Quote as: Di Felice LJ, Ripa M & Giampietro M (2017), 'Electric vehicles in the EU: between narrative and quantification,' in: Ulgiati S, Vanoli L, Brown MT, Casazza M & Schnitzer H (Eds.), *Proceedings of the 10th Biennial International Workshop Advances in Energy Studies (BIWAES): Energy Futures, Environment and Well-being*, Naples, Italy, 25-28 September 2017, Verlag der Technischen Universität Graz, pp. 390-398. DOI of the complete original proceedings: 10.3217/978-3-85125-513-3.

Electric vehicles in the EU: between narrative and quantification

Louisa Jane Di Felice*[1], Maddalena Ripa[1], Mario Giampietro[1, 2]

[1] Institute of Environmental Science and Technology, Universitat Autònoma de Barcelona, 08193 Bellaterra, Spain

[2] ICREA, Pg. Lluís Companys 23, 08010 Barcelona, Spain

Corresponding Author's e-mail: louisajane.difelice@uab.cat

Abstract

The EU transport sector is struggling to reach its renewable targets and remains the largest consumer of fuels across member states. Electric vehicles have been championed as a possible solution for multiple issues, from pollution in cities, to emissions, to energy security. Assessments of their performance have proven to be tricky, with large variety in results, partially due to the difficulty in assessing innovations. An alternative methodology, called Quantitative Story-Telling, is proposed, recognizing the role played by narratives both in the production of information and in shaping policies. Underlying narratives surrounding electric vehicles in EU documents are mapped across hierarchical levels, and their quality is checked by developing a scenario of 100% electric vehicles in urban centers, one of the goals of the EU's 2050 Transport Strategy. Preliminary results are presented focusing on three narratives identified in EU documents, mapping onto three core EU narrative domains: energy security, climate change and green growth. The quality of the three narratives associated with electric vehicles, namely that they can reduce imports, reduce emissions, and strengthen the competitiveness of the European car industry, is checked. The analysis suggests that issues arise at various levels, and that alternative narratives emerge when considering the behaviour of the system as a whole, including externalization.

1. Introduction

The EU's energy system faces many complex challenges in the near future. Attempts to diminish reliance on imports and to decrease the emission of greenhouse gases (GHG), amid growing levels of energy consumption and heavy reliance on fossil fuels, have proved to be challenging both for policymakers to shape and for governments to implement. The technological lock-in of infrastructure is a further obstacle to be faced in order to move away from the current fossil fueled socio-technological pathway towards a different type of metabolism. With the concept of energy transitions, in particular towards renewable sources of energy, as well as that of low carbon economy gaining momentum across different policy and politics realms, it is important to understand the role that energy plays in the metabolic pattern of society, not simply as an external power source but as a defining element shaping the way society has evolved so far.

From an energetic and environmental standpoint, the transport sector has proven to be particularly problematic. Not only does it consume more fuels than any other EU sector – over 60% in 2015 (Eurostat, 2015) – but it is also a sector which is struggling to make significant changes. In fact, both its consumption and its emissions have been growing over the past ten years (Eurostat, 2015). This is partially due to the fact that transport cannot be externalized: while many industries have moved away from the EU to other countries, giving a false sense of "de-materialization" and emission reduction, transport is inherently local, leaving little room for maneuver when it comes to reducing its impacts. The integration of renewables into the EU's transport sector

has also proven to be difficult. The 2009 Renewable Energy Directive set a specific target for 10% of EU countries' transport fuels to come from renewable sources by 2020. The 2016 revised Renewable Energy Directive recognized that transport is "lagging behind the other sectors" and addressed controversies over indirect land use change (ILUC) brought by the implementation of biofuels.

In order to speed up a renewable transition in the transport sector, the Alternative Fuels Infrastructure Directive was implemented in 2014. The directive anticipates the logic of the revised Renewable Energy Directive, which states that lack of appropriate infrastructure is one of the main reasons why member states are failing to meet their renewable transport sector targets. While striving to maintain technological neutrality across different forms of alternative fuels, the Alternative Fuels Infrastructure Directive sets specific targets for those fuels that require a change in infrastructure. Electrification of the transport sector is seen by many as the most likely option for the integration of renewable energy into transport, as the most mature technologies harnessing renewable sources, such as wind turbines and solar panels, are used to generate electricity. In particular, electric vehicles (EVs) have been gaining increasing popularity in political discourses as well as the media. They are often championed as the solution to a wide range of issues, from energy security (Jacobson, 2009) and climate change (Brady and O'Mahony, 2011) to grid intermittency (Kempton and Tomić, 2005) and pollution (Girardi et al., 2015).

The growing importance that EVs are gaining in socio-technological imaginaries is reflected by the number of studies and assessments being produced to answer questions regarding their overall contributions to emissions (Hawkins et al., 2013), their impact on the electricity grid (Hartmann and Özdemir, 2011) and their potential to store intermittent electricity through vehicle-to-grid (VTG) and vehicle-to-home (VTH) mechanisms (Liu et al., 2013). A number of LCAs have been produced to check how EVs compare with internal combustion engines (ICEs), and unsurprisingly the results vary greatly among studies. A recent publication by Tagliaferri et al. (2016) highlights how, when it comes to the energy required for the manufacturing of a battery system, results vary by an order of 300.

LCAs are known to provide varying results depending on the chosen set of assumptions and boundary conditions, however the assessment of EVs proves to be even more challenging due to the fact that the technology is not mature, and that the impacts on the energy system highly depend on the chosen electricity mix and driving patterns (Faria et al., 2013). The assessment of innovations that are still not widely implemented is tricky, and providing exact figures that rely heavily on a chosen set of assumptions, both on the production and on the consumption side, does not lead to a better understanding of the effects of the integration of EVs into the current system. Social-ecological systems are complex, and as such the relations among their parts and their evolution through time cannot be predicted.

In this paper, we propose an alternative methodology, called *Quantitative Story-Telling (QST)*, whose aim is to better understand how the metabolism of the system is operating now and what constraints may be posed on its future – not by predicting what will happen, but by checking the quality of underlying narratives being used to describe the system at hand. QST recognizes the inherent role that different framings

and storylines play both in the production of information and use of numbers, and in the policymaking process. Framing is “a way of selecting, organizing, interpreting, and making sense of a complex reality to provide guideposts for knowing, analyzing, persuading and acting. A frame is a perspective from which an amorphous, ill-defined, problematic situation can be made sense of and acted on” (Rein and Schön, 1996 found in Lenschow and Zito, 1998). The formulation of policies relies on framing of issues, sometimes simplifying complex problems to a single framing in order to flatten them to one dimension and to be able to propose a direct solution, often in the form of technology (Lenschow and Zito, 1998).

Different frames are also used by scientists in the production of knowledge. In fact, no representation of reality is possible without a chosen storyline. This holds even more for sustainability problems, where “facts (are) uncertain, values in dispute, stakes high and decisions urgent” (Funtowicz and Ravetz, 1993). In such uncertainty, a new type of science must be produced, aiming not at giving exact solutions – such as “which transport form is more sustainable” – but at better understanding the problems at hand, and which payoffs exist when implementing different types of solutions, something that is only possible by recognizing that payoffs are inevitable, and no win-win solution for all actors can exist.

Within this framework, and focusing back to the chosen case study of electric vehicles, the aim of this paper is: (i) to identify the main narratives surrounding EVs in EU documents, and organize them across hierarchical levels; (ii) to perform a quality check of the narratives, by quantitatively assessing whether narratives at the same level clash with each other, and whether narratives across levels hold true. In practice, this is done by developing an analysis to check the effects of a 100% electric vehicle fleet in EU cities on the metabolic pattern of the transport system. In the next section, the methodology of QST is described. Then, preliminary results are presented, with an initial appraisal of three narratives. Finally, preliminary conclusions are drawn, to be expanded on in the final version of the paper.

2. Methodology

As outlined in the Introduction, Quantitative Story-Telling (QST) is a methodology that recognizes the importance that storylines have in the organization of quantitative information and in the decision-making process. Therefore, in section 2.1 an overview of the tools used for narrative mapping is provided, while in section 2.2 we provide a synthesized version of the tools used for the quantitative assessment.

2.1. Narrative mapping

In order to identify the main narratives attributed to alternative fuels, and specifically to electric vehicles, a text analysis of the 2013 Clean Transport Package, together with documents associated to it, is carried out.

Table 1: Documents analysed

Type of document	Name	Year	Code
Directive	Deployment of alternative fuels infrastructure	2014	2014/94/EU
Communication	Clean power for transport: a European alternative fuels strategy	2013	COM(2013)17
Communication	Proposal for a directive on the deployment of alternative fuels infrastructure	2013	COM(2013)18
Press release	European parliament vote “milestone” in the roll out of clean fuels or transport	2014	IP(14)440
Memo	Clean power for transport – frequently asked questions	2014	MEMO-13-24
Press release	Transport 2050: Commission outlines ambitious plan to increase mobility and reduce emissions	2011	IP(11)372
White paper	Roadmap to a single European transport area – towards a competitive and resource efficient transport system	2011	COM(2011)144

The aim of the text analysis is to identify different types of narratives operating at different levels, specifically: *what* the EU wants to achieve in terms of sustainable transport, *how* it wants to achieve it and *why*. The aims and means change when going from lower to higher levels: the final aim at a certain level (for example, to decrease emissions), becomes the means to achieve a goal at a higher hierarchical level (for example, to decrease emissions in order to mitigate the climate change). A hierarchical organization of narratives, following the definition of level hierarchy proposed by Lane (2006), helps us identify how different storylines are linked, and at which points quantification can become a useful tool.

The organization of narratives across hierarchical levels will become clearer in the Preliminary results section, where electric vehicle narratives are mapped – the first part of this section will provide a mix of methodology and results, as the best way to describe the proposed methodology is through a practical example.

2.2. Metabolic analysis

In the quantitative part of the analysis, we check the metabolic changes brought by one of the goals highlighted by the 2050 Transport Strategy, i.e. the full integration of electric vehicles in cities, and how this related to the narratives identified in the first step .The analytical part of QST is performed using the method of Multi-Scale Integrated Analysis of Societal and Ecosystem Metabolism (MuSIASEM). The method has been described in detail elsewhere (see, for example, Giampietro et al., 2014). Here, we highlight the main tools implemented by MuSIASEM for the description of complex systems: the distinction between fund and flow elements, the distinction between structural and functional elements, and the use of processors. For a description of these three concepts, please refer to the methodological summary provided by Parra et al. (2017) in this same issue.

3. Preliminary results

Due to lack of space, a preliminary version of the results is presented, focusing on a limited set of narratives and their quality check.

3.1. Narrative mapping

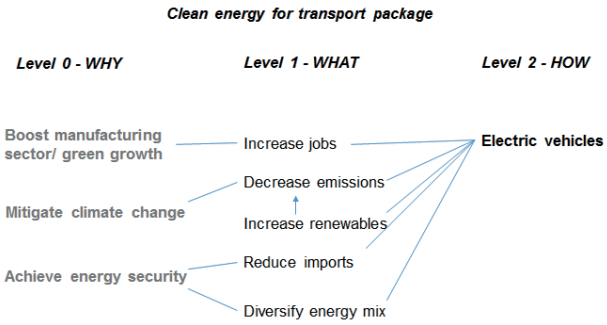

Figure 1: Electric vehicle narrative mapping

The narratives identified in the text analysis are organized across hierarchical levels. A schematic and simplified view of the narratives of the Clean Transport Package is shown in Figure 1 - where the only alternative fuel highlighted is electricity for cars. At the left side of the hierarchical scheme we find the underlying narratives to which all others connect. Following Lane's description of level hierarchy (Lane, 2006), these are the ones with a more extended socio-temporal scale. We can see that EVs are linked to various expected outcomes, and the outcomes can then be mapped onto what we define here as normative narratives, i.e. the accepted values justifying why a certain goal should be achieved. Aside from normative narratives, operating at the level of the whole of society, and setting targets for what *should* be done, the narratives cascading at lower levels reflect *how* these normative goals should be reached. At the interface between level 0 and level 1, quantification is not particularly useful. Here we are still at a generic, ambiguous and politicized level: for example, checking that a diversification of the energy mix improves security is not something to be done with numbers, as it stems from the definition itself of energy security, which moreover is a notably slippery term acquiring different meanings for different actors. The quality check of QTS can be performed at the level 1, and at the interface between level 1 and level 2, looking at:

1. Do electric vehicles (level 2) achieve what they are supposed to achieve (level 1)?
2. Do the level 1 targets contradict each other?
3. Do other alternative tools not appearing in level 2 reach the goals outlined in level 1, and why are they not being favoured?

In the following section, one of the goals of the EU Transport 2050 strategy, i.e. to only have electric cars in cities by 2050, is used to check the quality of three

narratives: that electric vehicles will "support economic growth and strengthen the competitiveness of European industry" (European Commission, 2013) , that they will reduce emissions and that they will reduce EU imports.

Table 2: Preliminary quality check of three narratives

NARRATIVE 1		
Core narrative (WHY)	**Specific EV narrative (level 2-->1)**	**Type of narrative**
Boost green growth	Electric vehicles will support economic growth and strengthen the competitiveness of European industry	**HOW-WHAT**: the tool (the HOW) is expected to lead to a desired result (the WHAT)
Issues		
1. The EV production chain requires less labour per car than the ICE one (but more energy)		
2. The EU does not have the industry needed to produce batteries or manufacture EVs		
3. An industry shift would require huge investments and structural changes		
Alternative narrative(s)		
Moving from ICEs from EVs could result in further de-industrialization of the EU and reliance on battery imports		
If industries shift from producing ICEs to EVs, they would more automated, requiring less labour and more energy		
NARRATIVE 2		
Core narrative (WHY)	**Specific EV narrative (level 2-->1)**	**Type of narrative**
Mitigate climate change	Electric vehicles will reduce emissions	**HOW-WHAT**: the tool (the HOW) is expected to lead to a desired result (the WHAT)
Issues		
1. The emissions of electric vehicles depend strongly on the electricity mix		
2. If we include the emissions of material extraction and transport of materials needed to produce batteries,		
EV emissions can be equal or superior to ICE ones (depending on the mix)		
Alternative narrative(s)		
Electric vehicles could lead to a local reduction of emissions, but only because of an externalization of their impact at two levels:		
1. reduction of emissions in cities, being externalized to areas where electricity is produced		
2. reduction of emissions in the EU, being externalized to countries where materials are extracted and batteries manufactured		
NARRATIVE 3		
Core narrative (WHY)	**EV narrative (level 2-->1)**	**Type of narrative**

Achieve energy security	Electric vehicles will reduce EU imports	**HOW-WHAT**: the tool (the HOW) is expected to lead to a desired result (the WHAT)
Issues		
1. Electric vehicles can only cover short term road transport. Urban road transport consumes less than 20% of all oil imported into the EU		
2. Depending on the electricity mix, the EU would have to import primary energy sources to produce more electricity		
3. The EU does not have lithium, or the raw materials needed to produce batteries		
Alternative narrative(s)		
A shift to EVs would not substantially reduce EU oil imports as they can only cover a small section of the transport sector		
Increased electricity needs could lead to an increase in primary energy source imports (such as uranium for nuclear power) as the resulting increase in electricity consumption will require additional power capacity		
If batteries are produced locally, the EU would have to import lithium and raw materials (only available in specific countries)		
If batteries are not produced locally, the EU would have to import batteries (only produced in specific countries)		

3.2. Quality check on narratives

MuSIASEM and relational analysis, with the set of tools described by Parra et al. (2017) in this issue – particularly through the tool of processors – are used for the quantification step of QST, to check the quality of EV narratives across different levels. This is done by disaggregating the different steps in the production chain of EVs and ICEs, as well as the material extraction needed for them, their operation, and the different energy mixes they rely on. A summary of preliminary results relating to three narratives is presented in Table 2. The narratives presented belong the same type, operating at the interface between level 1 and level 2, and their check relies on seeing whether (i) the tool (the HOW) produces the expected result (the WHAT) and (ii) whether it produces other unwanted results (alternative narratives). Other types of narratives, such as clashes between those operating at the same level, will be checked in the final work. It is important to note that the results presented, being still in the preliminary stage, simply point to issues which have appeared through the analysis. Final results will quantify such issues and provide a detailed overview of the situation.

4. Conclusions

In this short paper, we have applied Quantitative Story-Telling to the case study of electric vehicles in the EU. A simplified hierarchical organization of the policy narratives surrounding electric vehicles was presented, followed by preliminary results checking the quality of identified narratives, using MuSIASEM and relational analysis to check the effects of a 100% electric vehicle fleet in cities. Recognizing the role that uncertainty and impredicativity play in the assessment of innovations and how they interact with complex social-ecological systems, the aim was to check whether the narratives adopted by the EU regarding electric vehicles are consistent.

The preliminary results focused on three narratives: that electric vehicles will boost the EU manufacturing sector, that they will reduce emissions and that they will reduce EU's dependence on imports. It was highlighted that the electric vehicle production chain requires less labour and more energy per unit than its ICE counterpart; that the extraction and transport of materials, and manufacturing process, of EVs produces significant emissions, which are lower than ICEs only when certain electricity mixes are considered; and that EVs would only reduce oil imports by 20%, and increase imports either in raw materials and lithium, or in batteries.

In addition to the specific results related to the narratives, the analysis suggests that assumptions on the production side (what electricity mix is produced) and consumption side (how much cars are being used) lead to vastly different results when it comes to the aims of electric vehicles. This means that, when quantifying their sustainability: (i) assumptions should be stated clearly; (ii) a modular and open approach is needed and (iii) absolute results do not exist and cannot be produced. Further work will expand on the preliminary results to include a check among narratives of the same level, and to highlight alternatives available at the level 2 which could produce some of the desired results at level 1, such as car sharing.

Acknowledgments

This work has received funding from the European Union's Horizon 2020 research and innovation program under grant agreement No 689669. This paper reflects only the author(s)' view and the funding agency is not responsible for any use that may be made of the information it contains.

Bibliography

Brady, J., O'Mahony, M., 2011. Travel to work in Dublin. The potential impacts of electric vehicles on climate change and urban air quality. Transp. Res. Part D Transp. Environ. 16, 188–193. doi:10.1016/j.trd.2010.09.006

European Commission, 2013. Clean power for transport: a European alternative fuels strategy.

Faria, R., Marques, P., Moura, P., Freire, F., Delgado, J., De Almeida, A.T., 2013. Impact of the electricity mix and use profile in the life-cycle assessment of electric vehicles. Renew. Sustain. Energy Rev. 24, 271–287. doi:10.1016/j.rser.2013.03.063

Funtowicz, S., Ravetz, J., 1993. Science for the post-normal age. Futures.

Giampietro, M., Aspinall, R.., Ramos-Martin, J., Bukkens, S.G.F., 2014. Resource accounting for sustainability assessment: The nexus between energy, food, water and land use.

Girardi, P., Gargiulo, A., Brambilla, P.C., 2015. A comparative LCA of an electric vehicle and an internal combustion engine vehicle using the appropriate power mix: the Italian case study. Int. J. Life Cycle Assess. 1127–1142. doi:10.1007/s11367-015-0903-x

Hartmann, N., Özdemir, E.D., 2011. Impact of different utilization scenarios of electric vehicles on the German grid in 2030. J. Power Sources 196, 2311–2318. doi:10.1016/j.jpowsour.2010.09.117

Hawkins, T.R., Singh, B., Majeau-Bettez, G., Strømman, A.H., 2013. Comparative Environmental Life Cycle Assessment of Conventional and Electric Vehicles. J. Ind. Ecol. 17, 53–64. doi:10.1111/j.1530-9290.2012.00532.x

Jacobson, M.Z., 2009. Review of solutions to global warming, air pollution, and energy security. Energy Environ. Sci. 2, 148–173. doi:10.1039/B809990C

Kempton, W., Tomić, J., 2005. Vehicle-to-grid power implementation: From stabilizing the grid to supporting large-scale renewable energy. J. Power Sources 144, 280–294. doi:10.1016/j.jpowsour.2004.12.022

Lane, D., 2006. Hierarchy, Complexity, Society. Work. Pap. 81–119. doi:10.1007/1-4020-4127-6_5

Lenschow, A., Zito, A., 1998. Blurring or Shifting of Policy Frames?: Institutionalization of the Economic-Environmental Policy Linkage in the European Community. Governance.

Liu, C., Chau, K., Wu, D., Gao, S., 2013. Opportunities and challenges of vehicle-to-home, vehicle-to-vehicle, and vehicle-to-grid technologies. Proc. IEEE.

Rein, M., Schön, D., 1996. Frame-critical policy analysis and frame-reflective policy practice. Knowl. policy.

Tagliaferri, C., Evangelisti, S., Acconcia, F., Domenech, T., Ekins, P., Barletta, D., Lettieri, P., 2016. Life cycle assessment of future electric and hybrid vehicles: A cradle-to-grave systems engineering approach. Chem. Eng. Res. Des. 112, 298–309. doi:10.1016/j.cherd.2016.07.003