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Factors That Contribute to Changes in Local or Municipal GHG Emissions: A Framework Derived from a Systematic Literature Review

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Abstract: The changes observed in a municipal or local energy system over a period of time is due a number of concurrent dynamics such as the local social and economic trends, higher-level policies (e.g., national), and the local policies. Thus, a thorough identification and characterization of the many factors of change is key for an adequate assessment of the effectiveness of policies adopted at the local level, as well as for future planning. Such thorough identification and characterization of the factors that are determinant for the evolution of the local energy system is the content of this paper. The identification is performed through a systematic literature review, followed by a synthesis process. The factors identified are grouped into the categories of local context, local socio-economic and cultural evolution, higher-level governance framework, and local climate change mitigation actions. They are represented through a set of measurable variables. The factors and respective variables can be used to improve the disaggregation of changes in the local energy system into individual causes, leading to a better assessment of the evolution over time.

Keywords: local climate policy; municipal authorities; municipal energy planning; local GHG emissions; multilevel governance

1. Introduction

Local actions are crucial for the achievement of global climate change mitigation goals. Both the physical characteristics of the local energy systems and the regulatory competences of local authorities prompt local level as an appropriate level for action [1]. Moreover, local actions are becoming more common, due to the increasingly active role of local authorities and to the recognition of their importance by policy makers at higher governance levels. Thus, there is an increasing need to assess their contribution towards climate change mitigation, and to the achievement of global targets.

However, given the universal scope of climate policy and the link between the local energy system and local context, it is currently very difficult to properly assess the actual contribution of local policy actions. Indeed, the local energy system is influenced by numerous factors, of which only some are related with actions promoted by local authorities. The changes in the economic activity or on population are two examples. The assessment difficulties are amplified by the fact that local policies and actions are implemented as a part of a complex multi-level governance framework.

Previous studies have already highlighted the importance of considering external factors when evaluating local actions. Within the studies reviewed in [2], several factors were identified as key in the link between observed changes and actual effects of local climate change mitigation actions. For instance, the evolution of local socio-economic features (structure of local economy, demographic and economic conditions of local population, etc.), prompted by economic, social, and technological changes, is one of

the aspects that are commonly considered relevant for the observed variation in local GHG emissions. However, within existing studies, a comprehensive analysis of all the relevant factors that influence the local energy system and the corresponding GHG emissions was not found.

Moreover, the analysis of empirical studies focusing on assessing the effects of local actions has emphasized this need to thoroughly identify all the factors that contribute to changes in local GHG emissions [3–5]. For instance, in [3], Millard-Ball performed a quantitative analysis on the effects of city climate policy, without considering any external factors; although some scattered evidence of climate plans effects was found, the findings are not sufficiently robust (which could be partly explained by the non-consideration of other relevant factors). The evidence for impact of local climate plans in the different sectors is not demonstrated with the empirical analysis, which does not provide a coherent result across the different models that were tested. Similarly, in [5], the conclusions drawn were also insufficient to prove the causal link between local actions and GHG emissions. Within the results from the linear regression analysis with panel data, the coefficient associated with the effect of local actions is not statistically significant for any of the countries that were included in the study. However, in the same analysis, the relevance of municipality specificities as well as of higher-level context (i.e., country) for the assessment of local GHG emissions and their evolution over time was confirmed (resulting in coefficients that are statistically significant). Both these studies show the need for a comprehensive consideration of the different factors that impact local GHG emissions to ensure a robust and meaningful assessment of the specific impact of local climate change mitigation actions.

Thus, the identification of the factors of change of local GHG emissions is a crucial step towards a more complete understanding of the observed changes within the local energy system and assessment of the actual effects of local climate change mitigation actions. Indeed, to develop a model that is able to adequately represent the evolution of the local energy system, identifying the links between the changes in local GHG emissions and the different explanatory factors, it is necessary to first identify all the factors that may have an impact on local GHG emissions (factors of change). Herein, factors of change refer to all features and events that lead to changes in the local energy system and respective GHG emissions. These include factors related with local climate change mitigation actions as well as external factors (i.e., factors that are not directly influenced by actions promoted by local authorities). For instance, local demographic evolution—size and structure of local population—may lead to significant changes in the local energy system and, consequently, on the respective GHG emissions.

This paper attempts to perform a systematic identification and characterization of the factors of change of local GHG emissions. This comprises the identification of all factors that may potentially influence local emissions, even if their specific effects in the local energy system are not quantifiable or even relevant (depending on the local system being studied). In order for this to be applicable in the future, it is necessary not only to identify the relevant factors of change, but also to characterize them with indicators. Therefore, that is also covered by this paper. The work is presented in five sections. Section 2 describes the methodological approach that was used to identify the factors of change of local GHG emissions and the review process, including the documents used as reference to this analytical framework, as well as the presentation of the final list of factors identified. Section 3 is dedicated to the presentation of the results, including the description of the identified factors of change and the listing of the respective quantifiable indicators. Section 4 presents a brief discussion of the obtained results, focusing on their potential contribution for improved planning and evaluation of local climate change mitigation actions. The paper ends with some final remarks regarding the results obtained (Section 5).

2. Methodology

Considering the extensive research that has already been done on this topic, a wide literature review was considered an adequate methodological approach to identify and characterize the factors of change of local GHG emissions. More specifically, the method used consisted in a systematic literature review, using content analysis—which allowed reviewing, assessing, and aggregating a body of literature utilizing pre-specified standardized techniques to all the documents reviewed [6].

The definition of the specifications for data collection and analysis beforehand and respective use as a guide for performing the process aimed to avoid bias in the review.

A systematic literature review process consists of these four sequential steps: (i) definition of the objective; (ii) definition of the specifications to be followed; (iii) the retrieval and assessment of the information; and (iv) synthesis of the results obtained. In what concerns the specifications defined a priori as guidelines for the review, these consist in three types of rules/criteria: (1) the eligibility criteria to retrieve the literature; (2) the rules to retrieve information from literature; and (3) the rules for the analysis and screening of the obtained information. Table 1 presents the details of these three types of criteria.

Table 1. Systematic literature review specifications.

Objective	Identify and Characterize Factors of Change of Local Energy Systems
Documents Selection	
Search expressions	"Energy system characterization" "Energy system modeling/modelling" "Energy system planning" "Energy system scenarios" "Energy policy evaluation" "Local climate change mitigation"
Type of documents	Peer-reviewed articles Reports and working papers from internationally reputed entities PhD theses
Type of content	Factors that lead to changes in GHG emissions Characterizing variables of those factors Information on the relation between factors of change and local GHG emissions

The selection of relevant research covered the following keywords: "Energy system characterization"; "Energy system modelling"; "Energy system planning"; "Energy system scenarios"; "Energy policy evaluation"; and "Local climate change mitigation". The keyword selection was based on the different contexts within which this discussion has been raised, including planning, policy evaluation, and energy management.

To guarantee the reliability of the results, the documents considered in the review were restricted to peer-reviewed articles published in scientific journals or conference journals, reports or working papers published by internationally reputed entities (as e.g., International Energy Agency and European Union), and PhD theses. The reviewed documents were published between 1999 and 2017. A list of the documents with a description of their main focus of research is presented in Table 2.

Table 2. Characterization of the documents used for the identification of the factors of change.

Code	Study	Authors	Year	Topic/Theme	Doc. Type	Ref.
1	"Evaluating the effects of policy innovations: Lessons from a systematic review of policies promoting low-carbon technology"	Auld, G., Mallet, A., Burlica, B., Nolan-Poupart, F., Slater, R.	2014	Policy Evaluation	JP	[7]
2	"Energy and emission monitoring for policy use—Trend analysis with reconstructed energy balances"	Boonekamp, P.G.M.	2004	Policy Evaluation	JP	[8]
3	"Improved methods to evaluate realized energy savings"	Boonekamp, P.G.M.	2005	Policy Evaluation	PhD	[9]

Table 2. *Cont.*

Code	Study	Authors	Year	Topic/Theme	Doc. Type	Ref.
4	"A survey of urban climate change experiments in 100 cities"	Broto, C.B., Bulkeley, H.	2013	Multilevel governance	JP	[10]
5	"Reporting Guidelines on Sustainable Energy Action Plan and Monitoring"	Covenant of Mayors (European Union)	2010	Policy Evaluation	PR	[11]
6	"Cities, Climate Change and Multilevel Governance"	Corfee-Morlot, J., Kamal-Chaoui, L., Robert, A., Teasdale, P.J.	2009	Multilevel governance	WP	[12]
7	"The use of physical indicators for the monitoring of energy intensity developments in the Netherlands, 1980–1995"	Farla, J.C.M., Blok, K.	2000	Energy use	JP	[13]
8	"Long-term energy scenarios: Bridging the gap between socio-economic storyline and energy modeling"	Fortes, P., Alvarenga, A., Seixas, J., Rodrigues, S.	2015	Energy planning	JP	[14]
9	"Integrated technological-economic modelling platform for energy and climate policy"	Fortes, P., Pereira, R., Pereira, A., Seixas J.	2014	Energy planning	JP	[15]
10	"Multilevel governance, networking cities, and the geography of climate-change mitigation: two Swedish examples"	Gustavsson, E., Elander, I., Lundmark, M.	2009	Multilevel governance	JP	[16]
11	"Evaluating the effectiveness of environmental policy: A analysis of conceptual and methodological issues"	Gysen, J, Bachus, K., Bruyninckx, H.	2002	Policy evaluation	CP	[17]
12	"Model for Analysis of Energy Demand (MAED-2)—Computer Manual Series N° 18"	International Atomic Energy Agency	2006	Energy use	TR	[18]
13	"Energy Efficiency Indicators: Essentials for Policy Making"	International Energy Agency	2014	Energy planning	PR	[19]
14	"An analytical method for the measurement of energy system sustainability in urban areas"	Jovanovic, M., Afgan, N., Bakic, V.	2010	Energy use	JP	[20]
15	"Regions at Risk: Comparisons of Threatened Environments"	Kasperson, J.X., Kasperson, R.E, Turner, B.L.	1995	Policy Evaluation	Bk	[21]
16	"Evaluating the effectiveness of urban energy conservation and GHG mitigation measures: The case of Xiamen city, China"	Lin, J., Cao, B., Cui, S., Wang, W., Bai, X.	2010	Policy evaluation	JP	[22]
17	"Do city climate plans reduce emissions?"	Millard-Ball, A.	2012	Policy evaluation	JP	[3]
18	"A comparative analysis of urban energy governance in four European cities"	Morlet, C., Keirstead, J.	2013	Multilevel governance	JP	[23]
19	"A qualitative evaluation of policy instruments used to improve energy performance of existing private dwellings in the Netherlands"	Murphy, L., Meijer, F., Visscher, H.	2012	Policy evaluation	JP	[24]

Table 2. *Cont.*

Code	Study	Authors	Year	Topic/Theme	Doc. Type	Ref.
20	"Determinants of greenhouse gas emissions from Swedish private consumption: Time-series and cross-sectional analyses"	Nassen, J.	2014	Energy use	JP	[25]
21	"Outcome indicators for the evaluation of energy policy instruments and technical change"	Neij, L., Astrand, K.	2006	Policy evaluation	JP	[26]
22	"Simplified evaluation method for energy efficiency in single-family houses using key quality parameters"	Praznik, M., Butala, V., Senegacnik, M.Z.	2013	Energy use	JP	[27]
23	"Agent-based modeling of energy technology adoption: Empirical integration of social, behavioral, economic, and environmental factors"	Rai, V., Robinson, S.A.	2015	Energy planning	JP	[28]
24	"Indicators of Energy Use and Carbon Emissions: Explaining the Energy Economy Link"	Schipper, L., Unander, F., Murtishaw, S., Ting, M.	2001	Energy use	JP	[29]
25	"The impact of the economic crisis and policy actions on GHG emissions from road transport in Spain"	Sobrino, N., Monzon, A.	2014	Policy evaluation	JP	[30]
26	"A paper trail of evaluation approaches to energy and climate policy interactions"	Spyridaki, N.A., Flamos, A.	2014	Policy evaluation	JP	[31]
27	"Moving from agenda to action: evaluating local climate change action plans"	Tang, Z., Brody, S.D., Quinn, C., Chang, L., Wei, T.	2010	Policy evaluation	JP	[32]
28	"Global change in local places: How scale matters"	Wilbanks, T.J., Kates, R.W.	1999	Multilevel governance	JP	[33]

Legend: JP, peer-reviewed journal article; WP, working paper; CP, conference paper; Bk, Book; PhD, PhD thesis; PR, policy report; TR, technical report.

The information collected from the documents comprised three types of relevant information: (1) factors of change of GHG emissions; (2) variables that may be helpful to characterize the factors of change identified; and (3) information on the relation between the different factors of change and local GHG emissions.

In regard to the identification of the factors of change, Figure 1 presents a schematic representation of the whole process. The analysis of these documents resulted in a list composed of 511 variables with an impact on GHG emissions. The full list, as well as the reference to the documents where each variable has been referred, is presented in Table A1 (Appendix A).

Then, to reduce the list to the essential, both the eligibility criteria (Box 2 in Figure 1) and the screening filters (Box 3 in Figure 1) were applied successively. The following paragraphs describe this process in detail.

The eligibility criteria were defined to guarantee the applicability of the framework to the assessment of local climate change mitigation actions. Firstly, it was assumed that the respective change must be associated with energy-related GHG emissions, excluding, e.g., the emissions from crops and livestock. Then, the associated effect on the energy system should also be on Scope 1 and 2 emissions—GHG emissions that can be attributed to each municipality (i.e., that local inhabitants can be made accountable for). For instance, with this condition, changes in aviation and international commerce emissions are excluded, since typically an airport serves an area much larger than the municipality. Finally, it was also defined that factors should either change over time and/or influence

the effect of the other factors identified. As the goal is to decouple the observed changes in a specific local energy system into effects of the different factors of change, it makes sense that factors that are constant over time (even if determinant for local energy use) must be disregarded. For example, topography of the local territory can have significant implications for local energy use, but it cannot be considered a factor of change as it cannot lead to changes of a specific local energy system over time.

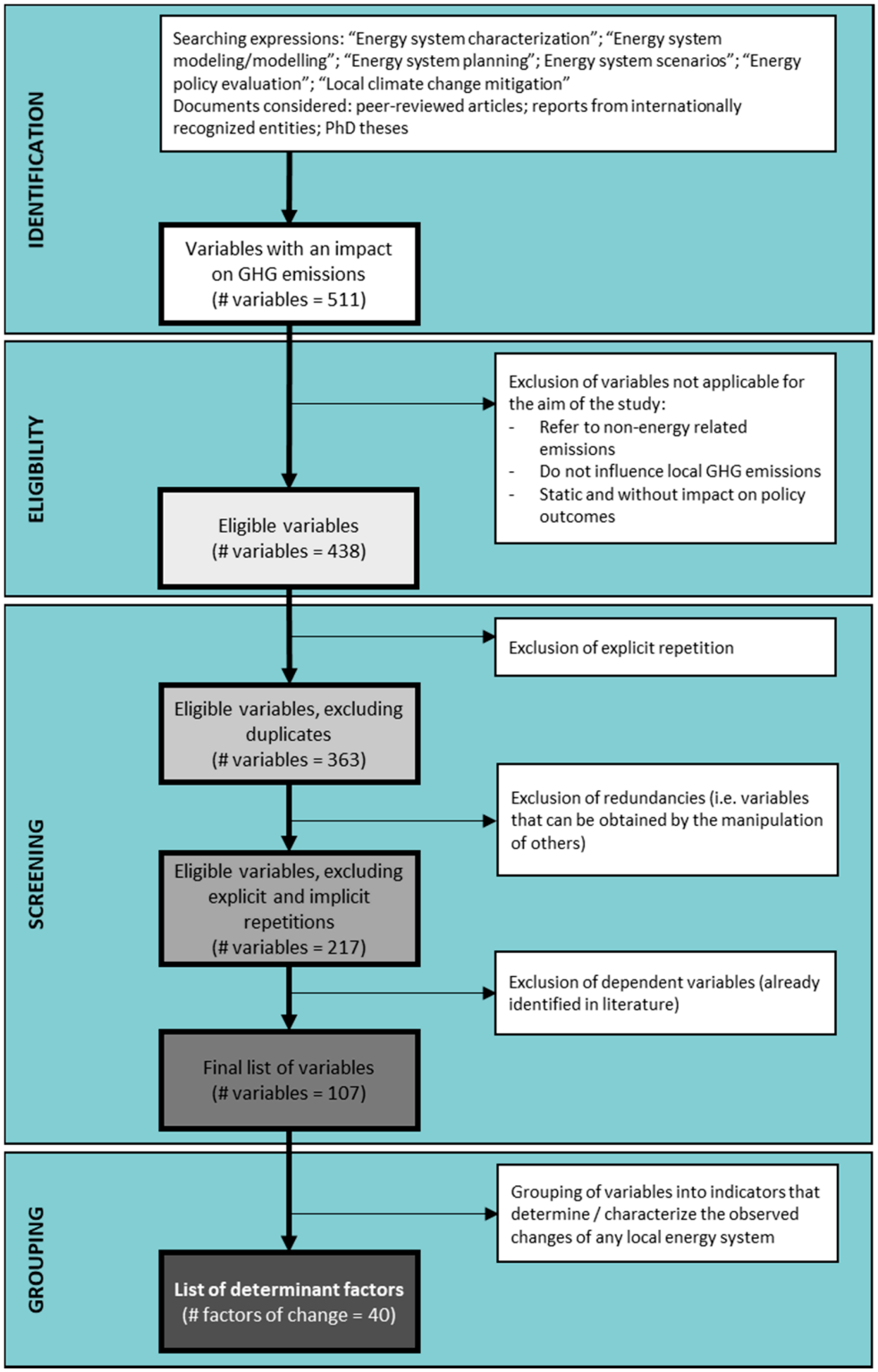

Figure 1. Schematic representation of the systematic literature review process.

The implementation of this step corresponded to the exclusion of variables that do not comply with at least one of the three eligibility criteria. The first eligibility criteria led to the exclusion of variables such as the "existence of strategies for landfill methane capture" and "changes in cattle production or fertilization strategies". Moreover, the constraint that implies that each factor must influence local GHG emissions led to the removal of variables such as "level of international trade" and "trade allowances between regions". Lastly, the criteria that exclude variables that do not change over time nor have an impact on policy outcomes implied the exclusion of factors "latitude", "topography", and others. Overall, with the application of the eligibility criteria, 73 variables were excluded from the list. The full list of the non-eligible variables is presented in the Appendix A (Table A2).

Furthermore, a screening process was defined and implemented to reduce the list of identified factors to the essential. This screening process is composed by three main steps that correspond to the application of three distinct filters: (1) explicit repetition; (2) implicit repetition; and (3) redundancy. The screening of the list of variables led to the exclusion of 331 variables. The full list of the excluded variables and the identification of the filters that led to their exclusion are presented in the Appendix A (Tables A3–A5).

The filter of explicit repetition refers to the removal of duplicates, i.e., factors that were identified by more than one document. For example, the number of inhabitants (or overall local population) and GDP were two of the variables that appeared more than once in the list.

Implicit repetition refers to factors that, even if not literally in duplicate, if withdrawn from the list do not imply an information loss. This includes factors that are a combination of other two or more factors that are also listed. For instance, average household area per capita can be considered as implicit repetition if both overall population and built area for residential purposes are already listed. This led to the exclusion of variables such as average household area per person (as total household area and overall population were also listed) and sectorial GDP (as GDP per subsector was also included).

Finally, the redundancy filter corresponds to the screening for dependent factors, whose relation has already been identified by literature. With this filter, for instance, average income per capita was excluded, considering that changes in private consumption (also linked to average income) would imply the exact same impact on local GHG emissions.

Once the variables with an impact on local GHG emissions have been identified and screened, a final list that is consistent with the goal of this work was obtained. The application of the eligibility criteria and the screening filters led to a final list of 107 variables that were grouped into 40 factors of change. This was done through an aggregation process, distinguishing policy-based factors from the ones that occur naturally, and factors related to actions implemented at local level from factors associated with governance actions at higher-levels. This grouping process is detailed in Table 3.

Table 3. Final list of variables and respective grouping into factors of change.

Factor of Change		Variables Identified in the Literature Review	
Statistical differences		3.002	Corrected statistics
Local inhabitants' characteristics	Educational level	17.004	Education
	Cultural diversity	15.021	Ethnic/religious views
	Willingness to act	18.006	Civic involvement (voting patterns)
		27.015	Concept of climate change (awareness of)
		27.016	Concept of GHG emissions (awareness of)
		27.017	Effects and impact of CC (awareness of)
Local administration characteristics	Competences	6.0005	Local authority's responsibilities and competences
	Qualified personnel	6.002	Existence of a dedicated institution/agency to deal with CC mitigation actions/plans
		6.003	Local authority's capacity and expertise on CC mitigation
	Economic situation	6.004	Local authority's ability to obtain funding
			Ratio between income and expenses

Table 3. *Cont.*

Factor of Change		Variables Identified in the Literature Review	
Climate variability		3.003	Climate (degree-days)
Demographic evolution	Population growth/change	15.002	Natural growth
		15.003	Migration
	Migration to urban areas	12.003	Share of urban population
	Age pyramid	14.003	Share of potential labor force
Social evolution	Household conditions	14.002	Persons per household
		24.002	Floor area per capita
		24.004	Heat per floor area
		13.005	Appliances ownership per capita
		13.006	DWH energy per capita
		13.007	Cooking energy per capita
		13.008	Lighting per floor area
	Commuting needs and transportation habits	13.010	Pkm
		12.023	Inverse of car ownership ratio
		13.011	Share of total pkm by mode
		27.009	Average commuting time
Economic evolution	Overall local economy	2.001	GDP growth
	Structure of local economy	8.004	GVA agriculture
		8.005	GVA services
		8.006	GVA transports
		8.007	GVA industry
		12.012	Distribution of sectors GVA by subsectors
	Economic situation of individuals	17.002	Employment
		8.003	Private consumption
Technology evolution	Market drivers/barriers	26.022	Technology market failures and other externalities related to electricity generation design
		9.006	Technical and costs evolution
		9.007	Availability and capacity limits (technology)
	Technical evolution	12.015	Average efficiencies of fuels for thermal uses per sector
		27.064	Energy intensity
	Technical evolution (Buildings)	14.010	Buildings insulation
		24.005	Intensity for different uses
		13.017	Energy per value-added (services)
	Technical evolution (Transports)	13.012	Energy per pkm by mode
		13.015	Energy per tkm by mode
	Technical evolution (Agriculture)	13.023	Energy per value-added by subsector
	Electricity generation and other energy transformation processes	3.010	Cogeneration end-users
		3.011	Fuel-mix end-users (actual energy use)
		3.012	Export (actual energy exports)
		3.013	Structure e-sectors (reference use refineries/gas supply)
		3.014	Cogeneration e-sectors
		3.015	Efficiency e-sectors (actual conversion efficiencies)
		3.016	Import (actual energy imports)
		3.017	Fuel-mix e-sectors
State and international governance framework	Existing policies	9.004	Energy and environmental policies
		15.012	International market
		15.013	National market
	Energy costs	18.012	Price of energy and relative share of any taxes or levies (energy costs)
	Synergies with local-level actions	6.001	Coherent multi-level policy framework (vertically and horizontally)
		6.006	Support from central governments to local policies

Table 3. *Cont.*

Factor of Change		Variables Identified in the Literature Review	
Actors involved	SEAP preparation	5.015	Decision body approving the plan
		5.003	Coordination and organizational structures created/assigned
		5.004	Staff capacity allocated
	SEAP implementation	10.001	Actors involved in local CC mitigation
		5.019	Origin of the action (local or other)
		5.020	Responsible body
Timeframe		5.014	Date of approval
		5.021	Implementation timeframe
Targets		5.001	Overall CO_2 reduction target
		5.002	Vision
Current implementation status		1.014	State of activity
		5.026	Newest inventory year
		5.031	Status implementation
		5.006	Overall estimated budget for the SEAP implementation
Estimated impact	Base year inventory	5.011	Final energy consumption per sector and carrier
		5.012	Energy supply sources
		5.013	CO_2 emissions per sector and carrier
	BAU projections	5.016	BAU projections
	Overall estimated impact	5.023	Energy savings
		5.024	Renewable energy production
		5.025	CO_2 reduction
	Mid-term inventory	5.028	Final energy consumption per sector and carrier
		5.029	Energy supply sources
		5.030	CO_2 emissions per sector and carrier
	Mid-term estimated impact	5.033	Renewable energy production from actions implemented so far
		5.034	CO_2 reduction from actions implemented so far
		5.009	Description of the impact of instruments
Budget	Overall	5.022	Estimated implementation costs
	Spent so far	5.032	Implementation cost spent so far
Financing sources		4.018	Funding
		5.007	Foreseen financing sources for the implementation
Actions characterization	Area of intervention	5.017	Area of intervention
	Technical measure	4.021	Action targeted sectors
		16.008	Measure/action
		16.009	Intensity of measure (degree of implementation)
	Instruments	4.012	Type of experiment
		4.014	Type of innovation
		1.017	Presence of flexibility mechanisms
		19.008	Policy theory associated with instruments applied
		5.018	Policy instrument
Other process characteristics		1.001	Agenda setting process
		27.046	Establish implementation priorities for action
		5.008	Monitoring process

Finally, to complete the theoretical framework, each individual factor was characterized with (preferably quantifiable) indicators. For most of the factors, the documents where they were extracted from also mentioned possible indicators. When more than one indicator was available, the choice fell back on the indicators whose data are more commonly available. When the documents did not mention possible indicators, these were searched for in national statistical agencies and policy reports from national or international governments. Within this step, there was an effort to choose indicators that use data that are commonly available for the municipality level, or equivalent scale, to avoid the need for downscaling.

3. Factors of Change of Local or Municipal GHG Emissions and Respective Characterization

This section presents the results obtained by the systematic literature review process described in the previous section. This includes discussion detailed description and an analysis of the final list of factors of change that were identified as well as the listing of the characterizing indicators for each factor of change.

To better understand the relation between the different factors of change and prompt a more fulfilling discussion, the 40 factors of change identified in the review were grouped into four distinct sets. Three of these groups correspond to three sources of change: local socio-economic and cultural changes; higher-level governance framework; and local climate change mitigation actions. The fourth group (herein referred to as local context) comprises variables that, despite not leading directly to changes of local GHG emissions, have influence on how the different sources of change impact local GHG emissions (e.g., climate awareness). A schematic representation of the relation between these sources of change and the observed changes in local GHG emissions, considering the local context, is presented in Figure 2.

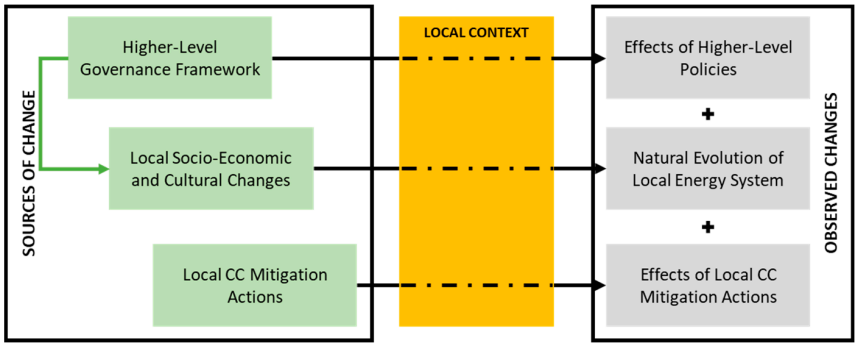

Figure 2. Framework of the sources of change and the observed changes in local GHG emissions.

3.1. Local Context

Local context refers to the local characteristics that, despite not leading directly to changes on the local energy system, influence the outcomes of both local and higher-level policies. On the one hand, this comprises the local inhabitants' characteristics, as education level, cultural diversity, and awareness towards the problematic of climate change. On the other hand, local context also includes characteristics referring to the local authority as an entity, including human and financial resources as well as legal competences. In general, the characteristics here referred as local context do not change significantly in the medium-term.

A complete list of the factors of change considered as local context is presented in Table 4, along with the respective characterizing indicators.

Table 4. Factors of change associated with local context with corresponding indicators.

Factor of Change		Characterizing (and Quantifiable) Indicator	Unit
Local inhabitants' characteristics	Education level	Distribution of local population per education level	Dimensionless (%)
	Cultural diversity	Valid permits by reason per 1000 inhabitants	# permits/1000 inhab.
	Willingness to act	Share of waste that is separated previous to collection (recycling)	Dimensionless (%)
	Awareness		
	Civic involvement	Number of environmental nonprofits per 1000 inhabitants	# groups/1000 inhab.

Table 4. *Cont.*

Factor of Change		Characterizing (and Quantifiable) Indicator	Unit
Local authority characteristics	Legal competences	Level of autonomy (High, Medium, Low)	Nominal variable
	Qualified personnel	Y/N (or Number of people assigned to CC mitigation issues)	# people
	Dedicated institution/agency for CC mitigation		
	Previous experiences related with CC mitigation	Y/N	n.a.
	Economic situation	Global ranking of the municipalities' financial situation	Dimensionless
	Ability to obtain funding		
	Relation between income and expenses	Ratio between income and expenses	Dimensionless

A summarized description of each of the factors of change associated with local context is presented below.

3.1.1. Local Inhabitants' Characteristics

Education level refers to the average level of education of the local population, e.g., whether the majority of local citizens have completed high school, or even a bachelor degree. Here, it was assumed that the distribution of local population per education level could be a good indicator.

Cultural diversity refers to the heterogeneity of local population in terms of cultural background. This is mostly linked with the scale of immigration to the city, currently but also in the last decades. Culture is associated with daily habits and, thus, with specific patterns of energy use and reaction towards certain policy actions/incentives. One of the possibilities to assess this diversity could be through the number of residence permits by reason (or by country of origin).

Willingness to act refers to the level of motivation of the local citizens in having an active role towards climate change mitigation, which is highly associated with their level of awareness to the problem and their civic involvement in the community. For instance, the level of awareness of local population on environmental and climate change issues can have a huge influence on the outcome of any related policy independently on the level of implementation. Even if waste associated emissions are not considered within this work, it is assumed that the share of waste separation could be a good indicator of the local population awareness on climate change issues. Moreover, the degree of civic involvement may be assessed by the number and scale of environmental nonprofits that were created at the local level.

3.1.2. Local Authorities' Characteristics

Legal competences refers to the regulatory competences of local authorities regarding climate change mitigation, i.e., their scope of action. These may vary significantly from country to country and are determinant for the type of actions that are promoted at the local level. The level of autonomy of local authorities can be seen as a good indicator of their scope of action.

Qualified personnel corresponds to the technical competences of the municipal staff for developing and implementing actions targeting climate change mitigation. This can be assessed through the existence of a dedicated agency or municipal department to climate change mitigation, and from past experiences with these issues.

Economic situation translates the economic capacity of the local authority in financing and promoting actions towards climate change mitigation. This can be assessed by the relation between

income and expenses of the local authority, which provides a characterization of their yearly profit or debt. Moreover, the ability to obtain funding, through private partnerships or public tenders, is also a relevant indicator.

3.2. Local Socio-Economic and Cultural Changes

Local socio-economic and cultural changes refer to the group of changes that result from local demographic, social, and economic changes, thus not directly caused by energy-related policies. In planning terms, this would correspond to the "business as usual" or "reference" scenario, i.e., the potential evolution of the system between two distinct moments in time, considering that no policies would be implemented in this timeframe. This comprises demographic, social, and economic changes, as well as climate variability.

The full list of factors of change associated with the local socio-economic and cultural changes that have been identified is presented in Table 5, along with the respective characterizing indicators.

Table 5. Factors of change associated with local socio-economic and cultural changes with corresponding indicators.

Factor of Change		Characterizing (and Quantifiable) Indicator	Unit
Climate variability		Heating Degree Days Cooling Degree Days	HDD CDD
Demographic evolution	Population growth	Change of overall population	# inhabitants
	Migration to urban areas	Share of rural population	Dimensionless (%)
	Age pyramid	Share of active population	Dimensionless (%)
Social evolution	Household conditions	Persons per household Floor area per person	Person/household m^2/cap
	Commuting needs	Average commuting needs	km/person.day
	Transportation habits	Car ownership	cars/cap
Economic evolution	Overall growth of local economy	Local GDP change	€
	Structure of local economy	GVA per sector (or number of employees)	€
	Economic situation of households: Employment Private consumption	Unemployment rate Private Purchase Power	Dimensionless (%) €/cap

3.2.1. Demographic Evolution

Demographic changes include the population growth (due to migration and natural growth) and also changes in the age pyramid and in the share of population living in urban and rural areas. All these variations imply changes in the local energy system—in the overall energy use as well as in the structure of this use. For example, energy use in urban areas differ from that in rural areas, due to the differences in heating options available (natural gas vs. traditional wood) and the different household conditions (housing type and size). A summarized description of each of the factors of change associated with demographic changes is presented below.

Population growth refers to the changes regarding the size of local population that occur within the studied timeframe. This is assessed through the number of local inhabitants and their evolution over time.

Migration to urban areas translates the level of urbanization of a municipality and its evolution over time. A change in the level of urbanization has an impact in the local energy system, in terms of preferred transportation modes, average distances traveled, and even in the type of housing. The changes in the level of urbanization can be assessed through the share of local population living in rural/urban areas.

Age pyramid refers to the distribution of the population according to their age. A change in this distribution implies changes in the local energy system, caused by the distinct energy service needs. The differences are more significant between active and inactive citizens. Thus, it is assumed that this factor of change can be assessed by the quantification of the share of active population.

3.2.2. Social Evolution

Social changes refer to the lifestyle changes of local inhabitants that occur naturally, not promoted by energy-related policies. These may include e.g., the increase of appliances ownership per capita and changes in the number of persons per household, in the residential sector, and a change in the average distance between home and work or school, in the transportation sector. Each of the factors of change associated with social evolution are described below.

Household conditions refer to lifestyle changes associated with the residential building. This includes changes in the average number of people per household (usually also linked with the evolution in families' typology) and changes in the average size of the household. These changes can imply significant changes in the energy use for space heating and cooling, lighting, and even cooking. Moreover, changes in appliances ownership must also be considered.

Commuting needs reflect the distance between home and work/school for the local inhabitants. A variation in this distance implies also a change in the daily transportation needs, and often even a change in the transportation modes that are used for commuting. It is assumed that this factor can be assessed through the average distance traveled per person per day, for commuting purposes.

Transportation habits refer to changes in the preferences for daily traveling, for both commuting and leisure purposes. These characteristics may change over time for multiple reasons—economic, social or other. It is assumed that a large share of these changes can be estimated based on the changes in car ownership of local population.

3.2.3. Economic Evolution

Economic evolution refers to the economic situation of local inhabitants and also to the evolution of local economic activities. The effect of these changes on local energy system may be affected, even if not in a very significant way, by local context. For instance, the increase in average income of local population leads to an increase in energy use; however, the growth rate may depend on the level of awareness of the local inhabitants towards climate change issues. The factors of change associated with the economic evolution at the local level are described below.

Overall growth of local economy refers to changes in the level of activity, i.e., the overall value of the local economy. Changes in the local gross domestic products (GDP) are a good indicator for the variation in the level of activity.

Structure of local economy refers to the weight that different economic sectors (or subsectors) represent to the overall local economy. Describing the structure of economy of a specific municipality would consist on identifying the sectors responsible for a larger share of gross value added or for employing more workers and which sectors are less relevant.

Economic situation of households translates the financial situation of individuals. This includes the employment situation, which has a significant impact in the local energy system given the difference in the daily habits between employed and unemployed citizens, and the individuals purchase power. On the latter, there are several studies that demonstrate the relation between private purchase power and energy use.

3.2.4. Climate Variability

Finally, the effects of differences in climate conditions have also been included in the natural evolution of the local energy system. These vary from year to year, and temperature differences lead to changes in energy needs (mostly for heating and cooling), which must be considered. It is assumed that these changes can be assessed through the variations in annual heating and cooling degree days.

3.3. Higher-Level Governance Framework

Higher-level governance framework refers to the characteristics of international, national, and regional governance frameworks existing within the studied timeframe and focusing on energy and climate issues. Considering the variables identified in the review, it is assumed to be appropriate to separate technology evolution from specific energy and climate policies.

The full list of factors that characterize higher-level governance framework is presented in Table 6, along with the respective characterizing indicators.

Table 6. Factors of change related to higher-level governance framework with corresponding indicators.

Factor of Change		Characterizing (and Quantifiable) Indicators	Unit
Technology Evolution	Technical evolution	National average energy intensity per sector	kWh/€
	Market evolution: Technology costs Market barriers	Over cost of A^{++} appliances compared to B equivalent Energy efficiency gap	€
	Energy supply sector: Fuel-mix of electricity and heat generation	Share of renewable energy sources (RES)	Dimensionless (%)
	Efficiency of energy transformation sector	Overall efficiency and losses	Dimensionless (%)
National and international energy-related policies	Existing policies	Public and private investments on environmental management and protection per economic activity (cumulative values)	€
	Energy costs	Average energy cost for final consumer	€/kWh
	Coherence with local policies	Alignment between different scales objectives?	(Y/N)
	Support of local action	Initiatives to promote local action (Number)	# initiatives

3.3.1. Technology Evolution

Technology evolution can be prompted by energy related policies (targeting energy efficiency and others) but it may also be market driven (following industry needs or an attempt to reduce costs). The evolution of the energy supply sector can be seen as a mix between natural technology evolution and an effect of energy and climate policies. The energy efficiency improvement on conversion plants is an example of the former, while the preference for renewable energy sources to produce electricity, due to fee-in tariffs in the technological maturation phase, is an example of the latter.

Technical evolution refers to the technology development that occurs naturally, i.e., excluding development that is promoted by energy efficiency policies and other related instruments. This evolution can be assessed by the variation in the energy intensity for each activity sector, at national or even international level.

Market evolution corresponds to the changes in the market that lead to changes in the technology choices by both individuals and companies. This can be translated into changes in technology costs, as well as the presence of market barriers that hamper the shift towards more efficient solutions. The variation in technology costs can be characterized by, e.g., the over cost of A++ appliances compared to a B equivalent. The presence of market barriers and respective evolution over time can be assessed by the quantification of the energy efficiency gap in different moments in time.

Energy supply sector represents the changes in the national and regional energy transformation and transport activities. It includes the evolution in electricity and heat production and transport, as well as the changes in the refinery of fossil fuels. Thus, it comprises the changes in the fuel-mix of electricity and heat generation, i.e., the increase/decrease in the share of renewable energy sources that are used in electricity production, as well as the changes in the efficiency of the energy supply sector (electricity and heat production, but also oil products transformation).

3.3.2. National and International Energy-Related Policies

On what concerns the factors of change associated to energy and climate policies, two distinct groups of factors were found: the ones that characterize the existing energy and climate related policies, e.g., in terms of implementation and specific targets, and the ones that characterize the existing institutional framework regarding the promotion and support of local actions towards climate change mitigation. It is also important to mention the influence that the local context may have on the overall effect of these factors of change on the local energy system. The effects of national and international policies depend on the reaction of targeted actors to the policy instruments put in place. In turn, their reaction depends on their level of education and awareness as well as cultural habits and financial situation. All the identified factors associated with energy and climate policies are briefly described below.

Existing policies correspond to the policies that are implemented at regional, national, and international level that have a climate and/or energy purpose. These may impact positively or negatively local GHG emissions, depending on the coherence between local policies and the ones defined at higher levels of governance. Here, it is assumed that the public and private investments on environmental management and protection could be a good indicator of the scale of existing policies at governance levels other than local.

Energy costs refer to the changes in the average cost of the different energy products and the impact that these may have in the local energy system. Energy prices are usually established at the national and/or regional level, and thus are included within the changes associated with the higher-level governance framework. The average unitary price per energy product in the consumer sector, as well as the respective evolution over time, is considered a good indicator to characterize this factor of change.

Coherence with local policies refers to whether national and regional policy objectives are aligned with those that were defined at the local/municipal level. Here, the quantification of this alignment is not feasible, thus a yes or no question is suggested.

Support of local action refers to the existence of initiatives promoted at national and international level that promote actions taken at the local level. This may include technical support for the development of action plans, and energy dedicated actions, and economic incentives and support (as low-rate loans). A possible indicator to characterize the level of support could be the number of initiatives promoted at higher levels of governance that support local action.

3.4. Local Climate Change Mitigation Actions

Finally, local climate change mitigation actions include any policy actions that are promoted at the local level, by (or with the support of) local authorities, with the aim of reducing local GHG emissions. These include actions taken under a formal and wider plan and also isolated actions with a very specific target (e.g., the improvement of energy efficiency in public lighting). Here, the factors of change that have been identified are mostly related with the characterization of these actions, in terms of objectives and targeted actors as well as in what concerns implementation procedures. The factors that were identified as important for the characterization of local climate change mitigation actions are briefly described below and presented in Table 7.

Table 7. Factors of change associated with local climate change mitigation actions with corresponding indicators.

Factor of Change		Characterizing (and Quantifiable) Indicators	Unit
Actors involvement	Action plan preparation	Groups of actors involved	Nominal variable
	Action plan implementation	Groups of actors involved	Nominal variable
Timeframe	Study	Base Year and Time Horizon	Year
	Action plan implementation	Beginning and End of action plan implementation	Year
Targets	Vision	Other goals besides GHG emissions reduction	(Y/N)
	GHG emissions reduction		ton $CO_{2\ eq.}$
Current implementation status	Overall	Share of the overall plan already implemented	Dimensionless (%)
	Per action	Share of the individual measure already implemented	Dimensionless (%)
Estimated impact	Base year inventory	In terms of final energy and GHG emissions reduction (measured)	GWh/a ton $CO_{2\ eq.}$/a
	BAU projections	In terms of final energy and GHG emissions reduction (predicted)	GWh/a ton $CO_{2\ eq.}$/a
	Latest inventory	In terms of final energy and GHG emissions reduction (measured)	GWh/a ton $CO_{2\ eq.}$/a
Budget	Overall		€
	Spent so far		€
Financing sources	Entity(s) responsible	Entities financing local actions (per category)	Nominal variable
	Share of overall investment costs	Fraction of overall investment that is financed by each entity	Dimensionless (%)
Actions characterization	Area of intervention	Sector and subsector targeted	
	Technical measure:		
	Measure	Building retrofit, modal shift in transports, led street lights, etc.	Nominal variable
	Level of implementation	Share of the sector/subsector impacted by the action	Dimensionless (%)
	Estimated impact	In terms of final energy and GHG emissions reduction	GWh/a ton $CO_{2\ eq.}$/a
	Policy instrument:		
	Type	Regulation, incentive, education, etc.	Nominal Variable
	Level of support	Share of financing provided by the instrument	Dimensionless (%)
	Stakeholders involvement		Nominal variable

Actors' involvement refers to the group of actors that were/are involved in the local climate change mitigation actions. A distinction is made between the actors that are involved in the planning process (where actions are defined) and the ones involved in the implementation stage. The involvement of different stakeholders in the planning and implementation of climate and energy actions is considered to be beneficial for the respective acceptance and adherence by local citizens. The characterization of this involvement may be achieved by the identification of the groups of actors that were involved (e.g., local authority, local/regional energy agency, external consultant, local NGOs, citizens, etc.) and their level of involvement (co-creation, draft version public consultation, etc.).

Timeframe refers to the time span of the actions being planned/implemented. Throughout the review, the consideration of the time span of the ex-ante planning exercise (when existing) was also

noted as relevant for the assessment of the outcomes of local actions. This is translated into the beginning and end years of the actual (or projected) action implementation.

Targets refer to the objectives that were defined at the local level. These include the level of GHG emissions reductions that is aimed, the wider vision concerning the local energy system, and whether there are other goals besides GHG emissions (such as creation of jobs or decrease in energy costs).

Current implementation status refers to the degree of implementation of the wider action plan (if existing) and of the different individual actions that are projected. It can be assessed as a percentage of the overall implementation target. For instance, considering an action that implied the installation of solar thermal systems for water heating in 100 residential buildings, the degree of implementation would correspond to the identification of the share of systems that were already installed.

Estimated impact corresponds to the projected outcome of the proposed actions, in terms of both energy use and GHG emissions. When a mid-term assessment is also performed, the quantification of the already achieved reductions could also be performed.

Budget refers to the level of investment needed to implement the proposed actions. Here, it is important to distinguish between the overall projected budget and the investments made thus far.

Financing sources correspond to the entities responsible for financing the actions' implementation. This may comprise different entities, both public and private. The characterization of the financing sources could be performed by the identification of the type of entities financing the local actions (local authority's own resources, national funds and programs, EU funds and programs, other), and the level of investment of each of the different entities.

Actions characterization corresponds to the characterization of the individual actions planned and/or implemented at the local level, in terms of: (1) area of intervention; (2) type of technical measure; and (3) policy instrument. Area of intervention is the sector and subsector of the local energy system which will be impacted by the action (residential, services, transports, etc.). Then, the technical measure refers to the type of change that is aimed at, as well as the degree of change that is intended. For instance, the shift of 10% of private cars passenger-kilometers to soft modes of transportation could be seen as a technical measure. Finally, the choice of policy instrument corresponds to the type of mechanism that is used to achieve the desired changes in the system. Using the same example, this could comprise the creation of dedicated bike lanes and/or the implementation of a congestion charge. When assessing the policy instruments, it is also useful to identify the level of financial support that is provided to the adopters of the measures (i.e., if there are economic incentives to change) and which actors are involved in their implementation.

Similar to what was said regarding the effects of higher-level policies, the influence of local context on the contribution of local actions cannot be disregarded. Local inhabitants' characteristics may influence the outcomes of policy actions in a significant manner. Moreover, local authorities' characteristics are an important feature on the definition and implementation of local actions. Thus, even if local actions are similar in their characteristics, their outcome can be very different if the context in which they are implemented is not the same.

4. Discussion

There are several studies that analyze the changes in local GHG emissions and potential explanatory factors. However, it was noted throughout the review that existing work is usually constrained to the consideration of a specific set of factors of change, disregarding others that may also have a significant impact on local emissions. For instance, it is common to narrow the focus to the actions that are being taken at the local level, disregarding the influence of higher-level governance framework in which they are being implemented and that may have confounding effects.

Such non-consideration of other potential factors of change hinders the accuracy of the results, as the effects calculated and associated with the considered factors may turn out to be either under- or overestimated. Indeed, the evaluation of the effects of local climate change mitigation actions will not lead to accurate results unless the remaining factors of change are taken into account. For example,

in [5], the impact of local climate actions was inconclusive, partly due to the non-consideration of factors associated with the changes in local socio-economic and cultural conditions. Moreover, a better understanding of all potential factors of change of local GHG emissions can lead to better planning at local as well as regional and national levels. The interaction between the policies implemented at different governance levels could be improved by a comprehensive consideration of all factors of change and their interactions.

It is worth noting the overly simplified consideration of the local context in most of the existing work. Some of the reviewed documents refer to its importance, and how the local context specificities can be determinant for the success of local actions implementation, yet quantification methods tend to be overlooked. The systematic identification of the factors of change associated with local context may thus be a step forward for their consideration in future empirical ex-post evaluation studies and/or ex-ante planning exercises.

5. Conclusions

This paper is dedicated to a comprehensive and systematic identification and characterization of the factors that are relevant for the assessment of the observed changes in GHG emissions associated with local energy systems. This is an important contribution for the assessment of the actual effects of local climate change mitigation actions, by establishing the bases for developing analytical frameworks.

The identification was performed through a systematic literature review process. The complete list of variables encountered in the review was reduced using eligibility criteria, as well as three screening filters (explicit repetition, implicit repetition, and dependent variables). A list of 107 variables that were grouped into 40 factors of change was finally obtained.

The factors of change were grouped into four subsets, corresponding to three sources of change plus the local context. The sources of changes subsets are: local socio-economic and cultural changes; higher-level governance framework; and local climate change mitigation actions. The local context corresponds to a group of variables that, despite not leading directly to changes in local GHG emissions, have influence on how the remaining factors impact the local energy system—e.g., local inhabitants' level of awareness and commitment towards environmental problems or local authorities' legal scope of action.

Even if the identification of the major categories has been previously accomplished in academic studies, the major advancement of this work corresponds to their disaggregation into individual factors of change and respective characterization.

The factors identified correspond to all the factors that may potentially lead to changes in local GHG emissions. The relevance of the effects associated with each factor of change will depend on the local system in question, as well as on the timeframe addressed. Moreover, even acknowledging the difficulty of empirical validation (and quantification) of each factor individually, the obtained results comprise an advancement from what was possible thus far, providing a basis for more accurate models and analyses of the evolution of the energy systems at the local level.

These results can be used to build an analytical framework to characterize and model the evolution of a local energy system, assessing the individual effect of each of the different explanatory factors. This will allow for more accurate energy planning at the local level, taking into account the potential interactions with the external factors of change (i.e., the factors that are not controlled by local authorities). For instance, it may be used for ex-post evaluation of local climate change mitigation actions, allowing for the disaggregation of the observed changes in local GHG emissions into the causes and the isolation of the effects that were solely associated to local policies and actions.

The outcome of this work can be seen as a fundamental step towards a comprehensive assessment of the evolution of local energy systems. Such assessment is crucial for a better evaluation of the actual contribution of local climate-related policies and actions towards climate change mitigation.

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Appendix A

This appendix presents in detail the process of identification and screening of the factors of change that are relevant for local GHG emissions. Table A1 presents the full list of variables identified in the literature. The four following tables are dedicated to the screening process: Table A2 presents the variables that were excluded for non-applicability; Tables A3 and A4 present the variables that were eliminated due to explicit and implicit repetition, respectively; and Table A5 presents the variables that were excluded to avoid dependent variables.

Table A1. Full list of variables identified in the systematic literature review process and respective sources.

Document	Code	Variable
Auld et al. (2014)	1.001	Agenda setting processes
	1.002	Favorable public opinion
	1.003	Favorable party platform
	1.004	Recent change in government
	1.005	Presence of champions
	1.006	Social appeal
	1.007	Availability of technology
	1.008	International processes
	1.009	Focusing events
	1.010	Action of feedback mechanism
	1.011	Timeframe
	1.012	Reporting nature
	1.013	Policy instruments
	1.014	State of activity
	1.015	Target of policy (actors)
	1.016	Source of authority at different stages (Hybrid or Government)
	1.017	Presence of flexibility mechanisms
Boonekamp (2004)	2.001	GDP growth
	2.002	Structure, main sectors
	2.003	Structure, subsectors
	2.004	Structure, final demand
	2.005	Savings, final demand
	2.006	Conversion efficiency end-users
	2.007	Co-generation end-users
	2.008	Fuel mix end-users
	2.009	Export
	2.010	Structure electricity production sectors
	2.011	Co-generation electricity production sectors
	2.012	Import
	2.013	Fuel mix electricity production sectors

Table A1. *Cont.*

Document	Code	Variable
Boonekamp (2005)	3.001	Energy statistics (statistical figures)
	3.002	Corrected statistics (corrections from trend breaks, etc.)
	3.003	Climate (degree-days and fraction room heating)
	3.004	GDP growth (GDP growth rate)
	3.005	Structure, main sectors (growth rate main sectors)
	3.006	Structure, subsectors (growth rate per subsector)
	3.007	Structure, final demand (Reference final demand per subsector)
	3.008	Savings, final demand (Actual final heat/electricity demand)
	3.009	Conversion efficiency end-users (Actual efficiency boilers, etc.)
	3.010	Cogeneration end-users (actual CHP figures)
	3.011	Fuel-mix end-users (Actual energy use)
	3.012	Export (Actual energy exports)
	3.013	Structure energy transformation sectors (reference use refineries/gas supply)
	3.014	Cogeneration energy transformation sectors (actual cogeneration figures)
	3.015	Efficiency energy transformation sectors (actual conversion efficiencies)
	3.016	Import (actual energy imports)
	3.017	Fuel-mix electricity production sectors (actual energy use)
Broto and Bulkeley (2013)	4.001	Country
	4.002	Urban area
	4.003	Population
	4.004	Density
	4.005	GDP
	4.006	GDP per capita
	4.007	World City Rank
	4.008	Annual population rank
	4.009	Location
	4.010	Dates
	4.011	Urban character
	4.012	Type of experiment
	4.013	Objectives
	4.014	Type of innovation
	4.015	Institutional factors
	4.016	Sector specific information
	4.017	Actors involved
	4.018	Funding
	4.019	Mode of governance
	4.020	Environmental justice
	4.021	Action targeted sectors
	4.022	Action type of schemes
CoM (2010)	5.001	Overall CO_2 reduction target
	5.002	Vision
	5.003	Coordination and organizational structures created/assigned
	5.004	Staff capacity allocated
	5.005	Involvement of stakeholders and citizens
	5.006	Overall estimated budget for the Sustainable Energy Action Plan implementation
	5.007	Foreseen financing sources for the implementation
	5.008	Monitoring process
	5.009	Year
	5.010	Population
	5.011	Final energy consumption per sector and carrier
	5.012	Energy supply sources
	5.013	CO_2 emissions per sector and carrier
	5.014	Date of approval
	5.015	Decision body approving the plan
	5.016	Business-as-usual projections

Table A1. *Cont.*

Document	Code	Variable
CoM (2010)	5.017	Area of intervention
	5.018	Policy instrument
	5.019	Origin of the action (local or other)
	5.020	Responsible body
	5.021	Implementation timeframe
	5.022	Estimated implementation cost
	5.023	Energy savings
	5.024	Renewable energy production
	5.025	CO_2 reduction
	5.026	Newest inventory year
	5.027	Population
	5.028	Final energy consumption per sector and carrier
	5.029	Energy supply sources
	5.030	CO_2 emissions per sector and carrier
	5.031	Status implementation
	5.032	Implementation cost spent so far
	5.033	Renewable energy production from actions implemented so far
	5.034	CO_2 reduction from actions implemented so far
Corfee-Morlot et al. (2009)	6.001	Coherent multi-level policy framework (vertically and horizontally)
	6.002	Existence of a dedicated institution/agency to deal with climate change mitigation actions/plans
	6.003	Local authority's capacity and expertise on climate change mitigation
	6.004	Local authority's ability to obtain funding
	6.005	Local authority's responsibility and competences
	6.006	Support from central governments to local policies
Farla and Blok (2000)	7.001	Total dwelling area
	7.002	Average number of inhabitants
	7.003	Number of appliances per type
	7.004	Number of vehicle-kilometers of personal cars per fuel
	7.005	Number of passenger-kilometers per mode (except car)
	7.006	Number of vehicle-kilometers of freight road transportation
	7.007	Number of ton-kilometers per mode (other freight transportation)
	7.008	Number of employee-years
	7.009	Production of goods per type (piece, kg or m^2)
	7.010	Cultivated land area
	7.011	Raising of cattle, pigs and chickens
	7.012	Volume index of production
Fortes et al. (2014)	8.001	Gross domestic product (GDP)
	8.002	Population
	8.003	Private consumption
	8.004	Gross value-added Agriculture
	8.005	Gross value-added Services
	8.006	Gross value-added Transports
	8.007	Gross value-added Industry
Fortes et al. (2015)	9.001	Annual growth rate of the socio-economic indicator
	9.002	Demand elasticity
	9.003	Autonomous efficiency improvement factor (industrial sectors)
	9.004	Energy and environmental policies
	9.005	Energy and environmental policy instruments
	9.006	Technical and costs evolution
	9.007	Availability and capacity limits
	9.008	Other information (discount rate, etc.)
	9.009	Endogenous resources potential and prices
	9.010	Import/export prices and boundaries

Table A1. *Cont.*

Document	Code	Variable
Gustavsson et al. (2009)	10.001	Actors involved in local Climate Change mitigation
	10.002	Formulation of the climate-policy strategy
	10.003	Results in terms of GHG emissions reduction
	10.004	Geography
	10.005	Business structure
	10.006	Physical circumstances
	10.007	Actors involvement
Gysen et al. (2002)	11.001	Objectives
	11.002	Instruments
	11.003	Means—Societal
	11.004	Means—Policy process
	11.005	Policy output
	11.006	Policy outcome
	11.007	Policy impact
IAEA (2006)	12.001	Total population
	12.002	Average annual growth rate of population
	12.003	Share of urban population
	12.004	Average household size in urban areas
	12.005	Average household size in rural areas
	12.006	Share of population of age 15–64 in total population
	12.007	Share of potential labor force actually working
	12.008	Share of population living in large cities
	12.009	GDP
	12.010	Average annual growth rate of GDP
	12.011	Distribution of GDP formation by kind of economic activity
	12.012	Distribution of sector gross value-added by subsectors
	12.013	Energy intensities in industry
	12.014	Penetration of energy carriers into useful thermal energy demand of the different sectors
	12.015	Average efficiencies of fuels for thermal uses per sector
	12.016	Share of transportation modes in the total demand for freight transportation
	12.017	Energy intensity of freight transportation modes
	12.018	Average intracity distance traveled per person per day
	12.019	Average load factor of intracity passenger transportation mode(s)
	12.020	Share of transportation mode(s) in the total demand for intracity passenger transportation
	12.021	Energy intensity of transportation mode(s) in intracity travel
	12.022	Average intercity distance traveled per person per day
	12.023	Inverse of car ownership ratio
	12.024	Average intercity distance driven per car per year
	12.025	Average load factor of intercity transportation mode(s)
	12.026	Share of car type(s) in the intercity transportation mode(s)
	12.027	Share of public transportation mode(s) in the intercity passenger travel by public modes
	12.028	Energy intensity of transportation mode(s)
	12.029	Fraction of urban dwellings in areas where space heating is required
	12.030	Degree days for urban dwellings
	12.031	Fraction of urban dwellings per type
	12.032	Average size of urban dwellings by type
	12.033	Fraction of floor area that is actually heated in urban areas per dwelling type
	12.034	Specific heat loss rate by urban dwelling type
	12.035	Share of urban dwellings with air conditioning, by dwelling type
	12.036	Specific cooling requirements by urban dwelling type
	12.037	Specific energy consumption for cooking in urban dwellings
	12.038	Share of urban dwellings with hot water facilities
	12.039	Specific energy consumption per urban dwelling for electric appliances

Table A1. *Cont.*

Document	Code	Variable
IAEA (2006)	12.040	Electricity penetration for appliances in urban households
	12.041	Specific fossil fuel consumption per urban dwelling for lighting and non-electric appliances
	12.042	Penetration of various energy forms into space heating in urban households
	12.043	Efficiency of various fuels use, relative to that of electricity use, for space heating in urban households
	12.044	Coefficient of performance of heat pumps for space heating in urban households
	12.045	Penetration of various energy forms into water heating in urban households
	12.046	Efficiency of various fuels use, relative to that of electricity use, for water heating in urban households
	12.047	Coefficient of performance of heat pumps for water heating in urban households
	12.048	Approximate share of water heating demand in urban households that can be met with solar installations
	12.049	Penetration of various energy forms into cooking in urban households
	12.050	Efficiency of various fuels use, relative to that of electricity, for cooking in urban households
	12.051	Approximate share of cooking demand in urban households that can be met with solar installations
	12.052	Share of air conditioning demand of urban households that can be met with electricity
	12.053	Coefficient of performance of electric air conditioning in urban households
	12.054	Coefficient of performance of non-electric air conditioning in urban households
	12.055	Fraction of rural dwellings in areas where space heating is required
	12.056	Degree days for rural dwellings
	12.057	Fraction of rural dwellings per type
	12.058	Average size of rural dwellings by type
	12.059	Fraction of floor area that is actually heated in rural areas per dwelling type
	12.060	Specific heat loss rate by rural dwelling type
	12.061	Share of rural dwellings with air conditioning, by dwelling type
	12.062	Specific cooling requirements by rural dwelling type
	12.063	Specific energy consumption for cooking in rural dwellings
	12.064	Share of rural dwellings with hot water facilities
	12.065	Specific energy consumption per rural dwelling for electric appliances
	12.066	Electricity penetration for appliances in rural households
	12.067	Specific fossil fuel consumption per rural dwelling for lighting and non-electric appliances
	12.068	Penetration of various energy forms into space heating in rural households
	12.069	Efficiency of various fuels use, relative to that of electricity use, for space heating in rural households
	12.070	Coefficient of performance of heat pumps for space heating in rural households
	12.071	Penetration of various energy forms into water heating in rural households
	12.072	Efficiency of various fuels use, relative to that of electricity use, for water heating in rural households
	12.073	Coefficient of performance of heat pumps for water heating in rural households
	12.074	Approximate share of water heating demand in rural households that can be met with solar installations
IAEA (2006)	12.075	Penetration of various energy forms into cooking in rural households
	12.076	Efficiency of various fuels use, relative to that of electricity, for cooking in rural households
	12.077	Approximate share of cooking demand in rural households that can be met with solar installations

Table A1. *Cont.*

Document	Code	Variable
IAEA (2006)	12.078	Share of air conditioning demand of rural households that can be met with electricity
	12.079	Coefficient of performance of electric air conditioning in rural households
	12.080	Coefficient of performance of non-electric air conditioning in rural households
	12.081	Share of service sector in the total active labor force
	12.082	Average floor area per employee in the Service sector
	12.083	Share of Service sector floor area requiring space heating
	12.084	Share of Service sector floor area requiring space heating that is actually heated
	12.085	Specific space heat requirements of Service sector floor area
	12.086	Share of air-conditioned Service sector floor area
	12.087	Specific cooling requirements in the Service sector
	12.088	Energy intensity of motor fuel use per Services' subsector
	12.089	Energy intensity of electricity specific uses per Services' subsector
	12.090	Energy intensity of thermal uses (except space heating) per Services' subsector
	12.091	Penetration of various energy forms into space heating in Service sector
	12.092	Penetration of various energy forms into other thermal uses in the Service sector
	12.093	Efficiency of various fuels use, relative to that of electricity use, for thermal uses in Service sector
	12.094	Coefficient of performance of heat pumps in space heating in Service sector
	12.095	Share of low-rise buildings in the total Service sector floor area
	12.096	Approximate share of thermal uses in the Service sector that can be met by solar installations
	12.097	Share of air-conditioning that can be met with electricity
	12.098	Coefficient of performance of electric air conditioning in Service sector
	12.099	Coefficient of performance of non-electric air conditioning in Service sector
IEA (2014)	13.001	Population
	13.002	Floor area per capita
	13.003	Persons per household
	13.004	Appliances ownership per capita
	13.005	Heat per floor area
	13.006	Domestic how water energy per capita
	13.007	Cooking energy per capita
	13.008	Electricity for lighting per floor area
	13.009	Energy per appliance
	13.010	Passenger-kilometers
	13.011	Share of total passenger-kilometers by mode
	13.012	Energy per passenger-kilometer by mode
	13.013	Tons-kilometers
	13.014	Share of total ton-kilometers by mode
	13.015	Energy per ton-kilometer by mode
	13.016	Services value-added
	13.017	Energy per value-added (services)
	13.018	Industry subsectors value-added
	13.019	Share of total value-added by subsector
	13.020	Energy per value-added by subsector
	13.021	Agriculture value-Added
	13.022	Share of total value-added by subsector
	13.023	Energy per value-added by subsector
	13.024	Changes in CO_2 intensity
	13.025	Changes in input coefficients
	13.026	Changes in the composition of final demand
	13.027	Changes in the level of final demand (economic growth)

Table A1. *Cont.*

Document	Code	Variable
Jovanovic et al. (2010)	14.001	Population growth
	14.002	Persons per household
	14.003	Share of the potential labor force
	14.004	Share of the population outside the community
	14.005	Share of rural population
	14.006	GDP
	14.007	GDP growth rate
	14.008	Monetary values per capita of the major sectors and subsectors
	14.009	Efficiency of appliances/vehicles
	14.010	Buildings insulation
Kasperson et al. (1995)	15.001	Population growth
	15.002	Migration
	15.003	Natural growth
	15.004	Irrigation development
	15.005	Mechanization
	15.006	Fertilization
	15.007	Pasture improvement
	15.008	Industrialization infrastructure
	15.009	Agricultural intensification
	15.010	Urbanization
	15.011	Poverty
	15.012	International market
	15.013	National market
	15.014	State policy
	15.015	Shift to commodity production
	15.016	Foreign debt, balance of trade
	15.017	Resource allocation rules and institutions
	15.018	Capital extraction
	15.019	Political corruption
	15.020	Frontier development
	15.021	Ethnic/religious views
	15.022	Mass-consuming view of nature
	15.023	Acceptance of corruption
Lin et al. (2010)	16.001	Population
	16.002	Population growth rate
	16.003	Size of households
	16.004	Number of households
	16.005	GDP
	16.006	Growth rate of GDP
	16.007	Measures and policies already promulgated
	16.008	Measure/Action
	16.009	Intensity of measure (degree of implementation)
	16.010	Competences of local authorities in implementation fields
	16.011	Investment costs
	16.012	Implementation experiences
Millard-Ball (2012)	17.001	Population
	17.002	Employment
	17.003	Average income
	17.004	Education
	17.005	Environmental voting
	17.006	Civic
	17.007	Non-residential building
	17.008	Latitude
	17.009	Ped/bike mode share
	17.010	Time

Table A1. *Cont.*

Document	Code	Variable
Millard-Ball (2012)	17.011	Number of certified buildings
	17.012	Share of renewable energy sources electricity microgeneration
	17.013	Street lighting expenditure
	17.014	Use of soft modes
Morlet and Keirstead (2013)	18.001	City power (EU, 2007)
	18.002	City size (population)
	18.003	Legal structure and status
	18.004	Spending power
	18.005	Control over income
	18.006	Civic involvement (voting patterns)
	18.007	Herfindahl–Hirschman index (degree of competition in the national electricity system)
	18.008	Degree of electricity generated in combined heat and power systems
	18.009	City's population
	18.010	Wealth (GDP per capita)
	18.011	Climate (Heating Degree Days)
	18.012	Price of energy (gas and electricity) and relative share of any taxes or levies—energy costs
	18.013	Carbon intensity of fuels
	18.014	Targets set by each city for GHG emissions reductions
	18.015	Annual energy demand
	18.016	Policy type (Financial/Non-financial)
Murphy et al. (2012)	19.001	Policy instrument combinations
	19.002	Obligating/Incentivizing balance
	19.003	Long-term program
	19.004	Non-generic instruments
	19.005	Primacy to energy efficiency
	19.006	Whole house/deep retrofit
	19.007	Energy sufficiency
	19.008	Policy theory associated with instruments applied
	19.009	Description of the impact of instruments (secondary sources and interviews)
Nassen (2014)	20.001	Total consumption
	20.002	Household size
	20.003	Age of occupants
	20.004	Education of occupants
	20.005	Dwelling type
	20.006	Urbanity
Neji and Astrand (2006)	21.001	Changes in knowledge
	21.002	Awareness and behavior of important actors
	21.003	Technology performance
	21.004	Price development
	21.005	Sales data
	21.006	Market share
	21.007	Changes in manufacturers assortment
Praznik et al. (2013)	22.001	Surface area to volume ratio
	22.002	Orientation of the facades' transparent elements
	22.003	Thermal zoning of the building and the separation of its unheated parts from the thermal envelope
	22.004	Heated area per occupant
Rai and Robinson (2015)	23.001	Attitude factors
	23.002	Economic factors
	23.003	Social factors (impact on agents' attitude)

Table A1. *Cont.*

Document	Code	Variable
Schipper et al. (2001)	24.001	Population
	24.002	Floor area per capita
	24.003	Persons per household
	24.004	Appliances ownership per capita
	24.005	Intensity for different uses
	24.006	Total passenger-kilometers
	24.007	Distribution of passenger-kilometers per mode
	24.008	Energy/passenger-kilometer per mode
	24.009	Distribution of value-added per subsector
	24.010	Average energy/value-added per subsector
Sobrino and Monzon (2014)	25.001	Carbon intensity of road transport
	25.002	Energy intensity of road transport
	25.003	Use intensity
	25.004	Motorization rate
	25.005	Job intensity
	25.006	Workers income intensity
	25.007	GDP
Spyridaki and Flamos (2014)	26.001	Electricity market structure and design
	26.002	Interconnection of domestic electricity markets in Europe
	26.003	Primary factor: labor, capital, conventional and non-conventional resources
	26.004	Supply and demand parameters
	26.005	Incumbent policy framework included in the reference scenario
	26.006	Different renewable energy sources penetration levels
	26.007	Renewable energy source potential
	26.008	Efficiency of the whole electricity system
	26.009	Emissions of other air pollutants
	26.010	Discount rate for investments
	26.011	Firm behavior
	26.012	Allowance trade patterns among regions
	26.013	Socio-demographic and lifestyle trends
	26.014	Interconnection of domestic electricity markets in Europe
	26.015	Political context in which policy instruments are imposed
	26.016	Supply and demand parameters
	26.017	Firm behavior
	26.018	Simplification in technology production options and load segments of electricity production
	26.019	Limited analysis of constraints in output
	26.020	Slope of demand and supply curves
	26.021	Electricity market structure and design
	26.022	Technology market failures and other externalities related to electricity generation design
	26.023	Trading options
	26.024	Banking of emissions
	26.025	Alternative compliance payments
	26.026	Distinctions between price based or quantity-based policy instruments with variations in prices and quotas for commodities
	26.027	Uniform/Differentiated feed in tariff rate
	26.028	Phase in of Renewable Portfolio Standard
	26.029	Annual digression rate of feed in tariff rate
	26.030	Limitation of the payment period
	26.031	Tariff reduction due to inflation
	26.032	Distinctions between price based or quantity-based policy instruments with variations in prices and quotas for commodities
	26.033	International emissions trading
	26.034	Uniform and unilateral imposition of carbon taxes across all EU-ETS regions
	26.035	Lump-sum treatment of additional tax revenues

Table A1. *Cont.*

Document	Code	Variable
Spyridaki and Flamos (2014)	26.036	Stringency levels
	26.037	Different application scope
	26.038	Nature of targets, the target groups, the policy-implementing agents, the available budget, the available information on the initially expected energy-savings impact, and the cost effectiveness of the instrument
Spyridaki and Flamos (2014)	26.039	Distinctions between price-based or quantity-based policy instruments
	26.040	Different renewable energy sources and support design elements
	26.041	Variable scenarios in the short and long run for key policy parameters such as price of certificate, level of obligation, level of sales tax and the level of penalty
	26.042	Fixed-price policies and endogenous price policies
	26.043	Technology specific hurdle rates reflecting market barriers, consumer preferences and risk factors limiting purchase of new energy technologies
	26.044	Conditions for implementation and proper utilization of saving options (technology equipment availability, familiarity with the policy, overcoming barriers, motivation to invest)
	26.045	Specific implementation of policy instruments with regard to their funding
	26.046	Transaction costs
	26.047	Stability and credibility in policy regime
	26.048	Implementation period of the policy instrument
	26.049	Circumstances in which to apply a policy instrument (challenges in addressing different target groups, challenges in addressing different scopes, addressing a financial, knowledge barrier, internalizing externalities, addressing market competition, conditions under which a policy combination is required, conditions of policy redundancy)
	26.050	Implicit and explicit assumptions in the policy implementation process and mapping the cause-impact relationships
	26.051	Transaction costs related to the combined policy cycle
	26.052	Regulatory decisions on the additionality of energy savings from individual projects
Tang et al. (2010)	27.001	Political will
	27.002	State-level mandates concerning climate change (national)
	27.003	Wealth
	27.004	Coastal distance
	27.005	Population density
	27.006	Hazard damage
	27.007	Energy consumption
	27.008	Light transportation (soft modes and public transportation)
	27.009	Average commuting time
	27.010	Vehicular emission
	27.015	Concept of climate change or global warming
	27.016	Concept of GHG emission
	27.017	Effects and impact of climate change
	27.018	Long-term goals and detailed targets for GHG emissions
	27.019	Emissions inventory
	27.020	Base year emissions
	27.021	Emissions trend forecast
	27.022	Vulnerability assessment
	27.023	Cost estimates for GHG emissions reduction
	27.024	Using analysis tools
	27.025	Public awareness, education, and participation
Tang et al. (2010)	27.026	Inter-organizational coordination procedures
	27.027	GHG emissions reduction fee
	27.028	Establish a carbon tax
	27.029	Disaster resistant land use and building code
	27.030	Mixed use and compact development

Table A1. *Cont.*

Document	Code	Variable
Tang et al. (2010)	27.031	Infill development and reuse of remediated brownfield sites
	27.032	Green building and green infrastructure
	27.033	Low-impact design for impervious surface
	27.034	Control of urban service/growth boundaries
	27.035	Alternative transportation strategies
	27.036	Transit-oriented development and corridor improvements
	27.037	Parking standards adjustment
	27.038	Pedestrian/resident friendly, bicycle friendly, transit-oriented community design
	27.039	Renewable energy and solar energy
	27.040	Energy efficiency and energy stars
	27.041	Landfill methane capture strategies
	27.042	Zero waste reduction and high recycling strategy
	27.043	Creation of conservation zones or protected areas
	27.044	Watershed-based and ecosystem-based land management
	27.045	Vegetation protection
	27.046	Establish implementation priorities for actions
	27.047	Financial/budget commitment
	27.048	Identify roles and responsibilities among sectors and stakeholders
	27.049	Continuous monitoring, evaluation and update
	27.050	Overall energy efficiency gains
	27.051	Final intensity
	27.052	Primary intensity
	27.053	Energy efficiency gains
	27.054	Energy intensity (industry, manufacturing, chemicals, European Union structure)
	27.055	Specific consumption (steel, cement, paper)
	27.056	Energy efficiency gains
	27.057	Consumption per unit of traffic (road car equivalent, freight, air)
	27.058	Car efficiency (fleet average, new cars)
	27.059	Mobility in transport (public transport, freight)
	27.060	Energy efficiency gains
	27.061	Consumption per dwelling (total, electricity, scaled to European Union climate)
	27.062	Heating consumption (per dwelling, per m^2)
	27.063	Energy consumption per employee (total, electricity)
	27.064	Energy intensity (total, electricity)

Table A2. Variables excluded for non-applicability in the systematic literature review process.

Code	Variable
1.004	Recent change in government
1.005	Presence of champions
1.008	International processes
1.009	Focusing events
1.010	Action of feedback mechanism
4.007	World City Rank
4.009	Location
9.002	Demand elasticity
9.009	Endogenous resources potential and prices
9.010	Import/export prices and boundaries
10.003	Results in terms of GHG emissions reduction
10.004	Geography
10.005	Business structure
10.006	Physical circumstances

Table A2. *Cont.*

Code	Variable
11.005	Policy output
11.006	Policy outcome
11.007	Policy impact
12.008	Share of population living in large cities
12.037	Specific energy consumption for cooking in urban dwellings
12.039	Specific energy consumption per urban dwelling for electric appliances
12.041	Specific fossil fuel consumption per urban dwelling for lighting and non-electric appliances
12.063	Specific energy consumption for cooking in rural dwellings
12.065	Specific energy consumption per rural dwelling for electric appliances
12.067	Specific fossil fuel consumption per rural dwelling for lighting and non-electric appliances
15.006	Fertilization
15.007	Pasture improvement
15.015	Shift to commodity production
15.016	Foreign debt, balance of trade
15.017	Resource allocation rules and institutions
15.018	Capital extraction
15.019	Political corruption
15.020	Frontier development
15.023	Acceptance of corruption
17.007	Non-residential building
17.008	Latitude
17.011	Number of certified buildings
17.013	Street lighting expenditure
18.007	Herfindahl–Hirschman index (degree of competition in the national electricity system)
18.013	Carbon intensity of fuels
18.015	Annual energy demand
20.001	Total consumption
21.007	Changes in manufacturers assortment
22.001	Surface area to volume ratio
22.002	Orientation of the facades' transparent elements
22.003	Thermal zoning of the building and the separation of its unheated parts from the thermal envelope
22.004	Heated area per occupant
26.001	Electricity market structure and design
26.002	Interconnection of domestic electricity markets in Europe
26.003	Primary factor: labor, capital, conventional and non-conventional resources
26.004	Supply and demand parameters
26.005	Incumbent policy framework included in the reference scenario
26.007	Renewable energy source potential
26.009	Emissions of other air pollutants
26.011	Firm behavior
26.012	Allowance trade patterns among regions
26.014	Interconnection of domestic electricity markets in Europe
26.016	Supply and demand parameters
26.017	Firm behavior
26.019	Limited analysis of constraints in output
26.020	Slope of demand and supply curves
26.049	Circumstances in which to apply policy instrument (challenges in addressing different target groups, challenges in addressing different scopes, addressing a financial, knowledge barrier, internalizing externalities, addressing market competition, conditions under which a policy combination is required, conditions of policy redundancy)
26.050	Implicit and explicit assumptions in the policy implementation process and mapping the cause-impact relationships
26.051	Transaction costs related to the combined policy cycle
26.052	Regulatory decisions on the additionality of energy savings from individual projects
27.004	Coastal distance

Table A2. *Cont.*

Code	Variable
27.006	Hazard damage
27.007	Energy consumption
27.019	Emissions inventory
27.020	Base year emissions
27.022	Vulnerability assessment
27.024	Using analysis tools
27.062	Heating consumption (per dwelling, per m^2)
27.063	Energy consumption per employee (total, electricity)

Table A3. Variables excluded for explicit repetition in the systematic literature review process.

Code	Variable
1.011	Timeframe
1.013	Policy instruments
1.015	Target of policy (actors)
1.016	Source of authority at different stages (Hybrid or Government)
2.002	Structure, main sectors
2.003	Structure, subsectors
2.004	Structure, final demand
2.005	Savings, final demand
2.006	Conversion efficiency end-users
2.007	Co-generation end-users
2.008	Fuel mix end-users
2.009	Export
2.010	Structure electricity production sectors
2.011	Co-generation electricity production sectors
2.012	Import
2.013	Fuel mix electricity production sectors
3.004	GDP growth (GDP growth rate)
4.003	Population
4.004	Density
4.005	GDP
4.010	Dates
4.011	Urban character
4.017	Actors involved
4.020	Environmental justice
5.010	Population
5.027	Population
7.002	Average number of inhabitants
9.001	Annual growth rate of the socio-economic indicator
9.008	Other information (discount rate, etc.)
11.001	Objectives
11.002	Instruments
12.009	GDP
12.010	Average annual growth rate of GDP
12.011	Distribution of GDP formation by kind of economic activity
12.013	Energy intensities in industry
13.001	Population
13.002	Floor area per capita
13.003	Persons per household
13.004	Appliances ownership per capita
13.016	Services value-added
13.018	Industry subsectors value-added
13.021	Agriculture value-Added
14.006	GDP

Table A3. *Cont.*

Code	Variable
16.001	Population
16.002	Population growth rate
16.003	Size of households
16.005	GDP
16.006	Growth rate of GDP
16.011	Investment costs
17.001	Population
17.006	Civic
17.010	Time
17.014	Use of soft modes
18.002	City size (population)
18.009	City's population
18.010	Wealth (GDP per capita)
18.016	Policy type (Financial/Non-financial)
20.004	Education of occupants
20.006	Urbanity
24.001	Population
24.003	Persons per household
24.006	Total passenger-kilometers
24.007	Distribution of passenger-kilometers per mode
24.008	Energy/passenger-kilometer per mode
24.009	Distribution of value-added per subsector
25.007	GDP
26.008	Efficiency of the whole electricity system
26.048	Implementation period of the policy instrument
27.008	Light transportation (soft modes and public transportation)
27.023	Cost estimates for GHG emissions reduction
27.047	Financial/budget commitment
27.049	Continuous monitoring, evaluation and update
27.059	Mobility in transport (public transport, freight)
27.061	Consumption per dwelling (total, electricity, scaled to European Union climate)

Table A4. Variables excluded for implicit repetition in the systematic literature review process.

Code	Variable
1.003	Favorable party platform
1.007	Availability of technology
1.012	Reporting nature
3.005	Structure, main sectors (growth rate main sectors)
3.006	Structure, subsectors (growth rate per subsector)
4.001	Country
4.002	Urban area
4.006	GDP per capita
4.008	Annual population rank
4.013	Objectives
4.016	Sector specific information
4.022	Action type of schemes
5.005	Involvement of stakeholders and citizens
5.009	Year
7.001	Total dwelling area
7.003	Number of appliances per type
7.004	Number of vehicle-kilometers of personal cars per fuel
7.005	Number of passenger-kilometers per mode (except car)
7.006	Number of vehicle-kilometers of freight road transportation

Table A4. *Cont.*

Code	Variable
7.007	Number of ton-kilometers per mode (other freight transportation)
7.008	Number of employee-years
8.002	Population
9.003	Autonomous efficiency improvement factor (industrial sectors)
10.002	Formulation of the climate-policy strategy
10.007	Actors involvement
11.003	Means—Societal
12.001	Total population
12.002	Average annual growth rate of population
12.004	Average household size in urban areas
12.005	Average household size in rural areas
12.006	Share of population of age 15–64 in total population
12.016	Share of transportation modes in the total demand for freight transportation
12.017	Energy intensity of freight transportation modes
12.020	Share of transportation mode(s) in the total demand for intracity passenger transportation
12.021	Energy intensity of transportation mode(s) in intracity travel
12.027	Share of public transportation mode(s) in the intercity passenger travel by public modes
12.028	Energy intensity of transportation mode(s)
12.029	Fraction of urban dwellings in areas where space heating is required
12.030	Degree days for urban dwellings
12.031	Fraction of urban dwellings per type
12.032	Average size of urban dwellings by type
12.033	Fraction of floor area that is actually heated in urban areas per dwelling type
12.034	Specific heat loss rate by urban dwelling type
12.036	Specific cooling requirements by urban dwelling type
12.038	Share of urban dwellings with hot water facilities
12.055	Fraction of rural dwellings in areas where space heating is required
12.056	Degree days for rural dwellings
12.057	Fraction of rural dwellings per type
12.058	Average size of rural dwellings by type
12.059	Fraction of floor area that is actually heated in rural areas per dwelling type
12.060	Specific heat loss rate by rural dwelling type
12.062	Specific cooling requirements by rural dwelling type
12.064	Share of rural dwellings with hot water facilities
13.019	Share of total value-added by subsector
13.022	Share of total value-added by subsector
13.024	Changes in CO_2 intensity
13.025	Changes in input coefficients
13.026	Changes in the composition of final demand
13.027	Changes in the level of final demand (economic growth)
14.005	Share of rural population
14.007	GDP growth rate
14.008	Monetary values per capita of the major sectors and subsectors
14.009	Efficiency of appliances/vehicles
15.009	Agricultural intensification
15.010	Urbanization
16.004	Number of households
16.010	Competences of local authorities in implementation fields
17.009	Ped/bike mode share
17.012	Share of renewable energy sources electricity microgeneration
18.001	City power (EU, 2007)
18.008	Degree of electricity generated in combined heat and power systems
18.011	Climate (Heating Degree Days)
18.014	Targets set by each city for GHG emissions reductions

Table A4. *Cont.*

Code	Variable
19.001	Policy instrument combinations
19.002	Obligating/Incentivizing balance
19.003	Long-term program
19.004	Non-generic instruments
19.005	Primacy to energy efficiency
19.006	Whole house/deep retrofit
19.007	Energy sufficiency
20.002	Household size
21.001	Changes in knowledge
21.002	Awareness and behavior of important actors
21.003	Technology performance
21.006	Market share
25.001	Carbon intensity of road transport
25.002	Energy intensity of road transport
25.003	Use intensity
25.006	Workers income intensity
26.018	Simplification in technology production options and load segments of electricity production
26.023	Trading options
26.024	Banking of emissions
26.025	Alternative compliance payments
26.026	Distinctions between price based or quantity-based policy instruments with variations in prices and quotas for commodities
26.027	Uniform/Differentiated feed in tariff rate
26.028	Phase in of Renewable Portfolio Standard
26.029	Annual digression rate of feed in tariff rate
26.030	Limitation of the payment period
26.031	Tariff reduction due to inflation
26.032	Distinctions between price based or quantity-based policy instruments with variations in prices and quotas for commodities
26.033	International emissions trading
26.034	Uniform and unilateral imposition of carbon taxes across all EU-ETS regions
26.035	Lump-sum treatment of additional tax revenues
26.036	Stringency levels
26.037	Different application scope
26.038	Nature of targets, the target groups, the policy-implementing agents, the available budget, the available information on the initially expected energy-savings impact, and the cost effectiveness of the instrument
26.039	Distinctions between price-based or quantity-based policy instruments
26.040	Different renewable energy sources and support design elements
26.041	Variable scenarios in the short and long run for key policy parameters such as price of certificate, level of obligation, level of sales tax and the level of penalty
26.042	Fixed-price policies and endogenous price policies
26.043	Technology specific hurdle rates reflecting market barriers, consumer preferences and risk factors limiting purchase of new energy technologies
26.044	Conditions for implementation and proper utilization of saving options (technology equipment availability, familiarity with the policy, overcoming barriers, motivation to invest)
26.045	Specific implementation of policy instruments with regard to their funding
27.002	State-level mandates concerning climate change (national)
27.010	Vehicular emission
27.018	Long-term goals and detailed targets for GHG emissions
27.021	Emissions trend forecast
27.025	Public awareness, education, and participation
27.026	Inter-organizational coordination procedures

Table A4. *Cont.*

Code	Variable
27.027	GHG emissions reduction fee
27.028	Establish a carbon tax
27.029	Disaster resistant land use and building code
27.030	Mixed use and compact development
27.031	Infill development and reuse of remediated brownfield sites
27.032	Green building and green infrastructure
27.033	Low-impact design for impervious surface
27.034	Control of urban service/growth boundaries
27.035	Alternative transportation strategies
27.036	Transit-oriented development and corridor improvements
27.037	Parking standards adjustment
27.038	Pedestrian/resident friendly, bicycle friendly, transit-oriented community design
27.039	Renewable energy and solar energy
27.040	Energy efficiency and energy stars
27.041	Landfill methane capture strategies
27.042	Zero waste reduction and high recycling strategy
27.043	Creation of conservation zones or protected areas
27.044	Watershed-based and ecosystem-based land management
27.045	Vegetation protection
27.048	Identify roles and responsibilities among sectors and stakeholders
27.050	Overall energy efficiency gains
27.053	Energy efficiency gains
27.054	Energy intensity (industry, manufacturing, chemicals, European Union structure)
27.055	Specific consumption (steel, cement, paper)
27.057	Consumption per unit of traffic (road car equivalent, freight, air)
27.058	Car efficiency (fleet average, new cars)
27.060	Energy efficiency gains

Table A5. Variables excluded to avoid the presence of dependent variables in the systematic literature review process.

Code	Variable
1.002	Favorable public opinion
1.006	Social appeal
3.001	Energy statistics (statistical figures)
3.007	Structure, final demand (Reference final demand per subsector)
3.008	Savings, final demand (Actual final heat/electricity demand)
3.009	Conversion efficiency end-users (Actual efficiency boilers, etc.)
4.015	Institutional factors
4.019	Mode of governance
7.009	Production of goods per type (piece, kg or m^2)
7.010	Cultivated land area
7.011	Raising of cattle, pigs and chickens
7.012	Volume index of production
8.001	Gross domestic product (GDP)
11.004	Means—Policy process
12.014	Penetration of energy carriers into useful thermal energy demand of the different sectors
12.018	Average intracity distance traveled per person per day
12.019	Average load factor of intracity passenger transportation mode(s)
12.022	Average intercity distance traveled per person per day
12.024	Average intercity distance driven per car per year
12.025	Average load factor of intercity transportation mode(s)
12.026	Share of car type(s) in the intercity transportation mode(s)

Table A5. *Cont.*

Code	Variable
12.035	Share of urban dwellings with air conditioning, by dwelling type
12.040	Electricity penetration for appliances in urban households
12.042	Penetration of various energy forms into space heating in urban households
12.043	Efficiency of various fuels use, relative to that of electricity use, for space heating in urban households
12.044	Coefficient of performance of heat pumps for space heating in urban households
12.045	Penetration of various energy forms into water heating in urban households
12.046	Efficiency of various fuels use, relative to that of electricity use, for water heating in urban households
12.047	Coefficient of performance of heat pumps for water heating in urban households
12.048	Approximate share of water heating demand in urban households that can be met with solar installations
12.049	Penetration of various energy forms into cooking in urban households
12.050	Efficiency of various fuels use, relative to that of electricity, for cooking in urban households
12.051	Approximate share of cooking demand in urban households that can be met with solar installations
12.052	Share of air conditioning demand of urban households that can be met with electricity
12.053	Coefficient of performance of electric air conditioning in urban households
12.054	Coefficient of performance of non-electric air conditioning in urban households
12.061	Share of rural dwellings with air conditioning, by dwelling type
12.066	Electricity penetration for appliances in rural households
12.068	Penetration of various energy forms into space heating in rural households
12.069	Efficiency of various fuels use, relative to that of electricity use, for space heating in rural households
12.070	Coefficient of performance of heat pumps for space heating in rural households
12.071	Penetration of various energy forms into water heating in rural households
12.072	Efficiency of various fuels use, relative to that of electricity use, for water heating in rural households
12.073	Coefficient of performance of heat pumps for water heating in rural households
12.074	Approximate share of water heating demand in rural households that can be met with solar installations
12.075	Penetration of various energy forms into cooking in rural households
12.076	Efficiency of various fuels use, relative to that of electricity, for cooking in rural households
12.077	Approximate share of cooking demand in rural households that can be met with solar installations
12.078	Share of air conditioning demand of rural households that can be met with electricity
12.079	Coefficient of performance of electric air conditioning in rural households
12.080	Coefficient of performance of non-electric air conditioning in rural households
12.081	Share of service sector in the total active labor force
12.082	Average floor area per employee in the Service sector
12.083	Share of Service sector floor area requiring space heating
12.084	Share of Service sector floor area requiring space heating that is actually heated
12.085	Specific space heat requirements of Service sector floor area
12.086	Share of air-conditioned Service sector floor area
12.087	Specific cooling requirements in the Service sector
12.088	Energy intensity of motor fuel use per Services' subsector
12.089	Energy intensity of electricity specific uses per Services' subsector
12.090	Energy intensity of thermal uses (except space heating) per Services' subsector
12.091	Penetration of various energy forms into space heating in Service sector
12.092	Penetration of various energy forms into other thermal uses in the Service sector
12.093	Efficiency of various fuels use, relative to that of electricity use, for thermal uses in Service sector
12.094	Coefficient of performance of heat pumps in space heating in Service sector
12.095	Share of low-rise buildings in the total Service sector floor area
12.096	Approximate share of thermal uses in the Service sector that can be met by solar installations
12.097	Share of air-conditioning that can be met with electricity
12.098	Coefficient of performance of electric air conditioning in Service sector
12.099	Coefficient of performance of non-electric air conditioning in Service sector

Table A5. *Cont.*

Code	Variable
13.009	Energy per appliance
13.013	Tons-kilometers
13.014	Share of total ton-kilometers by mode
13.020	Energy per value-added by subsector
14.001	Population growth
14.004	Share of the population outside the community
15.004	Irrigation development
15.005	Mechanization
15.008	Industrialization infrastructure
15.011	Poverty
15.014	State policy
15.022	Mass-consuming view of nature
16.007	Measures and policies already promulgated
16.012	Implementation experiences
17.003	Average income
17.005	Environmental voting
18.003	Legal structure and status
18.004	Spending power
18.005	Control over income
20.003	Age of occupants
20.005	Dwelling type
21.004	Price development
21.005	Sales data
23.001	Attitude factors
23.002	Economic factors
23.003	Social factors (impact on agents' attitude)
24.010	Average energy/value-added per subsector
25.004	Motorization rate
25.005	Job intensity
26.006	Different renewable energy sources penetration levels
26.010	Discount rate for investments
26.013	Socio-demographic and lifestyle trends
26.015	Political context in which policy instruments are imposed
26.046	Transaction costs
26.047	Stability and credibility in policy regime
27.001	Political will
27.003	Wealth
27.005	Population density
27.051	Final intensity
27.052	Primary intensity

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