Energy Research & Social Science 71 (2021) 101810

Contents lists available at ScienceDirect

Energy Research & Social Science

journal homepage: www.elsevier.com/locate/erss

Why does the European Union produce biofuels? Examining consistency and plausibility in prevailing narratives with quantitative storytelling

Juan J. Cadillo-Benalcazar [a], Sandra G.F. Bukkens [a], Maddalena Ripa [a], Mario Giampietro [a,b,*]

[a] Institut de Ciència i Tecnologia Ambientals, Universitat Autònoma de Barcelona, Bellaterra, Spain
[b] Institució Catalana de Recerca i Estudis Avançats (ICREA), Barcelona, Spain

ARTICLE INFO

Keywords:
Biofuels
Renewable Energy Directive
European Union
Narratives
Targets
Quantitative storytelling
The Netherlands
Used cooking oil

ABSTRACT

This paper seeks to clarify the confusion created by the simultaneous use of non-equivalent policy discourses about biofuels within the EU and addresses the inconsistency between long-term goals and short-term targets. To this purpose, a novel approach, quantitative storytelling, is employed to examine the plausibility of current policy narratives. It confronts quantitative data on the production and use of biofuels at member-state (the Netherlands) and EU level against the official storytelling. Our analysis shows that in the Netherlands the actual production and use of biofuels are motivated by economic incentives and trade opportunities rather than the original policy justifications and hitting biofuel targets has become a justification in itself (the phenomenon of displacement). At EU level, the vast majority of the current (inadequate) supply of liquid biofuels still consists in first-generation biofuels, which are to be phased out. Advanced and food-waste-based biofuels are unlikely to fill the void any time soon. The analysis shows incoherence among the narratives underlying the justification of policies and those used for their implementation. It is concluded that the quality of the biofuels policy debate could be improved by acknowledging the existence and influence of untold stories and hidden justification narratives.

1. Introduction

The complex trajectory of EU biofuels policy has attracted considerable attention in the scientific literature [1–6]. This is not surprising given its turbulent history, its challenging governance [7,8], and controversies regarding its impact [9]. The very idea of replacing non-renewable petroleum products with biofuels produced from agriculture dates back to at least the 1940s (to the use of biofuels in internal combustion engines in the USA) [10,11]. So does the criticism. "It is said that we should use alcohol and vegetable oils after the petroleum energy has been exhausted. This reminds one of Marie Antoinette's advice to the Paris poor to eat cake when they had no bread. Alcohol and vegetable oils are, of course, more expensive than petroleum fuels. Moreover, if all our crops were converted to alcohol and oil, they would not supply the present rate of petroleum-energy consumption"—Brody, 1945, p. 968 [12]. Detailed scientific assessments proving the inefficiency and high environmental impact of biofuels—and biomass in general—date back to the early 1980s [13–15]. MacKay, a highly distinguished British scholar, in his 2009 "Sustainable Energy—Without the Hot Air", argued that biomass is so inefficient we ought not even being talking about it [16]. Yet in 2020, we still are, policy-makers and scientists alike.

The persistent presence of biofuels on the EU's sustainability agenda is part of a more generalized problem that is generated by the powerful attraction of sociotechnical imaginaries [17,18]. Jasanoff and Kim [19] have defined socio-technical imaginaries as the production of collective visions of good and attainable futures through the advancement of science and technology. Indeed, the stability of the EU increasingly depends on rosy visions portraying painless solutions to sustainability problems thus avoiding uncomfortable discussions about our current life style and standard of living [20,21]. Official storytelling about energy policy is intoxicated by 'hero stories' (as opposed to learning or caring stories) [22]. As a result, policy discussions on alternative energy sources have become muddled, mixing justifications, strategies and explanations with expectations and desired solutions.

In this paper, we investigate the co-existence of different narratives surrounding the long-term goals and short-term targets for biofuels and the related (often contrasting) "scientific evidence". The analysis is motivated by the central question: Why does or should the EU produce biofuels? To answer this question, the following issues are examined:

* Corresponding author.
E-mail address: mario.giampietro@uab.cat (M. Giampietro).

https://doi.org/10.1016/j.erss.2020.101810
Received 8 April 2020; Received in revised form 21 September 2020; Accepted 26 September 2020

1. The policy discourses at EU level about the role that biofuels can and should play in our quest for sustainability (some of which have been officially endorsed in the formulation of policies, while others have implicitly influenced the political decision-making process);
2. The quality of the existing narratives about biofuels in relation to what is actually happening with biofuel production and consumption at member state and EU level, using a novel approach called Quantitative Story-Telling and using the Netherlands as a case study;
3. The consistency between justification, normative and explanation narratives in this policy domain.

Justification narratives are here defined as the concerns to be addressed, i.e., the overall goals to pursue. Normative narratives are the strategies and tactics adopted toward achieving these goals (actions to be taken), i.e., the provisions in the directives. Explanation narratives refer to the mechanism through which the strategies and tactics are expected to achieve the goals, i.e., the 'scientific evidence' used in the process of decision-making. These definitions are based on the report of Felt and Wynne [23].

The paper is structured as follows. Section 2 summarizes the terminology surrounding biofuels. Section 3 presents an overview of the various EU Directives on biofuels, i.e., the 'official' storytelling in the past 20 years. Section 4 presents the methodology adopted—quantitative storytelling—for performing a consistency check on EU biofuels policy in relation to the performance of the biofuel system. Section 5 presents the results of this check in relation to what is actually going on in the Netherlands and in the EU in terms of production and consumption of biofuels. The case study on the Netherlands focuses on the phenomenon of displacement (i.e., the target becoming a justification in itself) while the findings at EU level are discussed in relation to the discordance among the official justification, normative, and explanation narratives shaping EU biofuel policies. Section 6 concludes.

2. What are biofuels? — the Tower of Babel

One possible explanation for the confusion surrounding the biofuels debate lies in the confusion around the term biofuel itself and its categorization. What is a biofuel? While the definition of biofuels is legalized in the EU Directive on the Promotion of the Use of Energy from Renewable Sources (hereafter referred to as RED) —"'biofuels' means liquid fuel for transport produced from biomass" [24] (p. 104), the term is commonly used to refer to other types of energy carriers based on bioenergy (e.g., electricity and heat from firewood, woodchips, biomass pellets, biogas) in legal interpretations outside the EU, in particular in the USA, as well as in scientific and grey literature [25–27]. The categorization of biofuels has gradually changed in time, growing in complexity with the introduction of additional sustainability and greenhouse gas emissions saving criteria in the various updates of the RED [24,28]. At present, categorization is based on the type of feedstock (primary energy sources) used for its production, the ecological impact and potential alternative uses of the land from which the feedstock is obtained, and its climate mitigation potential. The criteria used in the categorization are relevant for the feasibility of meeting the biofuel targets set and for qualifying for financial incentives.

The European Commission uses the following definitions [26,29]: Conventionally produced or first-generation biofuels are "biofuels produced from food crops, such as sugar, starch and vegetable oils. They are produced from land using feedstock which can also be used for food and feed". Advanced or second and third generation biofuels are defined as "biofuels produced from feedstock that do not compete directly with food and feed crops, such as wastes and agricultural residues (i.e. wheat straw, municipal waste), non-food crops (i.e. miscanthus and short rotation coppice) and algae." Note, however, that with the 2018 recast of the Renewable Energy Directive, biofuels produced from used cooking oil and animal fats are explicitly excluded from the definition of advanced biofuels ("'advanced biofuels' means biofuels that are produced from the feedstock listed in Part A of Annex IX", p. 104 of [24]) and are loosely referred to as 'other biofuels' (thus formalizing the distinction already introduced in the 2015 amendment, Directive 2015/1513, [28]). Article 29 of the 2018 recast of the RED defines minimum GHG savings requirements for biofuels destined for the transport sector (compared to fossil fuels), which gradually become stricter in time [24].

Note that terminology in the USA differs markedly. The revised Renewable Fuel Standard (RFS2), based on the Energy Independence and Security Act (EISA) of 2007 [30], distinguishes between two renewable fuel categories: conventional biofuel and advanced biofuel. Conventional biofuel is defined as 'renewable fuel that is ethanol derived from corn starch'. Advanced biofuels comprise cellulosic biofuel, biomass-based diesel, and other advanced biofuels that meet life cycle GHG emissions thresholds, specific for each category, requiring a percentage improvement relative to the emissions baseline of the gasoline and diesel they replace. The latter category of 'other advanced biofuels' includes, among others, ethanol derived from sugar or starch (other than corn starch) and ethanol derived from waste material (including animal waste and food waste). Note that the RFS2 designates Brazilian sugarcane ethanol as an advanced biofuel with high mitigation potential (50%+ reduction in GHG emissions) [31,32].

The heterogeneous and changing classification of biofuels and the arbitrarily selected methods and assumptions used to measure compliance with the sustainability criteria (notably GHG emissions, e.g. [33–35])—as well as the changing regulatory frameworks and moving targets—have created a Tower of Babel situation in which the confusion distracts from the bigger picture (why are we producing biofuels in the first place?), focusing the attention on the targets and the criteria associated with incentives instead, outside of a proper semantic context.

For sake of clarity, throughout this paper, we use the legal definitions and classification of the European Commission, as laid down in the recast of the Renewable Energy Directive [24].

3. EU directives on biofuels — more than two decades of storytelling

The promotion of biofuels in the EU started back in the 1990s and has been implemented through a variety of policy instruments dealing with distinct aspects of the biofuels production chain. The evolving Common Agricultural Policy (CAP) supported the growth of energy crops, the Fuel Quality Directives allowed blending, and the Energy Taxation Directive made it possible for Member States to grant tax reductions/exemptions in favor of biofuels [36,37]. We provide here a short chronological overview, with an emphasis on the motivations (justification narratives) used for promoting biofuels on the EU political agenda.

The first motivation for the political debate on biofuels was related to agriculture [3,36,38,39]. The 1980s saw the problem of surplus wine and grain production in the EU. The crisis distillation mechanism of the wine Common Market Organisation created the need for an outlet of bioethanol produced from wine surplus [40]. The 1992 CAP reform required farmers to set aside 10 per cent of land mainly to counteract the surpluses of cereals. In 1993, a Non-Food Set Aside scheme (NFSA) was introduced as part of the CAP that allowed set aside land to be planted with energy crops, while farmers could still claim the set-aside premium [41]. The CAP Reform of 2003 introduced an additional aid mechanism supporting the production of energy crops also on non-set-aside land (decoupling) through the Energy Crop Scheme, which amounted to €45 per hectare with a maximum guaranteed area of 1.5 million hectares as the budgetary ceiling [42].

Even if around the turn of the century two other justification narratives—reducing global greenhouse gas emissions and guaranteeing security of energy supply—enter into the official discourse (e.g., [43–45]), it is commonly assumed that the 2003 Biofuel Directive, the first EU directive setting (indicative) targets for biofuels in transport, was born from the political ambition to develop new market outlets for the energy crops promoted through the CAP [37,38]. Agricultural interests remained relevant in shaping policy decisions about biofuels and the support for bioenergy eventually eliminated from the first pillar of the CAP in 2008 and 2010 reentered in the second pillar—rural development policy [46,47]—through several measures supporting bioenergy development, thus adding a further justification narrative to the discourse over biofuels—i.e., sustainable rural development [2,37].

The EU Biofuel Directive (Directive 2003/30/EC, 8 May 2003) formally aimed at contributing to reducing CO_2 emissions from transport, reducing dependence on imported energy (security of energy supply), and creating new opportunities for sustainable rural development [48]. The directive required Member States to strive for the replacement of at least 5.75% of transport fossil fuels with biofuels by 2010, with an intermediate target of 2% by the end of 2005 (see Table 1). Note that the targets were not mandatory and calculated on the basis of the energy content of all petrol and diesel for transport purposes placed on their markets. Member States could deviate from the reference values in the Directive when justified.

In 2009, following concerns of the Commission about Member States failing to meet their indicative targets [49] and the publication of a Biomass Action Plan [50] and comprehensive EU Strategy for Biofuels [51], the Biofuel Directive of 2003 was repealed by the Renewable Energy Directive (2009/28/EC) (RED-I). This directive sets a binding 10% target for renewables in transport for 2020, and introduces the multiple-counting of renewable electricity and advanced biofuels [52] (see Table 1). Although the 10% target includes not only biofuels, but also other renewable energy sources, the Commission (still) considers that “biofuels are the only available large scale substitute for petrol and diesel in transport” [53]. That same year also saw an amendment of the Fuel Quality Directive (FQD) imposing that the road transport fuel mix in the EU should be 6% less carbon intensive than the fossil diesel and gasoline baseline by 2020 [54], thus complementing RED-I. Reducing greenhouse gas emissions from transport and securing energy supply through reduced dependence on (oil) imports and diversification of energy sources remain the dominant motivations [51].

Meanwhile, the food price crisis of 2007–2008 had ignited a heated debate on the use of food as fuel feeding the cars of the rich [55–59] and evidence that crop-based fuels cannot provide significant GHG savings, if any [60–62], nor fossil fuel savings [63,64] was rapidly accumulating. The growing concern for the impact of indirect land-use changes (ILUC) on GHG emissions provided an important blow to the plausibility of the justification narrative associating the production of biofuels to a reduction of emissions [60,65–67]. In 2012, acknowledging the evidence that biofuels not necessarily contribute to the desired reduction of GHG emissions due to the effect of (indirect) land-use changes, as well as the evidence of other detrimental effects of biofuels production—such as the negative impacts on both food security [68] and the environment through destruction of tropical forests, loss of biodiversity, depletion of water resources, pollution of water due to the use of fertilizers [57,69]—the European Commission proposed a cap of 5% on the contribution of conventionally produced (first-generation) biofuels to the EU’s 2020 transport mix [70]. However, this proposal was not well received by the Council and the Parliament and some of the Member States pressed the Commission to raise the cap to 7% and to ignore the ILUC-effects in the accounting of greenhouse gas emissions [71].

A communication from the European Biodiesel Board accused the Commission of “purposely causing the death of the whole EU biodiesel industrial sector” [72] as the ILUC proposal would result in “closing hundreds of production sites worth many billions euros of recent investments and driving to the immediate loss of 50,000 direct and 400,000 indirect employments in the EU biodiesel production chain” [72]. Note that Charles et al. [73,74] estimated that in 2011 alone, the EU allotted approximately 5.5–6.9 billion EUR to subsidizing biofuels. This represents a significant amount if one considers that the size of the EU biofuel market was estimated at around 13–16 billion EUR for that year.

The RED-I was eventually amended by the ILUC directive in 2015 (Directive 2015/1513) [75], limiting the maximum contribution of biofuels to 7% of transport energy and requiring reporting of their ILUC emissions. Nonetheless, these emissions are not accounted for in the evaluation of the GHG performance of a biofuel, thus leaving open the possibility for high-emitting biofuels to access the Common Market and receive support [76]. As observed by Purkus et al. [4], the Council 2017

Table 1
Summary of the main targets for the use of renewable energy in the transport sector (mainly road and rail) by directives. Of these directives, all but the TBD are currently in force (simultaneously). Abbreviations: TBD: Transport Biofuels Directive 2003/30/EC of 08 May 2003; RED-I: Renewable Energy Directive 2009/28/EC from 23 April 2009 (in force); FQD: Fuel Quality Directive 2009/30/EC of 23 April 2009, amended 2016 (in force); ILUC: Directive (EU) 2015/1513 of 9 September 2015 (in force); RED-II: Renewable Energy Directive (recast) 2018/2001 of 11 December 2018 (in force).

TBD (2003)	RED-I (2009)	FQD (2009)	ILUC (2015)	RED-II (2018)
Replacing at least 5.75% of all transport fossil fuels (petrol and diesel) with biofuels by 2010. Intermediate target of 2% by 31 December 2005. Targets represent not mandatory reference values and refer to fuels for transport purposes placed on the market.	Renewable energy share in the transport sector at least 10% by 2020. Different renewable energy sources are factored in differently: the contribution of advanced biofuels counts 2 times and electricity from renewable sources 2.5 times.	Reduction in fuel GHG emissions of at least 6% by 2020.	Amends RED-I: Conventional biofuels smaller than 7% of final consumption of energy in transport in 2020 (cap). Advanced biofuels > 0.5% (voluntary). Harmonization of the list of feedstocks for biofuels eligible for double counting towards the 2020 target of 10% for renewable energy in transport (Annex IX).	Renewables: >14% of final energy consumption in transport in 2030. Advanced biofuels and biogas produced from feedstock listed in Part A of Annex IX: >0.2% of final energy consumption in transport in 2022; >1% in 2025; >3.5% by 2030. Biofuels and biogas from UCO and animal fat (Part B of Annex IX): <1.7% of transport fuels (cap). High ILUC biofuels: 0% in 2030. Definition of sustainability and GHG emission criteria for bioliquids used in transport to determine their eligibility for counting towards the overall 14% target and for financial support by public authorities.

proposal for the recast of the RED [77], launched shortly after, even if recognizing the limited future role of food crop-derived biofuels, "does not counter this assessment but stresses planning security for investors as the main argument for maintaining a transport sector target towards which first-generation biofuels can [still] contribute to a significant extent" [4] (p. 537). In other words, although the official justification for substituting oil-based fuels with biofuels is discredited, another one—-that of guaranteeing investor security—is used to cling to the original plan. Obviously, given that thus far the production of cellulose-based biofuels did not develop to any significant extent due to technological and economic hurdles, the first generation of biofuels, even if incompatible with the original justification narratives, was essential in keeping the policy discourse alive.

In the 2018 recast of the Renewable Energy Directive [24], the minimum share of renewable energy in the transport sector is increased to 14% by 2030; at least 3.5% of the transport energy must be derived from advanced biofuels and a progressive cap is placed on high ILUC biofuels until reaching 0% by 2030 (Table 1). Given the persistent difficulties in the development of advanced biofuels, in order to promote their development, the RED-II Directive retains the double-accounting system already proposed in RED-I. This means that the contribution of biofuels made from biomass not competing with food and not generating detrimental land-use changes (i.e., advanced biofuels listed in Part A of annex IX and other biofuels including used cooking oil in Part B of the annex) is double-counted in relation to the calculation of the mandatory share of renewable energy in the transport sector. Nonetheless, the production of biofuels from used cooking oil and animal fats (part B of Annex IX) is discouraged to less than 1.7% of the energy content of transport fuels supplied for consumption or use on the market. Hence, the recast of the RED hangs on to the original expectations about the supply of advanced cellulosic biofuels, and continues to promote their development.

A delegated act adopted by the Commission in May 2019 [78], supplementing the RED II, sets out the criteria for certification of low ILUC-risk biofuels, bioliquids and biomass fuels and for determining the high ILUC-risk feedstock for which a significant expansion of the production area into land with high-carbon stock is observed. With this act, palm oil diesel is considered 'high ILUC risk'.

Over time, we thus find not only a continuous increase in ambitions, but also a continuous complexification of the relation between the definition of justification narratives (the concerns to be addressed, i.e., the overall long-term goals) and the related normative narratives (the strategies and tactics adopted, i.e., the directives) resulting in a continuous patching of targets (short-term objectives).

4. Checking the plausibility of the narratives: Quantitative storytelling

Quantitative Storytelling is a novel approach that involves a quantitative exploration of multiple narratives in a given policy domain [79]. In the landscape of methodologies using stories, narratives or storytelling sketched by Moezzi et al. [80], quantitative storytelling positions itself as an approach that uses 'stories' as data. The stories used are government narratives on societal transitions. They are critically examined using predominantly quantitative methods, varying from integrated assessment models to simple back-of-the-envelope calculations. Rather than trying to compile evidence in support of a given narrative, or determine the 'best course of action', quantitative storytelling operates 'via negativa'; it attempts to test whether the examined framings are in conflict with quantitative analytical checks [81]. The theoretical foundation of quantitative storytelling is the theory of post-normal science, which explicitly acknowledges the unavoidable presence of scientific uncertainty and value plurality in the sustainability discussion [82,83]. Post-normal science was developed in response to 'wicked problems' [84] originating from societal concerns or policy issues for which a variety of legitimate and often contrasting perceptions about the 'truth' of knowledge claims co-exist, thus creating irreducible uncertainty, even ignorance, about the future state of the system. Post-normal science shifts the focus of quality control from the scientific information itself to the decision-making process and advocates the involvement of an extended peer community to check the quality of the narratives used to frame the problem.

Quantitative storytelling has first been systematically applied in the EU project 'Moving towards adaptive governance in complexity: Informing nexus security' (MAGIC) to check the robustness, the usefulness and the fairness of the narratives used to discuss and select EU policies related to sustainability and climate change [35,81,85]. It has been applied to agriculture [86], desalination [87], aquaculture [88], and renewable energy sources (wind and solar) [89]. This is the first time quantitative storytelling is applied to biofuels.

To check the plausibility and the expected impacts of biofuels policy solutions, the conceptual map shown in Fig. 1 is useful. The rectangles in Fig. 1 describe the relations over functional elements, the ovals describe the expected technical coefficients (profiles of inputs and outputs) associated with the identity of the structural elements. This multi-level representation of the set of expected (established) relations among functional and structural elements allows a simultaneous handling of quantitative assessments across different scales and dimensions of analysis [88]. In the quantitative storytelling of biofuels presented in the next section, relevant aspects of the pattern of production and consumption of biofuels are assessed at different levels of analysis. Indeed, it is evident from the map that different aspects of the issue can only be 'seen' from different levels of analysis:

(i) the whole network – the overall requirement of liquid biofuels (expressed as a mix of biodiesel and bioethanol) is assessed on the basis of the end-uses in society to check whether the supply of biofuels is or can be consistent with a given justification narrative;
(ii) any given functional elements of the network – the overall characteristics and limits of the supply of a given system of biofuels, in order to check whether a given policy aimed at boosting the production of that system is credible (the plausibility of targets);
(iii) any given components of a functional element – the specific characteristics of relevant production processes are assessed to describe the "state of the art" technology for that product;
(iv) any given structural elements of a component – the individual profiles of inputs and outputs of specific local production processes are assessed to estimate local environmental impact.

The conceptual map can be used in a 'diagnostic mode' (examining the current situation) as well as in an 'anticipatory mode'. In the anticipatory mode, alternative options are explored by replacing selected elements with the desired alternatives.

Based on the relational organization of the information illustrated in Fig. 1, the compatibility of the expected outcomes of the policy—the expected establishment of a new metabolic pattern of production and consumption of biofuels— is evaluated against the expected constraints (across levels) on both biofuel production and consumption. These constraints may be: (i) beyond human control (feasibility); (ii) under human control (viability); (iii) determined by existing institutions and normative values (desirability). A systemic quantitative application has been illustrated by [25]. In this work, the conceptual map is used to perform four interrelated quality checks in the quantitative storytelling – feasibility, viability, desirability and openness, as described in [90].

1. *Feasibility* is essential for the debate on biofuels because external limits define the maximum amount that can be produced: it determines the plausibility of the normative narrative. Depending on the type of biofuels, external limits have to be assessed in different ways. For first-generation biofuels the external limits are given by: (i)

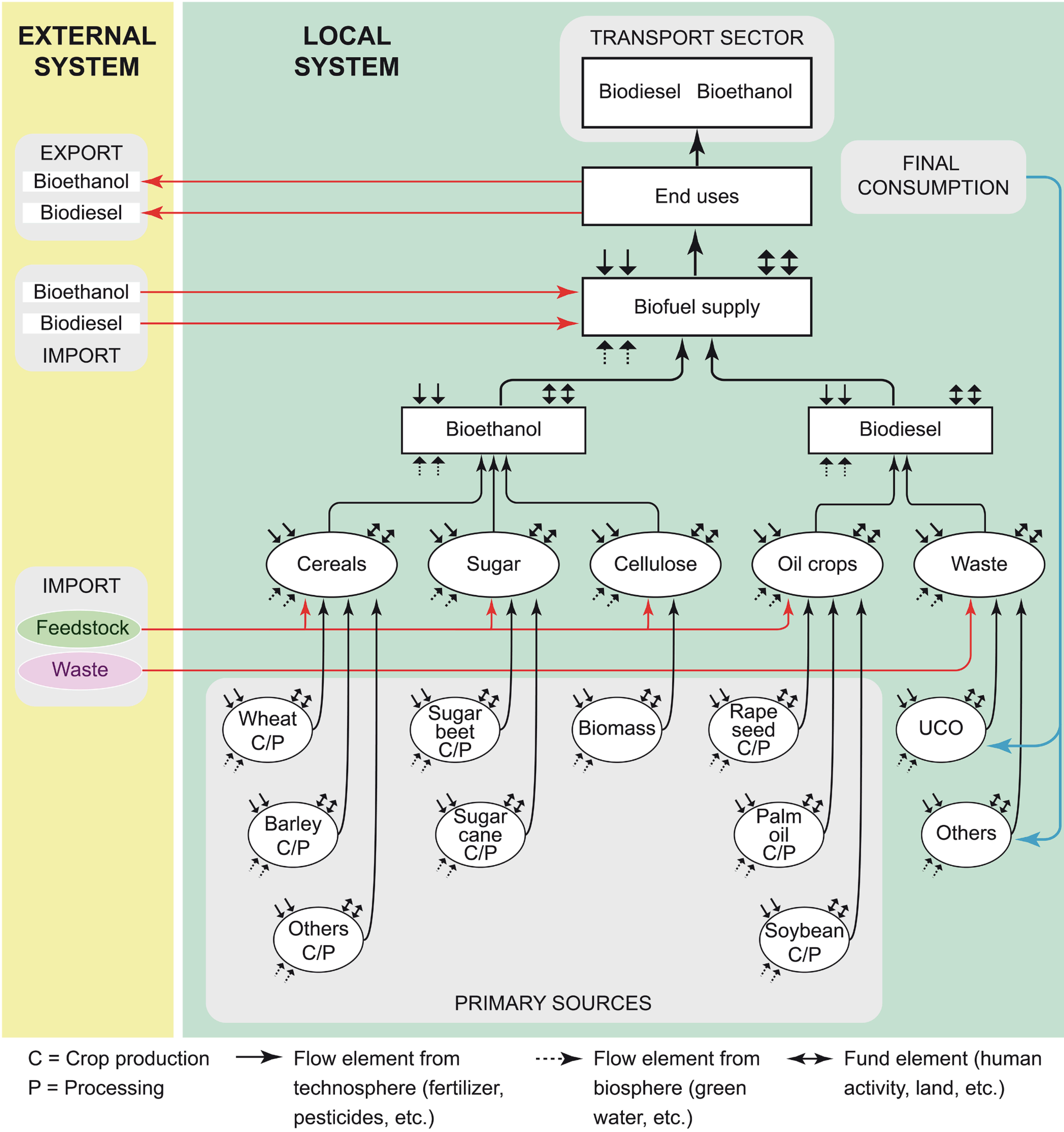

Fig. 1. The functional/structural relations of a biofuel production-consumption system.

the availability of land, water, soil, biodiversity, solar radiation needed to produce agro-feedstock; and (ii) the sink capacity required to handle the environmental pressure associated with the use of fertilizers and pesticides. The supply of cellulose-based advanced biofuels is limited by the availability of primary sources in the form of woody biomass. If this biomass is provided by crops, then they share the same set of limits with biofuels. In addition, if the biomass is derived from crop residues the limit is also associated with the need for leaving a fraction on the field for soil protection. The supply of biofuels produced from waste depends on the size of the waste flows available for their production.

2. The *viability* of specific processes of biofuel production depends on the availability of know-how and technology, the economic viability of the activity, which is affected by costs (labor requirement, fixed capital and inputs) and revenues, and the compliance with existent regulations. It is important to identify situations of *apparent* viability of biofuel production that depend on the existence of EU and/or national subsidies. The use of subsidies may be justified: (i) as a temporary solution to start a new viable/feasible process; (ii) as a stable cost for society that has to be justified by the expression of a required function.

3. *Desirability* refers to the consequences that the changes induced in the metabolic pattern of society (through the production and use of biofuels) have in terms of the concerns and quality of life of citizens (in relation to normative values). This includes potential indirect impacts on human health from pesticide and fertilizer use in feedstock production, as well as the perceived benefits of the public investment of tax payers' money.
4. It is essential to consider the *degree of openness of the system* as imports can be used to lose-up existing constraints. The solution of externalizing requirements to other social-ecological systems carries potential consequences for the overall performance of the system. For example, externalization of the requirements of land, water, and labor and of environmental pressures may undermine the plausibility of the justifications narratives (policy objectives) concerned with energy security and reduction of emissions (e.g., because of indirect emissions due to land-use changes elsewhere). It also entails ethical concerns about the environmental and social impacts generated elsewhere, mainly in developing countries [9].

In the application of quantitative storytelling presented in this paper, only liquid biofuels are considered, as defined in Article 2 of the directive (EU) 2018/2001 [24] (p. 104). The data on the production, importation, exportation and consumption of biofuels in the EU and the Netherlands are from [91,92]. Data on the Dutch population was obtained from [93] and land use in agriculture in the Netherlands from [94]. Renewable energy data for the Dutch transport sector with simple and double counting were obtained from [95]. The Dutch Government [96] provides the composition and country of origin of the raw material used for the production of biofuels that are delivered to the domestic market of the Netherlands. The reference year for the analysis of the Netherlands is 2017.

5. Results and discussion

5.1. Biofuel production and consumption in the Netherlands

The Netherlands was selected as a case study for the quantitative storytelling because it neatly demonstrates the discordance between justification, normative and explanation narratives. The Netherlands does not have a tradition in producing or using biofuels, like France or Germany, and has been relatively slow in developing biofuel market support mechanisms [97]. Nonetheless, its (physical) consumption of liquid biofuels in the transport sector steadily increased from 2 PJ in 2006 to 13 PJ in 2017 [95], and jumped to 21 PJ in 2018 [98] (p. 100). Whereas in 2017 the reported share of (all) renewables in transport amounted to only 5.9%, in 2018 it reached 9.6% (mainly due to the jump in biofuels use), thus bringing the 2020 target of 10% of the RED well within reach [99]. The majority of these reported renewables consisted of liquid biofuels (75% in 2017 and 83% in 2018) [98] (p. 25). Severe land limitations (0.06 ha of arable land per capita) might have been expected to limit the contribution of biofuels to reaching the renewable energy target in transport. Nonetheless, in spite of the land constraint, the Netherlands not only significantly increased its use of biofuels in transport but is well on the way of becoming a major biofuel exporter. An apparent paradox?

The two main liquid biofuels used in the transport sector in the Netherlands are bioethanol, which is generally added to the regular gasoline, and biodiesel. The production, export and import of these two biofuels are illustrated for the period 2011–2018 in Fig. 2.

Bioethanol—The Netherlands does not produce significant quantities of bioethanol and imports this fuel as such. In 2017, the Netherlands imported around 6 PJ (Fig. 2), ranking third in Europe with the highest import volume after Germany (17 PJ) and the United Kingdom (11 PJ). On a per capita basis, the Netherlands occupied the first place with 0.4 GJ/per capita imported per year, followed by Germany and the United Kingdom (0.2 GJ/per capita per year). In 2017, all of the imported bioethanol concerned biofuels; most of the feedstock used for this imported bioethanol was produced within the EU. In particular, 46% of the bioethanol was produced from wheat, of which 87% from the EU; 33% from maize, of which 60% from the EU; 9% from sugar beet, of which 96% from the EU; 11% from sugar cane, entirely from Latin America; 1% from rye and triticale, nearly entirely from the EU [96].

Biodiesel—During the period 2008–2017, biodiesel production in the Netherlands increased by 23 times. In 2017, despite the low level of internal biodiesel consumption, the Netherlands was the country with the third-largest production of biodiesel in Europe (71 PJ), surpassed only by Germany (119 PJ) and France (92 PJ), countries with a considerably larger size. Since 2012 the Netherlands has surpassed the production of Spain and Italy, in spite of the smaller size of its economy and available cropland. According to Sheng Goh et al. [100], this production has been based mainly on imported feed-stocks (predominantly palm-oil). Since 2010 the production of biodiesel has been mainly destined for export. For example, in 2017, 59 PJ of biodiesel were exported, which represents 83% of the total production [91].

The destination of the biodiesel exported by the Netherlands during 2012–2018 is shown in Fig. 3. The data show a steady decrease in the volume of exports to Western Europe. This is mainly due to Germany reducing its imports after the year 2014 because of an increase in its internal supply. In contrast, Northern European countries increased the volume imported from the Netherlands, especially Sweden (the country with the third highest consumption of biofuels in road transportation in the EU in 2017 after France and Germany [91]) and Norway. According to Eurostat [92], Sweden increased its import of biodiesel from the Netherlands from 2014 to 2017 by 9 times. While the available data allow to monitor the type of biomass (feedstock) used in the production of biofuels that are consumed within the Netherlands and counting

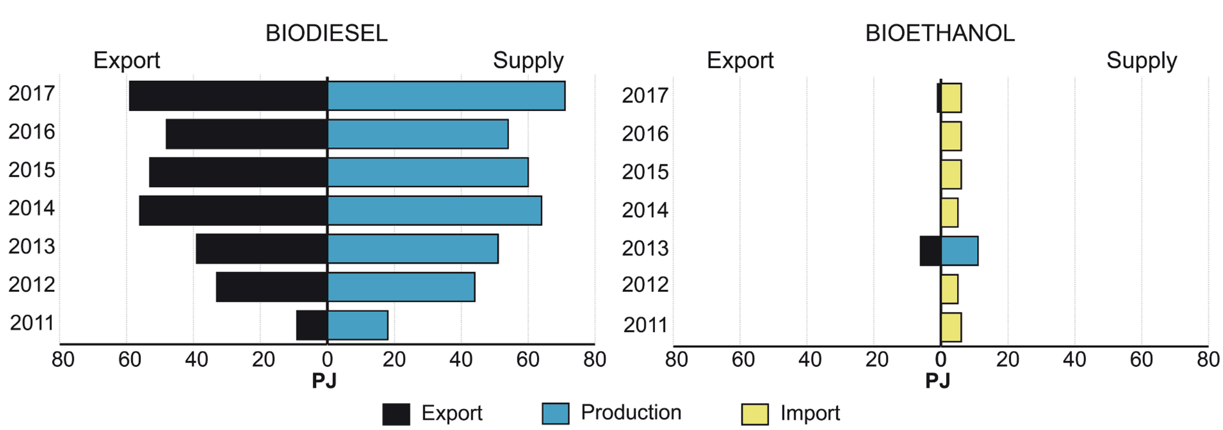

Fig. 2. Supply (local production and import) and export of biodiesel and bioethanol in the Netherlands for the period 2011–2017 [91].

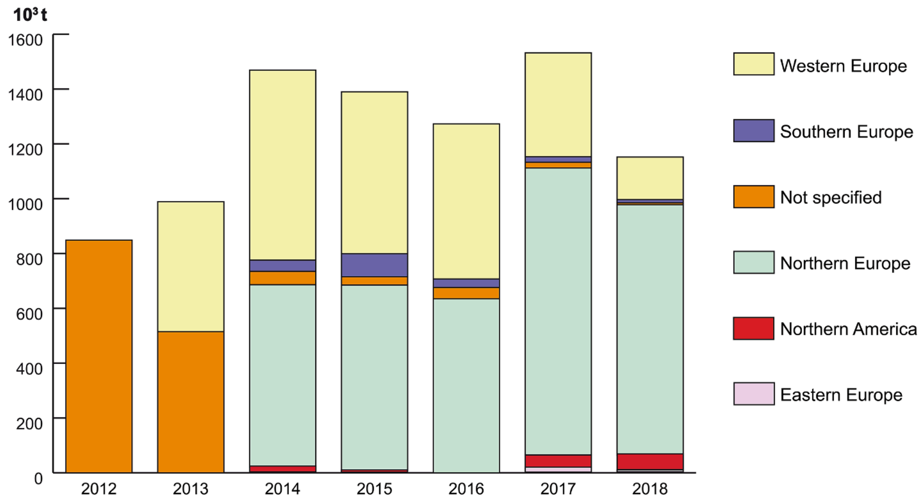

Fig. 3. Destination of biodiesel exports from the Netherlands in 2012–2018.
Source: [92]

toward the renewable energy target in transport, this is not the case for the biofuels exported.

As noted earlier, recent implementation of the RED has encouraged a growing trend in the use of biofuels that allow double counting. According to [95], the consumption of biofuels eligible for double-counting increased from 3 PJ in 2009 to 7 PJ in 2017 in the Netherlands (real consumption without double counting). The consumption of conventionally produced biofuels, not eligible for double counting, decreased from 12 PJ in 2009 to 5 PJ in the same period. Hence, in 2017, 57% of the consumption concerned double-counted biofuels (entirely consisting of biodiesel) and 43% single-counted biofuels (entirely consisting of ethanol blended fuels). Notwithstanding the benefit of double-counting, the share of renewable energy in transport reported for 2017 (5.91% of which 4.55% corresponds to total biofuels and 1.36% to renewable electricity) fell short of the Dutch national target for that year (7.75%) [95,101].

The effect of the double counting on the reported biofuel use in the transport sector of the Netherlands is shown in Fig. 4. The difference between double counting and net accounting corresponds to a virtual biofuel energy deployment that is mainly supplied by fossil fuels.

Apart from the questionable choice of solving real problems (how to reduce actual GHG emissions) with creative accounting solutions (by introducing double-counted imaginary savings subtracted from actual emissions), there is another question. How do we know if all the biodiesel that is double-counted in the bookkeeping effectively belongs to the category of biofuels that is eligible for double counting (those included in Part A and B of Annex IX of the RED) and does not include first-generation fuels?

According to [96], in 2017, biodiesel was the most commonly used biofuel in the Dutch transport sector (accounting for 57%). When considering the special category of biofuels eligible for inclusion in the double-counting scheme, the main raw material reported in the statistics is used cooking oil (UCO), representing around 90% of the total, and animal fats, representing around 10% of the total [96]. So it may be

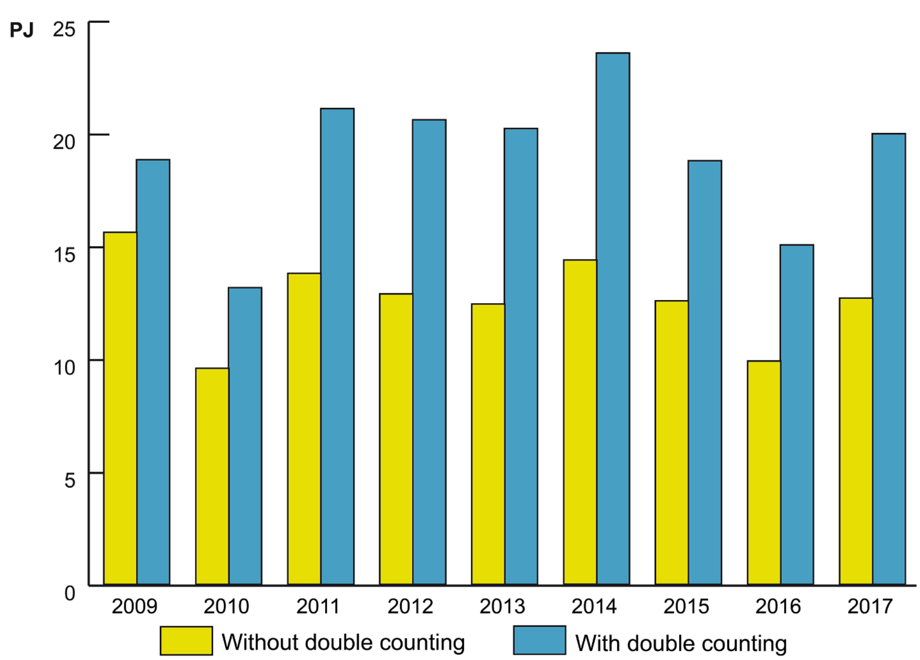

Fig. 4. The effect of double counting on biofuel energy use reported in the transport sector in the Netherlands. Data .
Source: [95]

concluded that the combination of these two raw materials – both eligible for double counting – constitutes the feed-stock used in the Netherlands to generate the (physical) (non-virtual) supply of the biofuels shown in Fig. 2. But is this possible?

Using official data from the Government of the Netherlands [96], in 2017, approximately 13 PJ (becoming 26 PJ with double accounting) of biodiesel from sources eligible for double-counting were delivered to the internal Dutch market. However, Eurostat [91] records that only 7 PJ (without double counting) were consumed in the transport system in that year. Possible explanations for this difference are the storage of this extra production in stocks or unrecorded exports. But could the Netherlands produce this quantity of double-countable biofuels? Based on the data, 90% of the actual flow of biodiesel (13 PJ) per year came from UCO [96]. This would require an availability of UCO in the Netherlands capable of producing 11.7 PJ per year, which corresponds to approximately 24 kg of UCO/person/year in terms of biomass. However, the UCO per capita collected in 2016 from household consumption was 0.21 kg/person/year [102]. Scaling up this value to the national level, this translates in 3600 tons of UCO collected on a year basis (ibíd.). Considering the losses of conversion (about 25%, see [25]) and the energy content of biofuels (37.8 MJ/kg) we find that with the UCO gathered from the households in the Netherlands, one could only cover 100 TJ per year, less than one hundredth of the claimed production of biodiesel eligible for double counting. Note that UCO may also be collected from restaurants, collective kitchens and food industry, so the potential supply is larger. However, even considering these additional sources, the potential domestic supply could not reach >7 kg per person per year (assuming an UCO density of 0.91 kg/l) [102,103], considerably short of the hundreds of kg of diesel fuels consumed per capita per year. Hence, scaling up the biodiesel production from *local* food waste is simply not feasible; it is incompatible with local boundary conditions. Hence, it is the openness of the system that permits the current biofuel supply in the Netherlands: imported feedstock allows to overcome the local biophysical constraints.

As discussed earlier, the plausibility of the production of biofuels can be checked not only in terms of feasibility and openness but also in terms of viability. In 2017, the international price of biodiesel and bioethanol was higher than that of diesel and gasoline, by 1.8 and 1.4 times respectively [104]. In spite of the regulations and subsidies, several biofuel producing companies in the EU, including in the Netherlands, had to close within a few years of operation [105]. Hence, if biofuels were not subsidized and helped by regulation, they would not be economically viable. Clearly, the cost for society of these subsidies could be justified if they would help resolve the original concerns (e.g., GHG emissions, dependence on imports). However, if the expected enlargement of scale of biofuel production cannot possibly materialize to supply a significant amount of alternative fuels, it is unclear why the policy was selected in the first place. For a policy to be desirable it must be able to achieve the results strived for by the justification narratives (responsible use of taxpayers' money). The impromptu strategy of double accounting adopted by the Commission may temporarily hide the failure of previous normative narratives, but it does not solve the problem: if the proposed solution is implausible, cooking the books will not change the situation. On the contrary, it creates negative effects by distorting the biofuels market and in this way encourages frauds [106,107]. In the case of the Netherlands, the use of UCO for the production of biodiesel has increased significantly from 2011 to 2018 (see Fig. 5) and so has the number of different countries supplying it [108]. For example, while in 2015 the imported UCO originated from around 50 different countries, in 2017 this number had risen to 70 countries. This complicates controls on the authenticity of the biofuel feedstock reported and traded [106]. Indeed, there are suspicions that during the period 2015–2016, 59% of the biodiesel sold by the company that accounted for almost one third of the total Dutch biodiesel production in 2015, was erroneously certified as sustainable [109,110].

This simple exercise of quantitative story-telling shows an incongruity between the official narratives about biofuels at EU level and the actual flows of biofuels observed at member state level in the Netherlands:

- In terms of feasibility, given the limited availability of land in the Netherlands, it is simply impossible to cover a significant share of liquid fuels for transportation from first-generation biofuels or cellulosic-based biofuels produced from *local* feedstock [111]. There are not sufficient local primary sources. The same is true for the production of biodiesel from UCO and animal fats. There is not sufficient *local* food waste.
- In terms of openness, the current deployment of biofuels is possible only because biofuels (bioethanol) and feed-stock (for biodiesel) are imported from elsewhere: not even 10% of the biofuels used in transport in the Netherlands is produced from local feedstock [108]. This questions the justification narratives of energy security (reducing the dependence on energy imports) and rural development. The observed increase in diversification of UCO suppliers in the Netherlands, while reducing dependence on any one supplier in particular, complicates the certification of the authenticity of feedstock supply and has encouraged fraud.
- In terms of viability, all current types of biofuels need financial support to survive on the fuels market, with required support being most pronounced for advanced biofuels [112]. As noted, most of the biodiesel produced in the Netherlands ends up being exported. Given that Rotterdam is a main entry point of international trade for the EU and biofuels and feedstock are bulk commodities, it makes eminent sense to do much processing/blending at ports. It is obvious that if support schemes guarantee a profit, feed-stocks will be imported and the biofuel produced exported, regardless of whether or not this responds to the original justification narratives.
- In terms of desirability, the fact that the production of conventional biofuels and biodiesel from UCO do not significantly contribute to the reduction of GHG emission, energy security or rural development in the Netherlands raises questions as to why the Dutch taxpayer should contribute to biofuel support schemes, especially if prone to fraud.

The case study of the Netherlands also shows that when implementing EU policies involving complex issues through national bureaucracies, the use of targets and simple indicators carries the risk of generating *displacement* [113]. National policy makers end up observing and judging results in relation to the 'artificial' representation of the problem given by the achievement of targets. They no longer appreciate the results in the context of the original justification narrative; the target becomes a justification in itself. The use of double-counting of UCOs and animal fats as well as statistical transfers of renewable energy—both facilitated by the RED (Articles 27 and 8, respectively)—to hit the renewable energy target in transport in the Netherlands [114–116] is a blatant example. The continuous patching of targets of the EU biofuel and renewable energy directives also distracts from the underlying concern (replacing liquid fossil fuels with biofuels to reduce GHG emissions and reliance on energy imports) and obfuscates the evaluation of the plausibility of the proposed policies. It is one issue whether or not it is possible to reach a temporary target (e.g., 3.5% of transport fuels from biofuels), but quite another whether or not this has led to a significant reduction in emissions and more energy security. The problem of displacement is not limited to biofuels policy but is evident in many policy areas in the EU (e.g., [117–120]) and elsewhere ([121]).

5.2. Biofuels at the EU level

In this section we provide the big picture at EU level based on the conceptual map shown in Fig. 1 and the Dutch case analyzed in section 5.1. Several key points emerge that question the formal justifications of EU biofuels policy.

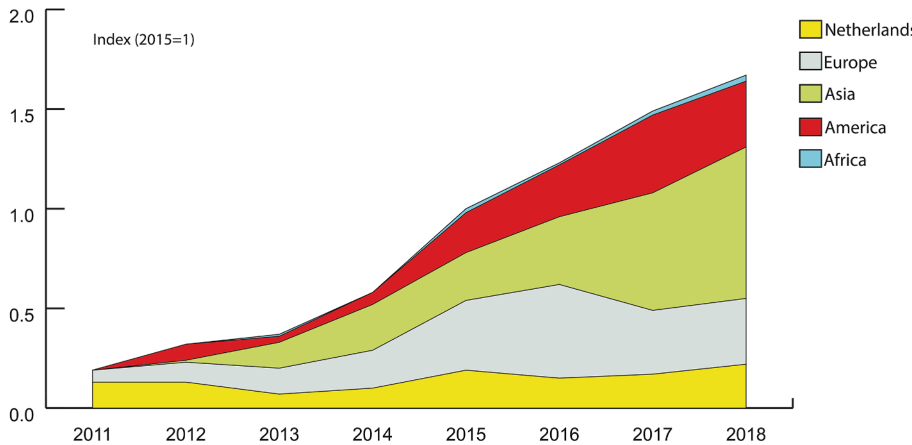

Fig. 5. Relative increase in and origin of used cooking oil used for the production of biofuels in the Netherlands for the period 2011–2018 (based on physical energy content). .
Source: [108]

The actual deployment of liquid biofuels (biodiesel and bioethanol) in the transport sector of the EU, compared to the use of liquid fossil fuels, is shown in Fig. 6. According to these data, the actual supply of biofuels in the EU would have to be increased by orders of magnitude in order to make a significant contribution toward the main goals stated in the justification narratives (energy security; reduction of emissions). But how can a significant increase in the actual supply of liquid biofuels possibly be realized when: (i) the RED II (normative narrative) limits the use of conventional biofuels to phase them out; (ii) advanced biofuels have not delivered on their promise; and (iii) 'other biofuels' based on food waste are not only limited in supply but also actively discouraged in the RED II? These data challenge the validity of the 'scientific evidence' used to defend the choice of current EU energy policy and flag a discrepancy between explanation and normative narratives.

The vast majority of the current (inadequate) supply of liquid biofuels (biodiesel and bioethanol) still consists in conventional biofuels (Fig. 7). This in spite of the fact that they have long been proven incompatible with the official justification narratives. Yet in 2016, biofuels still accounted for the vast majority of the subsidies paid in support of EU biofuel policy. As mentioned earlier, the slow adjustments in EU renewable energy policies could be defended as a way of protecting 'investor security' [4]. Nonetheless, in the long run, this justification may become politically unacceptable. Indeed, the continued production of conventional biofuel feedstock on cropland within the EU and the significant role played by biofuel feedstock (crops) imports (about 30–35% of feedstock for biodiesel and bioethanol is not of EU origin, see Fig. 7) question the desirability of the existing solution in face of the growing concern for future food and environmental security at both EU and global level [122–125].

For example, in 2016, the mix of biofuels in the transport sector of the EU (including UK) consisted of 80% biodiesel and 20% bioethanol [91]. Of the energy consumed as biodiesel, approximately 20% was derived from imported palm oil (around 91 PJ) (see Fig. 7) [126]. If the EU would replace the amount of biodiesel produced from imported palm oil (since 2019 palm oil diesel is considered 'high ILUC risk') with locally produced rapeseed, 1.8 million hectares of arable land would be required (based on an energy productivity of 52 GJ biodiesel/ha for rapeseed compared to 88 GJ biodiesel/ha for oil palm [127]). Note that these 1.8 million hectares cultivated with rapeseed would cover only 1% of the total diesel consumed in the EU, but significantly increase the tension between the Common Agricultural Policy objectives of increasing competitiveness and preserving landscapes and biodiversity [128].

As shown in Fig. 7, the contribution of cellulosic bioethanol is practically irrelevant and has failed to meet the original expectations raised by the Commission [45] (p. 37–39) to overcome the biophysical limits on the supply side. The supposition that any type of woody-biomass (including energy crops, wood and any other forms of biomass) can be used as feedstock for biofuel production resulted in a dramatic overestimation of the potential supply from cellulosic biofuels

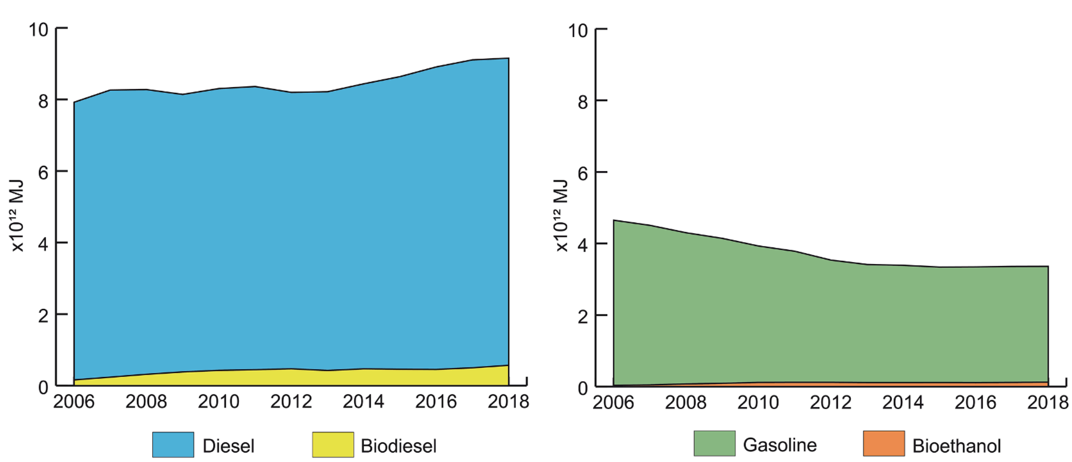

Fig. 6. Energy used in the EU transport sector (EU27 plus UK) in 2009–2017 by source: fossil fuels (diesel and gasoline) versus biofuels (biodiesel and bioethanol) [91].

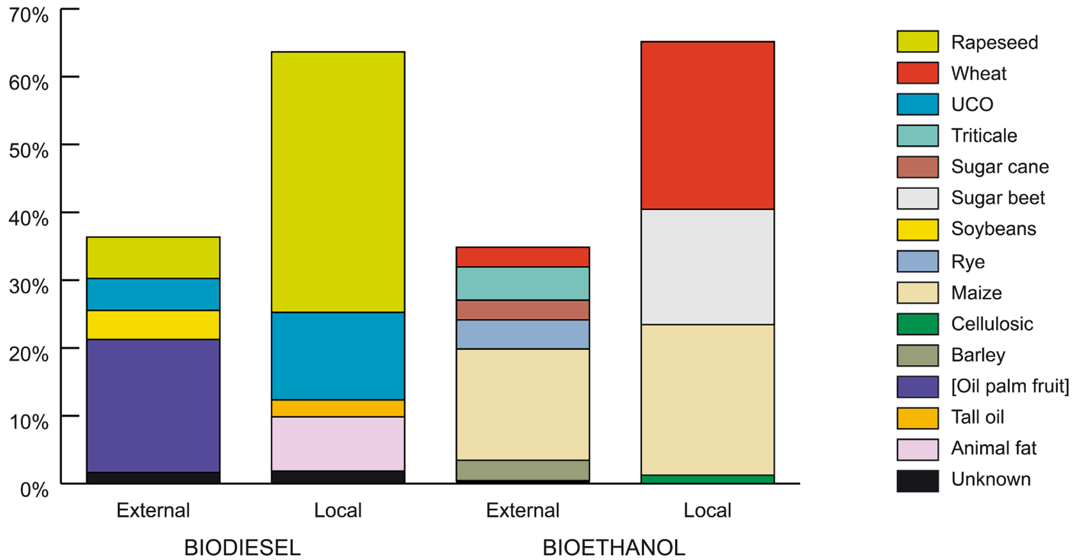

Fig. 7. Feedstock used for the production of the biofuels used in the European Union, according to its origin (external versus locally produced), in the year 2016 (data).
Source: [126]

and has played an important role in keeping biofuels alive in the policy discussion. The production of cellulosic ethanol has not fulfilled expectations because of technical and economic problems (viability) [111,129] and falls short even of minimum targets [5].

As for the production of biodiesel, only 29% is produced from feedstock listed in Annex IX eligible for double counting. However, these biofuels are based on the utilization of resources of limited availability: (i) 8% from animal fat (a by-product the production of which cannot be scaled up easily and the use of which is discouraged in RED II) and 3% from tall oil (a co-product of the production of wood pulp in northern European countries); and (ii) 18% from UCO, the limitations and the problems of which have been pointed out for the case study of the Netherlands. Biodiesel from local UCO could at most replace 1.5% of EU diesel consumption (2015 level) [130]. Note that the use of biomass waste as feedstock for biofuel generation carries the risk of discouraging the production of 'higher-value' materials [131]. A central pillar of the EU bioeconomy strategy is the principle of 'cascading use of biomass' that prioritizes exploitation towards added value products before eventual recycling and conversion to energy [132]. For instance, in order to meet RED II targets, it is expected that an increasing fraction of tall oil production will be diverted for the generation of advanced biofuels [133]. This could potentially limit its use for the production of bio-based chemicals and materials.

The current reliance on used cooking oil for the supply of liquid fuels is indicative of the absurdity of the situation. Given that UCO is only available in small quantities (about 7 kg per person per year– [103]) and difficult and expensive to collect, import of UCO cannot be considered a "sustainable solution" to guarantee energy security and reduce emissions (e.g., [116]). Indeed, even the Commission seems to recognize this: Article 27 of RED II states that "for the calculation of the numerator, the share of biofuels and biogas produced from the feedstock listed in part B of Annex IX shall, except for in Cyprus and Malta, be limited to 1.7% of the energy content of transport fuels supplied for consumption or use on the market". Thus, remarkably, UCO is still eligible for double counting to promote its use but at the same time its use is explicitly discouraged.

This shows again that the plausibility of biofuels policies boils down to the credibility of a large-scale cellulose-based fuel revolution. The technology necessary to achieve commercial development of advanced biofuels has yet to overcome several obstacles [134], and the doubts about the plausibility of the proposed solutions are growing [135].

A holistic picture of the pattern of production and end-uses of biofuels by category provides a better understanding of the different issues involved in biofuels policy. Indeed, we must keep in mind that targets in themselves may have nothing to do with the expectations of the underlying justification narrative. Modest intermediate targets may represent a good start for a transition to a low carbon economy, but only if the proposed solution is good and can grow to significant levels. If we cannot expect advanced biofuels to cover a significant fraction of the total fuel supply in the medium-long term, then we should not be very excited by the reaching of an initial target.

In Section 3 we saw that three 'official' justification narratives have been put forward in the EU discourse on biofuels policy: (i) solving the problem of energy security; (ii) solving the problem of greenhouse gas emissions in the transportation sector; (iii) stimulating rural development. Other justifications are implicit, such as solving temporary problems in the implementation of agricultural policies (e.g., creating market outlets) and guaranteeing investor security [3,4]. By falsifying official narratives, quantitative storytelling seeks to broaden the discussion and draw attention to other ('untold') perceptions of a given issue that may exist among other social actors. For example, with regard to biofuels, the following justifications supported by different types of social actors may have played and still play a role in the choice of biofuels policies:

1. Business sector: (i) Farmers may see another outlet for products and a justification for continued subsidies; (ii) Agribusinesses may see market expansion for agricultural inputs and diversification (guaranteed markets) for outputs, as well as a narrative supporting industrialized agriculture (increasingly challenged by consumers, but the only model capable of supplying biofuel feedstock at scale); (iii) The car and oil industries may play along as biofuels greenwash their business model and existing technology (Internal combustion engine running on liquid fuels), which are being increasingly challenged by concerns about climate change and resource exhaustion. They may prefer the trouble of integrating a token amount of biofuel to the alternative of higher fuel economy standards, higher car/road/fuel taxes, increased pressure towards other modes of transport, or other drivetrain technologies, such as electric cars.
2. EU consumers: Consumers' environmental conscience is salved if they can believe they have done "something" about transport emissions. The use of biofuels permits them to do so without having to restrict the use of their cars.

3. From EU politicians: they are forced to adopt discourses and narratives that please their voters.

All these perceptions and concerns are not necessarily equivalent in terms of the robustness of the underlying knowledge claims, but, at the level of the perceptions of social actors, equally legitimate. When dealing with complex problems, it is unavoidable that the adoption of a hegemonic narrative focusing only on a limited number of 'official concerns' (criteria of performance) and a closed set of options (chosen alternatives) generates hypocognition [136,137], i.e., the potentially dangerous (and possibly intentional) neglect of other potentially relevant concerns and useful alternatives in the definition of the option space. The ultimate goal of quantitative storytelling is to expose other justification narratives that may be in play and to dismantle 'socially constructed ignorance' [113].

6. Conclusions and policy implications

The quantitative storytelling presented points at the inadequacy of the explanation narratives currently used to inform EU decision makers in the policy domain of biofuels. The explanation narratives lack the systemic thinking that would be required for structuring the quantitative analysis of the metabolic pattern of biofuel production and consumption in order to suggest effective and meaningful targets. The embarrassing assumption that the first generation of agro-biofuels represents a feasible, viable and desirable alternative for replacing a significant fraction of liquid fossil fuels while reducing emissions simply indicates a poor semantic framing of the quantitative analysis.

In the case of the Netherlands, biofuels are produced from imported feedstock and then exported. This behavior is inconsistent with the main justification narratives and could have been anticipated given the implausibility of the policy: in the Netherlands there is not enough land nor sufficient wastes (UCO included) to produce the required amount of feed-stock. In this situation, the justification narratives of energy security and reduction of emissions (considering the effect of land-use change of imported inputs) definitely do not hold.

Indeed, our analysis shows that: (i) The official set of justification narratives does not refer to concerns that are addressed by the selected policies. The existing policies seem to address other legitimate concerns of specific groups of relevant social actors (citizens, consumers, entrepreneurs, politicians). Quantitative story-telling is useful to falsify official storytelling and points at the potential role of other (hidden) justification narratives that may be less defendable in public discussions; (ii) The targets proposed by the various overlapping directives are implausible. Not only have they been proven implausible by a simple quantitative exercise, but also by the systemic missing of the targets in time [4,5].

The existing confusion in the policy discourse has allowed a dangerous twist in the logic of target setting. The expected direction of the chain of policy decisions is: (i) *why* do we need biofuels? (the concerns to be addressed—justification narrative); (ii) *how* can we achieve these goals? ('scientific evidence'—explanation narrative) (iii) *what* actions should we undertake toward achieving these goals? (directives/targets—normative narrative). In a situation of extreme confusion, as is the case with biofuels policy, there is the risk of inverting this order and cutting corners. Depending on their specific legitimate perspectives, social actors may first identify a convenient target to set (or preserve) and then select a fitting justification (from among the many possible ones) to support that target. This phenomenon appears to be common in the policy domain of biofuels. Indeed, Skogstad and Wilder [5] (p. 350) claim that ambiguity is essential to create "opportunities for institutional agenda-setters to build coalitions in support of biofuel mandates/targets". A responsible process of policy making should not be based on the coupling of targets with justification narratives. Instead, the focus should be on the congruence between justification narratives (what are the concerns to be addressed) and normative narratives (the identification of what should be done) based on plausible explanations. A check on the plausibility of the proposed solution is essential. Setting policy targets on the basis of implausible solutions will not help solve the original concern and only generate (additional) confusion.

While this paper shows that biofuels remain a wicked problem [84] for decision makers, it cannot be denied that the various policy strategies and responses of member states did create a profitable biofuel industry as well as an arcane object of study for scientists[1] (thus adding a new category of social actors having a stake in the discussion).

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

This paper has greatly benefited from the detailed comments and constructive suggestions of two anonymous reviewers. The authors gratefully acknowledge funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 689669 (MAGIC) and the government of Catalonia (AGAUR) under grant agreement 2017-SGR-230 (IASTE). The Institute of Environmental Science and Technology (ICTA) has received financial support from the Spanish Ministry of Science, Innovation and Universities (MICINN) through the "María de Maeztu" program for Units of Excellence (CEX2019-000940-M). This work reflects only the authors' view; the funding agencies are not responsible for any use that may be made of the information it contains.

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