Water-Energy Nexus, Putting Pieces Together: Critical Review And Perspectives

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I hereby declare that the work submitted is mine and that where I have made use of another's work, I have attributed the source(s) according to the Regulations set in the Student's Handbook.

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Abstract

This dissertation was written as part of the MSc in Energy Law, Business, Regulation and Policy at the International Hellenic University.
The scope of this paper is not to be another general introduction to water-energy concept for newcomers to this subject, neither to be a collection of frequently asked questions and answers for every single aspect of nexus.
On the contrary, targets on providing the theoretical framework along with examples from literature and world practices in topics that are crucial for a more effective governance of nexus while providing useful insights for research, business opportunities and investments.
I would like to thank my supervisor, Prof. Raphael Heffron, as also to recognize his unambiguous interest and attention on my work, while responding to my questions and queries so promptly. Also, I would like to especially thank my dear beloved parents for being at my side, supporting me morally, all this time.

Keywords: water-energy, nexus, governance, policies, decision-making

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Preface

You cannot step twice into the same rivers.
(Heraclitus; As quoted in Plato, Cratylus)

Before you, lies the dissertation “Water-Energy Nexus, Putting Pieces Together: Critical Review And Perspectives”, which has been written to fulfill the graduation requirements of the postgraduate programme in «Energy Law, Business, Regulation and Policy 2015-2016» of International Hellenic University (IHU).
This dissertation is original, unpublished, independent work by the author, G. Zizopoulos.
This work, is the result of my industriousness and diligence to Principles of Science and it never would have taken place if I was resting assured by the fact that I all ready had in my possession one post-graduate title.
I am really delighted by the fact that my aforementioned view -- for augmenting personal Knowledge and on fixity to the Principles of Science -- met those of administrating and teaching personal of IHU.
Views that I inherited from my family, which supports me so much in this strenuous and long journey of Knowledge.
Finally, I would like to exploit the given flexibility of preface section, for stressing on the value of right choices, as of attending this postgraduate programme, and assure new students that it's not matter of rewards or punishments but of never be afraid of doing what's right because life is only consequences that you'll always find in front of you.

Georgios Zizopoulos
January 2017

Contents

Introduction

The parent paper has been written and submitted for fulfilling the requirements and purpose of dissertation's elaboration for postgraduate programme in «Energy Law, Business, Regulation and Policy 2015-2016» at International Hellenic University (IHU).

The discussed topic is the following: “Water-Energy Nexus, Putting Pieces Together: Critical Review And Perspectives”.

The scope of this paper is not to be another general introduction to water-energy concept for newcomers to this subject, neither to be a collection of frequently asked questions and answers for every single aspect of nexus.

On the contrary, targets on providing the theoretical framework along with examples from literature and world practices in topics that are crucial for a more effective governance of nexus while providing useful insights for research, business opportunities and investments.

Fact that was not an easy task, when considering both that nexus is progressively elevating from an operational tool to a new joint-resource management paradigm and that is described by complexity which entails the ability to carry out in-depth research in multi-disciplinary fields, while exhibiting analytical and synthetic critical thinking.

Moreover, the parent thesis aims in originality by involving features for which there is not any extended literature in the context of nexus; and under the certain scope.

Nevertheless, even though the discussed sub-subjects, are: conceptual confusion, implications of water pricing, game theory, transboundary issues, aspects of technology and green infrastructures, the view is much wider; like including data's validity, trade-offs, distributional justice, cooperation, stakeholders' engagement, unanticipated consequences of technology and obstacles in investments.

In order to succeed integration of all above within the frame of easy accessing information, the structure and sectioning of the parent paper has been made in both a linear and non-linear way.

In particular, the paper is being divided in two unequal in extent parts, which are being followed by the conclusions. The reason of the imbalance in parts' length is, the fact that technology and infrastructures are being used supplementary, in order to further incorporate interests of business sector and investors; not to be an engineering manual. The first part is developed around various issues of nexus governance, but from a more water-centric view. The second one is orientated around the green infrastructures' investments, with a more nature-centric view.

More analytically, for part one.

In chapter *"Setting The Context Of Water-Energy Nexus"*, the notion of Nexus is briefly being historically inspected up to today in relation to resource's management and public policies.

In chapter *"Conceptual Confusion In Nexus Context"*, is mainly being illustrated how a concept that initially developed by political scientists for describing concept misinformation in comparative politics, can apply as it is or adjusted in nexus along with the produced effects.

In chapter *"Implications Of Water's Pricing"*, is being discussed the need for water's appropriate pricing and if – under the main drivers (e.g. security) that necessitate such pricing – distributional justice has been put in secondary position. Also, a preliminary attempt to inspect reflection of water's pricing in datasets.

In chapter *"Game Theory In Service Of Nexus"*, is being exhibited the usefulness of game theory in the service of nexus, how it could help in stakeholders' engagement and how methods that do not integrate its advantages in providing solutions could at best generate large amount of information that is not easily managed and might complicate interpretation.

In chapter *"In Transboundary Basin Level"*, the concept of nexus is being deployed across dimension of basin level between upstream and downstream of river, littoral states; around the determinant of cooperation. Complementary to nexus, is considered the contribution of IWRM and international legal regime.

More analytically, for part two.

Chapter *"Technologies and Nexus"* mainly operates as a medium in between nexus and green infrastructure, by exhibiting the concept of unanticipated consequences of technology (e.g. water intensive energy technologies) in projects' competitiveness due to separated consideration of technological solutions in a "silo" approach of nexus components.

In chapter *"Natural Infrastructures On Nexus"*, is being discussed whether there is a coincidence of interests of concerned parts involved on green infrastructures, what kind of benefits does this kind of infrastructures do provide and inspect some key elements of investing on them.

Finally, in the conclusions – based on the reasoning of above chapters – the key issues are being highlighted and some suggestions are being made; intending to benefit decision and policy makers to better understand the concept of nexus across horizontal/vertical scales and dimensions, researchers to embrace validity of their research, help modelers to provide solutions that will be more stable and feasible, help business managers to make the connection between ecosystem's services, natural resources coupling and the business bottom line.

Part 1: Issues Of Nexus Governance

Not all issues are cross sectoral or cross-disciplinary (Davis, 2014). As also not necessarily water and energy components should be addressed all together in the framework of one single intervention (ADC, 2015). But when it comes to a holistic or ecosystem approach of cross-sectoral interactions across scales and dimensions, then all involved parts must be aware of the produced perplexities as described by the “traveling problem”.

Moreover, nexus is not only a matter of natural resources' interdependencies but also of factors like population growth, affluence, poverty and climate change, that are tacitly forcing stress on resources. This is apparent for example when considering published papers that connect nexus and various climate change aspects through game theory (Yang, 2008; Hasson, 2009; Kutasi, 2010; Bosetti, 2012). Generally, the involvement of game theory appears appealing due to the fact that in one hand operates complementary to computational models (Krause et al., 2006; Madani et al., 2011; Pinto et al., 2013) while on the other hand can lead to stable solutions (Madani et al., 2015a).

Of course resource coupling governance in order to be effective must be characterized from coherent, stepwise and consultive planning, especially in cases were friction occurs due to different states and legal regimes. Nexus approach in such cases does not offer many normative principles (Benson et al., 2015; UNECE, 2015a). Could international law and/or IWRM contribute effectively in such cases of transboundary management? What experience taught us when some or all riparian states are not part of UN / ECE Water Conventions (like in case of Lower Mekong River)? These are some important questions that must be answered in relation to nexus. Especially when considering that international watercourses approximately cover half of the land surface of the earth, account for 80% of global river flows and serve the livelihood of about 40% of the world’s population (Wolf et al., 1999).

Thus, this section will be focused on how nexus is being affected by conceptual confusion, the influence of value and pricing of water in nexus, the game theory approach of nexus and the transboundary dimension. And by that will be discussed among others:

- data's reliability, validity and consistency
- stakeholders' and actors' engagement and consent
- clearly signaled externalities, pricing and markets
- role of sectoral and business levels
- local and geographic peculiarities in connection to global dimension.

Finally, to be stated that despite in this section we stress a lot on water component of nexus – as seems that many scholars did after water-centric perception of nexus as put by Vonn2011 Conference (Hoff, 2011; Keskinen and Varis, 2016) – nevertheless this does not operate against the energy component. On the contrary, not only energy is constantly being discussed, but many times other components (e.g. agriculture) are being referenced additionally. Therefore, even if it is accepted that “water acts as a state variable and at the same time a control variable of change, and is placed centrally in the nexus” (Hoff, 2011), nevertheless this section is not considered as water-centric, rather use water as a concrete ground and many times as a starting point to exhibit and develop all above issues.

Setting The Context Of Water-Energy Nexus

Despite that the nexus concept is rapidly and increasingly gaining attention globally in research, business and policy making (Leck et al., 2015) – even though water-energy nexus just suggested at the end of 1970s (Bishop and Mirayanan, 1979) and water-energy-food (WEF) even later (Weatherfold and Ingram, 1984) – nonetheless, still today there is no single strictly clear definition acceptable by everyone (Benson et al., 2015; De Strasser, 2016).

This certain degree of freedom in setting the actual context of nexus, could provide more flexibility in notions with such complexity but also might produce perplexities and induce imprecise conclusions.

For example in terms of management and policy-making, the scope of nexus is to (Dubois et al., 2014; Howells and Rogner, 2014):

- move towards a more coordinated management and use of natural resources across sectors and scales (Welsh et al, 2014; Dale et al., 2015; Fulton and Cooley; 2015);
- identify and manage trade-offs;
- build synergies (Mekong River Commission, 2012; Benson et al., 2013b);
- shift towards a more integrated and cost-effective planning, decision-making, implementation, monitoring and evaluation; while maintaining the integrity of ecosystems (Mekong River Commission, 2012).

While, considering sustainability notion, resource scarcity and the balancing between resource user goals and interests, can be said that nexus concept is in the same vein to management and policy-making debate that triggered at the early 1970s – same decade when first water-energy nexus conceived – by the publication of “The Limits To The Growth”. To be noticed that in nexus, it is not necessarily the physical amount of such resources that cause them to be globally scarce but more likely how the access is governed along with the allocation and use of resources; even though shortage in water is probably more serious than in energy in the not-that-far future (Andrews-Speed, 2012). Hereon to be mentioned that despite the fact that water is not only more prone to scarcity than energy but also more fundamental concerning public health, still concerning economy this relation turns to be reversed since in a scenario of abundant and cheap energy the supply of water may be abundant and cheap (e.g., desalination) but not vice-versa in global terms (Ibáñez Martí, 2013).

In reference to global terms, energy and water are also considered global resources. This is because important energy resources are not evenly distributed in geographic space (Rempel, 2006), while power production is a significant contributer to carbon emissions (Shalizi, 2007). Also, due to the fact that water is related to global demand for food and other commodities through markets (Allan, 2011; Antonelli and Sartori, 2014; Hoekstra, 2014). Therefore, in addition to policy-making scope of nexus as described above, the dimension of global governance should also be considered. Under this prism and in connection to sustainable development, there is a growing demand for universal goals for the post-2015 era (Brandi et al., 2013); albeit with differentiated targets and actions (Nilsson et al., 2013; Weitz et al.; 2014).

Anyhow, the core idea behind nexus concept is to incorporate natural resources' management of those that are inextricably connected to water, energy, food, land and climate security; through an integrated resource management approach.

Conceptual Confusion In Nexus Context

At this chapter, will mainly be illustrated how a concept that initially developed by political scientists for describing concept misinformation in comparative politics, can apply as it is or adjusted in nexus along with the produced effects; while providing examples where there is such need.

In general “Traveling problem” describes conceptual stretching, when concepts and categories are applied to new cases. If concepts are able to 'travel' then they apply to large number of comparable cases, albeit not all concepts and categories are good at traveling (Caramani, 2009). So generally, “traveling” problem describes conceptual confusion; and the importance of the latter in cross-disciplinary dialogues is considered significant (Jacobsson and Jacobsson, 2014).

Not Like-For-Like Comparison

As stated above still today several definitions of nexus do variate (Benson et al., 2015; De Strasser, 2016). However, according to scholars, three complementary perspectives can be distinguished in relation to nexus notion (Keskinen and Varis, 2016; Keskinen et al., 2016). These perspectives are attained when approaching nexus from the point of view of analytical approach, governance framework and emerging discourse. The latter force an obvious impact on cross level linkages.

Nevertheless, the absence of a single definition is not the base but the stem of the problem. Causation partly could be traced in common shared features between nexus and other resource management approaches (i.e. IWRM) – like integration, optimal governance, scale, participation, resource use, and sustainable development – that could result to conceptual confusion and problems to comparative analyses; since are not being interpreted exactly the same (Harkness, 2011; Benson et al., 2015).

The comparison between features of nexus with those of IWRM, is really important especially after United Nations Conference on Sustainable Development (UNCSD), commonly known as Rio+20, according to which the formulation of Sustainable Development Goals (SDGs) regarding water should be build upon the existing concepts of Integrated Water Resource Management (IWRM) and the human right to water (Brandi et al., 2013); even though water (as energy also) was not explicitly included as one of the eight Millennium Development Goals (MDGs).

Beside common features with IWRM, water consumption and various other metrics (e.g. water withdrawal, water consumption, water utilization etc.) from “water to energy” literature, in principle considered to be valuable, complementary and informative. However, are facing hard controversy because of their inconsistency in their interpretation, so that their application has resulted in incomparable and sometimes contradictory results (Madani and Khatami, 2015).

All above, are known as the “traveling problem” (Sartori, 1970; Harkness, 2011; Benson et al., 2013), and potentially influence inferences. For example when perplexities are produced in comparative research (and thus in use of integrated models) that is attributed to a not like-for-like comparison (Madani and Khatami, 2015).

Effect Of Perspectives, Objectives And Experience

Letting apart the many dimensions of one notion, similar imprecise conclusions could be inherited either by different perspectives on knowledge management or because of varying levels of experience and different objectives (Delong and Seemann, 2000).

So the effect of “traveling problem” and various perspectives could also be identified in different organizational level of decision and policy making.

The issue of many dimensions of a concept could be apparent even when considering viewpoints that could come from same or equivalent organizational level(s) (Delong and Seemann, 2000). For example, when trying to tackle nexus trade-offs, one approach could be that of capturing best practices trough a shared database (ACEEE, 2011; IEA and WBCSD, 2014) and another approach is to stress on local peculiarities. Stressing on local peculiarities could be more useful in cases of states/territories/areas with the need to cope primarily with particular components of Water-Energy-Food nexus, like:

- water-energy,
  e.g in Praia of Capo Verde (ADC, 2015; MTIDE, 2015) or post-2014 Gaza Strip (IMF, 2014; ADC, 2015; UNRWA, 2016);
- or, water-agriculture,
  e.g in Burkina Faso (ADC, 2015; ODI, 2015).

'Pseudo-“Traveling”' Problem

Another example is related to critical consideration of both horizontal and vertical scales and of dimensions (Leese and Meisch, 2015; Endo et al., 2015; Keskinen and Varis, 2016). In particular, synergies, could be perceived as (Leese and Meisch, 2015):

- horizontal cross sectoral;
- vertical among different levels of administrative authorities,
  i.e. international, national, regional, local;
- or, across spatial boundaries,
  e.g. transboundary, basin-wide.

Furthermore, the “traveling” problem could be connected – and not attributed – to nexus management and public policy through different perspectives on management models as matter of a top-down or bottom-up approach. For example, if public policy is practiced in terms of a top-down technocratic instead of a bottom-up participatory approach then it could potentially encapsulate the contingency of narrowing down public audience; and as so, narrowing down the potential for multilaterally and fully implementing the aforementioned synergies at same time. This could be because leaders of top-down schemes consider that other than key actors – such as street level bureaucrats or local implementing officials – could lead whole endeavour to bottleneck and therefor strategic initiatives coming from them are being neglected (Elmore, 1979; Barrett and Fudge, 1981; Hanf, 1982; Hjern and Hull, 1982; Sabatier, 1986). While even if the leader of top-down scheme exhibits the willingness to engage the capacity of other actors, there still might be problem when the technocratic approach requires a highly technical understanding of role of evidence in policy (Hoppe, 2011; Hajer and Wagenaar, 2003).

So in practice vertical cross section synergies could not successfully been fully implemented. Thus, could be said that potentially the preference on management model could lead to a situation of a 'pseudo-“traveling” problem' not by direct choice but by the developments. So there must be a balance between a top-down or bottom-up approach at the point where endeavour considered to be viable.

Summary

Summarizing, we illustrated that despite “traveling” problem is a concept borrowed from political sciences – along with conceptual confusion in general – nevertheless the implications cannot be neglected and are well spread over policy-making, organizational governance, even on comparative analysis.

Initially, illustrated how the need for escaping from stagnated situation caused by the lack of adequate datasets, nexus research is phasing out to use of sketchy data, metrics with inconsistencies in their interpretation and shared notions (i.e. with IWRM) that do not have exactly the same content. Thence, in a not like-for-like comparison, which might influence inferences and produce perplexities in comparative research, that will eventually be inherited in policy-making procedure.

Also, illustrated that different perspectives:

- depending on knowledge management,
- based on experience level, and
- derived from different objectives

are affecting synergies, practices and policy-making. Fact that could be apparent both on different and same or equivalent organizational level(s).

Finally, the concept of 'pseudo-“traveling” problem' was introduced and developed, as a direct result of different perspectives on management models as a matter of top-down and bottom-up approaches.

Implications Of Water's Pricing

Today, the prevailed choice in water's pricing reform by policymakers mainly focused on household water use and partly to agricultural. But how price and value of water is connected to nexus? Are there “Market-Based Mechanisms” (MBMs), and if so, are they widely-spread and how well do they integrate distributional justice. Also, what's the connection of MBMs with “Virtual Water Trade” (VWT) concept or with adequacy of datasets. These are the main question that will be answered in this chapter; so to help policy-makers and highlight issues around emerging business opportunities; which are attributed to securitization of sustainable economy.

Importance Of Appropriate Pricing

From Adam Smith's “diamond-water paradox” (Smith, 1776), through idea of valuing only natural assets we own (Leopold and Schwartz, 1949), until today's “peak water” concept (Gleick and Palaniappan; 2010) – which still considered to be premature, even though there is an extensive literature on peak oil, years now – the value and pricing of water does not necessarily coincide; thus not only interfering with safety and security of water but also influencing the water-energy nexus.

This influence – in conjunction with the consideration according to which there are cases around the world where water rights tend to define right to use water but not to assign ownership of the entire stock of water leading to a situation where, in general, water tends to be over-used (Brady and Yoder, 2013) or water not efficiently marketed because of non well-defined transferable property rights (Frederick, 1998) – signifies the importance of water's appropriate pricing in water-energy nexus.

Besides, there is a genuine need for nexus components to be commodified so that to provide a harnessed and manageable basis for the green economy as envisaged to operate under the paradigm of security (National Intelligence Council, 2012; 2030 Water Resources Group, 2009; Leese and Meisch, 2015). Moreover, appropriate pricing can ensure that the environmental externalities of using natural resources and services are clearly signaled (EC et al., 2012). Else, in case of water availability below its fair or appropriate price, not only the water is being wasted (Gabaldon, 2012; Chebly, 2014) but also operates as an obstacle to a more efficient use of it (Prager, 2006; Chebly, 2014). Towards the direction of internalizing impact, the determinant for establishing monitoring systems to track and monitor nexus components and indexes (Bonn2011 Conference, 2012) could operate auxiliary.

Market-Based Mechanisms (MBMs)

In recognition to the aforementioned genuine need, MBMs are already been deployed for allocating water and cost recovery – mainly concerning irrigation – (Easter and Liu, 2005; OECD, 2009) or more general like in USA (Frederick 1998; DOI's USBR, 2009); though it's not an easy endeavour (Johansson, 2000; Donohew, 2009).

Versus Virtual Water Trade (VWT)

To be noticed that water's MBMs should not be confused with what is called as VWT, since the value of virtual water is as economically invisible and silently resolved through food market as economically invisible and politically silent is virtual water (Allan, 2011); even though, par example, on global average an imported/exported ton of wheat has been associated with 1300 cubic meters of free water (Antonelli and Sartori, 2014; Hoekstra, 2014). Nevertheless, VWT concept is connected to several constraints such as: land availability, self-sufficiency instead of food security as a choise of national policy, disambiguation between green and blue water. Additionally, VWT faced controversial critics by economists, although could explain consumption indirect effects that might be externalized to other countries through freshwater globalization (Antonelli and Sartori, 2014).

Distributional Justice And Other Argues

Of course, not all scholars' views about market-trade contribution are considered as optimistic. In particular there is the so called “Three Weddings and Avoiding Two Funerals” idea, according to which, economic diversification, socio-economic development and trade in enabling environments and sustainable economies (the third “wedding”) – along with water form energy and energy from water (first and second “wedding”) – will not deterministically help society to avoid depletion and degradation of environmental services of water (first “funeral”) and (as second “funeral” the) impairment of atmosphere (Allan, 2009). In order to be avoided must, both shifting from conventional energy to renewable and change in consumers and producers mentality, take place (ibid). But, to the latter could be said that the concept of value and pricing of water could probably help in mindsets' shift. Position that appears to be also accepted by the man that introduced the aforementioned idea; according some given lecture at the University of Saskatchewan at 2009 (Grzybowski, 2010).

Anyway, Foucault since 1977-78, already showed that there is an inextricable link between security and the economy (Foucault et al.,2007; Leese and Meisch, 2015). However, there is a long debate whether distributional justice being put in secondary position while “energy and food have been placed on top of the security agenda in order to push forward solutions to economic pressures” (Leese and Meisch, 2015). Contradictory answers, are being given by scholars, arguing on whether emerging opportunities for business and “marketisation” of green governance, is for survival of mankind or for the preservation of current economic setups (ibid). At this point, is noted the need for further research, since the dominant argumentation – like in carbon economy – stress on comparing neo-liberalism's perception with others.

Reflection Of Water Pricing In Datasets

Another point that should be aware of, is that water pricing maybe reflected in the absence of adequate datasets; i.e. of data on actual water consumption for energy systems (GAO 2009, Mielke et al., 2010; Macknick et al., 2011; Spang et al., 2014). Nevertheless, water use in agriculture is more documented (Siebert, 2010; Hoekstra, 2012; Steduto, 2012) and data are less sketchy. The aforementioned – within the lack of a standard framework for assessing and measuring the water impacts of energy

(Madani and Hadian, 2013) – could enhance biased interchangeable use of some metrics as mentioned during “travelling problem”.

So despite that energy economics may be amongst dominant components of driving developments in water-energy nexus (Gold and Bass, 2010), nevertheless water economics implications cannot be neglected.

Summary

Summarizing, some reasons for appropriate water's pricing, are:

- value and price of water does not coincide,
- connection of economy and security,
- situations where water tend to be overused as a result of water defind rights,
- to ensure that environmental externalities of using natural resources and services are clearly signaled,
- to provide harnessed and manageable basis for green economy

To this effect, some MBMs within nexus concept have already been deployed, though it's not an easy endeavour. And by referring to mechanisms, do not mean the so called VWT; which is connected to several constraints, while being economically invisible and politically silent.

Going back to MBMs, not all scholars are taking a favorable place deterministically in a priory, rather put on canvas pre-requicities that are not always under the economically technical prism of market's structure; that however could implicitly confirm the need for appropriate pricing.

Nevertheless, the main question is the effectiveness of such mechanism in terms of distributional justice. And besides the long debate, it has been highlighted the need for further research since most literature stress on traditional “war” between different economical schools of thought and not that much in optimum trade-off between “marketisation” and distributional justice, as per se.

Finally, the existence of some relation between the way we price water and datasets in the inter-linkages between water and energy or agriculture was pointed out.

Game Theory In Service Of Nexus

In this chapter, will be discussed why game theory could be used in water-energy nexus and compare game theory with other tools. The reason for such choice is to encourage modelers for using game theory in their models, so that to reach stable and feasible solutions which will feed back policy making procedure with enhanced liability.

In one hand, and especially after Aarhus Convention, policy process and decision-making is broadly considering stakeholders' involvement (Stec et al., 2000; UNECE, 2013a; UNECE, 2014; UNECE, 2015a; NEA, 2015); so that today is being in general seen as a meaningful part of formulating and implementing good policy (Gold and Bass 2010; Davis, 2014; Flammini et al., 2014; Hurford et al., 2014; NEA, 2015). Therefore, various approaches (concerning several issues) have been suggested, developed and assessed (Schmeer, 1999, Jones and Fleming, 2003; NEA, 2004, World Bank, 2010). Albeit practice showed that is not always easy to fulfill the context of engaging stakeholders, like in participatory methods (Kallis et al., 2007).

On the other hand, quite several papers towards optimality (Antipova, 2002; Hurford et al., 2014; Hurford et al., 2014a; Saavedra Antolinez, 2014) and trade-offs (Giampietro, 2013; Hurford et al., 2014; Hurford et al., 2014a) have been published.

Nevertheless, despite that modeling and visualization of patterns, trade-offs and optimal solutions let governance conflicts to become more understandable for stakeholders while providing useful insights to policy makers (Couclelis, 2000; Hurford et al., 2014), nonetheless modeling may also entail a potential weakness due to the excessive reliance on reductionism (Box, 1979; Giampietro, 2010).

Moreover, not only a model is as useful as the purpose for which it was constructed (Couclelis, 2000) but also is constraint by several factors as the referenced geographic place, climate conditions, and different production technologies (Chawla, 2015).

Besides, optimal solutions (from central planer's view) are not necessarily stable/feasible due to conflicting interests and objectives of multiple actors. The latter occurs because cooperation (group rationality) is not necessarily a stronger driving force than individual benefits (individual rationality) (Madani, 2009; Read et. al, 2014; Madani et al.. 2015a).

Moreover, politicians simply are not willing just to thoroughly do what is suggested by a model (Couclelis, 2000). A decision maker must ensure that the undertaking is not only physically, environmentally, financially and economically feasible, but also socially and politically feasible (Madani, 2009; Kolios and Read, 2013). Therefor their appropriate weight in decisions making should be given, albeit their impact is evaluated subjectively and at best cannot easily be quantified. (Gold and Bass, 2010).

But even modeling approaches that are not orientated around optimal solutions but rather identifying trade-offs at best, still are subjected to uncertainty and fuzziness while could generate large output of information; thus complicating interpretation (Giampietro, 2013). Like the trade-offs associated with multiple potential outcomes for case of Preliminary Revised Draft SGEIS in July 2011, after New York's placing drilling (shale gas) on hold at 2009 (Scott et al., 2009).

Not to mention that not all nexus problems are a win-win situation; like in cases where policy-makers are in the middle of an increasing resource scarcity event and have to make value judgments on many occurred trade-offs (Davis, 2014).

Having above in mind, can easily be concluded that trade-offs and optimal solutions are useful and informative, but are not enough by themselves for an effective governance of nexus. In addition to these, there must be the consensus and acceptance in practice of actors and stakeholders. Else optimal solutions might not be stable. And if such so, then some regulatory framework that will be based on them, might fail to promote competitiveness, investment and innovation, and by that to affect effective transition to a resilient water and energy secure system (Gold and Bass, 2010 ; Kolios and Read, 2013; Read et al., 2014).

The available multiple decision making tools lack in terms of replicating the capacity for compromise amongst stakeholders, where game theory can offer alternative approach by offering near-optimal solutions that could be proved as stable (Madani et al., 2015a).

Game theory, since first introduced (Von Neumann and Morgenstern, 1944) involved enough so that today covers a wide range and diversified areas of knowledge like from biology (Sigmund, 2005) to political and socials sciences (Ostrom, 1990; Kollock, 1994), and in general to all behavioral sciences (Gintis,2009). However, the output of theoretical such models is highly dependent on assumptions; like rationality which could be questionable in cases like those of asymmetric information (Simon, 1995). Such assumptions could lead from stable but not attainable solution (e.g. can mutually satisfy all players) in best-worst scenario to equilibrium points that may not exist in worst-worst scenario (Arthur, 1994; Epstein and Hammond, 2002; Fellman, 2011). Nonetheless, game theory can predict whether optimal resolutions are reachable, while could explain how decision-makers' rational behavior – trying to maximize their own objectives – might result in overall Pareto-inferior outcomes, despite the fact that stakeholders' decisions and behaviors might seem to be irrational from system's engineering perspective. However, modelers should be aware of variation in game's conditions during its evolution and the altering effect to its structure, equilibria and results (Madani, 2009).

Yet, game theory could contribute to questions, such as (Madani et al., 2015a):

1. How will an individual organization's strategy fare in relation to the strategies of other stakeholders?
2. How can multiple long-term aims of different organizations be reconciled?
3. What are the most robust strategies across stakeholders (e.g. for a particular region)?
4. What outcomes might result from different configurations for each of the stakeholders?

Game theory could be used complementary to computational models (Krause et al., 2006; Madani et al., 2011; Pinto et al., 2013), e.g. Agent-Based Models (ABM), Multi-Criteria Decision Making (MCDM).

Most of the literature in the wider considered WEF nexus concern the water-food interrelation focusing on irrigation and water allocation/conflict for farming (Yaron and

Ratner, 1990; Weissing and Ostrom, 1990; Dinar et al., 1992; Ostrom and Gardner, 1993; Xepapadeas, 1996; Zorba et al., 2001; Faysse, 2003; Madani, 2009; Kerachian et al., 2010; Finger and Borer, 2013; Kimmich, 2013; Msangi, 2014;); with a trend from cooperative – mainly during 90s – to non-cooperative games (Parrachino et al., 2006; Podimata and Yannopoulos, 2015). As far as energy is being concerned in the broader sense of WEF nexus, mostly game theory applies in conjunction or as a part to climate change aspects, e.g. carbon footprint, GHGs mitigation options. Or correctly could be said that, the notion of energy is tacitly implied in game theory through climate change dialogue; like from the perspective of common pool resource (CPR) problem (Kutasi, 2010), public goods game (Hasson, 2009), or based on integrated climate-economy models (Yang, 2008) and energy-economy model (Bosetti, 2012).

So the cornerstone to build upon has already been put – while there is whole field to play ball when it comes to joint assessment of energy and water using game theory methods – nevertheless more research has to be done towards this direction.

Also, to be pointed – on the pro et contra of water and energy components – that whichever noticed inadequacy of water in clearly signaled prices (as examined above), is being counterweighted by taking in consideration the game theory literature of actors' and stakeholders' involvement in attainable and stable solutions. Thus, joint consideration of nexus components does not only impose challenges but also provide opportunities for better integration.

Summary

Summarizing, could be said that stakeholders' involvement in policy-making is not an easy task. Participatory methods, modeling optimal solutions and trade-offs, bear its own weaknesses.

Concentrating on optimal solution and trade-offs, practice and literature provides an undeniable support in favor of trade-offs. This is not only due to their own nature, but also for reasons of actors mentality and political feasibility. Nevertheless, still modeling approaches oriented around trade-offs are in one hand subjected to uncertainties and fuzziness while on the other hand could generate a large amount of information that is not easily manageable and could complicate interpretation.

After all – besides that every situation is not a win-win one – the available multiple decision making tools do lack in terms of replicating the capacity for compromising amongst stakeholders; in relation to game theory.

And despite that game theory may involve not attainable solutions or equilibrium points that may not exist for some scenario, still can predict whether solutions are reachable and could explain how decision-makers' rational behavior could lead to overall Pareto-inferior outcome; as long as modelers are aware of game conditions variation during the game and their reciprocal implications.

In WEF's context, game theory mostly been used on water-food interrelation, trending from cooperative to non-cooperative games. So further work has to be done on joint assessment of energy and water using game theory; especially for non-cooperative games.

Finally, highlighted that joint consideration of nexus components does not only impose challenges but also provide opportunities for better integration when considering the pro and contras of energy and water components of nexus in relation to clearly signaled prices and game theory literature.

In Transboundary Basin Level

Across dimensions, due to inter-sectoral nature of water share and collaboration, the management of “coupled” resources in transboundary water basin level is facing difficulties but also opportunities for cooperation. And though, as was pointed in previous chapter, game theory does provide sound scientific method for whether optimal solutions are reachable, however cannot stand-alone provide the needed framework for forging cooperation. Thus, the contribution of IWRM and international legal regime will be inquired.

More analytic, will be discussed the determinant of cooperation; as a precondition for effective governance and avoidance of conflict escalation. The reason is not only because synergies should be perceived also across spatial boundaries, but also due to the fact that not always supra-national organizations exist in transboundary basins. Or simply, because international watercourses are a considerable part of earth's land and serve the livelihood of many people; notwithstanding that few water disputes have actually found their way to the International Court of Justice - ICJ (Grzybowski, 2010). Thence, it goes without saying, that is pointless to quantify on number of cases within the context of nexus – since is not even well established yet (like IWRM) in such transboundary basin scale – that have been reviewed by ECJ; though one of common concepts of friction between upstream-downstream littoral states is that of hydro-electric projects. Furthermore, various examples will be provided and the effectiveness of nexus versus IWRM and international legal regime's toolkit (wherever this serves the scope of parent paper) will be compared.

Before starting, to state that the purpose of this chapter is not to conduct a full analysis but to provide those key elements that are crucial for promoting concept of cooperation through nexus paradigm; using auxiliary knowledge on the topic coming from resource management (IWRM) and international legal regime practicing.

Beginning, as already stated water and energy are inextricably interlinked, while both being dependent on the ecosystems, but this does not necessarily imply that water-energy nexus should be resolved in the framework of a single intervention (ADC, 2015). This fragmented governance is reflected on the fact that water and energy are being subjected to different international legal regimes (Boute, 2016).

Nonetheless, even fragmented governance still requires coherent, responsible and consultative planning else spillover effects across sectoral policies could be proved more risky and therefor more expensive (Phillips et al., 2006; Mekong River Commission, 2012; Howells and Rogner, 2014; De Strasser, 2016). On the other hand, when it comes to “resource coupling” and due to the fact that few normative principles are provided (by nexus conceptualization itself) on how governance should occur, some scholars argue on how nexus can effectively contribute to “multi-tiered” institutional arrangements – especially when is governed by different institutional levels (Benson et al., 2015; UNECE, 2015a). Field where IWRM proved useful, by promoting transparency, collaborative decision-making principles, and use of specific policy instruments (ibid; Benson et al., 2012; Cap-Net, 2014; UNECE, 2015a). However, IWRM's traditional analytical scope considered by other scholars as limited, and without always taking into

consideration re-enforcing stresses or indirect links; like how climate change affects energy production through water demand (Phillips et al., 2006; Welsh et al., 2014; De Strasser, 2016).

Moreover, frictions between transboundary (water sharing) countries due to inter-sectoral nature of water share and allocation, is not rare phenomenon. For example, Egypt that is a country at downstream of Nile is opposed to Ethiopia's and Sudan's aspiration for building dams to produce electric power at the upper part of the stream (Andrews-Speed, 2012). Or like the case of Rogun Dam, for which over three decades only preliminary construction has been carried out due to occurred tensions between energy-starved Tajikistan and cotton-producing Uzbekistan (Škoba, 2013). Of course transboundary management does not imply only tensions but also opportunities for cooperation, as in the case of Mekong River Commission (MRC), in which four – known as the Lower Mekong River (LMR) basin countries – of six riparian countries are participating (Belinskij, 2015). Only the LMR serve the needs of more than 60 million people. But, the aforementioned cases are not the only ones; around the world were counted over 260 (Škoba, 2013).

So, easily can be understood that concerning transboundary basins, a stepwise progressive approach that provides parts with enough time to build trust and deepen the inter-sectoral approach between them, is an adequate condition. International law could be helpful towards this direction (Belinskij, 2015; UNECE, 2015a), while the purpose of other step-wise approaches – namely of nexus and IWRM – is mainly fulfilled in terms of a comprehensive economic analysis that could be handful for policy-makers (WEF, 2011; Benson et al., 2015). At this point, regarding international water law to be acknowledged that lacks in concrete specification for its procedural elements when it comes to transboundary nexus and mainly offers the institutional approach (Belinskij, 2015; Keskinen and Varis, 2016).

Such approach in service of nexus introduced during the 6th session of the Meeting of the Parties (MOPs) of United Nations' Economic Commission for Europe (UNECE) Water Convention (WC). It was the result different international legal regimes based difficulties and the need for a more integrated approach.

The determinant of cooperation is vital in effective governance and avoidance of conflict escalation (UNECE, 2013). In this spirit, seven key principles fur succeeding higher level of maturity concerning cooperation between riparian states through effectively operating joint bodies, are being mentioned (UNECE, 2015, UNECE, 2015a):

- The broad competence of a joint body, which on the basis of IWRM, addresses in a complex way the entire spectrum of issues related to the sustainable development, management, use (including infrastructure) and protection of transboundary waters;
- A sufficiently broad and complete representation of national authorities in the joint body, involving participation beyond the water management authorities to include representatives from the ministries of the environment, fishery, agriculture, transport, health, energy, hydrometeorology authorities, economy and finance, as appropriate;

- A certain flexibility of the agreement establishing the joint body that enables cooperation to develop progressively in terms of scope, mandate and the riparian countries involved;
- A regular exchange of information and consultation mechanisms;
- A process that facilitates the assessment of impacts (transboundary and intersectoral) from developments, and the negotiation of an agreement on them among riparian countries;
- A framework for monitoring long-term impacts (e.g. infrastructure);
- Mechanisms for public participation and stakeholder involvement.

Nevertheless, not always riparian states are part of Water Conventions, par example none of the Mekong countries is a party to the ECE Water Convention and only Vietnam is a party to the UN Watercourses Convention. Nonetheless, the general principles of the UN and ECE conventions can be regarded as a source of international customary water law also in the Mekong River context; for example in Article 4 of 1995's Mekong Agreement the determinant of cooperation is similarly described as in UN Water Convention following principles of sovereign equality and territorial integrity (Belinskij, 2015). Of course, even though 1995 Mekong Agreement is characterized from serious deficiencies in terms of nexus still provides tools for developing their cooperation within nexus notion (ibid).

Going further, the enforcement tools of Mekong River Commission are notably consultation, negotiation, diplomacy and persuasion (ibid). Such choices, are considered to be rather expected where will for understanding community interests is being exhibited (UNECE, 2015a); like in Sava sub-basin of Danube river basin in South-Eastern Europe, where International Sava River Basin Commission (ISRBC) already promotes exploration of energy and agriculture components of nexus (ibid). Otherwise, if lack of trust and understanding prevails, the likelihood of establishing effective cooperation is not the strongest case (Belinskij, 2015; UNECE, 2015a); like in Syr Darya sub-basin of the Aral Sea Basin in Central Asia where nexus assessment focuses on national policies and some foreign officers may discuss mainly bilaterally water issues ad hoc (UNECE, 2015a).

Summary

Summarizing, it's a fact that nexus concept lacks where IWRM proved useful, namely in providing tools for casting “multi-tiered” institutional arrangements; but the limited scope of the latter, operates as an impediment in relation with re-enforcing stresses and indirect links.

Furthermore, nexus and IWRM encourage stepwise approaches – like international water law offers, but with the difference – that are focusing in comprehensive economic analysis.

On the pros of international water law is that promotes cooperation, even though it lacks on procedural elements. Cooperation is a key element of a successful and effective governance, nevertheless not all riparian states are part of Water Conventions. Notwithstanding the latter, practice shows that general principles of the UN and ECE conventions can be regarded as a source of international customary water law (e.g. 1995 Mekong Agreement).

Additionally, provided examples highlighted the importance of trust, understanding of community interest and cooperation. So effectively promoting them is a challenge for nexus concept, that could also face difficulties when international leading organizations in nexus do tend to approach basin states with-in a top-down scheme in the absence of a supra-national organization between those states. Therefore, nexus concept should not only enclose within its context such provisions but also offer the respective tool set. Tools that should also take in consideration other facts, as fragmented governance of international nexus requires coherent, responsible and consultative planning.

Part 2: Technology And Green Infrastructures

Technologies and infrastructures are the core of nexus conceptualization in this chapter, since both do provide insides of resource use efficiency. Also, can provide valuable information for policy and decision makers, investors, undertakers and states.

In this part of the dissertation there is a shift from a more water centric view of nexus (that was apparent at first part), to a more:

- balanced water-energy view when considering technology role, and
- nature-centric view when considering natural (or green) infrastructures integration to nexus.

The reason for latter is that nature adds an extra dimension to nexus concept due to the beneficial potential coming from the securitization of nexus components, while operating as a mediate to the wider-perceived concept of nexus including other components as food, land, climate (Krchnak et al., 2011).

Furthermore, the chapter that discuss technological issues, does not aim in becoming an engineering manual but to operate as the intermediate link between nexus and green infrastructures while providing useful insights for decision and policy makers.

“Technologies and Nexus” chapter, will mostly be developed around unanticipated consequences, while “Natural Infrastructure On Nexus” chapter will be mostly concentrated in partially coupling of green infrastructure investments and nexus risks and dependencies.

Technologies and Nexus

In this chapter will be discussed the role of technology, in connection to research, investments, policies and future scenarios. Nevertheless, analyzing and assessing all technological solutions, is out of this paper scope. In this vein, will be used examples and data for certain technologies as a "vehicle" for identifying and highlighting key elements of the aforementioned aspects of nexus. Furthermore, the role of this chapter itself is to operate as a medium between nexus and next chapter (green infrastructure); due to the fact that new technologies ramps up the need for more advanced cooling systems. To be noted that a big part of this chapter is on unanticipated consequences of technology in: what causes them, challenges that must be addressed and suggestions.

"Silo" Consideration And Unanticipated Consequences

It's common knowledge that policies are being shaped by technology , while policies/regulations could induce innovation in technologies. For example, environmental regulations could induce innovations in green technologies and by that to help economies break away from a polluting economic trajectory and move to a "clean" one (Huenteler, 2011; Dechezleprêtre, 2014). But advancing in some way towards sustainability for one component of nexus, could impact on another. In particular, according to 2012's World Energy Outlook "New Policies" scenario, as a direct result of shifting towards higher-efficiency in power plants – with more advanced cooling systems and the increased production of biofuel – is likely expected an increase by 85% of water consumption for energy within the next two decades (IEA, 2012). Fact which is connected to higher water withdrawals (ibid). So, new technologies or technological advancements can give rise to unanticipated consequences (Healy, 2005). This could be partly attributed to complexity of a system or concept (Dörner, 1996; Healy, 2005); like nexus inter-linkages.

Another unanticipated consequence could be derived from the adoption of advanced cooling system by fossil fuel-based and nuclear power plants so that to reduce water requirements. However, in general such solutions do lack in competitiveness to existing competing technologies in terms of cost; in particular entails higher capital costs and reduces plant's efficiency (OECD, 2006; Weiss and Bonvillian, 2009; IEA, 2012). But nuclear and fossil fuel-based plants are not the only energy producers. When concerning undertakers that produce power from renewables – under the particular market conditions and policy frameworks – they bear a certain competitive status. For example, as estimated for 2010 and the state of Germany, the onshore wind energy was likely to be competitive with the fossil electricity by 2015, solar PV by 2020, and offshore wind by 2030 (Huenteler, 2011; Kost and Schlegl, 2010). But would it be the same if, a new introduced regulation enforce conventional electricity producers to lower their water footprint by means of advanced cooling system? Obviously this will lessen their competitive position by raising their capital cost and harming their efficiency.

Going further in unanticipated consequences, when technological advancements in horizontal drilling and hydraulic fracturing allowed the development of shale gas, water and energy resource coupling interfere with national security (Freeland, 2011; Medlock et al., 2011). Also, associated to multi-tiered decision-making and competing goals, little scientific agreement, limited time and resources, and inequalities in access to power and information that demand combined consideration at different spatial and temporal scales (Lachapelle et al., 2003; Scott et al., 2009).

After all above, could be said that separated consideration of technological solutions in a “silo” approach of nexus components, not only could affect (towards opposing directions) components' security due to complexity of nexus, but also when combined with regulatory interventions could drive changes in competitiveness status of market. Thus, there is an obvious need for a more efficient and cost-effective technological solutions, that depend less to water. At the mean time, policy-makers should consider promoting stronger the utilization of combined technological solutions or of technological-infrastructure solution, having in mind the complex nature of nexus. At this point to be acknowledged that, transition to less water intensive energy technologies is additionally limited by existing institutional arrangements created to support current electricity generating technology (Scott et al., 2009); therefore such arrangements should also be taken in consideration.

Preliminary Evidences From CSP Investments

Newer developed technologies for lower water consumption are still not that sufficient and cost more (OECD, 2006; IEA, 2012). Like dry cooling systems for CSP plants. Dry cooling systems demand higher capital costs, higher auxiliary operating power requirements and an overall lower plant performance, especially on hot days, when the peak power is needed most (U.S. Department Of Energy, 2009). Even hybrid wet-dry systems (that allow the plant to maintain design or near- design performance) do bear higher cost for the cooling system; compared to water cooling (ibid).

But, do such technological solutions for power plants that have such extremely low share of global electricity output – even if find no application in elsewhere – deserve such attention? Experienced showed that participation in produced power mix at some point of time does not necessarily pose constraints for future development. For the example of CSP, the participation was almost to be neglected for 2012 (IEA, 2012) and according to “New Policies” scenario of World Energy Outlook 2012 could reach 1% at 2035 (ibid), or according to “Advanced Scenario” of CSP Global Outlook 2009 the global CSP capacity is projected to be at 1500 GW by 2050 (Richter et al., 2009); when in 2010 was estimated approximately 1299 MW and already by 2012 increased to 1,9 GW worldwide (IRENA, 2012).

Furthermore, a power production technology with rising trend of its installed capacity, that is usually found in semi-arid areas, would ideally have to select between water and dry cooling system. But selection is not always an option, like when CSP is deployed in semi-arid areas with water scarcity or in arid areas; e.g. the case of “Solar Energy Generating Systems” in the Mohave Desert (IEA, 2012, IRENA, 2012). Or how much of an option, could it be for places prone to aridification due to climate change when

considering projects lifetime; e.g. in case of Nile Basin for which scientific reports recognizes a tendency for becoming more arid in the next 30-40 years (SFG, 2013).

So, investments under the prism of nexus should be assessed by policy-makers for all technological solutions – even if not such popular today – taking in account local peculiarities (e.g. water constraints), but also climate and impact of climate change. Additionally, the need for reliable toolkit and data in assessing risk relating to uncertainty from climate change impact on nexus, is also imposed by the need for selecting the most suitable technological solution. Or reversely, technological advancements should be ready to address problem of climate change impact based on reliable toolkits and climate data.

However, thermodynamics of energy infrastructures' operation (i.e. LNG) should not always be perceived as a problem. Under conditions could be exploited so that to produce (desalinated) water suitable for irrigation and other activities (Antonelli, 1983; Cao, 2015). Thus, not only technological advancements are in need, but also creative combinations of existing energy and water technologies in order to create smart solutions that efficiently will exploit system's potentiality; based on existed technologies.

Summary

Summarizing, unanticipated consequences could occur by use of technology or from technological advancements that are connected to nexus complexity. Additionally, there is an obvious need for more efficient and cost-effective technological solutions – that depend less to water – and creative combinations of existing energy and water technologies for maximizing benefits from their utilization. To be noted that transition to less water intensive energy technologies is constrained by existing infrastructures and by institutional arrangements created to support current electricity generating technology. Furthermore, investments under the prism of nexus should be assessed by policy makers for all technological solutions – even if not such popular today – taking in account local peculiarities (e.g. water constraints), but also climate and impact of climate change. In connection to latter, both more accurate climate data and assessment tools for climate change impact are in need. Finally, policy makers should be aware of technological advancements impact on national security, relation between water quality and individual economic gain.

Natural Infrastructures On Nexus

In this chapter will be discussed whether there is a coincidence of interests of concerned parts involved on green infrastructures, what kind of benefits does this kind of infrastructures do provide and inspect some key elements of investing on them. The purpose for such approach is to highlight how a cost-competitive and effective solution – that is not a totally new concept – could be impeded. Also to be noted, that this chapter is not a statistical survey of investments around the world, rather try to use statistical data only where this serve the scope of dissertation. Additionally, even though that taxation and incentives are an important part of investing causation, focusing on such not only could be at least one separate paper by itself, but also the big picture would be lost; therefore, they are implicit mentioned through "silo thinking".

Opportunities And Impediments

Despite that nature is part of infrastructure portfolio of every country and every economy based on its capacity to complement, augment or replace the services provided by traditional engineered infrastructure (Krchnak et al., 2011), for many years now governments and private sector were heavily relied on gray infrastructures (Ozment et al., 2015). Gray infrastructure is a general term referring to man-made engineered assets using non living, non-self-maintaining systems – typically of concrete and steel construction – designed to provide a required function; such as damns and water treatment plants (WBCSD, 2015).

Nevertheless, mitigation of gray infrastructures by integrating or engineering standalone green ones, can contribute to followings (Ozment et al., 2015; WBCSD, 2015; Bennett et al., 2016).

- Provide benefits to society, climate and the natural environment:
  - protect and restore ecosystem services;
  - water, food, energy security;
    1994 threat security case because of Diama dam (Senegal) was ignoring natural infrastructure value (Krchnak et al., 2011)
  - enhance resilience to climate change; and
  - provide a suite of additional social and economic benefits.
- Help business to address its own needs:
  - reduce costs,
  - reduce company risk and increase company's resilience,
    e.g Sarapiqui watershed case for Energia Global (now Enel Latin America) in 1990s (Hanson et al, 2012);
  - capitalize on business drivers and novel opportunities
    of those that (directly or indirectly) depend on environmental resources;
    e.g. Canaan Valley case for Allegheny Power (Hanson et al, 2012);
  - meet government, regulatory, or permitting requirements,
  - address stakeholder and community concerns,
    i.e. resource availability, HSE, biodiversity conservation.
    e.g. restoration project of Old Rhine River by Electricité de France (WBCSD, 2015)

Thence, it's easily understandable that there are overlapped interests on green infrastructures for business, investors, states and people to be met. Thus, natural or semi-natural designed systems could provide the ground for sustainable development, in a context of understanding common needs in private and public sector.

Unhelpfully, policy frameworks for economic development and poverty reduction tend to marginalize ecosystems as simply a conservation issue (Krchnak et al., 2011). Such silo thinking, at first could contribute in making problem more comprehensible and thus easier to be analyzed, but in long run could create fragmented responsibilities, leading up to legal inconsistencies, false incentives and disregard externalities (Özçevik, 2015).

Additionally, companies often fail to make the connection between the health of ecosystems and the business bottom line, or are not fully aware of the extent of their reliance and impact on ecosystems and the possible ramifications (Hanson et al., 2008). Luckily, after isolated success stories, investment in green infrastructure seems to rapidly increase. For example, between 2011 and 2013, the number of water utilities engagement in watershed investment programs reporting outcomes tripled, albeit is considered small relative to the sector's risk exposure; not to mention that is not known the real increase since part of it, is attributed to the fact that while going back to past less of realized investments were being reported (Bennett and Carroll, 2014). Also in 2013, food security and water-related energy risks, have attracted little investment (ibid). The latter imbalance observed at investment patterns, signifies only a partially coupling of green infrastructure investments and nexus risks and dependencies.

Moreover, on one hand is becoming more difficult and less appealing than it used to be in the past to build and maintain large scale gray infrastructures and on the other hand there is a noticeable uncertainty how land use change, climate change, and population growth will impact nexus security and thus in planning investments (Ozment et al., 2015). So not only new decision making processes and management strategies should be introduced (Stakhiv, 2011) but also there should be a diffusion of them; so that will become popular choice for decision-makers and executives boards.

At the top of it, another issue around investing arises from the point of top-down or bottom up scheme between nexus and investing in green infrastructures. In particular as mentioned at previous section, nexus concept tends to foster a top-down approach. While working on green infrastructures' benefits – e.g. social equity in development – is mainly succeeded by incorporating more bottom-up strategies and actions (Krchnak et al., 2011). This might partially explain the observed under-investment and not fully coupling in 2013 (Bennett and Carroll, 2014), since crucial role in green investing plays not only to prioritize investment activities but also the need to incorporate mechanisms for decentralizing decision making in multi-stakeholder processes (Smith and Cartin, 2011); where top-down scheme lacks.

A Loophole To Nexus?

Finally, misconception on the role of green infrastructures could be created due to the criticism that carbon sinks (LULUCF - Land Use, Land-Use Change and Forestry) – which are associated to afforestation, reforastation and forest management into the Kyoto

Protocol (UNFCC, 2000) – faced (Richards and Andersson, 2001; Rousseaux, 2005; Shishlov and Bellassen, 2012).

Nexus uses natural infrastructure as analogues. For example, power plants in order to avoid causing thermal pollution to aquatic ecosystems can either invest in expensive highly costly gray infrastructure (e.g. cooling tower, refrigeration units) or use using cooling shade from natural infrastructure. The latter in case of city of Medford (Oregon) helped in meeting its legal thermal requirements for wastewater at approximately half cost of what would have to cover in case of using mechanical means (Ozment et al., 2015).

There are cases that deforestation was threatening hydropower scheme. Like in case of Costa Rican hydro-power company Energia Global (now Enel Latin America) when in the 1990s was literally losing its source of power due to the deforestation that took place at slopes upstream of the company's dams by landowners to use land for livestock and agriculture. With deforestation leading to increment in soil erosion and thus in lowering reservoir capacity by increment of sedimentation rate in the reservoirs, the threat for deteriorating the hydro-power turbines was looming. For that, Enel now contributes to renumeration scheme through "National Fund for Forest Financing" to those landowners for conserving remaining forests or that agreed to reforest their land at upstream. In this case, green infrastructure contribute a lot in fragile balance of nexus inter-linkages, by rewarding farmers for sustainable agricultural practices, improving watershed health, and promoting energy security by reducing wear and tear on hydro-power facilities (Hanson et al, 2012; Ozment et al., 2015).

So green infrastructures not only should not bear the criticism of carbon sinks but should considered as a ready solution to offer its services wherever is in need without being a loophole for the nexus concept.

Summary

Summarizing, natural or semi-natural designed systems could provide the ground for sustainable development – due to overlapped interests for business, investors, states and people – in a context of understanding common needs in private and public sector.

Nevertheless, there is a noticeable imbalance at investment patterns, that signifies only a partially coupling of green infrastructure investments and nexus risks and dependencies. It could be because companies fail to make the connection between the health of ecosystems and the beneficial effect to business. Or, because business ignore the full extend of their exposure and dependence on ecosystems. Another factor, could be the silo approach in policy-making that in long run could create fragmented responsibilities, lead up to legal inconsistencies, false incentives and disregard externalities. Therefore, new decision making processes and management strategies should be introduced, especially today that building and maintaining large scale gray infrastructures considered less appealing choice.

The need for new decision making processes and management strategies is enhanced by introduced uncertainty due to land use change, climate change, and population growth. Also, due to constraint in green infrastructures' investments that might be inherited from the contradiction between a bottom-up approach of aforementioned

versus a top-down managed nexus; thus nexus should incorporate more bottom-up strategies and actions. Finally, to be noticed that green infrastructures not only should not bear the criticism of carbon sinks but are considered as a ready solution to offer its services wherever is in need without being a loophole for the nexus concept.

Conclusions

Various topics within nexus context have been elaborated through this paper, which are considered to be crucial for a more effective governance of nexus while providing useful insights for research, computational models, business opportunities and investments.

These topics, developed so that to benefit decision and policy makers to better understand the concept of nexus across horizontal/vertical scales and dimension, researchers to embrace validity of their research, help modelers to provide solutions that will be more stable and feasible, help business managers to make the connection between ecosystem's services, natural resources coupling and the business bottom line.

While various conclusions, have been separately provided at the end of each chapter, here will be highlighted the key ones.

First of all, having in mind all above, can be said that though nexus concept is constantly being evolved, nevertheless does not impose only challenges but also opportunities for coupled resource management.

Concerning data (like in metrics and notions) both researchers and policy-makers should be aware of the perplexities that could be inherited from a not like-for-like comparison; and should always provide/require accurate metadata. The not like-for-like comparison could be partly attributed to the effect of water pricing politics that weakly delineate the real value of water or because environmental externalities of using natural resources and services aren't clearly signaled.

Nevertheless, deployment of MBMs concerning water – within nexus context and for setting appropriate pricing, under the paradigm of security – is being challenged by accusations for incomplete integration of distributional justice.

One way or another, actors and stakeholders should be engaged in nexus decision-making and planning. Even though, it is not always easy to induce participatory methods. Addressing this need, game theory comes to provide its services. And even if may involve not attainable solutions or equilibrium points that might not exist for some scenario, still can predict whether solutions are reachable and could explain how decision-makers' rational behavior could lead to overall Pareto-inferior outcome; as long as modelers are aware of game conditions variation during the game and their reciprocal implications. Nevertheless, further research for non-cooperative games within joint assessment of water-energy components is in need.

Engaging stakeholders is as essential as building cross sectoral and cross dimensional synergies. In transboundary basin level, step-wise approaches are in need to build trust and deepen the inter-sectoral approach; especially if water-energy nexus governance is fragmented and is not resolved through a single framework. Nexus, in order to stronger

promote cooperation should be able to provide such capable tools; especially since international water law lacks on procedural elements on promoting cooperation.

In case of transboundary basin level, building trust and synergies – that will forge cooperation – is a fragile concept when considering that not always supra-national organizations do exist. The latter gets more problematic when international leading organizations in nexus do tend to approach basin states with-in a top-down scheme.

The issue of selecting top-down or/and bottom-up schemes is not limed to synergies in international level but also can force constraints on investing in green infrastructures. Thus, in general, more bottom-up strategies and actions should be incorporated in nexus. Of course, more impediments can be identified when concerning imbalance at investment patterns; which signifies only a partially coupling of green infrastructure investments and nexus risks and dependencies.

Like the fact that companies might fail to make the connection between the health of ecosystems and the beneficial effect to business, which signifies the need for introducing new decision making processes and management strategies.

Management strategies that will also be able to assess investment opportunities in green infrastructures. Green infrastructures, which proved that are not a loophole for nexus and provided adequately their services in many cases. Like when compared with cases of attaining unanticipated consequences by use of technology (e.g. dry/water cooling technologies) due to nexus complexity. Nevertheless, the latter does not cancel the need for more efficient and cost-effective technological solutions that depend less to water.

Finally, investments under the prism of nexus should be assessed by policy makers for all technological solutions – even if not such popular today – taking in account water constraints, climate and impact of climate change. In connection to latter, both more accurate climate data and assessment tools for climate change impact are in need.

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