trade volumes have been used as indicators for global market development. This seems like a rational choice. In *chapter 3,* it was explained that improved supply chain operation leads to larger supply, whereas increased demand will stimulate the rate of production (see *chapter 3*, *Table 5*). However, it remains questionable if an increase in trade volumes and production rates can merely be prescribed to market development. Other variables influencing such volumes include economic expansion, mandated markets and energy price. Especially energy price has shown to have a large impact on international trade patterns.

Method 2: A review of biofuel standardisation and the development of biofuel markets

A stakeholder analysis (SA) was performed to determine the role of standardisation in market development of biofuels. A number of themes were developed to function as a foundation during the execution of the SA. These themes have been based on the different phases existing within technological diffusion theory, starting with initial format creation towards full embeddedness in economy and society.

Execution of an online survey

An online survey was used to address stakeholders on global scale. However, the demand for simplification in such surveys often leads to a decrease in elaborateness and detail of required data. Regarding the diffusion of standards, is can be questioned if results gathered from this analysis provide sufficiently founded insights regarding the four main elements of innovation, communication channels, time and social system within diffusion theory (see *chapter 3*, *Table 7*).

Linked to the need for simplification, all respondents were asked to select only one biofuel market and stakeholder group for answering the survey. However, this might not be a representative description of reality. Some organisations can fulfil multiple functions within biofuel supply chains. Also, certain organisations have indicated to be active in multiple biofuel markets. Although respondents were asked to answer questions based on their main role in a prime market, such inter-organisational integration of stakeholder roles might have influenced the accuracy of data.

Statistical limitations of acquired data – Representativeness of samples

The value of standardisation is based on standard stability and number of adopters (*Figure 10*). It is unknown to what extent the gathered data forms a sufficient foundation to determine the value of biofuel standards. It is questionable if the stakeholder samples represent the overall stakeholder populations in an accurate way. Representativeness of a sample is justified by the procedure in which such a sample is made. The extent of selectivity influences such representativeness. In our case, the required sample was biased by not being selected in a non-selective manner, since it was mainly based on contacts present within available networks. As a result, all interviewees and a large share of the online survey respondents originate from the Netherlands. Based on current biofuel market dynamics, this overrepresentation of Dutch stakeholders is not an accurate representation. The execution of an F-test[a] could not be executed due to the low respondent representation within some of the differentiated groups.

Statistical limitations of acquired data – Representativeness of data points

Stakeholders were clustered according to which stakeholder group they belonged and what biofuel markets they were active in. Testing differences between these differentiated groups

[a] An F-test is a frequently used tool to assess if data points are drawn for one population. This assessment is made by analysing the internal variance of data points.

has been carried out using the analyses of variance method[a] (ANOVA). In order to execute the ANOVA, obtained raw data from the online survey was converted. The converted data represents averages of a subjective or objective stakeholder assessment. However, due to absolute differences regarding stakeholder group and biofuel market representativeness, this average is not always based on an identical number of assessments.

Also, in case of multiple regression execution, the possibility to find identical average values between groups, despite large variation in sub-values, introduces a statistical type II-error[b]. Furthermore, an observed significant difference in variation excludes statements based on two or more specific groups. Only assertions over a complete set of groups could be made. In other words, distinguished clusters were only assessed as belonging to one population or not. Extracting certain data, in order to make comparison between specific groups, would bias and distort an accurate representation of the overall interrelations active within biofuel markets.

6.3 Outlook and implication of results

Taking into account the uncertainty of the gathered data, implications of results are made. In the last section of this chapter, future biofuel standardisation and the potential of developing global biofuel markets is discussed. Regarding the development of global biofuel markets, the role of standardised contracts in institutionalised markets is discussed in detail.

Development of biofuel standards

Importance of standardisation in developing markets

Proper management of biofuel supply chains has proven to be very important. Supply chain management is especially crucial for biofuels based on marginal profits. The cost-efficiency and consistency related to supply and demand dynamics is crucial for the competitiveness of such biofuels. Standards are able to steer a number of variables determining the operation of supply chains. Standards can provide stability, benefit and greater growth, by sharing knowledge and information to stimulate markets or discover unanticipated applications [131].

Especially for developing markets, standards can be prerequisite by creating rules regarding the governing of a certain application. Standards can eliminate variance within end-products and supply chain processes, eradicating barriers of commercialisation and facilitating up-scaling of production levels [204]. According to the developed standard diffusion model, standardisation might be a crucial underlying factor for further market development of biofuels. The observed high correlation between standard development and commoditisation of the coal and palm oil markets confirms such statement.

Of all researched commodities and biofuels, the market of coal is found to be most developed. This statement is based on the extent of global standardisation and global physical market volumes. On a mass basis, volumes of coal differ considerable compared to biofuels, ranging from a factor 500 for vegetable oils to over a factor 1000 for wood pellets (*Table 20*). Also, the total amount of global formal technical standards developed for the coal market is considerable larger when compared to the market of palm oil. Although there are many variables influencing biofuel production (see *chapter 3, Table 4*), such observation implies a determining role of standardisation.

[a] ANOVA is used to determine the degree of variation between groups of data points.
[b] A type II-error occurs when a null hypothesis is not rejected despite being false.

Table 20 Comparing fuels based on standardisation and market development

	Global production (MT)	*Global trade (MT)*	*Global standards***
Coal	12.600	1.800	161
Palm oil	48	32	117
Vegetable oils	92	42	27***
Ethanol	59	8	-
Biodiesel	21	22	-
Wood pellets	12*	1*	-

An overview is presented of production volumes, trade volumes and developed global standards. * based on production and inter-trading data between Europe and Northern America; ** based for use as fuel; *** based on standard development from 2005 onwards.

Standardisation as a facilitating or driving factor in market development

It might be questioned if increased standardisation is a consequence of a growing market or vice versa. The answer is probably both. In international standard creation, networks are important in encouraging mutual agreements and generate support among competing organizations. Like globalisation has stimulated the development of international standards, international standards can also drive the development of global markets by providing a common global lexicon for markets and inter-organisational network development.

Chronological prioritisation & development of specific standard types

A clear pattern regarding standard type development has been observed. Standardisation seems to occur parallel with market development and supply chain specialisation. For the markets of coal and palm oil, quality standards have been found most important for initial market development. However, sustainability standards are regarded equally important in biofuel markets.

In combination with the discussed inter-dependency of market development and standardisation, a graphical representation is suggested concerning the development of specific standard types in biofuel markets over time (*Figure 32*). Other distinguished standard types will follow initial standardisation of quality and sustainability, dependent on their need in an evolving market.

Potential and barriers of developing global biofuel markets

It is expected that competition between energy sources will increase. Furthermore, the trend of increased growth in derivatives and options trade is likely to continue, due to greater demand in risk management and low volatility. Institutionalised markets are able to facilitate growing markets and improved risk management. In the performed case studies of coal and palm oil, a potential relation between institutionalised markets and global production and trade volumes was assumed.

It might be expected that biofuel markets will follow a similar development of institutionalisation as observed for coal and palm oil. There is much potential for the initiation and creation of an institutionalised market for biofuels in the Netherlands. There exists a favourable logistic infrastructure to import biofuels or biofuel feedstock. Such imports can be utilised for biofuel production and consumption or transfer to other parts of Europe.

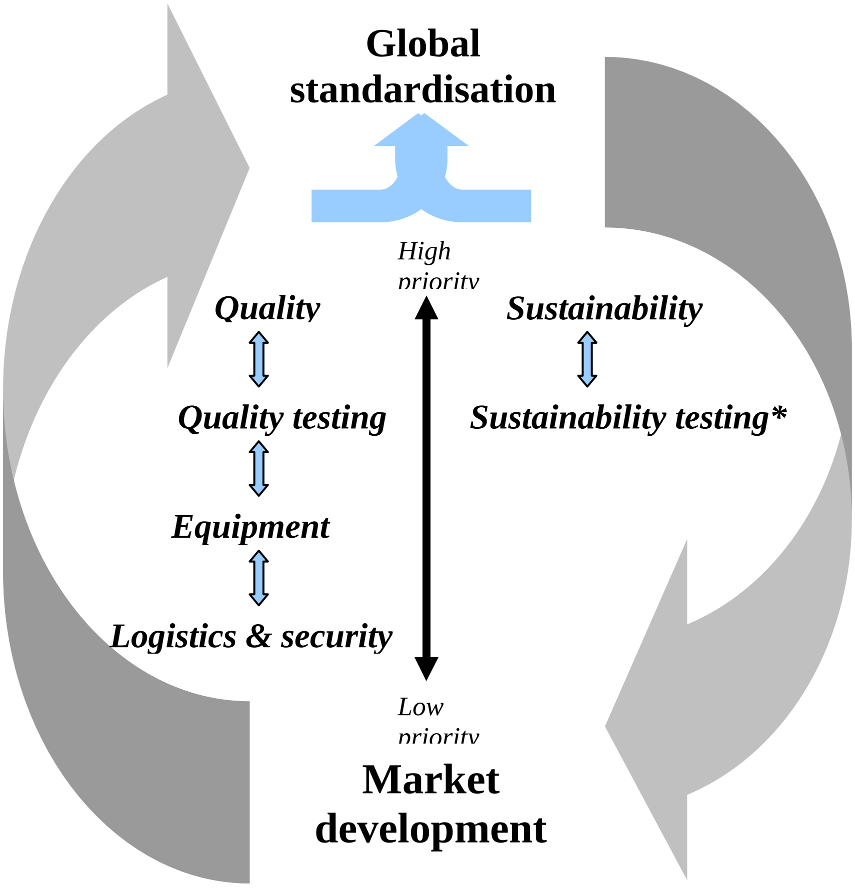

Figure 32 Relation between market development and standardisation
A graphical depiction of the relation between market development and prioritisation of specific standard types in global standardisation. Based on gathered data and information. *Sustainability testing has not been mentioned previously in this report. However, related to quality testing, sustainability testing standards might be developed based on protocols or methodologies needed for measuring sustainability.

However, the institutionalisation of biofuel markets might prove difficult on short term. There are a number of barriers that might impede the development of an institutionalised market for biofuels. In the next section, barriers related to network structures and scales of biofuel supply chains are discussed. Complexity concerning the development of standardised contracts will be discussed in the final part of this chapter.

Networks of biofuel markets

The enormous step from an immature market towards a fully developed institution is difficult. Creating the needed network structure of an institutionalised organisation takes time. Five key dimensions have been identified to influence the institutionalisation of organisations, including age, size, industry growth rate, evolution and revolution [205]. According to this theory, a number of evolutionary and revolutionary stages are required to create optimal network density[a]. Optimal network density is needed for successful organisational proliferation and expansion [206]. The growth rate of an industry can influence the speed of progressing towards such an optimal network density. It also relates to sufficient stakeholder support needed to create a balanced authority regime in a developing organisation.

[a] Optimal network density describes the most optimal relation between existing stakeholder interactions and value generation of an institutionalised market. It is needed to ensure effective opportunity discovery.

Biofuel markets are also represented in man-made technological networks. However, it is questionable to what extent biofuel market networks are matured enough to facilitate the step towards institutionalisation. The observed interrelations between stakeholders active in biofuel markets might not qualify sufficient as a fundament towards the creation of an institutionalised market (*Figure 18*). The amount of participants active in biofuel networks might prove critical for the institutionalisation of biofuel markets. The amount of potential participants, when compared with the institutionalised coal market, might be limited for certain biofuels due to narrow application possibilities and limited industrial players on industry and sector level. Such underrepresentation might lead to biased product pricing and insufficient flexibility for physical and paper trading.

Scale of biofuel supply chains

The lack of globalised trade might not only be the result of insufficient global standardisation and institutionalised markets, but might be a fundamental consequence of optimised local use of biofuels. Biological species and species characteristics are adapted to function most optimal in a certain climate or environment. As a consequence, the workings of molecular components and larger elements from such species have increased performance in similar environments. This has been especially relevant for oil based energy utilisation and has been encountered in vegetable oil and biodiesel consumption. Decreased performance has been observed for biofuels based on feedstock grown in different climates compared to the environment of its utilisation. Some parties are expecting that consumption of most biofuels might become based on local production. In such scenario, trade will be based mainly on biofuel overcapacity. This implies the requirement of decentralised production and consumption of biofuels. Looking at current trade patterns for biofuels, this might already be the case.

Development of standardised biofuel contracts

Standardised contracts are important in the institutionalisation of biofuel markets. For both coal and vegetable oil markets, standardised contracts have facilitated trading and increased security of supply. Based on expected future institutionalisation of biofuel markets, the importance of standardised contracts is likely to increase.

However, the development of standardised contracts might be problematic. Stakeholders have indicated the necessity of addressing both sustainability and quality in such contracts. Concerning quality and sustainability issues for biofuels, the creation of a legal framework is considered to be very complicated. For both solid and liquid biofuels, the required internationally accepted quality and sustainability standards for standardised contracts are still being developed.

Quality standards for biofuels

Biofuels display large variation in used feedstock and refining processes, leading to a substantial amount of quality based heterogeneity within the final tradable product. In this sense, biofuels differ considerably with coal. Compared to biofuels, coal displays a relative high degree in quality consistency. This high consistency is mainly caused due to the stable quality coal in abundant geological areas and its unrefined nature.

There are tendencies to develop biofuel quality standards on a certain aggregated level, in order to create equal market conditions and boundaries for all existing and future biofuels. Not withstanding the many similarities between biofuels, it might be questioned if such aggregated standards can suffice in a diversifying market in which an increasing number of qualitative variable feedstock sources are entering the biofuel domain. Although biofuel quality is always focussed on consumer demands, certain barriers may arise during supply chain specialisation requiring more detail and less variance for a growing number of parameters.

Sustainability standards for biofuels

Nonetheless, quality will probably not be the largest obstacle towards the development of a standardised contract for biofuels. Although there are local differences regarding set limits for certain quality parameters, such issues are expected to be solved within contracts. Sustainability might prove to be a larger obstacle in the formation of a standardised contract. In the final section of this chapter, difficulties concerning harmonisation, legislation and certification of sustainability are discussed.

<u>Non-harmonisation of sustainability perception and execution</u>

It is still debated how the theoretical concept of sustainability should be translated to the practical world. There are discussions regarding how sustainability should be measured and to what criteria sustainable products should commit. The true value of certain sustainability parameters is still undecided and the development of constructive indicators and methodological assessment is still unfinished.

An opted possibility relates to the creation of different contracts based on origin of involved parties, by tuning such contracts to local legislation and needs [196]. At the moment sustainability declarations are already being added as supplements to current contracts [191]. However, such a concept would still lack a true tradable and transparent standardised contract.

<u>Burden of legislation</u>

Legislation of sustainability might be another critical point. Stakeholders of solid and liquid biofuel markets have indicated a preference for governmental involvement regarding sustainability issues. In such an anticipated regulated market, sustainability standards could still have a function. In biofuel markets including the pre-requisite of sustainability, standards could function as a tool for legislation execution or the facilitation of corporate strategies to act above regulated limits.

However, the burden of legislative sustainability requirements might prove to be too heavy for small size biofuel markets. Furthermore, the inability to align global political will in order to unite sustainable behaviour decreases the potential to regulate sustainability. In many areas, sustainability has yet to reach political, social and economical agendas. In numerous countries that function as nursery grounds for biofuel and biofuel feedstock production, there are still signs of massive land clearance and deforestation leading to unsustainable biofuel production.

<u>Sustainability certification</u>

Implementation of sustainability control in practice poses another obstruction. Stakeholders have indicated an important role for sustainability certification in future biofuel markets. However, the development of an internationally agreed certification system might prove difficult. In contrast with quality certification, sustainability certification is much more complex. Quality certification contains single or a series of measurements at a certain point in time. For sustainability certification, a historic background is needed. It is believed that sustainability certification should be based on a life-cycle approach, in order to measure the complete impact of biofuel consumption on parameters of greenhouse gas emission, indirect land use change (ILUC) and biodiversity impact.

Regarding such structure, the development of a single sustainability certification scheme for both solid and liquid biofuels might be harmful for biofuel markets. Due to differences in structure and complexity between supply chains of solid and liquid biofuels, different biofuels have distinctive sustainability foot print. The inclusion of irrelevant parameters could unnecessarily complicate track & tracing systems for certain biofuels, leading to increased certification costs.

The life-cycle approach to measure sustainability of biofuels is currently adopted by the European Commission. However, the disclosure of sensitive supply chain related information might violate the concept of free trade and could jeopardise abilities for joint-venture. A nation-based system for sustainability validation, by using bilateral agreements between countries as a declaration for sustainability, has been proposed as a counter solution towards the currently adapted European system [201]. The creation of standardised contracts could be based on such an approach.

7 General conclusions and recommendations

Objective

The objective of this research was to investigate how and to what extent standardisation could facilitate global trade in biofuels. In the introduction of this report, the following two research aims were addressed:

1. *To analyse the contribution of standardisation to the development of commoditised markets.*

2. *To analyse the value and necessity of standardisation concerning the development of biofuel markets, including an assessment of the need for adaptation and creation of current and new standards.*

Based on these two research aims, the following conclusions are drawn:

Conclusions

1. Standards contribute to market development.

A relation has been found between standardisation and market development. For both coal and palm oil, a strong correlation between developed global formal technical standards and global production volumes has been found. Also, a strong correlation between developed global formal technical standards and global trade volumes has been observed for both coal and palm oil. Stakeholders active in biofuel markets regard standards as being able to improve biofuel production, trade and consumption.

2. Patterns within the standardisation process

For this research, a differentiation in standard types has been constructed based on their function in a supply chain. These standard types were tested according to importance and relevance in the development of markets. Of all distinguished standard types, quality and quality testing standards have influenced market development of coal and palm oil most. For market development of biofuels, standard types of quality, quality testing and sustainability are considered most important.

3. Stakeholders active in biofuel markets prioritise sustainability- and quality standards

According to stakeholders active in biofuel markets, sustainability and quality standards should be prioritised in standardisation or standard adaptation practices. Concerning sustainability, several standards have been developed on small scale. However, the absence of an internationally accepted standard is regarded as hampering the current development of biofuel markets. Also, various quality standards have been developed for a number of biofuels. However, local differences between such standards impede trading and large scale geographical exchangeability of biofuels.

4. There are still barriers concerning the institutionalisation of biofuel markets

Networks of biofuel markets might be insufficiently developed to facilitate short term realisation of an institutionalised market. The extent and nature of observed interconnections between stakeholders active in biofuel markets indicate the absence of an optimal network density. Furthermore, it is unclear to what extent current biofuels will be used in future sustainable global trade patterns.

5. The development of standardised contracts for biofuels might be difficult
According to the neo-classical economy theory, standards can be used as market optimisers. However, evolutionary economics have indicated the complexity of standard creation in reality. Concerning the development of standardised biofuel contracts, this might be the case. A number of barriers obstruct the development of global biofuel standards needed for standardised contracts. Concerning sustainability, non-harmonisation of global politics and current inability of defining adequate measurement methods hinders the development and implementation of global sustainability standards.

Methodological conclusions

During the identification of relations between standardisation and market development, a hypothetical standard diffusion model was created. This model was based on similarities between the process of standardisation and innovation diffusion. The gathered data from this research does not reject this hypothetical model, although not all aspects of this model could be validated.

Two historic case studies were performed to analyse the relation between standardisation and the commoditisation of markets. For both coal and palm oil, the insights gathered regarding the relation between market and standard development contributed to the validation of the developed hypothetical standard diffusion model.

A stakeholder analysis was developed to determine the value of standardisation, certification and assess existing relationships between stakeholders active in biofuel markets. Although a number of limitations of the applied methodology have impacted the significance of some of the acquired results (see *chapter 6*), a number of observations and relations could be identified and used for the validation of our standard diffusion model. Furthermore, a number of parallels could be drawn between results from the performed case studies and data gathered from the stakeholder analysis.

Recommendation for further research

Based on the data and information obtained during this research, a number of recommendations are made for further research.

Creating standards for the use on a exchange based on physical delivery

The observed complexity of developing global standards for quality and sustainability hinders the institutionalisation of markets. Although a number of international standardisation initiatives have commenced, it is not expected that these will finalise in usable standards in the next coming years. Therefore, a recommendation is proposed to investigate the development of a committee of primary stakeholders that are likely to benefit from an institutionalised market. Such committee could define internal boundaries and values for standardised trading at an exchange.

Influence of standardised contracts on market volumes

Standardised contracts can have an effect on global trade patterns and stimulate the institutionalisation of markets. Investigating the effect of standardised contracts on trade volumes might provide additional information regarding their contribution to market development.

Effect of vertical integration on market development and institutionalisation

A number of large power companies have indicated to invest in vertical integration in biofuel supply chains. Increased individualistic company control of supply chains could lead to increased protectionism and decreased transparency. Such inclination is comparable with the anti-globalism tendencies that have been identified as obstructions for market development. Investigating the occurrence and effect of vertical integration on biofuel market development might provide insights regarding the potential of an institutionalised market.

Estimating optimal network density for global biofuel markets

It is unknown to what extent biofuel market networks are matured enough to successfully initiate institutionalisation. The amount of participants active in biofuel networks might prove critical for such institutionalisation. Investigating biofuel networks might reveal possibilities to increase network density. Potential tools for making such an assessment include social network analysis and biofuel network modelling.

Governmental influence on biofuel markets

European policy is being heavily debated regarding its effect on a uniform and homogeneous European trading climate for biofuels [18, 207-212]. According to stakeholders in biofuel markets, there is a considerable negative influence of governments and NGOs on market development. However, there is also a low perceived influence by governments and NGOs themselves on market development. Explaining the origin and causes of governmental influence might reveal solutions or improvements concerning policy and regulatory structures.

Standardisation and biofuel price development

It is unknown to what extent standardisation could influence biofuel prices. Price can have distinct effect on market development [2]. Biofuel price might be influenced by many variables, including fossil fuel prices, biofuel feedstock price and feedstock availability. A relation with feedstock availability has also been observed in the palm oil market, in which increased demand and inter-sectoral competition for feedstock has influenced palm oil pricing. In our developed hypothetical standard diffusion model, standards are assumed to influence supply and demand. Based on the effect of product price on the supply-demand equilibrium, it might be interesting to determine the effect of standards on biofuel price development.

Storage of biofuels

The expected increase in global demand for coal has urged the need to invest heavily in the facilitation of sufficient storage capacity. The expected increase in biofuel demand will enhance the importance of storage capacity. At the moment, storage capacity is still a limiting factor in biofuel supply chains. A shortage in storage can have a negative influence on supply security. There is need for a certain critical capacity in order to facilitate consistent market operation and development.

Furthermore, there are certain practical issues related to biofuel storage. In contrast with coal, showing a relative high degree of stability in quality, biofuels are subject to biological degradation. Biological degradation has an effect on biofuel quality and security procedures. This impact is especially relevant for solid biofuels. Currently no formal technical standards exist related to storage of biofuels. In order to standardise such issues, it might be useful to make a comparison study with other biobased goods being traded on large scale, including all sorts of edible or non-edible biological entities. Studying auctions might provide valuable insights, since auctions facilitate trade in several quality grades of a certain product. It might be interesting to investigate the effect auctions had on market development of such bio-degradable products.

Effect of standardisation on the development of new generation biobased products

This research has focussed on biofuel markets with a certain degree of development or having large market potential on short term. However, technological improvement and innovation have resulted in the development of a number of other potential biobased products that could serve a future biobased economy. It might be analysed to what extent standardisation and institutionalisation could facilitate the development of such products.

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Appendices

A Port of Rotterdam: Feasibility for developing a wood pellet exchange

This research is part of a larger project concerning the feasibility of an exchange with physical delivery for wood pellets. The development of logistic services and facilities needed for transhipment of wood pellets can improve the position of Port of Rotterdam (PoR) in biomass trading [213]. A collaboration between PoR and the energy clearance company APX-ENDEX has been made to study the feasibility of a wood pellet exchange. In the past three years a number of projects have been performed studying the feasibility for the development of a wood pellet exchange with physical delivery.

In 2008, current and potential opportunities for market improvement of wood pellets were explored [108]. Based on this research, a number of conclusions were made. First of all, an exchange did not appear to be feasible based on price fluctuation and number of market participants. However, current stakeholders would like more price transparency for wood pellets. The development of price indices for both industrial and retail market could achieve such a goal. Furthermore, the need for quality standardisation regarding the pellet grades was stressed, since price index requires a volume unit. Also, a lack of a sustainability certification scheme could jeopardise the continuation of a price index and the market as a whole [108].

As a consequence of these market findings, APX-ENDEX published a price index for industrial wood pellets late 2008. This price index is published on the APX-ENDEX website and through several data vendors, including Pellet@tlas, Propellets, Forest Energy Monitor and Wood pellets association Canada.

In 2009, a future pellets market was modelled after the current coal market and the current heating oil market [214]. Based on a future scenario, in which increased production, trade and consumption of wood pellets on national and international level was depicted, a number of conclusions were drawn. Conclusions included the emergence of standardised qualities and certification schemes and a more centralised and transparent trade market. These markets included spot markets, internet trade, index development and exchange-based trade [214].

In 2010, a questionnaire carried out by APX- ENDEX among stakeholders in the wood pellet sector identified the preference for a physical settled product over financial settlement [215]. As a consequence, a letter of intent between PoR and APX- ENDEX was signed in March for joint engagement in a feasibility study for developing physical exchange trading in wood pellets.

In October of 2010, the feasibility of such a physical exchange was explored [216]. The outcome of this research validated the development of such an exchange, based on current flows of wood pellets to Rotterdam, projected future market growth of wood pellets and presence of potential end-users of wood pellets in the area. Recommendations of this research included (1) the development of a trading portal to trade futures with varying delivery times, (2) development and aligning of contracts that would qualify for quotation, (3) create sufficient physical capacity, and (4) implementation of a sustainability system linked to biofuel markets.

B Technical parameters for biofuels

B - I Technical parameters for biodiesel

Table B-I Technical parameters for biodiesel.

Parameter	*Description & origin*	*Influence*
Sulphated Ash	Ash content describes the amount of inorganic contaminants and the concentration of soluble metal soaps contained in the fuel.	▪ Cause of oxidation during combustion Cause of ash formation ▪ Related to engine deposits and filter plugging
Alkali and Alkaline Earth Metals	Metal ions are introduced into the biodiesel fuel during the production process.	▪ Sodium and potassium are associated with the formation of ash within the engine ▪ Calcium soaps are responsible for injection pump sticking
Free glycerol	The content of free glycerol in fatty acid methyl ester (biodiesel) is dependent on the production process. High values may stem from insufficient separation or washing of the ester product.	▪ Can lodge in the vehicle fuel filter ▪ Can result in damage to the vehicle fuel injection system ▪ Can also cause injector coking
Mono-, di- & triacylglycerols	Related to the concentration of free glycerol. The amount of glycerides depends on the production process.	▪ Can lead to fuel coking ▪ Cause the formation of deposits on injector nozzles, pistons and valves.
Methanol / Ethanol content	Used as feedstock in the processes of transesterification or alcoholysis.	▪ Can cause fuel system corrosion, low lubricity and adverse affects on injectors due to its high volatility ▪ Could be harmful to some materials in fuel distribution and vehicle fuel systems ▪ Both methanol and ethanol affect the flash point of esters
Acidity	Acid number or neutralisation number is a measure of free fatty acids. It is influenced by feedstock type, production process and fuel degradation.	▪ Causes corrosion to copper, zinc and bronze parts of the engine and the storage tank
Phosphorus content	Phosphorus in FAME stems from phospholipids and inorganic salts contained in feedstock.	▪ A strongly negative impact on the long term activity of exhaust emission catalytic systems
Solid contamination	Total contamination is defined as the quota of insoluble material retained after filtration of a fuel sample under standardized conditions.	▪ Increases concentrations of soaps and sediments ▪ Cause blockage of fuel filters and injection pumps
Water content	Water is introduced into biodiesel during the final washing step of the production process and has to be reduced by drying.	▪ Free water promotes biological growth causing blockage of fuel filters and fuel lines. ▪ Associated with hydrolysis reactions, partly converting biodiesel to free fatty acids causing fuel filter blocking. ▪ Cause corrosion of chromium and zinc parts within the engine and injection

		systems ▪ Can cause phase separation.
Sulphur content	By nature biodiesel has very low amounts of sulphur. It is used as a benchmark for fossil fuel content, containing much larger concentrations of sulphur.	▪ Cause corrosion to copper, zinc and bronze parts of the engine and the storage tank ▪ Cause engine wear and reduce the efficiency and life-span of catalytic systems ▪ Cause negative impacts on human health and on the environment
Antioxidant additives	Antioxidant additives might have to be added to ensure the fuel will still meet the specification.	▪ Hydroperoxides, formed with oxidative degradation of biodiesel, can polymerise with other free radicals to form insoluble sediments and gums ▪ Sediments and gums are associated with fuel filter plugging and deposits within the injection system and the combustion chamber

B - II Technical parameters for ethanol

Table B-II Technical parameters for fuel ethanol.

Parameter	*Description*	*Influence & Effects*
Presence of other alcohol types	Other alcohol types are produced during fermentation process.	▪ Defines purity of ethanol
Water content	Water enters during the processing phase.	▪ Phase separation can cause engines malfunctioning
Hydrocarbons	Hydrocarbons are often used as a denaturant.	▪ Can influence temperature related parameters
Contamination of solids	Total contamination is defined as the quota of insoluble material retained after filtration of a fuel sample under standardized conditions.	▪ Cause blockage of fuel filters and injection pumps
Sulphate content	Enters during the processing phase.	▪ Cause of corrosion
Copper content	Copper enters during the processing phase. It is an oxidation catalyst.	▪ Increases the oxidation rate of fuels
Sodium & Iron	Enters during the processing phase.	▪ Cause of corrosion
Chloride content	Enters during the processing phase.	▪ Cause of corrosion
Acidity	Ethanol manufactured from wine alcohol contains complex acids.	▪ Cause corrosion to copper, zinc and bronze parts of engines and storage compartments
Phosphorus content	The source of phosphorus may be the fertilizers and nutrients used in the fermentation process or from the feedstock.	▪ Powerful poison for the exhaust catalyst.

B - III Technical parameters for solid biofuels for combustion

Table B-III Technical parameters for combustion.

Parameter	*Description*	*Influence & Effects*
Origin	Feedstock can be derived directly from forests & plantations or from residual streams of the wood processing industry. When derived from residual streams, feedstock can be chemically treated.	▪ Chemicals of treated wood reducing efficiency/operation of equipment. ▪ Type wood influences efficiency
Moisture content	Moisture content is expressed as percent water of the total weight.	▪ Scale/equipment dependent ▪ Combustion efficiency (lower heating value) ▪ Storage
Particle size distribution	Size of particles in a certain amount of matter.	▪ Equipment
Dust & Spores	Presence of fungal spores generated by bacterial and fungal biological conversion processes during storage.	▪ Can be the cause of severe allergy. ▪ Influenced by ventilation ▪ Priority for low visiting frequency
Ash content	Ash is a term used to describe minerals and other inorganic material of a fuel.	▪ Efficiency energy generation ▪ Can cause instability of combustion equipment
Nitrogen content	Occurs naturally only in very small quantities in wood. Often increased in chemical treatment. Low nitrogen content indicates that the pellets were made from pure sawdust.	▪ High levels in the flue gas emissions can give rise to corrosion.
Chlorine content	Occurs naturally only in very small quantities in wood. Often increased in chemical treatment. Low chlorine content indicates that the pellets were made from pure sawdust.	▪ High levels in the flue gas emissions can give rise to corrosion.
Sulphur content	Occurs naturally only in very small quantities in wood. Often increased in chemical treatment. Low sulphur content indicates that the pellets were made from pure sawdust.	▪ High levels in the flue gas emissions can give rise to corrosion.

C Questions online survey

Standardisation of goods and products has proven to be an important element for the expansion and maturing of markets. In the past standards have reduced complexity in trading and have improved supply chain processes for a number of commodities. This short survey investigates the function of standardisation and certification of biobased products. Data obtained from this survey will provide valuable information on how, and to what extent, standardisation stimulates the development of expanding and more transparent markets of biobased products.

The survey has been developed in cooperation with the Copernicus Institute of Utrecht University and the Port of Rotterdam. The survey consists of 17 questions with an expected duration of approximately 5-10 minutes. At the end of each topic space is provided to place any additional comments. All provided answers will be treated anonymously.

Before we start with the survey we like to know some general aspects regarding your organisation.

1. In which country is you company situated?

2. Which biobased product stands most central within the core tasks of your organisation (*possible answers: bioethanol, biodiesel, pure plant oil (PPO), wood chips, wood pellets, agricultural residues, other*)? Please provide only one answer. In case more answers are applicable, you can mention these in the comments box below.)

3. What most important function or role does your organisation have in the supply chain (*possible answers: producer, logistic service provider, standardisation institute, trader, consumer, quality assurance company, trade facilitator, NGO, policy maker*)? Please provide only one answer. In case more answers are applicable, you can mention these in the comments box below.

4. What is your level of expertise regarding the market of biobased products (*possible answers: low, medium, high*)?

C - I Effect of stakeholders on market development of biofuels

We like to know about the influence of your organisation and other stakeholders on market development of biofuels.

5. In your opinion, to what extent does your market segment influence the overall market development of biobased products (*possible answers: none, weak, medium, strong*)?

6. In what manner and to what extent is your market segment affected by other stakeholders (*possible answers: very negative, negative, neutral, positive, very positive, N/A*)?

C - II Effect of standardisation & certification on market development

The following questions try to identify the effect standards and certification schemes can have on the market of biofuels.

7. To what extent can standards effect (*possible answers: very negative, negative, neutral, positive, very positive*):
    a. The supply chain
    b. Competition
    c. Free trade
    d. Product pricing
    e. The social performance of your organisation
    f. The financial performance of your organisation
    g. Market transparency

8. To what extent can certification schemes effect (*possible answers: very negative, negative, neutral, positive, very positive*):
    a. The supply chain
    b. Competition
    c. Free trade
    d. Product pricing
    e. The social performance of your organisation
    f. The financial performance of your organisation
    g. Market transparency

C - III Importance, use and prioritisation of specific standard types

Standards can focus on several aspects present within the supply chain of biofuels. In this survey 7 standard types are being distinguished, being:

Quality: Standards regarding the chemical, physical and biological properties of a product.
Quality testing: Standards regarding the determination of sample properties, analysis equipment & reference materials.
Equipment: Standards regarding technical specifications of equipment used in the supply chain.
Safety and security: Standards regarding the management of supply chain related safety and security issues.
Logistics: Standards regarding the collection, transportation & storage of products, and standards regarding the disposal of waste streams.
Air, water & soil quality: Standards regarding the direct effect of emissions and disposal of waste streams on the quality of air, water and soil.
Sustainability: Standards regarding the indirect effect of production, trading and consumption of biobased products on environmental and social variables.

The following questions try to identify the importance of these standard types for your company and for market development of biofuels as a whole.

9. In relation to the number of transactions dealt with by your company, how often are these standard types currently used by your organisation (possible answers: no, little, medium, often, all the time)? And by whom have these standards been developed (possible answers: standardisation institute, market party, NGO, government, other, N/A)?

10. In your opinion, how important are each of these standard types for the development of your market segment (*possible answers: not important, neutral, important, don't know*)?

11. In your opinion, to what extend need the following standard types to be enhanced or prioritised to achieve improved market conditions (*possible answers: low priority, medium priority, high priority*)?

C - IV Development of standards

Development of standardisation for biobased products includes the initiation and management of standards. These tasks can take place on as well national as international level and could be executed by one or more different parties. Furthermore, the use of standards can be voluntary or mandatory.

12. Depending on the indicated standard types for biobased products, by whom should standardisation be initiated & managed (*possible answers: national / international – market / government / standardisation institute*)?

13. Which of the indicated standard types should be voluntary or mandatory (*possible answers: voluntary, mandatory, don't know*)?

C - V Development of certification schemes

Certification is a market tool to identify products that comply with certain standards. It is however unknown to what extend certification is able to improve trade. Furthermore, like with standards, the development of certification includes the initiation and management of certification schemes. These tasks can take place on as well national as international level and could be executed by one or more different parties.

14. Regarding the indicated standard types for biobased products, how important is certification for the development of your market segment (*possible answers: not important, neutral, important, don't know*)?

15. Regarding the indicated standard types for biobased products, by whom should certification schemes be initiated and managed (*possible answers: national / international – market / government / standardisation institute*)?

C - VI Biofuel contracts

Contracts are very important in optimising trade and for the development of institutionalised markets. However, contracts used currently for trade in biobased products are not uniform, non-transparent and underdeveloped regarding certain important trade related aspects. The following questions try to identify the need for standardised contracts for trade in biobased products and to what extent reference to standards within these contracts needs to be improved.

16. How do you judge functionality and transparency of current contracts used for trade in biobased products (*possible answers: very negative, negative, neutral, positive, very positive*)?

17. To what extent need the following standard types to be included or prioritised within standardised contracts used for trade in biobased products (*possible answers: low priority, medium priority*, *high priority*)?

D Data online survey

D - I Effect of stakeholders on market development of biofuels

Table D-I Influence of a specific biofuel market on the total development of biofuels.

	Agri-residues	*Biodiesel*	*Bioethanol*	*Pure Plant Oil*	*Wood chips*	*Wood pellets*	**Total**
To what extent does your market segment influence the overall market development of biofuels?							
All respondents	0,77	0,67	0,67	0,33	0,48	0,78	0,69
High expertise	0,76	0,78	0,50	0,22	0,33	0,82	0,72

Table D-II Influence of a market segment on biofuel market development.

	Consumers	*Logistic service providers*	*NGOs*	*Policy makers*	*Producers*	*Quality assurance companies*	*Standardisation Institutes*	*Trade facilitators*	*Traders*	**Total**
To what extent does your market segment (stakeholder group) influence the overall market development of biofuels?										
All respondents	0,81	0,78	0,63	0,67	0,55	0,71	1,00	0,58	0,83	0,69
High expertise	0,78	1,00	0,58	0,58	0,59	0,92	-	1,00	0,83	0,72

Table D-III Influence of other stakeholders on market development.

	Consumers	*Logistic service providers*	*NGOs*	*Policy makers*	*Producers*	*Quality assurance companies*	*Standardisation Institutes*	*Trade facilitators*	*Traders*	**Total**
In what manner and to what extent is your market segment affected by other stakeholders?										
All respondents										
Consumer	0,19	0,39	-0,06	-0,28	0,39	0,00	0,17	0,00	-0,07	**0,08**
Logistic service	0,17	0,50	-0,17	0,25	0,50	0,00	0,17	0,50	0,50	**0,25**
NGO	0,33	0,36	0,50	0,33	0,64	0,17	0,17	0,14	0,14	**0,31**
Policy maker	0,31	0,13	0,00	0,56	0,31	0,07	0,21	0,14	0,00	**0,20**
Producer	0,29	-0,04	-0,15	-0,29	0,08	0,04	0,00	-0,04	0,07	**0,00**
Quality assur.	0,33	0,07	0,14	0,07	0,36	0,29	0,29	0,17	0,14	**0,20**
SI	0,00	0,50	0,50	0,50	1,00	1,00	-	0,00	0,00	**0,44**
Trade facilitator	0,63	0,33	0,50	0,63	0,75	0,33	0,33	0,38	0,38	**0,48**
Trader	-0,06	0,25	-0,31	-0,38	0,13	0,25	0,06	0,25	0,06	**0,03**
Total	**0,25**	**0,19**	**0,03**	**0,02**	**0,35**	**0,14**	**0,14**	**0,12**	**0,10**	0,15
High expertise										
Consumer	0,00	0,33	0,00	-0,42	0,33	0,08	0,25	-0,08	0,00	**0,06**
Logistic service	0,00	1,00	-0,50	0,00	1,00	0,00	0,50	0,50	0,50	**0,33**
NGO	0,67	0,50	0,63	0,50	0,75	0,17	0,17	0,00	0,13	**0,39**
Policy maker	0,50	0,25	0,00	0,88	0,38	0,00	0,38	0,38	0,38	**0,35**
Producer	0,33	-0,11	0,00	-0,33	0,00	0,11	0,11	-0,11	0,06	**0,01**
Quality assur.	0,38	0,25	0,00	0,13	0,38	0,38	0,38	0,17	0,13	**0,24**
Trade facilitator	1,00	0,00	1,00	1,00	1,00	0,50	0,50	1,00	1,00	**0,78**
Trader	-0,17	0,33	-0,25	-0,42	0,08	0,25	0,08	0,25	0,17	**0,04**
Total	0,25	0,23	0,04	-0,04	0,32	0,16	0,22	0,10	0,16	0,16
In what manner and to what extent is your overall biofuel market affected by other stakeholders?										
All respondents										
Agri-residues	0,04	0,25	-0,12	-0,12	0,38	0,00	0,00	-0,09	-0,04	**0,04**
Biodiesel	0,14	0,00	0,07	0,07	0,36	0,14	0,00	0,14	0,21	**0,13**
Bio-ethanol	0,42	0,08	0,00	0,25	0,33	0,17	0,08	0,33	0,08	**0,20**
Pure Plant Oil	0,25	-0,50	0,13	-0,38	-0,17	0,00	0,13	-0,50	-0,25	**-0,14**
Wood chips	0,29	0,43	-0,07	0,14	0,36	0,07	0,00	0,14	0,00	**0,15**
Wood pellets	0,34	0,30	0,10	0,05	0,39	0,24	0,30	0,27	0,24	**0,25**
Total	0,25	0,19	0,03	0,02	0,35	0,14	0,14	0,12	0,10	0,15
High expertise										
Agri-residues	-0,07	0,36	-0,21	-0,36	0,21	0,07	0,07	-0,07	0,07	**0,01**
Biodiesel	0,17	0,17	0,00	0,33	0,33	0,17	0,17	0,33	0,50	**0,24**
Bio-ethanol	0,75	0,25	0,25	0,75	0,50	0,00	0,25	0,25	0,25	**0,36**
Pure Plant Oil	0,33	-0,67	0,17	-0,67	-0,25	0,00	0,17	-0,50	-0,17	**-0,17**
Wood chips	0,50	0,50	0,50	0,50	0,50	0,00	-0,50	-1,00	-1,00	**0,00**
Wood pellets	0,31	0,32	0,08	0,00	0,39	0,25	0,33	0,28	0,24	**0,24**
Total	0,25	0,23	0,04	-0,04	0,32	0,16	0,22	0,10	0,16	0,16

Bold numbers indicate significant difference in observed variance. (0 = no influence; - = no data)

D - II Effect of standardisation & certification on market development

Table D-IV Effect of standardisation & certification on market parameters.

	Agri-residues	*Biodiesel*	*Bioethanol*	*Pure Plant Oil*	*Wood chips*	*Wood pellets*	**Total**
To what extent can standardisation effect:							
All respondents							
Competition	0,31	0,29	0,29	0,25	0,11	0,50	0,35
Free trade	0,38	0,21	0,36	0,38	-0,06	0,36	0,29
Market transparency	0,58	0,50	0,50	0,50	0,50	0,54	0,53
Product pricing	0,19	0,17	0,29	0,25	0,06	0,38	0,26
Financial performance	0,12	0,00	0,29	0,00	0,06	0,22	0,15
Social performance	0,23	0,25	0,43	0,25	0,50	0,36	0,34
The supply chain	0,46	0,50	0,36	0,38	0,22	0,42	0,40
Total	0,32	0,27	0,36	0,29	0,20	0,40	0,33
High expertise							
Competition	0,36	0,00	0,25	0,33	-1,00	0,50	0,36
Free trade	0,43	-0,33	0,50	0,50	-1,00	0,34	0,29
Market transparency	0,64	0,50	0,25	0,67	0,00	0,50	0,51
Product pricing	0,21	0,00	0,25	0,33	-1,00	0,39	0,28
Financial performance	0,00	0,00	0,25	0,00	-1,00	0,21	0,10
Social performance	0,21	0,25	0,00	0,33	0,00	0,39	0,31
The supply chain	0,43	0,75	0,25	0,50	-1,00	0,53	0,46
Total	0,33	0,13	0,25	0,38	-0,71	0,41	0,33
To what extent can certification effect:							
Competition	0,19	0,42	0,29	-0,13	0,28	0,40	**0,30**
Free trade	0,12	0,07	0,14	0,00	-0,06	0,28	**0,15**
Market transparency	0,42	0,50	0,29	0,00	0,06	0,44	**0,34**
Product pricing	-0,04	0,17	0,29	-0,13	-0,06	0,24	**0,12**
Financial performance	0,04	0,08	0,29	-0,25	-0,06	0,20	**0,10**
Social performance	0,27	0,33	0,29	0,25	0,39	0,36	**0,33**
The supply chain	0,38	0,21	0,43	-0,13	0,06	0,30	**0,26**
Total	**0,19**	**0,24**	**0,29**	**-0,05**	**0,09**	**0,32**	0,23
High expertise							
Competition	0,14	0,50	0,25	-0,17	-1,00	0,42	0,26
Free trade	0,07	-0,33	0,25	0,00	-1,00	0,29	0,13
Market transparency	0,17	0,50	0,25	0,00	-1,00	0,42	0,29
Product pricing	-0,07	0,00	0,75	-0,17	-1,00	0,26	0,13
Financial performance	-0,14	0,00	0,25	-0,33	-1,00	0,21	0,04
Social performance	0,21	0,25	0,00	0,33	0,00	0,39	0,31
The supply chain	0,21	0,00	0,75	-0,17	-1,00	0,39	0,26
Total	**0,08**	**0,09**	**0,36**	**-0,07**	**-0,86**	**0,34**	0,20

Bold numbers indicate significant difference in observed variance.

D - III Importance, use and prioritisation of specific standard types

Table D-V Current status of standards: Use, need for prioritisation.

	Air, water & soil quality	*Equipment*	*Logistics*	*Quality*	*Quality Testing*	*Safety & Security*	*Sustainability*	**Total**
How often are the following standard types currently used by your organisation?								
All respondents								
Agri-residues	0,41	0,29	0,32	0,73	0,73	0,41	0,53	**0,49**
Biodiesel	0,32	0,55	0,48	0,65	0,61	0,55	0,34	**0,50**
Bio-ethanol	0,36	0,17	0,33	0,46	0,17	0,29	0,68	**0,36**
Pure Plant Oil	0,54	0,71	0,50	0,79	0,75	0,63	0,75	**0,67**
Wood chips	0,39	0,36	0,20	0,43	0,48	0,34	0,50	**0,39**
Wood pellets	0,35	0,36	0,54	0,80	0,71	0,60	0,56	**0,56**
Total	**0,38**	**0,39**	**0,42**	**0,68**	**0,63**	**0,49**	**0,54**	0,51
High expertise								
Agri-residues	0,38	0,31	0,44	0,84	0,78	0,47	0,47	**0,53**
Biodiesel	0,15	0,35	0,25	0,55	0,55	0,40	0,30	**0,36**
Bio-ethanol	0,00	0,00	0,00	0,50	0,00	0,00	0,50	**0,14**
Pure Plant Oil	0,67	1,00	0,67	1,00	1,00	0,75	0,92	**0,86**
Wood chips	0,00	0,13	0,38	0,50	1,00	0,00	0,38	**0,34**
Wood pellets	0,30	0,35	0,61	0,85	0,77	0,63	0,57	**0,59**
Total	**0,29**	**0,36**	**0,49**	**0,79**	**0,74**	**0,52**	**0,53**	0,53
How important are each of these standard types for the development of your market segment?								
All respondents								
Agri-residues	0,62	0,38	0,61	0,97	0,80	0,57	0,90	0,70
Biodiesel	0,59	0,64	0,73	1,00	0,95	0,77	0,73	0,77
Bio-ethanol	0,57	0,58	0,58	1,00	0,75	0,67	0,93	0,73
Pure Plant Oil	0,75	0,67	0,60	0,83	0,67	0,67	1,00	0,74
Wood chips	0,64	0,59	0,59	0,77	0,82	0,68	1,00	0,73
Wood pellets	0,63	0,65	0,74	0,88	0,88	0,73	0,88	0,77
Total	**0,63**	**0,59**	**0,67**	**0,90**	**0,84**	**0,69**	**0,89**	0,75
High expertise								
Agri-residues	0,50	0,36	0,56	1,00	0,81	0,56	0,88	**0,67**
Biodiesel	0,60	0,60	0,70	1,00	1,00	0,60	0,60	**0,73**
Bio-ethanol	0,25	0,25	0,25	1,00	0,50	0,25	1,00	**0,50**
Pure Plant Oil	0,83	1,00	1,00	0,83	0,83	0,67	1,00	**0,88**
Wood chips	0,00	0,75	0,50	0,50	1,00	0,50	1,00	**0,61**
Wood pellets	0,60	0,63	0,80	0,86	0,86	0,76	0,88	**0,77**
Total	**0,55**	**0,59**	**0,71**	**0,89**	**0,85**	**0,66**	**0,87**	0,73
How important is certification, related to the different standard types, for the development of your market segment?								
All respondents								
Agri-residues	0,65	0,29	0,33	0,62	0,54	0,46	0,85	0,54

Biodiesel	0,42	0,50	0,33	0,92	0,83	0,50	0,50	0,57
Bio-ethanol	0,57	0,25	0,25	0,86	0,83	0,42	1,00	0,60
Pure Plant Oil	0,63	0,38	0,25	0,50	0,75	0,63	0,88	0,57
Wood chips	0,50	0,43	0,29	0,88	0,88	0,43	0,88	0,63
Wood pellets	0,50	0,48	0,57	0,85	0,70	0,58	0,85	0,65
Total	**0,54**	**0,40**	**0,41**	**0,79**	**0,72**	**0,51**	**0,83**	0,60
High expertise								
Agri-residues	0,50	0,14	0,21	0,50	0,43	0,36	0,79	**0,42**
Biodiesel	0,25	0,50	0,25	1,00	0,75	0,25	0,50	**0,50**
Bio-ethanol	0,25	0,25	0,25	1,00	1,00	0,25	1,00	**0,57**
Pure Plant Oil	0,67	0,50	0,33	0,50	0,67	0,67	0,83	**0,60**
Wood chips	0,00	0,50	0,00	0,00	0,50	0,00	0,50	**0,21**
Wood pellets	0,50	0,44	0,61	0,83	0,68	0,59	0,83	**0,64**
Total	**0,47**	**0,38**	**0,44**	**0,73**	**0,64**	**0,48**	**0,80**	0,56

To what extend need the following standard types to be enhanced or prioritised to achieve improved market conditions?

All respondents								
Agri-residues	0,46	0,17	0,32	0,82	0,54	0,38	0,83	0,52
Biodiesel	0,50	0,44	0,56	0,90	0,85	0,56	0,88	0,67
Bio-ethanol	0,58	0,30	0,60	0,86	0,50	0,30	1,00	0,63
Pure Plant Oil	0,50	0,33	0,42	0,67	0,58	0,50	1,00	0,57
Wood chips	0,41	0,45	0,36	0,73	0,77	0,59	0,91	0,60
Wood pellets	0,44	0,48	0,54	0,74	0,65	0,60	0,88	0,62
Total	**0,46**	**0,39**	**0,46**	**0,78**	**0,66**	**0,52**	**0,90**	0,60
High expertise								
Agri-residues	0,38	0,19	0,31	0,88	0,63	0,38	0,69	0,49
Biodiesel	0,50	0,50	0,38	0,88	0,88	0,50	0,88	0,64
Bio-ethanol	0,00	0,00	0,50	0,75	0,50	0,00	1,00	0,50
Pure Plant Oil	0,67	0,50	0,67	0,50	0,33	0,67	1,00	0,62
Wood chips	0,00	0,50	0,00	0,50	1,00	0,25	0,50	0,39
Wood pellets	0,37	0,40	0,55	0,68	0,58	0,58	0,87	0,57
Total	**0,38**	**0,37**	**0,46**	**0,72**	**0,62**	**0,50**	**0,83**	0,55

Bold numbers indicate significant difference in observed variance.

Table D-VI Need for regulation.

	Air, water & soil quality	*Equipment*	*Logistics*	*Quality*	*Quality Testing*	*Safety & Security*	*Sustainability*	**Total**
Which of the following standard types should be voluntary or mandatory (law & regulation)?								
All respondents								
Agri-residues	0,83	0,00	0,00	0,23	0,25	0,73	0,77	**0,41**
Biodiesel	0,75	0,50	0,43	0,63	0,75	0,75	0,50	**0,62**
Bio-ethanol	0,71	0,17	0,17	0,57	0,50	0,67	0,71	**0,51**
Pure Plant Oil	0,83	0,20	0,20	0,50	0,60	0,67	0,60	**0,53**
Wood chips	0,56	0,11	0,00	0,22	0,22	0,78	0,50	**0,35**
Wood pellets	0,71	0,33	0,35	0,50	0,60	0,82	0,78	**0,59**
Total	**0,73**	**0,23**	**0,21**	**0,43**	**0,49**	**0,76**	**0,68**	0,51
High expertise								
Agri-residues	0,71	0,00	0,00	0,43	0,43	0,50	0,71	**0,41**
Biodiesel	0,67	0,67	0,33	0,67	1,00	0,33	0,33	**0,57**
Bio-ethanol	0,50	0,50	0,50	0,50	0,50	0,50	1,00	**0,57**
Pure Plant Oil	0,67	0,33	0,50	0,33	0,33	0,67	0,33	**0,45**
Wood chips	0,50	0,00	0,00	0,00	0,00	0,50	0,00	**0,14**
Wood pellets	0,75	0,29	0,35	0,45	0,55	0,89	0,76	**0,58**
Total	**0,70**	**0,27**	**0,28**	**0,43**	**0,51**	**0,71**	**0,65**	0,51

Bold numbers indicate significant difference in observed variance.

D - IV Development of standards

Table D-VII Development and management of standards.

	Air, water & soil quality	*Equipment*	*Logistics*	*Quality*	*Quality Testing*	*Safety & Security*	*Sustainability*	**Total**
By which organisation type are the currently used standards developed?								
All respondents								
SI	0,24	0,45	0,18	0,43	0,62	0,29	0,18	0,35
Government	0,62	0,13	0,20	0,13	0,06	0,37	0,27	0,24
Market party	0,00	0,24	0,44	0,28	0,25	0,12	0,24	0,23
NGO	0,07	0,03	0,02	0,05	0,02	0,05	0,13	0,05
Other	0,07	0,16	0,16	0,10	0,06	0,17	0,18	0,13
Total	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
High expertise								
SI	0,17	0,42	0,14	0,43	0,61	0,25	0,11	0,32
Government	0,67	0,05	0,18	0,17	0,06	0,30	0,25	0,22
Market party	0,00	0,26	0,46	0,26	0,19	0,15	0,29	0,25
NGO	0,06	0,05	0,04	0,03	0,03	0,00	0,18	0,06
Other	0,11	0,21	0,18	0,11	0,10	0,30	0,18	0,16
Total	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
By whom should standardisation be initiated?								
All respondents								
Int. government	0,26	0,02	0,03	0,13	0,08	0,24	0,46	0,18
Int. market	0,08	0,34	0,48	0,47	0,33	0,17	0,20	0,30
Int. SI	0,18	0,19	0,17	0,20	0,39	0,14	0,16	0,20
Nat. government	0,41	0,17	0,05	0,09	0,08	0,29	0,12	0,17
Nat. market	0,07	0,29	0,25	0,11	0,11	0,14	0,03	0,14
Nat. SI	0,00	0,00	0,02	0,00	0,02	0,03	0,03	0,01
Total	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
High expertise								
Int. government	0,27	0,03	0,07	0,17	0,09	0,28	0,54	0,21
Int. market	0,07	0,27	0,43	0,39	0,29	0,14	0,20	0,26
Int. SI	0,20	0,30	0,30	0,28	0,47	0,24	0,17	0,28
Nat. government	0,43	0,17	0,03	0,03	0,03	0,21	0,00	0,12
Nat. market	0,03	0,23	0,13	0,14	0,12	0,10	0,03	0,11
Nat. SI	0,00	0,00	0,03	0,00	0,00	0,03	0,06	0,02
Total	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
By whom should standardisation be managed?								
All respondents								
Int. government	0,15	0,02	0,03	0,09	0,06	0,19	0,30	0,12
Int. market	0,07	0,23	0,28	0,24	0,11	0,07	0,15	0,16
Int. SI	0,30	0,30	0,33	0,39	0,58	0,32	0,34	0,37
Nat. government	0,35	0,11	0,03	0,04	0,05	0,14	0,10	0,11

Nat. market	0,08	0,21	0,22	0,13	0,12	0,16	0,03	0,13
Nat. SI	0,05	0,14	0,10	0,11	0,09	0,12	0,07	0,10
Total	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
High expertise								
Int. government	0,14	0,04	0,04	0,08	0,06	0,21	0,33	0,13
Int. market	0,00	0,18	0,29	0,25	0,09	0,07	0,12	0,14
Int. SI	0,34	0,43	0,46	0,47	0,65	0,46	0,42	0,47
Nat. government	0,41	0,07	0,00	0,03	0,03	0,07	0,06	0,09
Nat. market	0,03	0,14	0,07	0,11	0,09	0,11	0,00	0,08
Nat. SI	0,07	0,14	0,14	0,06	0,09	0,07	0,06	0,09
Total	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00

Abbreviations: SI = Standardisation Institute; Nat. = national; Int. = International.

D - V Development of certification schemes

Table D-VIII Development and management of certification schemes.

	Air, water & soil quality	*Equipment*	*Logistics*	*Quality*	*Quality Testing*	*Safety & Security*	*Sustainability*	**Total**
By whom should certification be initiated?								
All respondents								
Int. government	0,22	0,02	0,00	0,14	0,09	0,26	0,34	0,16
Int. market	0,18	0,35	0,40	0,52	0,42	0,17	0,22	0,33
Int. SI	0,16	0,17	0,12	0,13	0,18	0,13	0,17	0,15
Nat. government	0,33	0,10	0,10	0,06	0,12	0,26	0,15	0,16
Nat. market	0,09	0,35	0,38	0,13	0,16	0,17	0,10	0,19
Nat. SI	0,02	0,02	0,00	0,02	0,04	0,02	0,02	0,02
Total	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
High expertise								
Int. government	0,25	0,00	0,00	0,18	0,10	0,30	0,44	0,19
Int. market	0,18	0,38	0,46	0,50	0,38	0,15	0,19	0,32
Int. SI	0,21	0,35	0,23	0,21	0,31	0,26	0,22	0,25
Nat. government	0,29	0,12	0,00	0,03	0,07	0,15	0,06	0,10
Nat. market	0,04	0,15	0,31	0,09	0,10	0,11	0,06	0,12
Nat. SI	0,04	0,00	0,00	0,00	0,03	0,04	0,03	0,02
Total	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
By whom should certification be managed?								
All respondents								
Int. government	0,22	0,02	0,02	0,03	0,02	0,15	0,20	0,09
Int. market	0,09	0,19	0,35	0,29	0,21	0,09	0,10	0,19
Int. SI	0,18	0,27	0,19	0,41	0,47	0,26	0,35	0,31
Nat. government	0,16	0,06	0,08	0,05	0,09	0,17	0,15	0,11
Nat. market	0,16	0,27	0,27	0,11	0,09	0,15	0,10	0,16
Nat. SI	0,18	0,19	0,10	0,11	0,12	0,19	0,10	0,14
Total	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
High expertise								
Int. government	0,21	0,04	0,04	0,03	0,03	0,19	0,19	0,10
Int. market	0,14	0,19	0,38	0,35	0,24	0,07	0,16	0,22
Int. SI	0,21	0,38	0,31	0,47	0,55	0,33	0,44	0,39
Nat. government	0,14	0,00	0,04	0,03	0,10	0,07	0,13	0,07
Nat. market	0,11	0,19	0,15	0,03	0,00	0,11	0,06	0,09
Nat. SI	0,18	0,19	0,08	0,09	0,07	0,22	0,03	0,12
Total	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00

Abbreviations: SI = Standardisation Institute; Nat. = national; Int. = International.

D - VI Biofuel contracts

Table D-IX Current contracts used in biofuel trading.

	Functionality	*Transparency*	**Total**
How do you judge functionality and transparency of current contracts used for trade in biobased products?			
All respondents			
Agri-residues	-0,12	-0,12	-0,12
Biodiesel	-0,21	-0,07	-0,14
Bio-ethanol	-0,21	-0,21	-0,21
Pure Plant Oil	-0,25	-0,50	-0,38
Wood chips	0,11	0,06	0,08
Wood pellets	0,12	-0,13	-0,01
Total	-0,02	-0,13	-0,08
High expertise			
Agri-residues	-0,07	-0,07	**-0,07**
Biodiesel	-0,17	-0,17	**-0,17**
Bio-ethanol	0,00	0,00	**0,00**
Pure Plant Oil	-0,17	-0,33	**-0,25**
Wood chips	0,50	0,50	**0,50**
Wood pellets	0,05	-0,16	**-0,05**
Total	0,00	-0,13	-0,06

Bold numbers indicate significant difference in observed variance. Abbreviations: Agri-residues = Agricultural residues

Table D-X Standard biofuel contract development according to biofuel markets.

	Air, water & soil quality	*Equipment*	*Logistics*	*Quality*	*Quality Testing*	*Safety & Security*	*Sustainability*	*Total*
To what extent need the following standard types to be included or prioritised within standardised contracts used for trade in biobased products?								
All respondents								
Agri-residues	0,58	0,20	0,55	0,83	0,59	0,50	0,75	0,59
Biodiesel	0,63	0,50	0,38	0,80	0,70	0,75	0,70	0,65
Bio-ethanol	0,50	0,10	0,30	1,00	0,70	0,38	1,00	0,60
Pure Plant Oil	0,50	0,38	0,67	0,88	0,63	0,50	1,00	0,65
Wood chips	0,50	0,21	0,17	0,81	0,88	0,43	0,88	0,58
Wood pellets	0,45	0,59	0,61	0,81	0,76	0,66	0,83	0,68
Total	**0,51**	**0,39**	**0,50**	**0,84**	**0,72**	**0,57**	**0,84**	0,63
High expertise								
Agri-residues	0,50	0,33	0,58	0,86	0,64	0,42	0,71	0,59
Biodiesel	0,50	0,50	0,50	0,75	0,50	0,50	0,75	0,60
Bio-ethanol	0,25	0,25	0,25	1,00	0,75	0,25	1,00	0,54
Pure Plant Oil	0,33	0,33	1,00	0,83	0,50	0,50	1,00	0,63
Wood chips	0,00	0,50	0,00	0,00	1,00	0,00	0,50	0,29
Wood pellets	0,39	0,56	0,61	0,79	0,72	0,67	0,79	0,65
Total	**0,39**	**0,47**	**0,58**	**0,79**	**0,68**	**0,55**	**0,79**	0,61

Bold numbers indicate significant difference in observed variance.

Table D-XI Standard biofuel contract development according to primary stakeholders.

	Air, water & soil quality	Equipment	Logistics	Quality	Quality Testing	Safety & Security	Sustainability	**Total**
To what extent need the following standard types to be included or prioritised within standardised contracts used for trade in biobased products?								
All respondents								
Consumer	0,43	0,25	0,33	0,94	0,79	0,33	0,88	**0,59**
Logistic service provider	0,50	0,50	0,67	1,00	0,75	0,50	1,00	**0,74**
Producer	0,50	0,39	0,54	0,80	0,77	0,62	0,93	**0,66**
Trader	0,36	0,43	0,57	0,71	0,57	0,57	0,57	**0,54**
Total	**0,45**	**0,38**	**0,52**	**0,83**	**0,73**	**0,54**	**0,85**	0,62
High expertise								
Consumer	0,40	0,30	0,40	0,90	0,70	0,40	0,90	**0,57**
Logistic service provider	0,00	0,00	0,50	1,00	0,00	0,00	1,00	**0,83**
Producer	0,50	0,56	0,86	0,78	0,72	0,81	0,94	**0,74**
Trader	0,25	0,50	0,67	0,67	0,50	0,50	0,50	**0,51**
Total	**0,40**	**0,47**	**0,66**	**0,79**	**0,65**	**0,61**	**0,81**	0,63

Bold numbers indicate significant difference in observed variance.