

Design of Green IS for electric systems: An information flow perspective

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Background

Green Information Systems (Green IS)

- Green IS assists in generating, exchanging, and analyzing information to improve economic and environmental sustainability (Dedrick, 2010).
- It is an important and emerging area of research to improve environmental sustainability (Watson, 2008; Watson et al., 2010; Dedrick, 2010; Malhotra & Hill, 2013; Gholami et al., 2016).

Motivation

Green IS on energy systems

Energy informatics is a subdomain in Information Systems (IS) research that studies Green IS on energy systems (Watson et al., 2010).

The main research question of **Energy Informatics** is:

How can an IS integrate the optimal granularity of supply and demand information to increase the efficiency of an energy system?

(Watson et al., 2010).

Research question

The integration of supply and demand information is specified in IS design.

IS Design is an artifact (Simon 1988)

A blueprint that defines how information is exchanged and analyzed (Chen & Nunamaker, 1991; Hevner et al., 2004).

Therefore, answering energy informatics question requires us to be able to answer the following question:

How to design Green IS on energy systems?

Research outline

We develop an analytical framework to study the design of Green IS for **electric systems**.

- Physical and economic differences between electric and other energy systems require special considerations. **e.g., physical laws governing electricity networks and regulation.**

We apply the analytical framework to evaluate the representation of the **information flow** on a specific technology, Vehicle-to-Grid (V2G).

- V2G is a socio-technical system enabling the management of the energy demand and supply from Electric Vehicles (EVs).

Literature review

A Green IS needs to tie together at least the three following elements:

- A flow network:

e.g., the cable and pipes transporting energy

- A sensor network:

e.g., the components monitoring physical objects

- Sensitized object:

e.g., the interphase between humans and IS.

Literature review

Watson et al. (2010) propose nine research questions to address the design of Green IS on energy systems.

Stakeholders	Energy system components			Information System
	Sensor Network	Flow Network	Sensitized objects	
Suppliers	What is the optimum level of information granularity of the sensor network to optimize a given flow network?	What information, and at what level of granularity, is required to optimize a given type of flow network?		How can an information system integrate supply and demand data to increase energy efficiency?
Consumers			What information do consumers need about the usage of the objects they own to manage to increase their energy efficiency?	How can information systems be used to change social norms to increase energy efficiency?
Governments	What information granularity enables effective enforcement of energy policy?	What government policies and regulations will impel flow network managers to make them more energy efficient? What government policies and regulations will impel flow network consumers to shift to more energy-efficient networks or radically reduce the energy consumption patterns of specific networks?		What data should be reported by an energy information system to inform governments' energy policies?

Designing Green IS on electric systems

Electric systems require special considerations that are different from other energy systems.

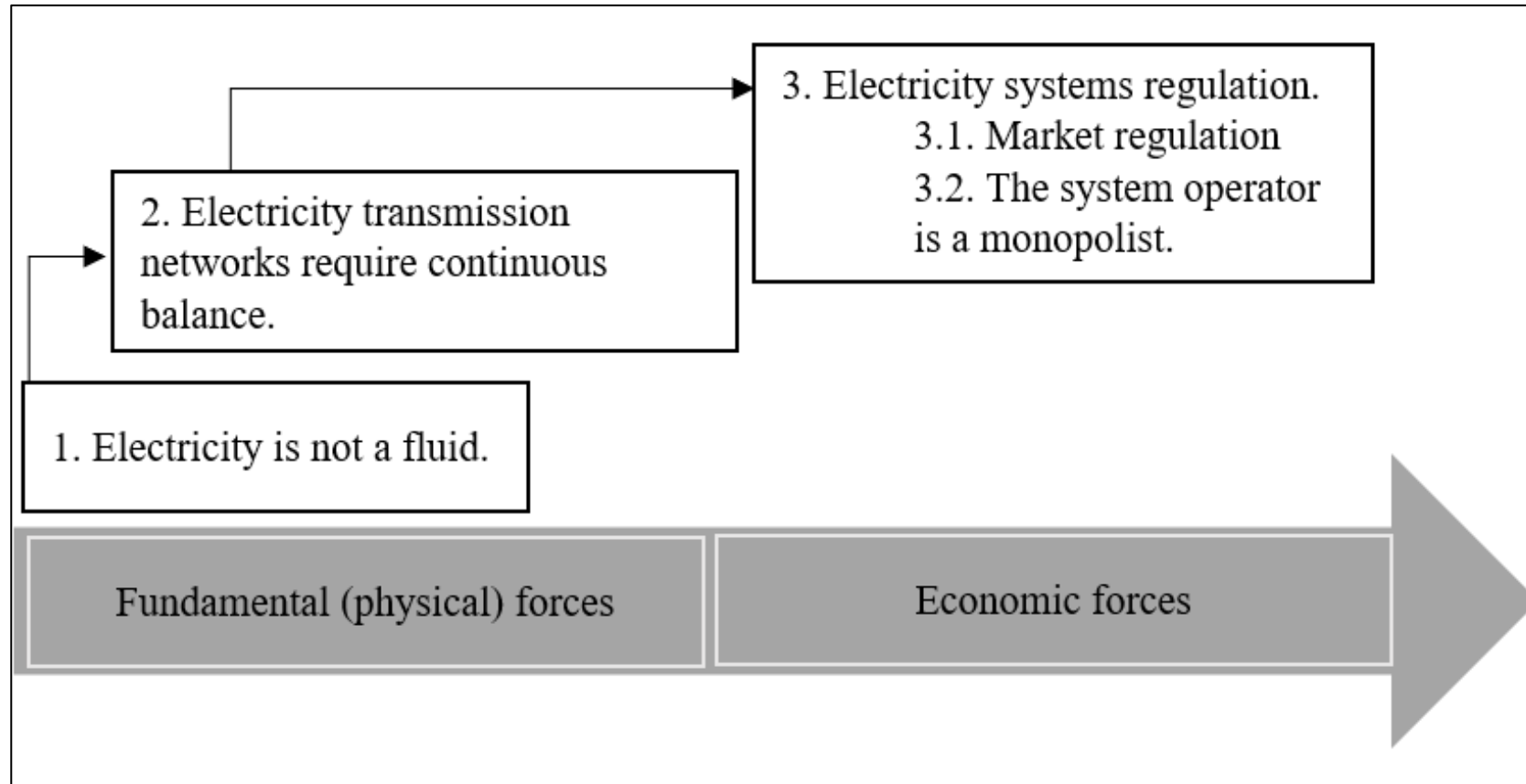
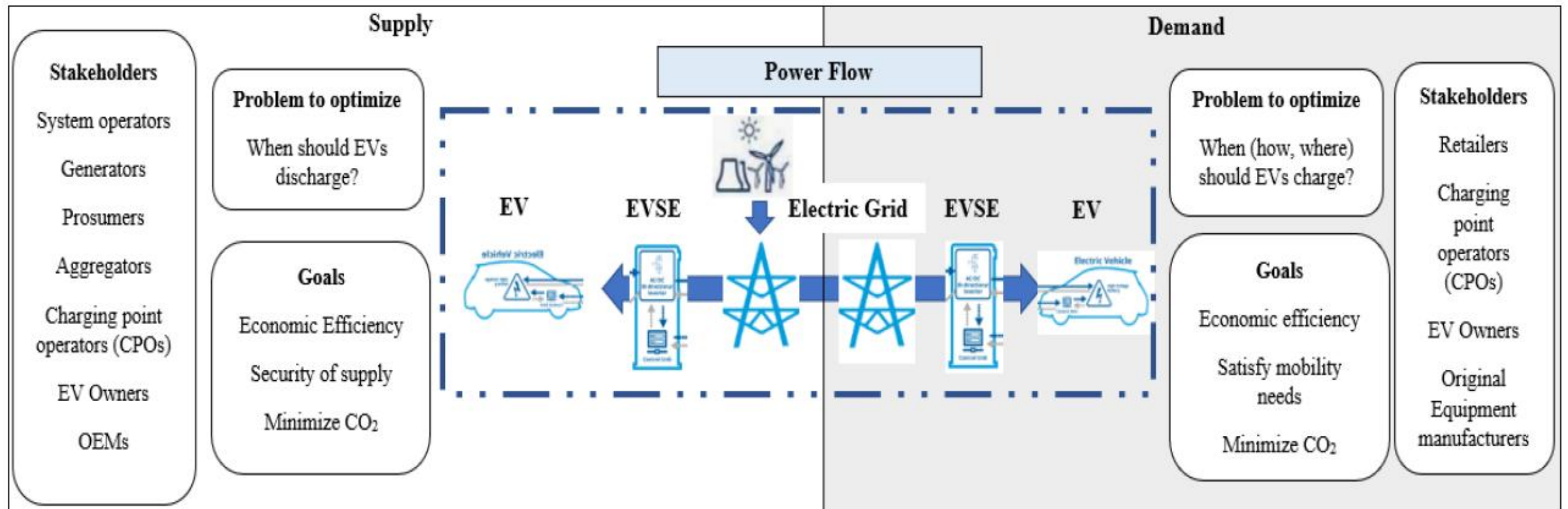


Figure 1: Forces affecting the design of electric systems (Authors).

Vehicle-to-Grid (V2G)

It is a technology that allows the coordination of the charge or discharge of several EVs, using their batteries as distributed energy storage sources (Kempton & Tomić, 2005; Lund & Kempton, 2008; Turton & Moura, 2008).



Information flow design

A design (Simon, 1988), is a blueprint that defines the work, organization, and resources required to support the exchange and analysis of information for a specific purpose (Chen & Nunamaker, 1991; Hevner et al., 2004).

Building a standard representation of information flow

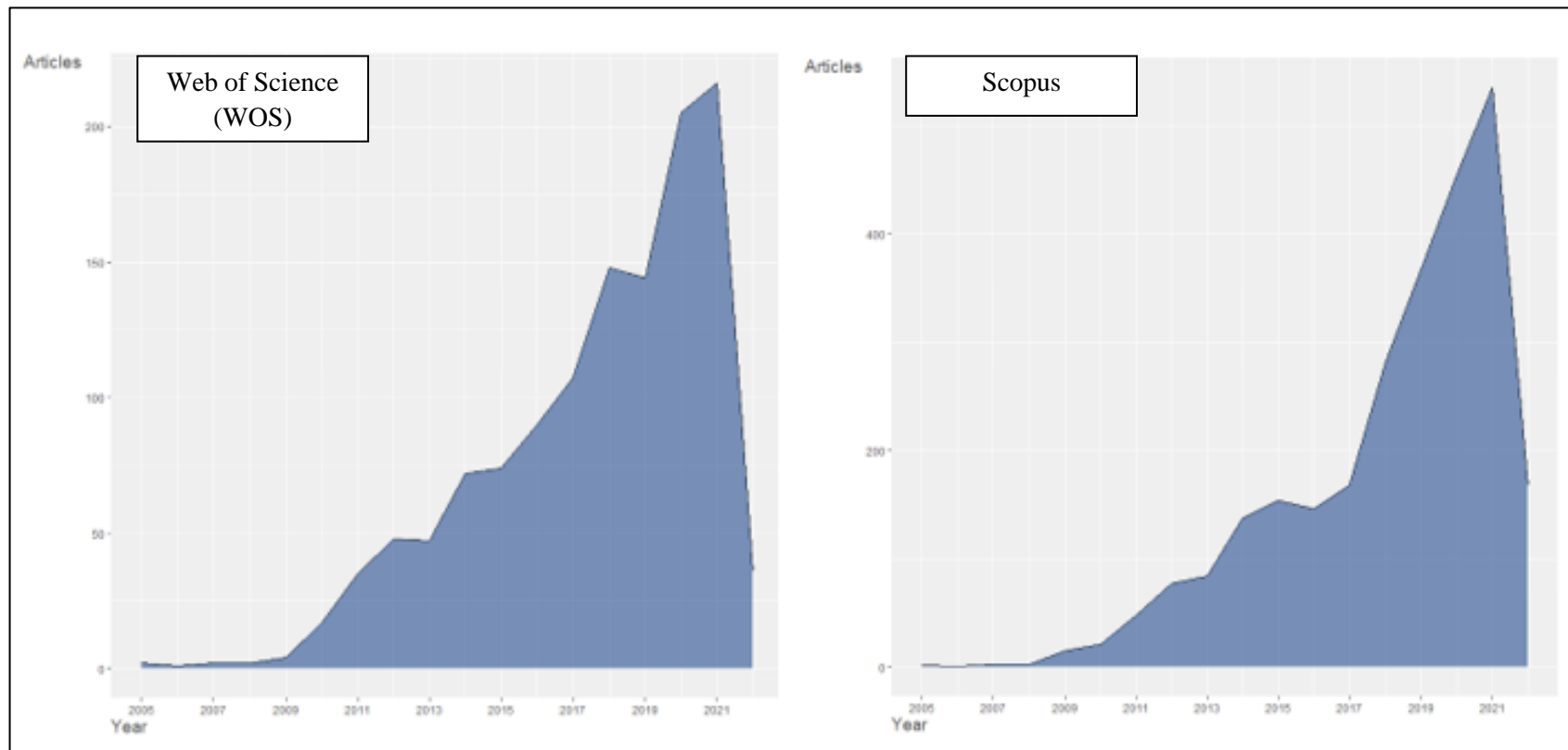
1. Systematic Literature Review on V2G.
2. Identify the actors exchanging information.
3. Identify the task on the information exchange.
4. Build a network graph, connecting the actors: an information flow.
5. Compare and analyze the information flow to deduce their design patterns.

Analyzing V2G information flow design

Systematic literature review

Search of V2G articles. We found 2 667 publications in the Scopus search and 1 213 in WoS.

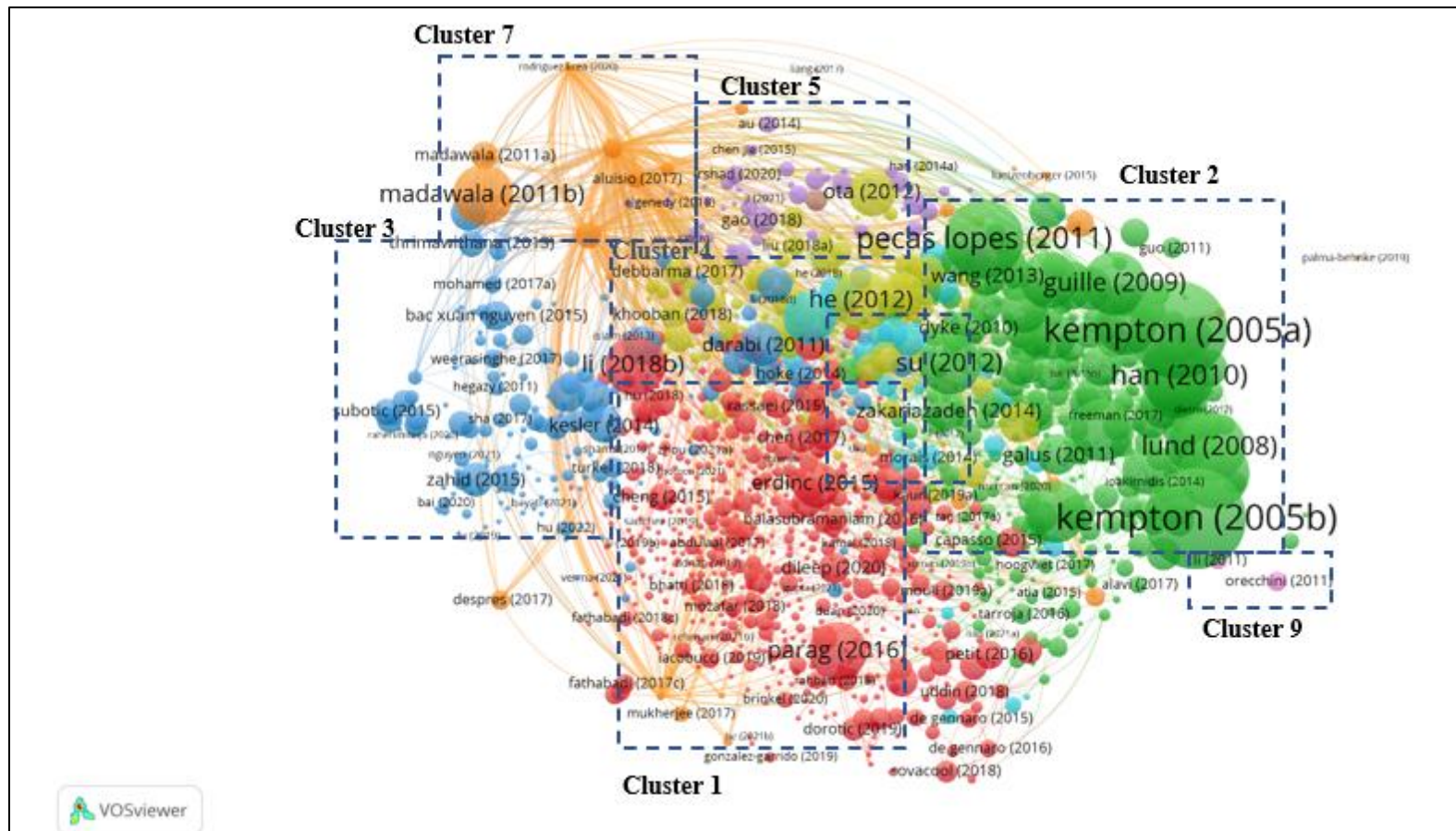
Figure 4: Evolution of V2G publications in academic journals. (Authors)



Analyzing V2G information flow design

We use bibliographic clustering and selected 150 papers to analyze on detail in each cluster according to their citation and centrality.

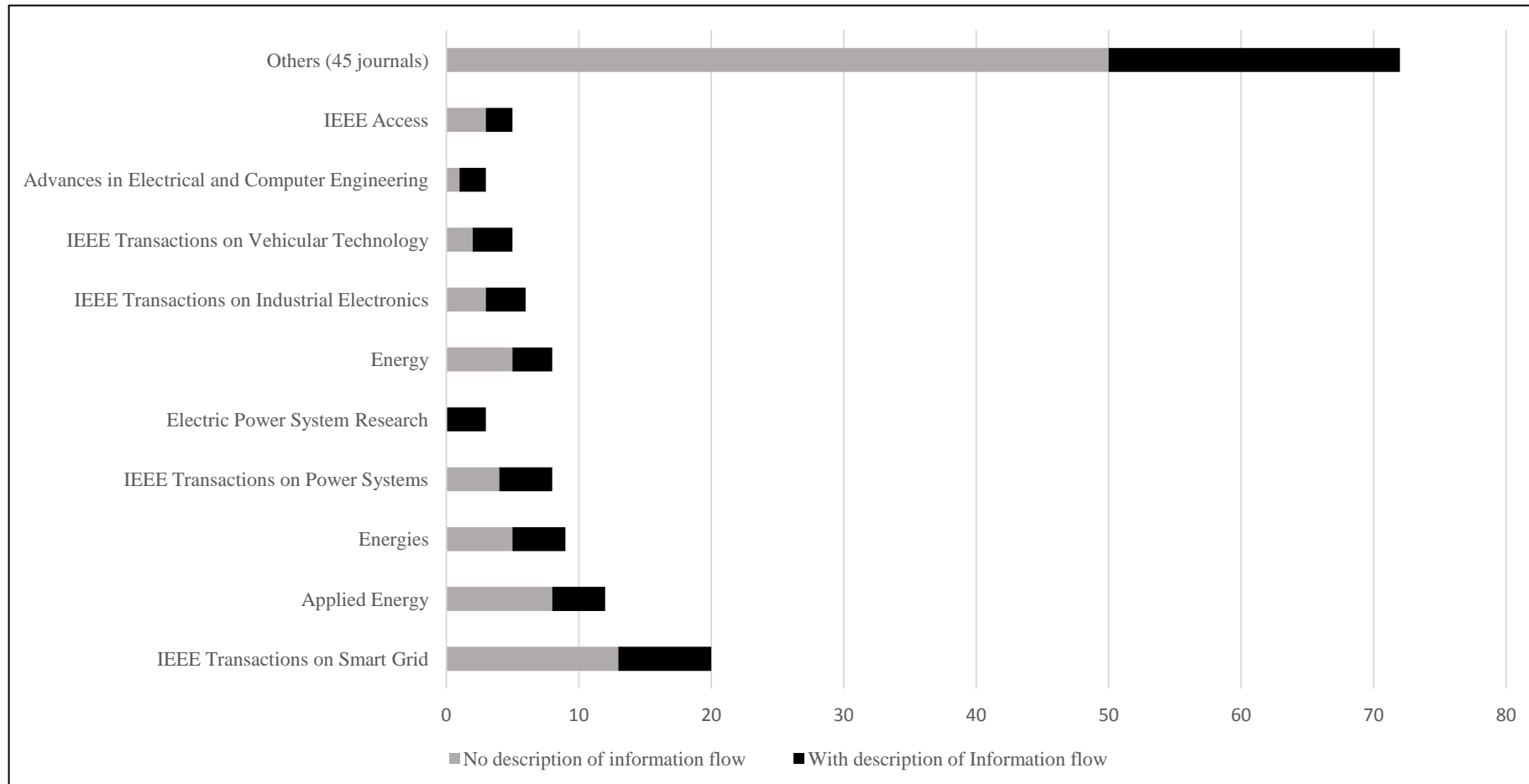
Figure: Clusters of V2G publications in Web of Science . (Authors)



Analyzing V2G information flow design

We found several engineering journals in the sample, and only 30% of the articles had explicitly defined an information flow.

Figure : Presence of information flow on publications by journals . (Authors)



Analyzing V2G information flow design

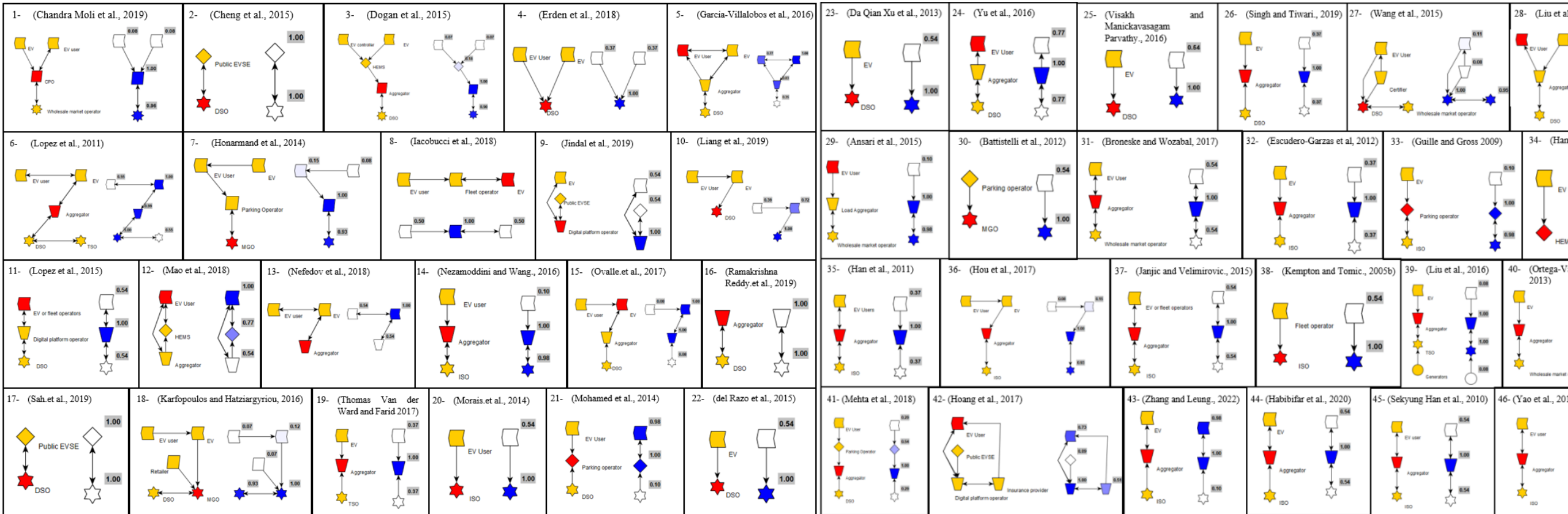
There is a large diversity of actors that might participate in the information flow. There are no actors that are required for all publications.

Table: Presence of actors involved in the information flow. (Authors)

Analyzing V2G information flow design

Analyzing V2G information flow design

Figure : Network analysis of information flow . (Authors)



Analyzing V2G information flow design

Comparing the information flow, against the different components of an energy system, we induce four information flow archetypes from the patterns on the publications.

Table : Dimensions of comparison for the information flow. (Authors)

Discussions

- Energy informatics aims to provide research guidance on how to design Green IS that effectively improve the environmental sustainability of energy systems.
- However, our analysis of V2G information flow shows that two stakeholders are not considered in the guiding research questions:
 - Information aggregators,
 - Prosumers: Actors who are both consumers and producers
- We proposed to amend the research framework and define specific questions for electric systems considering these missing actors.

Discussions

Aggregators: the questions are related to how it might challenge the forces that have shaped the electric system: to have a monopolist system operator.

- Indeed, it might be the case, that with enough granularity of information, and specialization on the management of specific DER technologies, they might challenge the assumption of centralized grid operator.
- In economics, hierarchical relations are explained whenever they are market frictions (Williamson 1973). In electric systems, frictions arise because markets might not respond as fast as a central operator (Joskow and Tirole, 2008).

How can decentralized information aggregation support the network's physical balance of the grid and increase the electric system's environmental sustainability?

Discussions

Prosumers: Watson et al. (2010) suggests to ask the following question about consumers: *What information do consumers need about using the objects they own or manage to increase their energy efficiency?*

- However, the fact that prosumers can also supply energy imposes additional requirements on the sensitized objects from which they will interact with other actors on the electric grid
- Indeed, they must also provide information to signal their willingness to supply energy and at which cost.

What information do prosumers need to share about using the DERs they own to signal their willingness and availability to supply energy?

Discussions

We propose that these research questions can be integrated into the energy informatics research questions to add a perspective on electric systems.

Stakeholders	Energy system components			Information Systems
	Sensor Network	Flow Network	Sensitized Objects	
Aggregators				How can decentralized information aggregation support the network's physical balance of the grid and increase the electric system's environmental sustainability?
Prosumers			What information do prosumers need to share about using their DERs to signal their willingness and availability to supply energy?	

Conclusions

- Watson et al. (2010) have identified the specific questions that should be answered for energy informatics. In particular, he looked at these questions from the perspective of three critical actors: energy suppliers, consumers, and governments.
- However electric systems need some design consideration; we use a design science research lens as an analytical framework to analyze Green IS information flow, which we apply to a specific application of Green IS on electric systems, namely Vehicle-to-Grid.
- Our analysis of V2G shows that for green electricity IS to be designed, two sets of actors need to be added to the ones considered in Watson's framework: prosumers and aggregators. We propose research questions to consider these stakeholders in energy informatics.
- Finally, from our information flow analysis, we can derive avenues for future research in Green electricity systems, and therefore, Green IS, but also new design criteria for making V2G systems possible.