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Integrating Individual Behavior Dimension in Social Life Cycle Assessment in an Energy Transition Context

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Abstract: Energy transition is a result of mankind's reaction to climate change and individuals are expected to have a crucial role in achieving it in developed countries. The purpose of this study is to apply the social life cycle assessment (S-LCA) tool and investigate the social performance of the Dutch energy transition while focusing on individual behavior, and if this is not possible, to develop indicators focusing on individual behavior dimension. The social performance of the energy transition in the Netherlands was assessed on a hotspot level. Additionally, the S-LCA guidelines were examined to identify the human dimension and behavior in the existing subcategories, and environmental psychology literature was explored to identify drivers and behavior that are important for the energy transition. Existing subcategories fail to show the extent of social progress of the Dutch energy transition nor how individuals perceive it. As a result, a total of 8 subcategories and 25 indicators at a hotspot and site-specific levels are developed. These subcategories and indicators focus on prosumer's and individual's behaviors, and traits of local communities. Application of the developed hotspot indicators shows that the Dutch government still subsidies fossil energy and, even though Dutch citizens show environmental concerns, the energy transition is delayed due to insufficient top-down coordination. Developed indicators are considered to be both feasible and relevant to investigate the social aspects of the energy transition in developed countries.

Keywords: individual; values; social life cycle assessment; prosumer; energy transition

1. Introduction

The energy transition is an unstoppable phenomenon [1] and a result of mankind's reaction to climate change. Its solution must cover the environment, economy, and society, and consists of steps aimed at decreasing the environmental footprint of our production and consumption patterns. However, energy transition entails also a social cost due to prices increase. For instance, McKinsey has recently produced an estimate of social costs of the Dutch transition to sustainable mobility of approximately €30 billion up to 2040 which will be borne by users [2]. In the built environment, energy transition refers to the production and consumption of electricity and heat, and actions of individuals shape the demand for renewable energy and affect new energy technologies investments [3]. So far, the environmental and economic aspects of sustainable development were investigated heavily, but social and behavioral sciences are, to this date, under-represented on international panels [4] and energy studies [5]. In addition, recent international literature has focused on the decisive need for a firmer engagement of social and behavioral sciences and climate change with the human dimension [6–11].

1.1. Roadmaps to Energy Transition

Costa Rica is the first country to convert to 100% renewable electricity. This benchmark was achieved while maintaining a centralized electricity system with major investments from the government [12].

However, studies show that energy transition will be achieved via a certain degree of decentralization of the electricity system globally [13–15] and in the Netherlands [16], as illustrated in Figure 1. For instance, the successful renewable energy implementation in Spain was significantly affected by natural and demographic factors. Spain shows large wind and solar energy potential, it is the second most mountainous country in Europe and has a low population density. Therefore, the installation of wind and solar farms in the country occurred with little public opposition [17]. On the other hand, for countries with larger population density and less geographical variety, such as the Netherlands, having the consumers becoming the electricity producers may result in public opposition. As a result, fierce public opposition was observed in communities where large renewable energy projects were to be implemented [18].

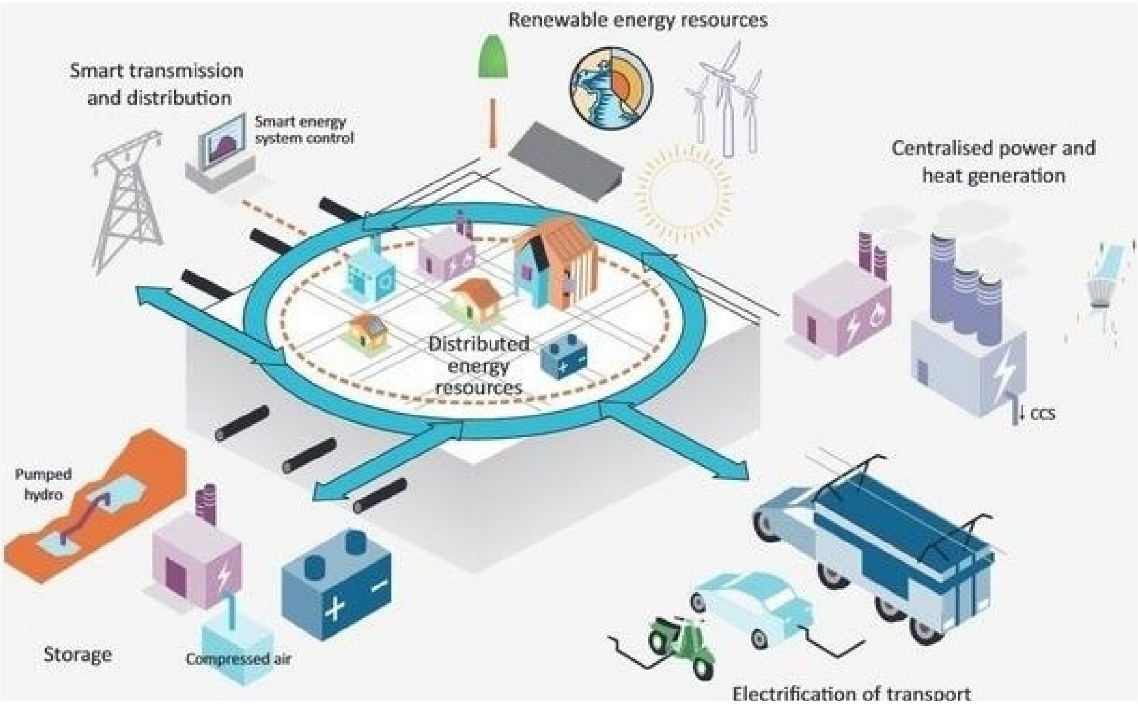

Figure 1. The energy transition as perceived from the University of Groningen Reproduced from University of Groningen [19].

So far, the Netherlands has been slow to adopt renewable energy on a large scale, but the Dutch government aims for 49% carbon reduction by 2030 [20], to stop producing natural gas by 2030, and to make the country entirely free of natural gas by 2050 [21]. This target is highly ambitious as the Netherlands has currently approximately 50% dependency on natural gas for heating and electricity generation [22]. Additionally, coal plants are to be shut down in this decade, and more offshore wind farms will be installed in the North Sea [20]. Since energy transition progresses slowly in the Netherlands, several renewable energy initiatives have emerged. However, Dutch society is sometimes hostile to projects that are even part of national decarbonization scenarios. In many cases, public opposition was observed from communities where large renewable energy projects were to be deployed [18]. In 2012, citizens of Urk town had strong feelings against a wind farm project, and community action was mobilized against it [23]. Demonstrations postponed the development of carbon capture and storage systems [24] and people opposed the construction of a wind farm in the north of the country [25]. On the other hand, the biggest Dutch onshore wind farm will soon become community-owned [26].

A study by Koster and Anderies [17] found that no single financial mechanism leads to high renewable energy use. Th energy sector is a complex system that cannot rely on a single mechanism [27,28].

Thus, governments have to develop an array of financial incentives, subsidies such as tax incentives, and governmental subsidies, rebates, and loans. If a country faces barriers to innovation on a national level, stakeholder participation and community building are important drivers to promote energy transitions and social acceptance [17]. Wüstenhagen et al. [29] conceptualized social acceptance of renewable energy technologies based on three dimensions that are often interdependent: sociopolitical, community, and market. In addition, Ostrom [30] argued that multi-agency efforts and a self-governed polycentric system increase research and development as well as the successful deployment of renewable energy technology. Therefore, governmental action is important, as well as a multi-agent, particularly individuals, participation at a local level.

Scholars have argued that users have an important function in transitions and should be re-conceptualized as important stakeholders in the innovation process who will shape new routines and enact a change of the system [18,31]. In addition, people actively shape their environments and the public should not be assumed to be passive. Studies indicate that planners, industry, and other involved stakeholders in developing renewable energy tend to envisage a hostile public to new developments [32]. For instance, Cuppen [25] made the presumption that, even with well-organized participation, social conflict will remain during the energy transition. Furthermore, even if local residents are compensated due to burdens associated with projects, the conduction of consultations with residents is important before deciding on compensation measures [33]. Studies [18,34] highlighted that sustainable energy transition will fulfill its potential when the public accepts and properly employs the related energy sources, technology, and infrastructure, makes the required behavioral changes, and accepts related policies. Thus, effective policy targets and removes important drivers of relevant behavior and important barriers to change early in the planning process, respectively [18,35].

1.2. The Role of Values in Energy Transition

One of the crucial general motivational factors that influence energy behaviors is values. Values are defined as general life goals that people strive for [35]. As Carl Jung discovered, "we cannot invent our own values, because we cannot impose what we believe in our souls" [36] (p. 193). There are four types of values based on environmental psychology which are most relevant to understand sustainable energy behavior: hedonic, egoistic, altruistic, and biospheric [35]. While the former two values may inhibit sustainable energy behaviors in the long term, altruistic and especially biospheric values encourage sustainable energy behaviors. Altruistic and biospheric values concern caring for others or the environment, respectively, and they are both positively related to environmental concern. Whereas, hedonic and egoistic values regard caring for comfort and money, respectively. Hedonic values are important predictors for environmental concern and egoistic values are generally negatively related to environmental concern [37]. Therefore, for a sustainable energy transition, it is beneficial to use hedonic and egoistic values to help initiate the transition, but authorities and planners should invest in altruistic and biospheric values to make the energy transition last [35].

1.3. Social Assessment of Energy Transition

Since energy transition concerns the environment, society, and economy, there is a need to identify and measure factors influencing these aspects. The environmental aspect can be assessed with environmental LCA, the economic aspect with life cycle costing, and the social aspect with social life cycle assessment (S-LCA) [38], social return on investment, or social impact assessment. Among these methods, S-LCA is preferred in this study because it prevents the shifting of negative impacts from one life cycle stage to another, or from one social issue to another, and it is under development for smoother integration with environmental LCA and life cycle costing. Nevertheless, the social aspect is bipolar, it includes individual and collective levels [39] and one-solution-fits-all does not work when the public is targeted [18]. At the same time, the guidelines of S-LCA aim to "provide a map, a skeleton and a flash light for stakeholders engaging in the assessment of social and socio-economic impacts of product life cycle" [38] (p. 5). S-LCA uses the framework of environmental

LCA and focuses on the social impacts of organizations or products. In addition, in the impact assessment phase, the considered social implications are associated with the conduct of organizations along the product's life cycle [38]. S-LCA guidelines [38] describe two levels of analysis, a hotspot level and a site-specific level. The hotspot level of analysis consists of generic data to the case study usually on a national level, while the site-specific level consists of data collected from the considered stakeholders. However, because S-LCA is still in its infancy, several challenges exist which prohibit at this point standardization. For instance, there is still a lack of consensus on selecting indicators [40], qualitative and quantitative types of data used (possibly) in the same study, and a range of models exist for impact assessment [41]. Integration of these three tools results in the life cycle sustainability assessment which is still a field under development, especially regarding redefining areas of protection, accounting for interconnectedness among areas of protection, and assessing both benefits and burdens to the areas of protection [42].

The problem for planners is to understand and predict the behavior of a specific audience when it is impossible to accurately measure whether, when, and if a behavior is performed. The need for quantitative data is obvious, but it is very challenging to measure behavior. To our knowledge, no S-LCA study exists that aims to expand S-LCA based on environmental psychology. The aim of this study is to apply for the first time the S-LCA to assess the social performance of foreground systems of the energy transition in the Netherlands and investigate the human dimension of the energy transition. If this is not successful, then introduce indicators for those societal attributes that have an effect on energy transition based on individual behavior. This is performed through the expansion of S-LCA to include the human dimension and cover social traits that promote energy transition.

2. Materials and Methods

First, a literature search was performed regarding the application of S-LCA in energy studies in the Scopus database. Second, a recent S-LCA study [43] focusing on the Netherlands was investigated and additional indicators were considered to assess the social impacts of the energy transition in the Netherlands on a hotspot level. Third, in case existing indicators failed to show what are the potential bottlenecks of accelerating the Dutch energy transition, the S-LCA guidelines and methodological sheets [38,44] were examined to identify the human dimension and behavior in the existing stakeholder groups, and subcategories and indicators were developed based on literature findings of environmental psychology. In addition, national policy reports were collected to identify national targets. To narrow down the reviewed material and still maintain a complex societal perspective, this study aimed to expand S-LCA to investigate the, social behaviors of developed economies, such as the Netherlands, because individuals are expected to have a crucial role in energy transition [13–15].

Examination of S-LCA guidelines and methodological sheets and literature was performed based on the following questions:

- How much does an "individual dimension" exist in S-LCA guidelines and methodological sheets?
- Which are the relevant studies regarding S-LCA and energy systems and do these assess the human dimension and behavior?

These questions were developed under the assumption that the main environmental driver for energy transition is climate change. The terms individual, consumer, citizen, and public do not hold the same meaning, but it is assumed that the term individual can capture all these different roles of a person. Therefore, in the rest of the paper, the term individual is used.

2.1. Literature Source and Search

The Scopus repository was searched in order to identify relevant S-LCA peer-reviewed scientific journal publications. The search was conducted based on various combinations of keywords, such as "Social LCA" AND energy, "Social LCA" AND electricity, and "social life cycle assessment" AND energy, in title, abstract, and keywords. The search in the Scopus repository resulted in a total of 37 publications, and after duplicates and books or conference papers were removed, 12 peer-reviewed publications were identified. Furthermore, the S-LCA guidelines and methodological sheets were searched for the term "individual" or aspects which exhibit an individual dimension.

2.2. Case Study: The Netherlands

The S-LCA approach is applied to identify social hotspots and opportunities for organizations in a supply chain to improve a product's social performance. In an energy transition context, S-LCA is used to identify how to enable individual participation and accelerate the development of a renewable energy system. The latter does not imply an electricity system that is entirely renewable.

The selected case study concerns the energy transition in the Netherlands because addressing public acceptability requires a specific scope [18]. The Netherlands as a case study has specific characteristics because information for the Netherlands can be found in the English language, the renewable electricity share is low, the national greenhouse gas emissions are higher than other European countries, and the Dutch government's approach aims at individuals and organizations taking responsibility [45]. The uniqueness of the case study lies in the fact that the Netherlands has a developed economy, a strong industrial sector, high population density, a decentralized electricity system is anticipated (to a certain extent), and citizens show environmental awareness of climate change but all these factors cannot reflect the Dutch status of energy transition.

The goal of the case study is to identify if the application of S-LCA on the Dutch electricity system shows which are the societal attributes that result in the Netherlands slowly adopting renewable energy and observing fierce public opposition when large renewable energy projects were to be implemented [46].

The S-LCA community faces the challenge to relate social impacts to a functional unit. A relatively recent review by [47] presented that out of 35 S-LCA studies, only 12 used a numerical-functional unit. The functional unit relevant to energy transition can be 1 kW_h of energy. However, we agree with established authors in the field of S-LCA who have spoken in favor of not having a functional unit-based SLCA perspective [48] and we suggest that for assessing a social phenomenon, a functional unit may not be necessary.

The system boundaries can be local or national in S-LCA studies that focus on energy transition. Both spatial levels concern the individual perception in participation and how the latter is reflected against national policy, targets, and achievements concerning energy transition. For this case study, the system boundaries regard the country of the Netherlands.

The characterization step for data summarizes qualitative data and summing up quantitative data. Thus, a scoring system can be helpful to compare different data types in a standardized manner and arrive at meaningful results. For this purpose, average European data were used as performance reference points, i.e., thresholds to show the magnitude and significance of collected data, and the scoring scheme of Hosseinijou et al. [49] was selected due to its simplicity and inclusion of positive and negative social impacts. The scoring scheme is illustrated in Figure 2.

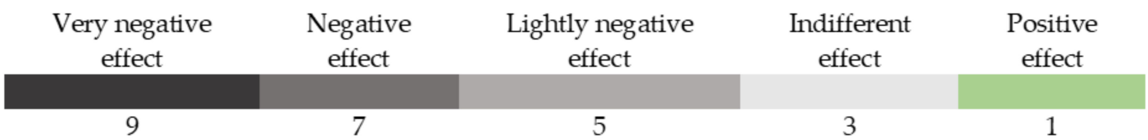

Figure 2. Scoring scheme for social inventory indicators.

Data collection for all existing indicators (added in Table 1) was performed from the literature [43], international organizations, national reports, and official national statistical data sources. Data collected for developed indicators corresponds to the years between 2017 and 2020, except for the "Civil society actors involvement in decision making" indicator which corresponds to 2013.

3. Results and Discussion

The current version of S-LCA guidelines [38] describes five stakeholder groups: the local community, value chain actors, consumer, worker, and society. This happens due to the S-LCA focusing on assessing the societal impacts of organizations and products. In these five stakeholders, an "individual" dimension exists but is not emphasized.

3.1. Assessing the Social Performance of the Case Study with Existing S-LCA Indicators

3.1.1. S-LCA Literature Review Results

A few S-LCA studies [50–62] exist that focus on the social performance of energy systems. S-LCA studies exist where the researchers consider all indicators described in the S-LCA guidelines, such as [62]. However, it is typical that practitioners omit social indicators that they do not perceive relevant for their case study, such as considering child labor in a case study for a country with a developed economy. These studies focus primarily on "Health and safety" and "Employment". The former is quantified based on how many accidents and fatalities occur, whereas the latter concerns the number of jobs created. Other subcategories used less frequently are "Equal opportunities" in the working environment [55,56], "Project-related infrastructure" with mutual community access and benefit, "Potential for material resource conflict" [55], "Laws and regulations" [57], and "Labor hours" [61]. In addition, researchers have also assessed the "Human rights", "Labor rights", "Health and safety", "Community", and "Governance" impact categories because they employed the Social Hotspot Database [58,59].

3.1.2. Life Cycle Impact Assessment with Existing Indicators

The scoring scheme in Figure 2 was used to convert collected data for the presented indicators. Table 1 shows the evaluation of the social performance of the Dutch energy transition when S-LCA hotspot indicators are considered. First, it is shown that individual behavior is largely missing from current subcategories and indicators. Second, many indicators in S-LCA are not relevant in the selected case study regarding energy transition in a European country context, such as the "International Migrants as a Percentage of Population", "Human Rights Issues Faced by Indigenous Peoples", etc. However, this is expected due to the broad range of subcategories considered by S-LCA and the goal of S-LCA to be capable of assessing the social impacts of various products. Indicators of these subcategories were assigned to the "Indifferent effect" score. Third, current indicators fail to evaluate the socioeconomic aspects or the evolution of the Dutch energy system due to energy transition. In general, the Dutch renewable energy system scores high in "Fair competition", "Access to immaterial resources", and "Promotion of social responsibility", and positive social impacts can be found in "Public commitment to sustainability issues", "Contribution to economic development", and "Fair competition". On the other hand, social burdens were identified for "Relevance for the national economy" and "Sectoral regulation" indicators. For instance, social risks regarding the Dutch energy transition exist due to the regulatory instability in renewable energies (found for "Sector regulation"). Even if the findings based on positive subcategories may seem to prevail over negative subcategories, there is still a long way to go for the Dutch energy system to achieve energy transition [63]. Therefore, based on the current findings, it is not possible to understand "On what aspects should policy planners focus in order to increase public co-operation and accelerate the energy transition in the Netherlands?"

Table 1. Social performance based on the scoring scheme of Figure 2 of the Dutch energy sector with current S-LCA indicators, adapted from [43] and modified based on the Goal and Scope.

Stakeholder Categories	Subcategories	Hotspot Indicators	Netherlands
Local community	Delocalization and migration	International Migrants as a Percentage of Population (%)	10–15 [64]
	Community engagement	Public Trust of Politicians (%)	57 [65]
		Freedom of Peaceful Assembly and Association (qualitative)	1 [66]
		Transparency of Government Policymaking (ranking)	6th [67]
	Respect of indigenous rights	Human Rights Issues Faced by Indigenous Peoples (qualitative)	Undocumented migrants continued to be deprived of their rights [68]
		Indigenous Land Rights Conflicts/Land Claims (qualitative)	A legal process exists for claimants to request the return of property looted during the Holocaust [68]
	Local employment	Unemployment Statistics by Country (%)	Low [69]
		Poverty and Working Poverty by Country (%)	Low [70]
		Presence of Local Supply Networks (qualitative)	Yes
	Access to immaterial resources	Freedom of Expression in Country of Operation (qualitative)	Good [68]
		Levels of Technology Transfer (ranking)	8
	Access to material resources	Changes in Land Ownership (%)	94.27 [71]
		Levels of Industrial Water Use (%)	88 [72]
		Extraction of Material Resources (ktons)	7.93 [73]
		Percent of Population (Urban, Rural, Total) with Access to Improved Sanitation Facilities (%)	99.95 [72]
	Safe and healthy living conditions	Burden of Disease by Country (per capita) (DALY)	0.0 [74]
		Pollution Levels by Country (µg PM2.5/m^3)	Ok [75]
		Presence/Strength of Laws on Construction Safety Regulations by Country (ranking)	16.84 [76]

Table 1. *Cont.*

Stakeholder Categories	Subcategories	Hotspot Indicators	Netherlands
	Secure living conditions g	State of Security and Human Rights in Country of Operation (qualitative)	Civilian authorities in the entire kingdom maintained effective control over the security forces [66]
		Strength of Public Security in Country of Operation (index)	10.14 [76]
Value chain actors	Fair competition	Natural law and regulation (qualitative)	Liberalized and open market
		Sectoral regulation (qualitative)	Regulatory instability in renewable energies
	Respect of intellectual property rights h	General Intellectual Property Rights and related issues associated with the economic sector (qualitative)	Yes
	Promoting social responsibility i	Industry code of conduct in the sector (%)	Large percentage of corporations publishing GRI and CSR reports
Consumer	Health and safety	Quality of or number of information/signs on product health and safety	Not applicable
		Presence of consumer complaints (at a national level) (qualitative)	Not applicable
	Feedback mechanism j	Presence of feedback mechanisms (by country) (qualitative)	Yes [77]
	Privacy k	Country privacy ranking (1–5 scale) (ranking)	2.1 [78]
		Country ranking related to the strength of laws protecting privacy against organizations and government (ranking)	Good
	Transparency	Presence of a law or norm regarding transparency (qualitative)	Government obliges reporting [79]
		Sector transparency rating; the number of organizations by sector which published a sustainability report (GRI) (amount)	All [79]
	End-of-life responsibility	Strength of national legislation covering product disposal and recycling (amount)	Not applicable [80]
Worker	Freedom of association and collective bargaining	Evidence of restriction to Freedom of association and Collective bargaining (qualitative)	0 out of 5 [81]
		Evidence of country/sector non-respect or support to Freedom of association and Collective bargaining (qualitative)	0.5 out of 5 [81]
		Operations identified in which the right to exercise freedom of association and collective bargaining may be at significant risk, and actions taken to support these rights (qualitative)	0.5 out of 5 [81]

Table 1. *Cont.*

Stakeholder Categories	Subcategories	Hotspot Indicators	Netherlands
	Child labor	Percentage of children working by country and sector (%)	None [81]
	Fair salary o	Minimum wage by country (€)	1578 [81]
		Non-poverty-wage by country (€)	780–1030 [81]
	Hours of work	Excessive Hours of work (qualitative)	Done but paid and protected [81]
	Forced labor	Percentage (estimate) of forced labor by region (%)	0.1 [81]
		Government response rating to modern slavery (rating)	3 out of 10 [82]
	Equal opportunities	Women in the Labor force participation rate by country (%)	58.7 [83]
		Country gender index ranking (rating)	11.1 [83]
	Health and safety	Occupational accident rate by country or sector (%)	0.59 per 100,000 [81]
	Social benefit/social security	Social security expenditure as a percentage of GDP (%)	11 [81]
Society	Public commitment to sustainability issues	**Existence of (legal) obligation on public sustainability reporting (qualitative)**	Yes [84]
		Engagement of sector regarding sustainability (qualitative)	Ok [84]
	Prevention and mitigation of conflicts	Is the organization doing business in a region with ongoing conflicts? (qualitative)	Not applicable
		Is the organization doing business in a sector that features linkages to conflicts? (qualitative)	Not applicable
		Is the organization doing business in a sector otherwise linked to the escalation or de-escalation of conflicts? (qualitative)	Not applicable
	Contribution to economic development	Economic situation of the country (USD)	Rich and developed economy [85]
		Relevance of the considered sector for the economy (%)	0.17% [85]
	Corruption	Risk of corruption in the country and/or sub-region (ranking)	18 [86]
		Risk of corruption in the sector (%)	No data
	Technology Development	Sector efforts in technology development	0 out of 5
		Research and development costs for the sector (M€)	600 [87]

3.2. The Individual Dimension in the Existing S-LCA Method

Existing S-LCA Guidelines and Methodological Sheets Results

Table 2 demonstrates that an individual dimension partially exists in S-LCA in three stakeholder groups: "Local community", "Consumer", and "Worker". Subcategories which concern the individual and already belong to S-LCA are: the "Health and safety", "Local employment", "Community engagement", and "Privacy". Furthermore, in certain subcategories that concern the society and local community, and as a consequence, the individual is also covered by the S-LCA guidelines. These subcategories are very important if we want to achieve energy transition sustainably because they refer to human existence, society's productive potential, and society's options for development and action. These subcategories are: "Safe, healthy living conditions", "Secure living conditions", "Public commitment to sustainability issues", "Contribution to economic development", and "Technology development". In indicators of those subcategories, the "individual" exists passively or indirectly, or the "individual" may be considered by S-LCA practitioners if the term "organization" is replaced with the word "individual" (see Table S1 in the Supplementary Materials). Nevertheless, existing indicators still fail to show how likely it is for individuals to oppose national actions to achieve energy transition, how much people are in favor of energy transition on a local or national level, etc. The following section introduces indicators that aim to address these specific points.

Table 2. Subcategories targeting the individual in S-LCA.

Stakeholder Group	Subcategory
Consumer	Health and safety Privacy
Worker	Health and safety
Local community	Community engagement Safe and healthy living conditions Secure living conditions Local employment
Society	Public commitment to sustainability issues Contribution to economic development Technology development

3.3. Expansion of the Individual Dimension in S-LCA Method

So far, we have mentioned that the energy transition is expected to result in a certain degree of decentralization of the electricity system and, as a result, the individual human dimension is crucial. We have also presented the extent that the human behavior dimension is presented in S-LCA. In order to expand S-LCA indicators, we suggest modifications in the stakeholder groups. Thus, in the consumer stakeholder group, a sub-group is created: the prosumer. Prosumer refers to someone who consumes and produces electricity. In energy transition, this sub-group concerns mainly the environmental self-identity of individuals. The local community and society stakeholders are extended with subcategories and indicators which are based on environmental psychology studies [18,35,88–91]. Following the guidelines [12], stakeholders are divided into subcategories, and each subcategory has its own hotspot and specific analysis indicators. Quantitative, semi-quantitative, and qualitative data are used and integrated according to [12]. In Tables 3–5 subcategories and 25 indicators are recommended.

Table 3. Prosumer's subcategories and indicators.

#	Inventory Indicator	Unit of Measurement	Data Source
	Social acceptability		
	Hotspot indicators		
1	Individual's awareness of climate change	Semi-quantitative	Eurobarometer [a]
	Specific analysis indicators		
3	Individual factors	Semi-quantitative	Questionnaire
4	Distributional justice	Qualitative	Questionnaire
5	Effect on personal comfort	Qualitative	Questionnaire
6	Setting personal goals for environmental improvement	Qualitative	Questionnaire or LCRI [c]
	Educational level		
	Specific analysis indicators		
7	Lifelong learning promotion	Quantitative	National statistics [b]
8	Sufficient knowledge to get started	Qualitative	Questionnaire
	Common enemy		
	Hotspot indicators		
9	Environmental concern	Semi-quantitative	Eurobarometer [a]
	Policies for end-users		
	Hotspot indicators		
10	Ease of installing or converting to RE	Qualitative	Governmental agencies or questionnaire
11	Governmental budget for environment	Quantitative	National statistics [b]
12	Civil society actors involvement in decision making	Quantitative	National statistics [b]
	Specific analysis indicators		
13	Policies developed to defend producers-users	Qualitative	Governmental agencies
14	Decentralized policy coordination	Quantitative	
15	Financial support for small scale projects	Quantitative	National statistics [b]
	Communication to individuals		
	Hotspot indicators		
16	Effective two ways communication or one way?	Qualitative	Questionnaire
	Specific analysis indicators		
17	Diverse communication and planning team (project developers, engineers, and policy-makers)	Qualitative	Questionnaire
18	Possibilities to voice individual opinion	Qualitative	Questionnaire

[a] Eurobarometer [92], [b] CBS [93], [c] Low Carbon Readiness Index [94].

Table 4. Local communities' subcategories and indicators.

#	Inventory Indicator	Unit of Measurement	Data Source
	Community engagement		
	Hotspot indicators		
19	Number of energy cooperatives engaged in renewable energy plants on a national level	Quantitative	National statistics [a]
	Specific analysis indicators		
20	Number of energy cooperatives engaged in renewable energy plants on a regional level	Quantitative	Questionnaire
	Community identity		
	Hotspot indicators		
21	Percentage of entrepreneurs in the country	Semi-quantitative	National statistics [a]
	Specific analysis indicators		
22	Community attributes (age, education, municipality board dynamics)	Qualitative	Questionnaire
23	Respecting alternative opinions and deep opposition [a]	Qualitative	Questionnaire
24	Inclusiveness amongst local businesses	Qualitative	Questionnaire

[a] CBS [93].

Table 5. Society's subcategory and indicator.

#	Inventory Indicator	Unit of Measurement	Data Source
	Environmentally focused mainstream mass media		
	Hotspot indicators		
25	Number of mass media and their popularity	Quantitative	Questionnaire

3.3.1. Stakeholder: Prosumer

Social Acceptability

Social acceptability refers to the public preference to deploy or use certain technology to generate electricity. It consists of those values that are expected to result in benefits for the energy transition, such as knowledge on the causes and consequences of climate change [61]. Social acceptability is also used as an energy transition indicator and is linked with the "perceived risk" of the technology [62].

Educational Level

Educational level refers to the population that finishes higher education. Educational level is used as an energy transition indicator due to knowledge of climate change being higher among people with a higher level of education. Nevertheless, correlations are not strong [63].

Common Enemy

Common enemy refers to the individual's perception that climate change is a global phenomenon that must be mitigated [64]. The common enemy is used as an energy transition indicator due to the addition of a common trait of people which may result in common egoistic values.

Policies for End-Users

Policies for end-users refer to the selection of a policy instrument that depends on national conditions, state of the energy market, technology, and goals to achieve. For instance, ways to support decentralized electricity generation are net metering and net billing. Therefore, decentralized electricity generation can result in more benefits and less cost. However, careful consideration is needed to avoid jeopardizing the cost recovery of the electricity system and prevent cross-subsidization between those consumers who self-consume and those who do not [61,65–67].

Communication to Individuals

Communication to individuals refers to two-way communication (between the individual and authorities/planners) because it provides opportunities for the individual to participate in decision making. Two-way communication is usually rare but can be critical for the success of energy transition because it increases motivation and decreases opposition [19].

3.3.2. Stakeholder: Local Community

Community Engagement

Community engagement refers to individuals joining decision-making processes and can be extended to community initiatives, such as green energy cooperatives owning the energy infrastructures, community charities running the plant, co-ownership of green energy projects by local communities, enterprises, and local government [95]. Community engagement can result in increased awareness of energy issues and more sustainable practices regarding energy consumption [96].

Community Identity

Community identity refers to a socially constructed phenomenon, which is territorial-based and social relations-based. It can be summarized as: "Feelings of attachment to the community, taking pride in the community, and having friends within the community" [97]. The existence of a community identity has a positive effect on individual participation [98]. Furthermore, in this subcategory, quantitative characteristics of the citizens comprising the community are added, such as age and educational level, and citizens' decisions, such as voting. Research has shown that older age groups, and those with fewer years of formal education and/or politically conservative men tend to be skeptical about the reality and anthropogenic cause of climate change [99,100] and, subsequently, are less concerned about the climate change burdens [101,102].

3.3.3. Stakeholder: Society

Environmental Focused Mainstream Media

The press is important because it spreads news and issues every day. Johnnie Manzaria and Jonathon Bruck [103] explained that control of the media results in potential control of an individual's opinion. Thus, environmentally focused mainstream media refers to press specialized in environmental news and is expected to influence the individual positively regarding climate change behavior.

3.4. Life Cycle Impact Assessment with Suggested Hotspot Indicators

Table 6 presents the re-evaluation of the social performance of the Dutch energy system with developed hotspot indicators. A detailed version of Table 6 can be found in the Supplementary Materials (Table S2). It is found that on one hand, the Dutch citizens are aware of the seriousness of climate change (but do not think climate change is a very serious problem when compared to the EU average) and have taken at least one environmentally friendly action in the last 6 months. Furthermore, the number of renewable energy cooperatives is high, the Netherlands ranks 8th in entrepreneurs among the most innovative economies and the country has more favorable frameworks for collective prosumers than other EU countries. On the other hand, the government of the Netherlands still spends a considerable budget on financial benefits, such as tax exceptions, for the fossil sector, has entrusted the country's different regions to develop their own, local strategies to meet climate goals, and mainstream mass media do not cover climate change substantially.

Table 6. Social performance based on the scoring scheme of Figure 2 of the Dutch energy sector with developed S-LCA hotspot indicators.

Stakeholder Categories	Subcategories	Hotspots Inventory Indicators	Netherlands
Local community	Community engagement	Number of energy cooperatives engaged in renewable energy plants on a national level	[104]
	Community identity	Percentage of entrepreneurs in the country	[105]
Prosumer	Social acceptability	Individual's awareness of climate change	[106]
	Common enemy	Environmental concern	[106]
	Policies for end-users	Ease of installing or converting to RE	[107]
		Governmental budget for environment	[108–110]
		Civil society actors involvement in decision making	[111,112]
	Communication to individuals	Effective two ways communication or one way?	[113,114]
Society	Environmentally focused mainstream media	Mass media and their popularity	[115]

3.5. Overview

The recommended indicators can be classified into four values that researchers [35,37] recognize relevant for sustainable behaviors: hedonic, egoistic, altruistic, and biospheric values. Most of the indicators reflect more than one value and the altruistic values appear more than the rest (see Table 7). The latter does not mean that altruistic values are the most important for accelerating the energy transition, but they are related to environmental concern positively [37].

Table 7. Classification of site-specific analysis indicators based on the values system [35].

Indicators	Hedonic	Egoistic	Altruistic	Biospheric
Prosumer				
Individual factors	X	X	X	X
Setting personal goals for environmental improvement	X	X	X	X
Distributional justice			X	
Effect on personal comfort	X			
Lifelong learning promotion	X	X		
Sufficient knowledge to get started	X	X	X	X
Policies developed to defend producers-users	X	X		
Decentralized policy coordination		X		
Financial support for small scale projects		X	X	
Diverse communication and planning team (project developers, engineers, and policy-makers)			X	
Possibilities to voice public opinion			X	
Local community				
Number of energy cooperatives engaged in renewable energy plants	X	X	X	
Respecting alternative opinions and deep opposition			X	
Inclusiveness amongst local businesses			X	

3.6. Limitations

A major limitation of the study is time-intensity because site-specific data have to be collected with questionnaires. This was expected because the focus of suggested indicators aims to map the "individual" and, as a result, this kind of data cannot be collected from databases. This limitation results in increasing the complexity of a S-LCA study which would use the suggested set of indicators and the need for a practitioner with experience in S-LCA. In addition, due to the nature of the data required and new European regulations for the protection of personal data, the practitioner needs to ask interviewees for authorization in order to use the data. Furthermore, suggested indicators account for qualitative data, and the latter can be challenging to be assigned to functional units in S-LCA studies. Lastly, the case study focused on foreground renewable systems in the Netherlands, systems which generate renewable electricity, and thus, did not account for social impacts such as impacts with regard to mining fossil fuels or materials for renewable technologies.

4. Conclusions

The energy transition is an unstoppable phenomenon that has to be addressed from an environmental, economic, and social aspect. In addition, the problem for planners is understanding and predicting the behavior of a specific audience when they cannot accurately measure whether, when, and if a behavior is performed prior to the implementation of a renewable energy project. S-LCA covers some drivers and metrics for energy transition but it was developed for companies and product assessment. We believe that the individual, in the form of public, citizen, or prosumer, has a key role in the current energy transition in developed countries, and as a result, we aimed to expand S-LCA to cover those forms.

The recommended indicator expansion set aims to be more than the sum of indicators addressing various aspects of energy transition because it provides a theoretical link between the S-LCA method and the individual human dimension in the energy transition. The individual behavior dimension in the current S-LCA method was investigated and considered limited. The current study proposes an expansion of S-LCA indicators to quantify drivers for sustainable behavior and identify societal incentives for participation and acceleration of energy transition. It can be used as an instrument for describing, assessing, and managing sustainable developments of socio-technical energy systems. Application of the developed hotspot indicators shows that Dutch citizens are aware of the importance to combat climate change and are active in forming energy cooperatives. However, the existence of governmental fossil fuel subsidies and the lack of top-down coordination resulted in the relative slow progress of energy transition and in the Netherlands, consuming the lowest percentage of renewable energy among EU countries. Application of developed site-specific indicators may provide to planners and authorities a holistic perspective of the goals of communities and individuals, and thus provide specific incentives on regional and local levels. The recommended indicators are considered to be both feasible and relevant to investigate the social aspects of the energy transition in developed countries because literature which reflects human behavior was used, we explained why the indicators are relevant and how they can be quantified, and individuals are expected to play a crucial role in achieving energy transition.

Supplementary Materials: The following are available online at http://www.mdpi.com/1996-1073/13/22/5984/s1, Table S1. Subcategories indicators based on social impacts targeting organizations and individuals shown in Table 2. Table S2. Social performance based on scoring scheme of Figure 2 of the Dutch energy sector with developed S-LCA hotspot indicators, detailed version of Table 6.

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