Defining Smart Gas Grids – A Min/Max Approach

Bringing Technology to Society's Values

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Paper Layout

A. Introduction

The following paper discusses the term 'smart gas grid', both its meaning as well as its limitations. This is a critical exercise for the industry because without a more cohesive and shared understanding of industry terminology, knowledge accumulation and industrial structuring are hindered. With this in mind, the paper's aim is not to assert *the* definition of this terminology. Indeed, the aim lies more closely to the contrary – showing that there can be no single definition, but rather a range of definition which expresses a description of elements which are either 'inside or outside' the scope of what could be considered to be a gas grid of the 'smarter' kind. The used method has been borrowed from political science theory. By using this 'minimum and maximum' approach, an area is defined in which we could speak of a smart gas grid. We will give examples of innovative gas grid components and some market solutions for grid networks. Technical development of instruments will be focused on first. But it is impossible to define and discuss "smart gas grid" as a stand-alone term. Its meaning is wider and cannot be discussed without putting it into perspective of the gas market transition, and the wider energy transition. In this context, elaborating on the model of defining a gas grid, we see a shift in customer involvement. As technology facilitates the control of gas flows, the customer and user are likewise brought into a higher degree of control.

Following these findings, we come to the conclusion that the term 'smart gas grid' has been an easy adaptation from other disciplines, particularly electricity, because it does bare some applicability, and perhaps because it simply sounds good. However it is vague in different perspectives and therefore weak. We therefore recommend allowing for, and facilitating, continued development in relevant terminology. Further we suggest that, where possible, the meaning of the term in its scope should be *described* when it is being used. This is due to the fact that it will carry a different meaning in scope, depending on its context of use.

Lastly, the meaning of the word 'smart' itself is briefly investigated in the context of gas grids, whence we posit the aim of aligning the design of gas grids with present and future social values. This can be considered as a prerequisite to the development of gas grids as a key player in the energy transition which is directed by these values.

The paper begins with the background of the terminology in the first section. The second section describes what is hoped to be achieved in this paper's endeavors, namely that of clarifying the industry priorities with respect to developing its infrastructure. The following section focuses on the literature of John Gerring & Paul A. Barresi in developing the so called Min-Max strategy of concept formation. We continue with applications of this strategy to the exercise of defining smart gas grids. Here the technological components of dynamic and integrated grids are organized into a schema. This charting, we hope, helps give structure to the very complex interpretation of 'smart gas grid' as a term. The results then show the span of meaning, and the limitations of the words. We proceed with a deeper regard for the emergence of the customer, an integral change in the transformation toward future grids. Some recommendations concerning word use precede the closing remarks.

B. Background

1. History introducing the term smart gas grid

It is worthwhile to consider briefly the usage of the term smart grid with respect to electricity, because this usage is much more widely known in the electric context. In fact, it is in the power grid that the smart grid concept and terminology first took shape. It can be considered therefore the predecessor of the term smart gas grid.

One report on the development of electricity smart grids in 2010 stated, "The European Technology Platform Smart-Grids defines a Smart Grid as an electricity network that can intelligently integrate the actions of all users connected to it – generators, consumers and those that do both – in order to efficiently deliver sustainable, economic and secure electricity."[1] An article in the journal of the Institute of Electrical and Electronics Engineers (IEEE) written in 2009 stated, "'Smart grid' is a relatively new term that refers to the application of information technology to power systems....Consider the 'smart grid' as a term defining opportunities to improve the operation of the power system."[2] The first definition lays out briefly the purpose-context of the term smart grid, while the second quoted definition lays out the way in which this purpose is achieved: information technology. This second definition, in the electric context is at center-stage in the electricity play because it is well aligned with the purpose of the smart electricity grid itself. The technology can do a fine job of integrating the generators and consumers, and those that do both.

The present usage, combined with its intimate relationship with the recent development of the smart grid concept in electricity already presents a challenge: Intuitively, the meaning in the electricity context is automatically ascribed to the gas context, once we begin speaking of 'smart gas grids'. This is easily done without having an actual understanding of what 'smart' means in either context, electric or gas. At first sight the word "smart gas grid" is associated with smart technology used in a grid; it is thereby a development of metering, measurement and sophisticated (at least newly developed) technology. It should be inserted here that the smart meter is not smart or clever by itself but still has to be *used* in a smart way by its user, consumer, grid operator etc.; the data measured and shown by the meter is only solo data. Data left to itself, does not speak for itself, and even if it does speak, it will need a human interpretation, regardless of what new technological interface may be used. This brings us to some of the problematics of the 'smart gas grid' word usage.

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[1] UCPartners 2010 trendsformation report (5.1, p.111)

[2] Building a Smarter Smart Grid through Better Renewable Energy Information, IEEE 2009, Potter, Archambault, Westrick.

2. Concerns (over the term smart gas grids)

Two problems have begun to arise with the use of this terminology. First, there exists the risk that the meaning of 'smart grid' in the electric context is automatically translated into the gas context without necessary adaptation of meaning, once the term is used with respect to the gas networks. The second is that 'smart gas grid' suffers from a severe case of polysemy (having multiple meanings[3]). That is, there are multiple variations of meaning attached to the label. Because of these two problems, the *intention*[4] of the use of the words is at risk of not being achieved because its meaning is not clear. This lack of clarity prohibits sufficient information accumulation. As is the case in many other contexts, 'productive argumentation' becomes impossible[5]. These issues call into being existential questions concerning the term itself. If the questions are not first asked, and then answered, the gas industry will stymie itself from developing its grid according to the aggregate aims that its body of participants has.

Let us set out with briefly addressing the first problem – pulling the smart grid concept directly into the gas grid context. This is not necessarily a major problem, as there are a lot of overlapping principles between the two grids (load-balancing, monitoring, etc). But there are differences as well (gas involves physical delivery, and has greater storage capacity). Of course it is also problematic to borrow the terminology, if the understanding of its meaning with respect to electricity is also hollow. Therefore, what constitutes a smart grid, and distinguishes from a non-smart grid should be investigated, within whatever context it is being used.

The multiple and incongruent usage of 'smart gas grids' is the second problem. Indeed, as of yet there is not a known construct of meaning established for this very new terminology. This lack of construct results in a potential inability to accumulate, and organize knowledge in an adequate body of knowledge. Without mutual understanding of basic underlying terminology, or worse yet, with discrepancy in assumed meanings, productive discussion and argumentation is halted, or warped. So the polysemy needs a cure. But this is where a caveat must be introduced. The temptation here lies in finding the definition that works best, and then plug it in and let it remain fixed that way in the industry lexicon. Then we are faced with another problem: we have then cornered ourselves into a definition that is much too narrow. We have discouraged the emergence of enrichment in meaning, or disallowed the evolutionary processes perhaps that may bring us to refined meanings in the future. Thus we walk the razor's edge: on our left lies the abyss of unending vagueness, and on our right a steep and constraining wall of simple-minded definition. How to walk ourselves off this perilous edge to a meaningful understanding of these grids will be introduced in the 'methods' section of this paper.

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[3] http://www.merriam-webster.com/dictionary/polysemy, accessed February 1, 2012.

[4] The intention of the industry's use of the term 'smart gas grid' is taken here to be, to bring about what has been envisioned as the harnessing of modern technology to allow for a dynamic and adaptive system that can facilitate increased renewable energy, and integrate with a future smart energy grid.

[5] Gerring, J & Barresi, P.A., "Putting Ordinary Language to Work – A Min-Max Strategy of Concept Formation in the Social Sciences", 2003, Journal of Theoretical Politics 15(2):p. 202.

Naturally, the argumentation leads us to recognize that the solution (the label, ‘smart gas grids) we have created for ourselves may be part of the problem. Let us lay it out in two parts:

1) First, industry experts have recognized a need and opportunity to modify the current grids. We need to adapt the grid by harnessing current technological devices in order to follow current beneficial societal trends such as carbon emissions reduction, and community involvement.

2) We may call this envisioned thing a smart gas grid. But if we lean on that word too heavily to provide answers for us, we will not find it trustworthy. In fact, with a closer look, we may find that by trusting the word as a crutch, we have been limping in the wrong direction.

We have to stay close to the underlying aims and real methods for achieving those aims if progress is to be made. This provides for an introduction into the reasons behind the effort to address the conceptualization of ‘smart gas grids’ embodied in this paper.

C. Aims

The aim of this paper is to assist gas industry participants in becoming more specific about the term smart gas grid, and to solve the problems its usage creates. The term is used frequently and experts from the energy industry as well as academics may have different opinions, and interpretation about the term.

The description about what is included in the playing field of smart grids, the scope it carries in the energy industry, and the possible effects and flaws of the term itself help to clarify and structure the opinions and give a better description and hopefully a deeper understanding of the term, and of the position and direction of the gas industry itself.

To give more solid ground to the use of the word, while refraining from over simplifying, and constraining the definition, the aim of the paper can be described in 5 objectives:

1) Address the physical characteristics of different ‘smart gas grid’ configurations, from a minimal point of view, up to an ‘all possibilities employed’, maximum point of view.

2) Suggest strengthening words to surround smart gas grid discussions. Such strengthening words include: smart energy grids, integration and diversification, transformation facilitation, and flexibility, and context specificity (or thereby, tailor-made solutions). Ultimately, these can be clustered in two main dimensions: Flexibility and Customer-orientation.

3) Position the term smart gas grids within the energy transition field and elaborate on the effect of the developments on the approach/ position of the customer and end-user.

4) Identify the persistent weakness of the terminology, which should be recognized in order for the industry to not get itself on a path dependency that is misguided from its true aims (i.e. take a blind course of technology being the great answer, while much more fundamental issues are at stake).

5) Reassert the fundamental aim of grids, which is to be aligned with current social values. Future values are to be strongly taken into consideration, as any infrastructure has a reasonable degree of permanence, making considerations of future values all the more crucial.

D. Methods

We proceed toward these aims now by first building a construct of what 'smart gas grid' *can* mean. That is, when smart gas grids are talked about what are the minimal ingredients that a smart gas grid may be expected to possess? Further, what is the summation of present possibilities that are evoked when smart gas grids are spoken of? Of course, such a 'summation' cannot be expected to be exhaustive, and no pretense is made of that attempt. Nevertheless, we believe it is a worthy endeavor to gather different components that are inferred by various industry participants, and structure them in a format that facilitates more development and understanding to be built upon itself.

This construct is based upon a 'strategy of concept formation' as put forth by two political scientists, John Gerring and Paul A. Barresi in their 2003 article in Journal of Theoretical Politics[6]. Although there exist enticing and engaging scientific reasons to indulge in the exploration of concept formation and the methodologies involved, the present article focuses on the particular and practical example of 'smart gas grid', out of sheer practical necessity. The min/max strategy was chosen because its suggested approach of laying out a spectrum of meaning may offer an insightful look into the diverse meanings that can be intended when a speaker says 'smart gas grid'. As a second step, this wider definition-building can result in a shared understanding of previously dis-integrated parts. This shared understanding has, as an end, the effect of enriching the meaning itself into a more full and usable body of knowledge.

The example that Gerring and Barresi employ in their article to demonstrate the utility of the method, is the word 'culture' - a fairly evasive word when it comes down to pinning a straightforward and consistent definition to it[7]. If they were to assign an ideal-type definition to it, they might find that they are excluding many other possibilities of the meaning of the word, that are pertinent, even if they aren't ideal in someone's estimation. But on the other

[6] Gerring, J & Barresi, P.A., "Putting Ordinary Language to Work – A Min-Max Strategy of Concept Formation in the Social Sciences", Journal of Theoretical Politics 15(2): 201-232, 2003.

[7] Just for clarification sake, our choice of this methodology has nothing to do with their choice of this example. We are not including the role of cultural influence in differing definitions of smart gas grid. This could be an element of study, but it is not one that this paper engages. We simply set forth the example here, as the authors chose to, in order to clarify the development and reasoning of this method of definition.

hand, if the ‘bare essentials’ were instead employed to describe the minimal components of culture, a very vast amount of work would be excluded from the reader’s scope, prohibiting adequate opportunity to develop a grasp on the word, and even to allow for the word itself to develop through the process of readership, and eventually scholarship.

We therefore apply this approach below to ‘smart gas grids’. Here we adhere to the technological components of the physical grid (although they may be conceptual in nature – concepts such as integration for instance), with the purposeful intent of attempting to construct a purely technological definition. Whether this will be tenable or not is to be determined, and will be revisited later.

The first step is to define what the minimal characteristics of a smart gas grid are. We reduce the minimal defining characteristic of a smart gas grid to the following:

- The gas in the system and the system itself can be measured and monitored, and thereby anticipate behavior based on data.

In addition however to this minimal component, an array of other important possible smart components and configurations exist. Whether these would be employed, or which ones, or to what degree is determined by the different contexts that surround each system. We identify two themes of these additional possibilities as follows:

- The gas grid is capable of handling multiple gases - gases from different resources with different qualities.
- The gas grid is integrated with other energy systems, in a holistic energy system

Once the array of these possibilities are organized and observed, two dimensions of change are elucidated, when comparing the different possible grid configurations. These two dimensions of change are:

I. Flexibility in the system
II. System-wide customer-orientation

These dimensions, along with the grid characteristics are illustrated in Figure 1.

The simultaneous motivation behind the need for flexibility including various types of gases and multiple injection points is the increased number and degree of decentralized production, participation in supply, and fluctuation in demand. Spelled out, this means increased customer participation. The role of the customer is redefined from a passive and marginalized (non)actor, to a pro-active participant with decision making power in the process of the full supply chain.

From this baseline of components numerous additions can be made of detailed system characteristics or specific technological implements which facilitate these aims. However, these numerous additions no not change the baseline components, they merely give varying degrees of weight to their role and impact in the network.

The following compilation of possible components draws heavily from a report that was assembled by an expert group commissioned by the European Union[8]. This recent report has gathered together what can be conceived as possible elements of a smart gas grid. We therefore extract from this report the substantive elements that are described in chapters 5 and 6, inserting a few additions where necessary. However, the report falls short in providing any configuration of this great variety of operating parts of the smart gas grid system.

In the opening statement for chapter three from the same report[9], on *Smart gas grid concept and definition,* the following statement is made:

"The smart gas grid concept is based on maximizing the efficiency of overall energy usage and taking full advantage of all the opportunities that the gas grid can offer." This is clearly a very inclusive way of approaching the 'smart' concept of the grid. We will lay out below a bit of 'all the opportunities that the grid can offer' in a simple list. Following the list we'll proceed toward identifying these items, not as components that define the smart gas grid, but possibilities for grids that may or may not be optimal, given their local context.

Smart Gas Grid Opportunities:

Smart gas utilisation

- Smart gas utilisations could include:
- Gas fired heat pumps for residential and commercial use
- Cogeneration, micro-CHP and fuel cells
- Gas fired cooling systems
- Dual fuel appliances
- Natural Gas Vehicles.

Grid operation and safety - management of continuity of supply

Interaction between gas, electricity, heat and cooling

Solutions for oversupply - flow management[10]

-WKK connected to the gas grid for responding to oversupply

[8] EU Commission Task Force for Smart Grids, Expert Group 4, "Smart Grid aspects related to Gas", June 6, 2011.
[9] Ibid, p. 5.
[10] Adjustments to the original tekst by autors of this paper

-Buffering (power-to-gas)

-Season buffering for biogasgrids

Injection of non-conventional gases into natural gas grid

-New foreign imports with differing Wobbe index qualities

-LNG

-SNG

-Biogas

-Hydrogen

Gas quality monitoring

Storage (seasonal – longer term or diurnal - immediate)

-Depleted gas reservoirs

-Salt Cavities

-Liquefied natural gas (LNG)

-The grids (pipes) themselves (line-pack) [11]

> low pressure to high pressure interconnection for storage

Monitoring of activity of flows and pressure[10]

Dynamic grid management

Tracking an tracing of the gasflow-Remote control

-Remote grid management

Cogeneration (CHP, mini and micro CHP)

-Large Industrial and commercial cogeneration (10MW and upwards) -
Mini- or micro CHP (1MW -1kW)

[11] Some technological capabilities are intertwined with other capabilities. The co-dependence is in itself an interesting and complex aspect to smart grid functionalities. An example here is that line-packing is dependent on other high tech components. The EU Commission task force writes: “A smart gas grid could offer this functionality when equipped with the necessary pressure, flow and gas quality monitoring and with smart pressure regulators guaranteeing the needed pressure at the consumers’ level.” p 12.

Natural Gas Vehicles (NGV)

Dual fuel appliances

Enhancing efficiency in day-to-day grid operation

Better planning and design of future network investment

A. Results

Of course, if the list of elements is this broad, some may ask, "what *isn't* a smart gas grid?" Here it is good to compare the above list with a conceptualization of what is 'less than', 'before', or 'below' a smart gas grid, and what is 'beyond' the smart gas grid. The following schema may help frame smart gas grids among other grids, and within the broader energy context that surrounds it. By so doing we can frame our understanding of 'smart gas grids' by knowing where the borders of its meaning lie. If we know the borders, we can know what lies within the relevance of the term, and what lies outside of its applicability.

Figure 1

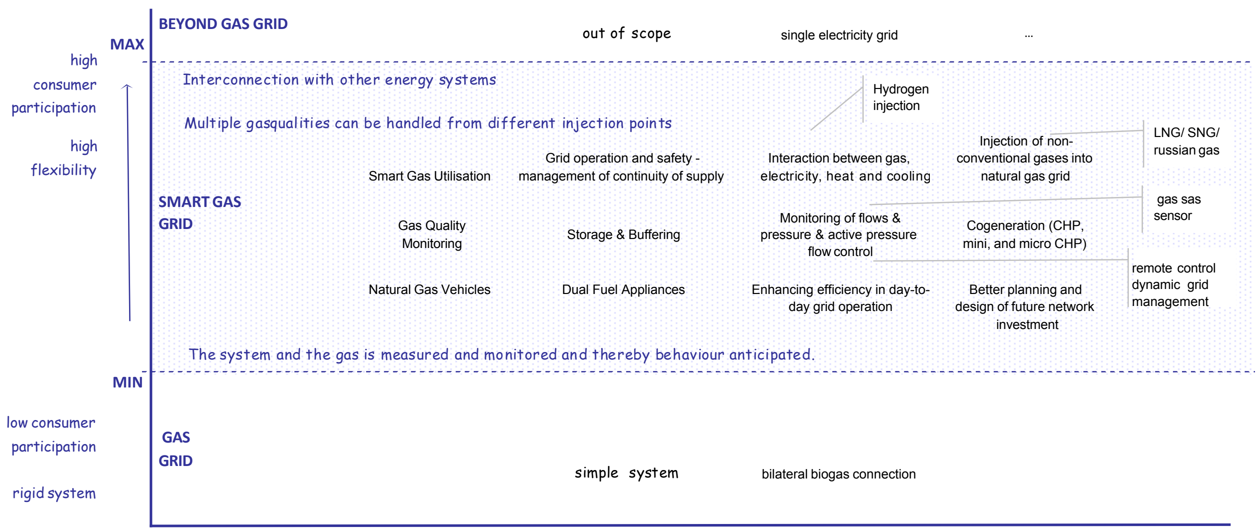


Figure 1 demonstrates the range of components that can constitute the variety of smart gas grids that can take shape. Below this range is the gas grid that pre-exists the smarter versions, or that simply does not meet the standards to qualify as such. Positioned above the smart gas grid spectrum lies the components that are beyond the smart gas grid scope, though they may be elements that are interdependent with the existence of smart gas grids (e.g. integrated energy systems).

We propose that after all these added details are put in place, and ‘stacked up’, an emerging picture comes into focus, where the spectrum of variations of smart gas grids could be placed on a vertical axis of two variables: customer involvement and grid flexibility.

Whereas the conventional grid does not require the same degree of customer inputs, a smart grid may be determined by the customers themselves, designed and adaptive with respect to the their demands, and even their own production. This, in contrast to components of the grid, is not unique to the gas network context. It is believed that this may be a relevant axis when considering the electricity context, or broader energy networks as well.

What smart gas grid *can* stand to mean, we have laid out here in brief. Whether it *should* stand, or whether it should be discarded for other vocabulary, will probably be determined by a little passing of time. Though it is not within the scope of this paper to make such predictions, we do wish to suggest what alternatives to this word usage may prove to be plausible for enriching our description of future ‘ideal type’ grids. Those words have been identified in the minimal characterization of smart gas grids, as well as the possible additive components of such grids.

We can perhaps reconcile this ‘conflict of terms’ by broadening our scope of our understanding of smart grids to be more inclusive than we are all accustomed to. Indeed, smart grids in the electricity context is increasingly dependent on gas grids, as the volatility of renewable become more important to power grids. What we are all talking about ultimately, is a smart energy grid. Perhaps this energy grid is something that can be dissected[12] into smart gas grid and smart electricity grid, etc, but it should not be separated, it should not be reduced to its parts. This may mean that the vocabulary of the industry must likewise broaden, and itself become more integrated, bridging even different energy sourcing.

Therefore designing a system with deliberate priority given to social values in this context is not just a matter of preventing disaster, by checking to make sure that all the components of the system are aligned with the aims of greater society (though this in itself is quite obviously worthwhile). Rather, the direction of the system takes a different trajectory than the traditional one. The previous trajectory was based on cost optimalisation, the future trajectory perhaps is based on social acceptance which has been empowered by customer participation who are not looking just at profit and loss, but through their value-lenses of sustainability, of carbon neutrality, of independence, will make very different calculations, and decisions than would have been made by the TSO 15 years ago.

Role in the Energy transition

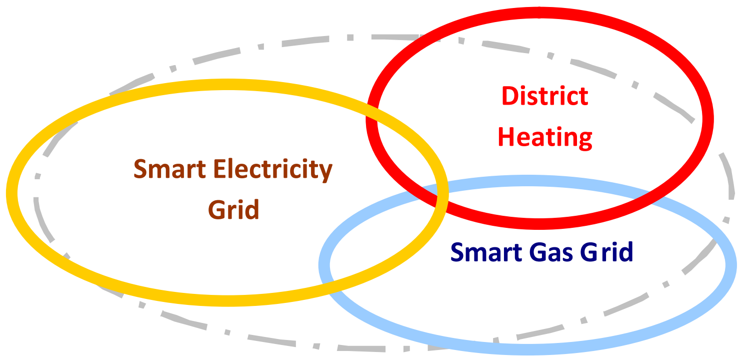
The recent development with gas grid and the industry as a whole, towards increasing its ability to adapt to different gas qualities, development new gas markets such as the biogas market, facilitate emergence of decentralized self-controlled energy neutral grids are all

[12] The human body can be dissected to understand its complex arrangement and function of components, but a single part of the body, left to itself apart from the body, is essentially meaningless.

considered to be part of the *gas transition.* The usage of the gas grid to store electricity by (e.g. hydrogen injection, the usage of the electricity grid by CHP in cases of oversupply and overcapacity of biogas) show the need of connecting these grids for optimal flexibility of energy supply. We certainly can think of the gas transition as embedded in the energy transition. Smart use and inter-changability between the different disciplines to use our energy, gas, electricity and heat in a most optimum and efficient way is part of the energy transition of upcoming decades. To be smart, we should think of combining and integrating the different technical systems of the different disciplines together. The smart gas grid will be embedded in an even broader context of a *smart energy system* . The *energy transition* is about sustainability (solar, wind energy, biogas), integration of different energy sectors (heat and electricity and gas interconnected), energy for mobility (Liquid Biogas) and market facilitation. The gas grid is not independent from any of this. The playing-field of the energy transition is a combination of the various energy sources, not a single isolated utility.

Figure 2

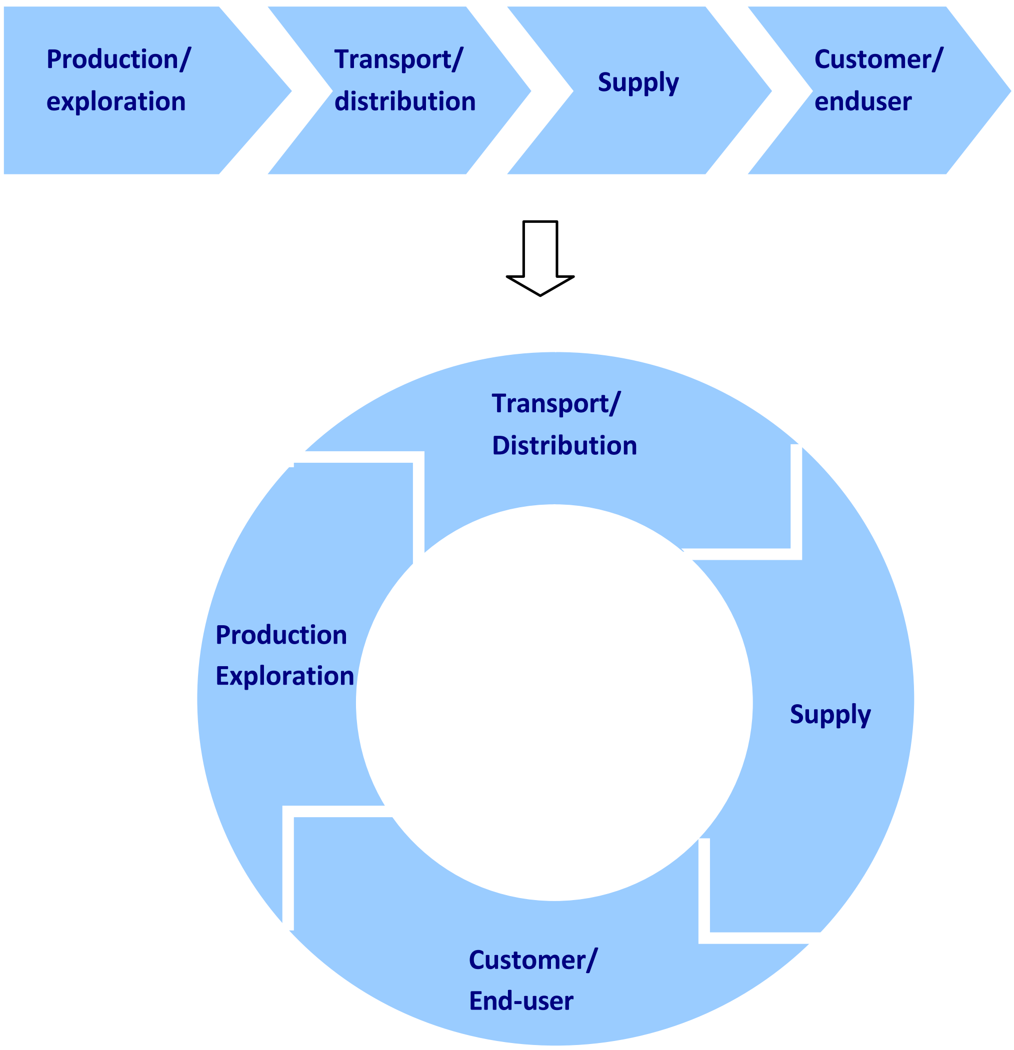
"Playing field" of the Energy Transition



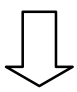
Customer in control

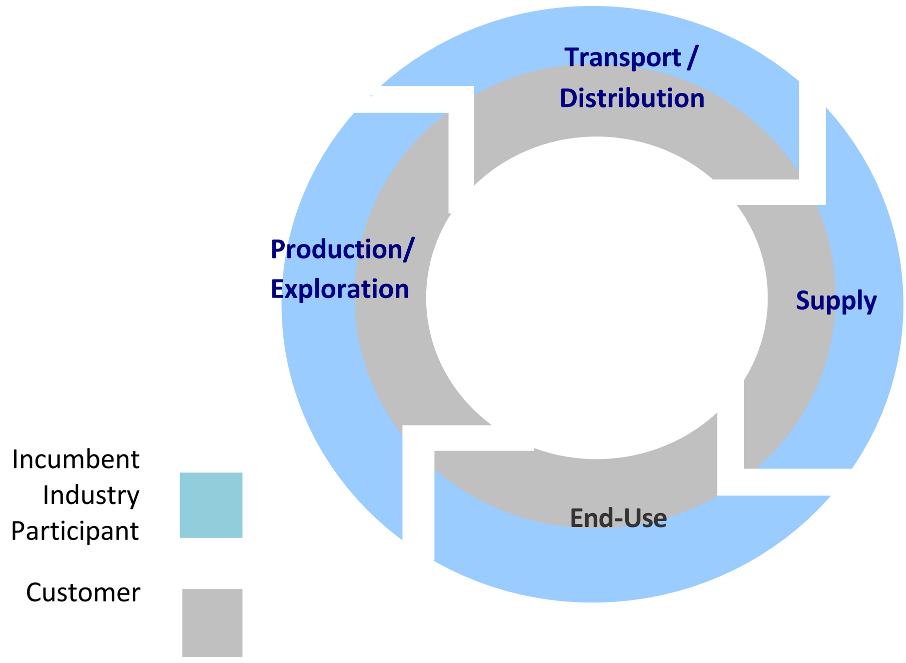
Elaborating on the matter as described above we can go a step further. The measuring and monitoring of the grids to be able to optimize flow keeps control over the system. The new technological and system developments, and the liberalization of the customer who is able to choose supplier and who could produce energy flow by himself (i.e. solar electricity or biogas) opens up new markets. The market offers the opportunity for the customer to be in control. We might see in some years a shift from energy control by energy suppliers and grid managers towards a system where the customer and end-user are in control. This would be a major shift in the approach of customer supply. It will change the way we look at the supply chain. From the grid managers' perspective there is a change from inward focus (to be in control) to customer involvement (get them into control) The figure below demonstrates this process as the closing of the circle of the value chain:

Figure 3



Then we may see the customer, not only as the end-user but as an integral participant in the entire supply chain





F. Conclusion

This article has set out to describe the challenges of defining the word smart gas grids. In so doing however, a discovery is made which is that 'smart gas grid' terminology falls short of achieving the aim for which its usage is most likely intended. It is therefore a concluding recommendation of the paper that focus be given to terminology that conveys directly the aims that the term embodies. Further, what defines 'smart' will be largely dictated by social acceptance, and the values that are embedded therein. 'Smartness' ultimately will not lie in precision, or speed, but in the ability to adapt to changing social values, and thereby valuations, as well as possess the ability to even facilitate the coordination of these societal changes, for a cohesive furtherance toward benefits that are shared by all actors in the societal action arena. [13]

[13] Ostrom, E. "Understanding Institutional Diversity"Princeton University Press, 2005.

G. Acknowledgements

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