Legal Knowledge Framework for Identifying Water, Energy, Food and Climate Nexus

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Abstract. The paper inclines to briefly articulate major problems and critical questions exist in water, energy, food and climate (WEFC) nexus from artificial intelligent and law perspective. Then a legal knowledge framework, based on computational ontology, Akoma Ntoso and LegalRuleML standard, is proposed to identify WEFC nexus. It also presents a brief use case on the existing legislations of quality standard of drinking water from EU and UK that covers WEFC nexus, where the proposed framework will be used. At the end, it states briefly fundamental methodologies for the proposed framework and their strengths, related tools for environmental decision support systems and their limitations, and other related works like "Fill the Gap" project in order to rationalize the degree of innovativeness and necessity of this proposed legal knowledge framework for identifying WEFC nexus.

Keywords. Legal knowledge framework, WEFC nexus, artificial intelligent and law, Akoma Ntoso, LegalRuleML.

Introduction

Traditionally water, energy and food regulations are managed in separate legislative branches due to their sectorial approach [1]. Therefore it is not easy to detect the implications that a legal textual provision of one domain could have over the others. Additionally the collective approach of mutil-sectorial legal rules of WEFC nexus is often neglected in the public policy analysis, particularly in the case of favoring technical requirements (e.g. soil characteristics, energy plant requirements) of one domain to others [2][3]. Similarly when a policy of one domain is adopted and implemented, it is also difficult to maintain aligned policies of same or other domains within the legislative system in order to not create paradoxical situations in other legislative areas (e.g. taxation policy) that could be against the WEFC nexus's approach [3][4]. Besides, when once it is possible to detect WEFC nexus and make evident the relationships, the next further difficulty is to resolve the conflicting rules that exist within WEFC domain in order to decide the best policy to adopt. For these reasons, a legal knowledge framework might be useful to understand and manage WEFC nexus in a better way as well as to simulate multi-sectorial scenarios of WEFC domain, these all scenarios are equally legally valid in scope and nature but depending to a specific expert interpretation or operative implementation.

Considering this context, the paper presents a comprehensive legal knowledge framework for detecting WEFC nexus based on the possibility to use original legal texts and to formalize the legal knowledge of WEFC domain for permitting legal reasoning among different rules (normative, social, technical, ethical, cultural) with the help of the legal knowledge engineer.

In definitional point of view, legal knowledge framework encompasses the scope for utilizing legal knowledge formalization by implementing three indispensable chronological technological requirements: (a) to systematically documentize the content of legislations in such a way that makes machine to understand the process, e.g. implementing Akoma Ntoso standard [5], (b) to use computational ontology [6], that is legal, social, ethical and scientific-information based ontology, in order to make machine to understand meaning of the prescribed content or

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document, and (c) to use operational-rules-based-logic, e.g. implementing LegalRuleML standard [7], expecting machine to apply legal logic for enhancing evidence-based-hybrid-reasoning.

The fundamental aspiration beyond the legal knowledge framework is that, from the rule of law perspective, nothing is above the rule of law [8]. Everything that happens within the WEFC domain must be comply with the rules prescribed in some forms of legal instruments. In contrast, if there is any legal structural constraints within WEFC nexus, it must be first detected and resolved before further proceedings in order to make system effective and efficient with sustainable efficacy within WEFC domain by avoiding consequential loops of disorder. Therefore under WEFC nexus discourse it is very crucial to detect how existing rules of each domain, e.g. water or carbon tax, affect and reinforce other domains.

Moreover, the paper uses a brief use case on "Quality Standard of Drinking Water of EU and UK" and how proposed legal knowledge framework will be useful to detect WEFC nexus within that problematic context.

1. Brief State of Art

During last five years, responsive citizens, researchers, environmentalists, lawyers and policy makers have demonstrated a great level of importance to understand dynamics and complex relationships between WEFC nexus [1] [9]. On December 10, 2012, the National Intelligence Council (NIC) of USA mentioned in its report "Global Trends 2030: Alternative Worlds" that growing food, water and energy nexus is one out of four megatrends in coming transformative world, which will be responsible for major power shifts, human insecurity and geopolitical risks [10]. European report on Development 2012 recommended that a radical transformation is needed to cope with nexus's requirements [11]. As a result, EU has already taken a number of initiatives in order to support activities related with nexus [12].

Rules of these three sectors, water, energy and food, interact and reinforce each other. Water, for example, is used for fuel extraction, refining and production. It also generates electricity and cools power plants. Scarcity of water affects food processing, generating electricity, crop and livestock yields. The overuse of water also affects negatively quality of crop, soil and other elements of social and environmental interaction. Energy is required for water transfer and treatment. Food prices increase as fuel, fertilizer and transportation costs rise [13]. In order to understand better, however, the concept of nexus, following statistics might be helpful:

- Global population has been increasing by some 80 million in a year. By 2030, it is expected that the total global population would be 9 billion. That will need 30% more water, 40% more energy and 50% more food in order to survive [14].
- To manage the demand of global drinking water, energy and food, the human community will face 40% water gap by 2030 [15][16].
- 1.1 billion people have lack of clean drinking water, 1.3 billion are living without electricity, and more than one million are hungry [17].
- 20% of world's electricity comes from hydroelectric power, e.g. 99% in Norway and 50% in developing countries. 70% of global freshwater withdrawals accounts for agriculture [18]. 32 million to 54 million barrels of oil was used to generate energy to produce amount of bottled water consumed in US in 2007 [19].
- The number of middle class consumer will increase from 1.8 billion to 3 billion by 2030 [20]. That will reinforce water, energy and food market.
- The water is required for producing food is 70% times greater than the water is used for domestic uses like drinking, bathing and washing [21].

However, it is very little that policy makers or citizens know about this nexus's complexities, specially how rules and/or legislations of each domain affect and reinforce other domains [22][23][24]. It is also noteworthy to mention that in the current state of art of WEFC nexus there is no such constructive case yet has been developed in line with examining utility and efficacy of the legislation of one sector of WEFC over the others and using artificial intelligent and law.

2. Major Critical Problems and Questions in WEFC Nexus

2.1. Major Critical Problems of WEFC Nexus

Traditional way of formulating policy documents, legislative, administrative and institutional rules within WEFC domains, as a resource of policy, are still segregated and sectorial wise [1] [3]. The substantive and institutional rules of respective sector of WEFC that help to install the political administrative programing and arrangement for implementing public policies are isolated too [3], as in Figure 1. However, in the context of WEFC nexus, from artificial intelligent and law perspective, the following major problems have been detected in order to framing a legal knowledge framework:

2.1.1. Lack of Detection Mechanism for Revealing Legal Textual Implications of One Domain over the Others

The implication of legal textual provision of one domain of WEFC nexus, generally, affects and reinforces other domains, which is not easy to detect [25].

2.1.2. Difficulties to Maintain the Rules of Policies and/or Legislation of One Domain with Aligned Polices and/or Legislation of Other Domains

There are always a number of rules of one policy documents and legislations have legal relationship with other aligned policy documents and legislations. But generally these rules are subject of different institutions to implement and to prepare necessary financial allocations. That plays an important role to make difficulties in the process of detecting WEFC nexus. So, in order to simplify the process, it is essential to maintain linked-rules of different policy documents and legislation [26].

2.1.3. Lack of Mechanism for Integrating between "Related Institutional Rules" and "Rules Coming from Policybased Legislations" of WEFC Domain

The rules of game of WEFC domains are not only determined by policy documents and legislations, rather institutional rules play an important role in determining ideas, interests, process, content and what need to be done at the ground time to time of WEFC domains [27]. Hence making functional links between institutional rules and rules coming from policy documents and legislations may help to coordinate legal knowledge of WEFC domains more efficiently.

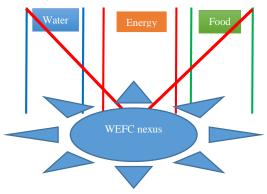


Figure 1. WEFC nexus in political administrative arrangement

2.1.4. Lack of Mechanism for Cross Compliance Check among Rules (Legal, Institutional, Social, Cultural, Ethical and Technical) of WEFC Domain

Cross compliance check between and within policy documents and legislations of WEFC domains is not enough. Besides, it is also very crucial to have integrated mechanism for cross compliance checking among rules coming from different sources such as legal, institutional, social, cultural, ethical and technical perspectives of WEFC domains [28]. These two types of cross compliance checking jointly are very requisite not only for detecting the WEFC nexus as well as for legal reasoning in favor of WEFC domain.

2.1.5. Unresolved Conflicting Rules within WEFC Nexus

Detecting of conflicting rules within WEFC nexus adds another degree of efficiency in order to adopt most appropriate set of rules for WEFC domain [29].

2.1.6. Lack of Collective Approach based on Multi-sectorial-Linked-Legal-Rules of WEFC Nexus

Legal rules of one particular domain of WEFC might create goal-conflicts to the legal rules of the others. Hence it is necessary to have collective approach based on multi-sectorial-linked-legal-rules for detecting WEFC nexus in a synchronized way [30].

2.1.7. Absence of Implication of Technical Rules of One Domain over the Others and Detecting Contradicting Technical Rules

Generally, but not always, technical rules are guided by legal rules within a specific domain of WEFC. Hence traditional way of applying technical rules is limited to the respective domain. But, in order to detect WEFC nexus cautiously, technical rules of one domain must need to apply to the others in its appropriate scope and context. However, in the case of not having appropriate technical rules within the policy documents and legislations of one specific domain of WEFC, it is necessary to include technical rules from scientific investigations [31]. Moreover, detecting of contradicting technical rules is too essential for detecting WEFC nexus in most appropriate way.

2.1.8. Absence of Standardized and Systematized Documentation of Contents and Rules (Legal, Institutional, Social, Ethical and Technical) of WEFC Domain

Policy documents, legislations, authoritative reports and other legal documents of WEFC domains are not systematically documentized in according to any international standard such as Akoma Ntoso. Hence it is very difficult to process mechanically the contents and rules of WEFC domains, which can be considered as a fundamental obstacle for detecting WEFC nexus automatically.

2.1.9. Lack of Formalization of Legal Knowledge of WEFC Domain Using Computational Ontology and Standardized Legal Reasoning Approach

Once standardized and systematized documentation of contents and rules of WEFC domains are processed, it is required to formalize legal knowledge of WEFC domains using computational ontology and standardized legal reasoning approach in order to detect the WEFC nexus spontaneously in real time application and with legal reasoning for legitimizing detection of WEFC nexus.

2.1.10. Lack of Legal Knowledge Network for detecting WEFC Nexus

Existing networks of WEFC nexus's initiatives are neither based on Akoma Ntoso and LegalRuleML standard nor use computational ontology. These networks are merely preserving information in pdf or html format and also not independent from technology, language, machines and platform. Most importantly these networks are not designed for formalizing legal knowledge of WEFC domains. Therefore, usages of these networks are very limited.

2.1.11. Lack of Rule-based Simulation of Multi-Sectorial Scenarios of WEFC Nexus

Existing simulation techniques for Environmental Decision Support Systems (EDSS) are mainly based on mathematical models [32], but the rules of the game for WEFC domains are based on mostly legal and institutional rules including other relevant rules such as social, cultural, ethical and technical. Therefore, in order to simulate WEFC nexus pragmatically with legal reasoning, it is required to simulate based on all available exiting and legally valid rules.

2.1.12. Lack of Change Management within WEFC Nexus

Existing WEFC domains, on the one hand, are mainly closed and non-adaptive in nature towards the changes transported by new rules coming from new legislation, institutional, social, cultural, ethical and technical requirements. On the other, there is no the best solution for detecting the WEFC nexus, but the most appropriate one based on available open-linked-data. Because rules of game for WEFC domains get changes over time to time.

Therefore, flexibility and adaptability must be ensured towards the new rules in order to update the detection of WEFC nexus.

2.2. Major Critical Questions of WEFC Nexus

Two major questions is expected to resolve are: (a) How is it possible to use artificial intelligent and law using Akoma Ntoso and LegalRuleML standards, and computational ontology for performing a legal knowledge framework for detecting WEFC nexus? And (b) what functionalities or systems or sub-systems should be designed in order to resolve following major problems?

3. Legal Knowledge Framework for Identifying WEFC nexus: Main Pillars and Features

The proposed legal knowledge framework for identifying WEFC nexus is based on three main pillars:

- *Akoma Ntoso standard*, that is a machine readable and technology neutral XML standard for digital representation of substantive and institutional regulations and policy based legislation and documents. It is for systematizing documentation of related legal documents of WEFC domains.
- on a *Computational Ontology*, that is to represent the main concepts and relationships of the WEFC domains, and
- *LegalRuleML standard*, that is for modeling rules for formalizing legal knowledge related with WEFC domains using logic-based theory of legal and evidence-based hybrid reasoning. It is also intended to use for legitimizing the identifications of WEFC nexus by proving legal reasoning.

This framework is also intended to provide the following features:

- *A Knowledge network*, that is for connecting legal texts relevant in WEFC domains aiming to create a knowledge network that could help the legislator and policy makers to maintain updated legal knowledge of WEFC domains over time in a coordinated way;
- Identification of WEFC nexus, that is by modelling rules for detecting WEFC nexus not immediately explicit;
- *Evidence based Hybrid Reasoning* [33] that is for using non-monotonic logic reasoning (defeasible logic) in order to manage the conflicts among the above mentioned rules and to provide different scenarios where the decision maker and the policy maker could use for evaluating the impacts on the WEFC.

4. Use Cases on Legislations of Quality Standard of Drinking Water in EU and UK and identification of its WEC nexus

4.1 Brief Background Information

UN Water's statistics inform that the fresh and drinkable water is only 3% of total world's water. Out of which, over 2.5% is frozen and not available to human being and rest .5%, equivalent to 200,000 square km, is for the survival of humanity [34]. Generally, however, the legal rules related with quality standard of drinking water dominate the massive market of bottle water as well as water treatment and reuse that typically ingests 1 to 2% of GDP [35]. Energy is required for water transport and treatment and carbon is released when water is supplied to where the demand is.

There are particular enforced legislations in EU and UK in order to guide the water industry, market and community people to be aware about it. However, these legal rules of these legislations do not concern about energy consumption and related carbon emissions in order to water transfer, treatment and reuse.

4.2 Major Functionalities

There are two major functionalities, as it is showed in Table 1:

• Twofold legal compliance checks – (a) between EU's directive and UK's legislation related with quality standard of drinking water, and (b) between the legal quality standard of drinking water and the water citizen uses to drink from market,

• Simulation based on non-binding technical rules of (a) the energy and drinking water transfer and treatment nexus, (b) water-energy nexus, when water required for producing electricity in order to water transfer, treatment and reuse, (c) simulation of supplied water-carbon nexus.

Stages	Functionality	Legal and technical Rules		Rule's type
First	Legal Compliance checking	EU Quality Standard of Drinking water UK quality standard of Drinking water		Legal rules based on legislation
	-			
Second		Source of drinking water and required energy [36]		
	Simulation of required	When water comes from	Then required energy	
	energy for water transfer	lake/Water	.37 kWh/m3	
	and treatment	Ground water	0.48 kwh/m3	
		wastewater treatment	0.62 to 0.87 kwh/m3	
		Waste water reuse	1.0 to 2.5 kwh/m3	
		Sea water	2.58 to 8.5 kwh/m3	
Third		Types of energy plant and required water [37]		Technical rules based on social
		When energy comes from	Then required water	and scientific investigation
	Simulation of water	Solar plant with dry cooling	80 gallons Mwah/m3	
	required to produce electricity for water transfer and treatment	Nuclear plants (with closed-loop cooling)	700-1100 gallons Mwah/m3	
		Nuclear plants (with open-loop cooling)	25,000-60,000 gallons Mwah/m3	
		Coal-fired plants (closed-loop)	500-600 gallons Mwah/m3	
		Coal-fired plants (open-loop)	20,000-50,000 gallons Mwah/m3	
		Biomass (crops grown for the purpose of	40,000 to 100,000 gallons	
		fuel)	Mwah/m3	
		Natural gas fracking	2-10 million gallons per well	
Fourth	Simulation of carbon emission responsible for maintaining and delivery of drinking water	Carbon emission of every litter of water supplied 0.29 g/co2 [38]		

Table 1: Quality Standard of Drinking Water and its Energy-Carbon Nexus

4.3 Targeted Legal Documents

Target legal documents and rules for the use case are: (a) Article 5 and Annex 1 (Part A and B) of European Council Directive 98/83/EC of 3 November 1998 on the quality of water intended for human consumption [39], (b) Schedule 2 of the Water Supply (Water Quality) Regulations 2000 of UK [40].

5 Methodology

The methodology for proposed legal knowledge framework for identifying WEFC nexus can be compartmentalized into following three major segments, where each of these segments has its own objectives and desired tools and languages to be used, as it is illustrated in Table 2:

5.1 Documentation Stage followed by Akoma Ntoso Standard

In order to documentize systematically the targeted legal documents of quality standard of drinking water of WU and UK followed by Akoma Ntoso standard, following tools is preferred to be used:

• Functional requirements for bibliographic records (FRBR) system based URI (Uniform Resource Identifier) is intended to be used to identify a uniform name of a web resource of each targeted legal documents, e.g. article, section, which will enable interactions between content of each resources over the proposed knowledge network using specific protocols of World Wide Web (WWW) [41].

- XML (EXtensible Markup Language) [42] that is to transport and store data and its related metadata of respective targeted legislations in a software-and-hardware independent and machines understandable way, and XML schema [42] that is to describe the structure of the targeted legislation.
- RDF (Resource Description Framework) that is to describe resources of target legislative documents on the web written in XML, and RDF schema (RDFS) [43] that is to extend RDF vocabularies in order to allow describing taxonomies of classes and properties of targeted legislative documents.

Major Stages	Objectives of the methodology	Desired Tools and Languages to be used	Expected Outcomes
Documentation	To documentize systematically the specific content	URI, XML, XML Schema, RDF, RDF	
stage based on	of legislations of Quality Standard of Drinking	Schema, Akoma Ntoso, LIME editor	
Akoma Ntoso	Water of EU and UK following Akoma Ntoso		
Standard	standard.		
Computational	To represent main concepts and relationships within	OWL (Web Ontological Language)	Cross compliance
Ontology stage	specific legal rules of Quality Standard of Drinking		check and
	Water of EU and UK, and other related technical		simulation of water-
	rules.		energy-carbon
Hybrid	To model defeasible logics of legal rules, coming	SPINDLE engine for hybrid reasoning and	nexus
Reasoning	from specific content of legislation of Quality	simulation and RAWE (an editor for rule	
stage	Standard of Drinking Water of EU and UK, and	markup of legal texts)	
-	non-binding technical rules, coming from scientific		
	communities, following LegalRuleML standard.		

Table 2: Methodology for proposed Legal Knowledge Framework for identifying WEFC nexus

- LIME, that is an open source based the Language Independent Markup Editor developed by CIRSFID at University of Bologna, will be used to structurize the targeted legislations maintaining Akoma Ntosao standard [44].
- Akoma Ntoso 3.0 Schema will be used as the standard for documenting targeted legislations in an XML based document format.

5.2 Computational Ontological Stage

OWL (Web Ontology Language) Full [45] will be used for legal and technical knowledge representation of related terms and concepts of targeted legislations. That will help to use the predefined relevant vocabularies stored in RDF.

Even through the state of art of computational environmental ontology is very new and on-growing, there is no such computational ontology for WEFC nexus has been yet developed. In recent literature, following types of ontologies have been evolved for expressing environmental terms and concepts, but it is noteworthy to mention that all of these ontologies are based on specific purpose or sectorial wise which are far behind the WEFC nexus's terms and concepts:

- *XeO (XEML Environmental Ontology)* expresses terms and concepts related with plant in order to help plant scientists [46].
- *Ontologies for Energy Efficiency* is dedicated exclusively to the terms and concepts of energy supply chain [47].
- In *EcoLexicon*, the terms and concepts are structured by terminological knowledge base (TKB) which is hosted in a relational database. The basic environmental conceptual underpinning are taken from the environmental event (EE) which represents the location of conceptual sub-hierarchies [48].
- *EnvO (the Environmental Ontology)* contains a comprehensive controlled and structured vocabulary of terms and concepts related with biomes, environmental features, and environmental materials [49].
- *Biome* articulates terms and concepts connected with particular patterns of ecological succession and climax vegetation [50].

These above mentioned examples give a strong observational result is that it is fundamental requirement to develop computation ontology for WEFC nexus. In the case of formalizing terms and concepts related with the above mentioned use case of WEFC domains, the differential ontological model [51] is intended to use.

5.3 Evidence based Hybrid Reasoning Stage

Following LegalRuleML, RAEW editor [52], a web editor for rule markup in LegalRuleML, and SPINDLE engine [53] will be used for evidence based hybrid reasoning [54].

5.4. Schema for the Legal Knowledge Framework for Ex-ante and Ex-post of Policy Life Cycle

The following, as in Figure 2, schema will be used in order to help the process each stages (analysis of the requirement, draft of the policy, implementation of the policy, monitoring of the policy and then the refinement of the policy) of entire policy life cycle of WEFC domains from standardized and systematized documentation to simulation of the multi-sectorial scenarios. The simulation and evidence based reasoning are jointly expected to play a crucial role by using norms and rules coming from various sources at every stages of WEFC domain in order to adopt the most appropriate rules and norms for policy.

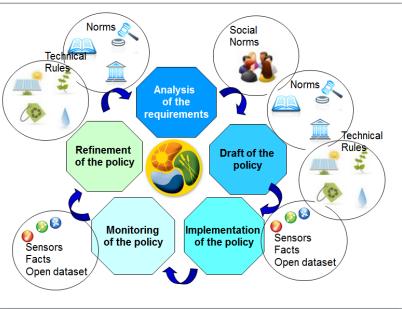


Figure 2. Schema for proposed legal knowledge framework

6 Related Works

Even though in the state of art of Environmental Decision Support Systems (EDSS), there are many useful tools, but they are very limited in scope and their functionalities, in order to simulate scenarios of different policy decisions, these tools can be clearly distinguished from this proposed framework in following ways:

- Existing EDSS tools are based on mathematical models that does not comply with legal rules, and with other relevant rules, of WEFC domain. In some extend, EDSS also integrates geographic information systems (GIS), mathematical process models, monte carlo simulation, linear programing optimization, and expert systems etc [55].
- Human rules coming from legal, institution, society, culture, ethics and news scientific discoveries usually only considered in ad hoc ways. Therefore, historically, EDSS has very limited success despite considerable effort has been made in the development of EDSS during last 25 years [56].
- They are not independent from jurisdiction, machine, language and platform. Hence these tools are not useable as anywhere policy makers want to use [57].
- They are not designed for evolutionary and evidence-based hybrid logic reasoning and creating a knowledge network for WEFC domain [58].
- They are also not designed for standardized and systematized documentation of legal documents.

However, many important learning can be shared, in the development of this proposed legal knowledge framework, from "Fill the Gap" project organized, led and funded by CIRSFID-University of Bologna [59]. Because this project

has designed an information system based on XML standards to store, in an integrated way, legal resources and rules in order to serve important roles for supporting legal knowledge engineers and end-users.

7 Critical Issues Encountered

The most critical issues encountered are : First, in the case of computational ontological representation of different terms and concepts coming from legal, institutional, social, cultural, ethical and technical perspectives of WEFC domains, the critical issue encountered is to maintain hierarchy among representations of related terms and concepts, e.g. legally binding and non-binding terms and concepts. Second, in the case of formalizing rules, using LegalRuleML standard, how the legal status of each rules coming from different legal and non-legal sources of WEFC domains will be maintained in the process of applying these different rules for evidence-based hybrid reasoning.

8 Conclusion

The paper presented a very primary idea of a legal knowledge framework for identifying WEFC nexus based on Akoma Ntoso, computational ontology and LegalRuleML standard. This proposed framework is intended to establish a knowledge network using systematized original legal documents integrated with other relevant institutional, technical, social, ethical rules of WEFC domains in order to simulate multi-sectorial scenarios of WEFC nexus with evidence-based hybrid reasoning. A use case from legislations on quality standard for drinking water of EU and UK is taken to show the possible implications of this proposed legal framework.

Acknowledgement. An especial thanks to Prof. Monica Palmirani, the Director of Erasmus Mundus LAST-JD program and Associate Professor at Department of Law in University of Bologna and also supervisor of this doctoral project, who has been providing a great level of aspirations to think in emergent and transformative way to solve the most critical problems of WEFC nexus using artificial intelligent and law.

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