SOCIO-TECHNICAL MAPS AND SCENARIOS OF ELECTRIC URBAN MOBILITY: SOME INTERMEDIATE RESULTS

Gerardo Marletto
DiSEA/CRENoS, Università di Sassari
marletto@uniss.it

Abstract

This paper analyses current innovative strategies for low-carbon mobility and provides new knowledge and hints for the analysis of the future of urban mobility. Conceptual tools used in the analysis are drawn from the socio-technical approach to innovation and from the institutional and evolutionary theories of economic change.

Actors, systems and local practices of urban mobility are mapped with reference to propulsion technologies and business models. A specific attention is given to those innovative actors who are interested in reproducing the existing car-based system of urban mobility, and to those actors who are interested in embedding emerging – both technological and organizational – innovations into new systems of urban mobility.

Using different hypothesis about the future coalescing of actors, systems and practices, three 2030 scenarios of urban mobility are then generated: 1) 'Automobility', which results from the ability of the automotive industry to reproduce the existing system of the individual car; 2) 'Ecocity', which emerges from local coalitions that foster new systems of low-carbon urban mobility; 3) 'Electricity', where an integrated energy + transport system is led by electric operators.

Agency, power and space are keys to discuss the likelihood of these scenarios and provide some hints for further analysis on policy issues.

Keywords: Urban mobility; Scenarios; Electric car; Socio-technical approach

1. Introduction

In recent years several scholars have tried to analyse the future of the transport sector, with the aim of understanding how its environmental impacts may be reduced drastically: mid- and long-term scenarios have been developed in order to select those policies which can de-carbonize transport activities (Hickman and Banister, 2007; Bristow et al., 2008; Lutsey and Sperling, 2009; Mc Collum and Yang, 2009; Hickman et al., 2012); both car and post-car futures have been discussed in detail by economists, planners, sociologists, technologists (Moriarty and Honnery, 2008; Dennis and Urry, 2009; Sperling and Gordon, 2009; Mees, 2010; Wells, 2010; Zapata and Nieuwenhuis, 2010); some of these future studies have explicitly considered the interaction of economic, institutional and technological variables in the transition towards more sustainable transport systems (Nykvist and Whitmarsh, 2008; Anable et al., 2012; Geels et al., 2012); others have focussed on the crucial role played by dominant actors in the generation of – and resistance to – incremental and radical transport innovations (Kendall, 2008; Freyssenet, 2009; van Bree et al., 2010).

This paper is located at the intersection of such research streams and it is aimed at studying the future of urban mobility, starting from the analysis of the innovative strategies implemented in the field of low-carbon mobility. Such an analysis is developed by mapping the current positioning of actors, systems and local practices of urban mobility, with reference to both propulsion technologies and business models. A specific attention is given to those innovative actors who are interested in reproducing the existing car-based system of urban mobility, and to those actors who are interested in embedding emerging innovations into new systems of urban mobility.

Different hypothesis about the future coalescing of actors, systems and local practices are used to build three 2030 scenarios of urban mobility: 1) 'Automobility', which results from the ability of the automotive industry to integrate new suppliers of electric components and keep selling individual cars; 2) 'Ecocity', which emerges from local coalitions that foster a new system of low-carbon urban mobility which is based on the full integration of all non-car transport options; 3) 'Electricity', where the (electric) car becomes an element of an integrated energy + transport system which is led by electric operators.

Both the mapping and the scenario exercises start from existing information on innovation in urban mobility; the organization and analysis of this information is based on the theoretical and conceptual apparatus provided by the socio-technical (ST) approach to the study of radical innovation (Geels, 2005). The ST approach is positioned in the wider research field of the institutional and evolutionary economic theories, where a representation of structural change is provided which is: a) genuinely dynamic, that is, it explicitly considers non-reversibility, strong uncertainty, path-dependence and lock-in; b) systemic, that is, it explicitly considers all the relevant interactions between institutional, technological and economic phenomena; c) agent-based, that is, it explicitly considers individual and collective actors, their material and immaterial endowments and the cumulative process of acting and learning[1]. Starting from this representation, the ST approach is able to analyse the relevant structural changes that are at the heart of radical and pervasive innovation processes. The ST approach is particularly effective when alternative trajectories that involve different actors are to be considered, which is currently the case of innovation for low-carbon urban mobility.

[1] For more details on the institutional and evolutionary analysis of economic change, see the first three chapters of Marletto (2012).

The rest of the paper is composed of five paragraphs. Paragraph 2 explains the basic concepts of the ST approach; the following paragraph builds the map of actors, systems and local practices; paragraph 4 develops the three ST scenarios. The last two paragraphs discuss **???** the scenarios and conclude, respectively.

2. The socio-technical approach to innovation

2.1. What is specific of this approach

This paper is based on a socio-technical (ST) approach to the analysis of innovation processes. It goes beyond the scope of this paper to review all the contributions coming from scholars who refer to the ST approach; here we just want to stress two of its specificities which are relevant for the subsequent analysis.[2] The first specificity is that the ST approach is not reductionistic: complexity is explicitly considered as a relevant feature of the process of innovation; this is why the overall picture is never explained by looking at – or by starting from – one or more specific elements. In particular technology is not considered as the core driver of innovation, but just as a structural element of the functioning of the economy which interacts with other institutional and economic constituents, and with agency (Geels 2005; Geels and Kemp, 2012). Another specificity is that rather than focusing on functions, the ST approach focuses on actions.[3] At the heart of the analysis one can find the purposeful action of individuals and groups. All relevant attributes which connote action stay at the centre of the analytical scene: power, interests, agendas, conflicts, intentional pressure for – and resistance to – change, etc. This does not mean that the approach is deterministic, with individual and collective action as the cause and innovation as the intended effects; it only means that there is no innovation without human action.

2.2. Socio-technical systems[4]

The ST system is the basic concept of the ST approach to innovation. Societal functions (housing, feeding, production, provision of energy, etc.) are fulfilled by one or more ST systems. All ST systems are (more or less) stable configurations. The ST system is a meso-concept: at the micro level we find its individual constituents (rules, artefacts, knowledge, actors, preferences, financial resources, etc.); at the macro level (which is considered exogenous) socio-economic phenomena and trends can be found.[5] The functioning of ST systems can be conceptualized as structured agency (Giddens 1984): a structure of coevolving sets of institutions, technologies and markets is replicated and changed through individual and collective action and learning, which in turn are enabled and constrained by the above structure. Institutions are considered here as a coherent and relatively stable set of general rules that (together with other structural variables) structure agency; such a set of rules is also called 'ST regime' (Geels, 2005). Two more basic concepts complete the framework: 1) the dominant ST system, that is, a stable and powerful ST system which strongly influences the dynamics of all other subaltern or residual ST systems and generates pervasive lock-in phenomena (Geels and Kemp, 2012); 2) the ST 'niche', that is, a space which is partially or totally protected from the interaction with other ST systems (Schot and Geels 2008). ST niches are particularly relevant for the generation and experimentation of innovations and for the gradual

[2] For critical analyses of this research field see Markard and Truffer (2008), Geels and Kemp (2012) and the opening paper of the new journal "Environmental innovations and societal transitions" (van den Bergh et al., 2011)**.**

[3] For a structured approach to the study of the functions of innovation systems see Jacobsson and Bergek (2011).

[4] The content of this paragraph has been partially revised after a stimulating discussion with Frank Geels; I thank him and I take full responsibility of what is written.

[5] This is the 'landscape' in the terminology used by Geels (2005) and others scholars of the so-called multi-level approach.

structuring and empowerment of new ST systems (Avelino and Rotmans 2009; Smith and Raven, 2012).[6]

2.3. Actors and power

Actors – all featuring bounded rationality – are the engine of a coevolutionary process of change: through action and learning, they replicate the structure of the ST system, whilst generating – directly or indirectly, intentionally or unintentionally – the variation and selection of structural variables. Every actor features a vector of material and immaterial endowments (physical and financial resources, knowledge and skills, social capital and legitimacy, etc.) and is motivated by his interests, ideas and visions. Every actor's power – hence her/his ability to influence the dynamics of ST systems – is a function of the above vector. In this approach, power is cumulative; in particular, because increasing power is generated by action and learning (Avelino and Rotmans 2009), and because power, legitimacy, coalition building and access to resources are linked by an endogenous and self-reinforcing process (Bergek et al. 2008; Geels and Verhees, 2011). The role of collective actors (that is, groups) in the functioning of ST systems is stressed by the literature, so that some authors explicitly consider ST systems as groups (however they are named) and institutions as sets of rules shared by that group (Holtz et al., 2008; Avelino and Rotmans, 2009; Geels, 2010). Actors' membership is then crucial to understand the dynamics and interactions of ST systems; in particular : 'core-actors' are interested in – and actively act for – the reproduction of an existing ST system (Smith et al. 2005), whilst 'enactors' try to transform an innovation into a social practice, in order to establish a new ST system (Suurs et al. 2010). Power, legitimacy and networking ability are essential for both kind of actors (Avelino and Rotmans 2009; Glasbergen, 2011; Smith and Raven, 2012): core-actors of a dominant ST system use their endowments to "capture" institutions, politics and policy; successful enactors – usually starting from a ST niche – needs to affect political discourses and informal rules, before achieving durable credibility and a stable influence on agendas, formal norms and policies.

2.4. Actors and change

The dynamics of ST systems may be grouped into two large families: adaptation of existing ST systems and the creation of a new ST system. Adaptation can be conceptualized as a cumulative process: innovations in institutions, markets and technologies take place along a dominant trajectory; the alignment of such innovations is granted by the incremental alteration of the structure and it is sustained by actors that are internal to the system and are committed to its survival (Unruh 2000). Things radically change in the case of the creation of a new system: new institutions, technologies and markets must be built; a process of extrication is needed to free resources, knowledge, actors, etc., that are locked into dominant systems; intentional and unintentional forces that generate their inertia must be overcome; a new process of multidimensional alignment must be triggered and made viable (Amendola and Gaffard 2006; Foxon 2011). But no structure is available to coordinate all these efforts, because the structure itself is created through innovation; in such a situation, one can even doubt if the creation of a new system is possible without the purposeful and increasingly coordinated action of enactors committed to innovation. ST niches may play a relevant role in both kinds of dynamics: in the case of adaptation, novelties emerging from niches may be incorporated into an existing ST system; in the case of creation, novelties emerging from niches contribute to the threats to the existing ST systems and to the establishment of a new one (Schot and Geels 2007; Smith and Raven, 2012). A taxonomy of the dynamics of dominant ST systems, in

[6] Vergragt and Brown (2007) use a similar concept, but with a different terminology: 'bounded socio-technical experiment' instead of niche.

which the role of actors is explicitly considered (Geels and Schot 2007), is at centre stage of the analysis proposed in this paper: 'transformation' occurs when core-actors gradually adjust a dominant ST systems after pressures coming from the macro level or from outsiders, in particular from social groups and grassroots movements; 'reconfiguration' takes place when core-actors are able to respond to external or internal pressures by partially changing the structure of the dominant ST system, in particular by linking to (or by incorporating) non-core actors and the innovation they developed in one or more ST niches; 'substitution' is the result of a 'battle': actors coming from other ST systems, profit from the pressures on the dominant ST system and – after taking over the old core-actors – radically change it; 'de-alignment and re-alignment' involve enactors – usually coming from one or more ST niches and subaltern systems – who, whilst the dominant ST system is destabilized by major external pressures, experiment radical innovations and eventually establish a new dominant ST system.

2.5. Change and space: the role of the city

ST systems are usually analysed at a national/international level because this is the spatial dimension of their reproduction. The city – and the local level – is taken into account, but just as a recipient of the implementation of a process of innovation generated at higher scale. Only in recent years the active role of the city has raised the interest of scholars of ST dynamics. The city is considered as a place where: coalitions for innovation can be build more easily; local knowledge and relational resources may be mobilised for innovative practices; political deliberation is more fluid – that is, the city is a friendly environment for the establishment and reproduction of ST niches (Hodson and Marvin, 2010; Smith et al., 2010; Moloney et al., 2010; Bulkeley et al., 2011). But – as clearly stated by Geels (2011) – the city can feature a more relevant role than the mere hosting of niches: 1) local ST systems may co-exist with a national/international dominant system (e.g., in the case of urban mobility); 2) ST niches may be located at the local/urban level, but then the dynamics of the dominant system takes place at the national/international level (e.g., in the case of energy networks); 3) the local/urban level is not relevant for the reproduction and change of the dominant ST system (e.g., in the case of ICT mass products).

3. A socio-technical map of innovation in urban mobility

3.1. Introducing the socio-technical map

In the rest of the paper a socio-technical map will be used to position actors, systems and scenarios, of urban mobility. The positioning refers to two axis. An x-axis where three different business model are considered, from left to right: 'sell', that mostly refers to selling cars (but also other transport means) to individual consumers; 'rent' that refers to both rental (of transport means, but also of batteries) and sharing schemes of cars and two-wheels; 'manage', that mostly refers to (integrated) urban transport systems, but can also include energy systems. An y-axis where four propulsion technologies are considered, from the bottom to the top: 'non-motorized', that refers to bicycles and pedestrians; 'internal combustion', that refers to both gasoline and diesel cars (but also to vans, buses, trucks, etc.); 'non-plugged-in electric', that almost exclusively refers to the first generations of hybrid cars; 'plugged-in electric', that considers both plugged-in electric hybrid and battery electric cars, and all other electric vehicles (trolleys, tramways, metros, full electric buses, etc.).

3.2. Systems of urban mobility and innovative actors (Figure 1)

Three systems and a niche of urban mobility are considered, represented with black rectangles.

a) The ‘individual car’.

Authoritative scholars recognize the individual car as the dominant ST system of urban mobility (this is the reason of the thicker line); not so much for its striking share of the mobility market (more than 80% of total journeys in all developed countries), as for the ability of its core-actors (the automotive and oil industries) to influence institutions and the society as a whole[7]. This system is well centred on the business model of ‘selling’ cars to individuals – nowadays with an increasing attention to emerging economies – but it is already able to span from the propulsion technology of ‘internal combustion’ (which powers 99% of the today circulating fleet) to that of ‘plugged-in electric‘ (this is the reason of the black vertical arrow) (Oltra and Saint Jean, 2009; Freyssenet, 2009; Zapata and Nieuwenhuis, 2010; Orsato et al., 2012). The automotive industry is the main core-actor of this system; some individual automotive companies are positioned into the map in order to explicit the existence of different innovative strategies. Fiat and Volkswagen are just two example of the more conservative – and until today, more diffused – innovation strategy, based on efficient internal combustion and downsizing[8]: a strategy implemented by most leading manufacturers too, such as Daimler, Ford, Hyundai, Nissan, Honda and Toyota (Wells et al., 2012). Toyota and Honda are also the main promoters of the “hybridization” of the car:[9] they have chosen the hybrid propulsion as the entry-point to a process of technological innovation which, at the same time: a) it is compatible with the current core competences, sunk investments, dominant design and interdependencies of the automotive industry, and b) it is flexible enough to allow the future access to full electric cars (Hekkert and van den Hoed, 2006; Avadykian and Llerena, 2010). Some other leading automotive companies – e.g. Citroen and Mitsubishi – jumped directly into the full electric car technology, but mostly as a residual option to internal combustion cars. Also small specialized assemblers and manufacturers (as Heuliez, Pininfarina and Valmet) are trying to develop their electric vehicles on a limited productive and commercial basis (Wells, 2010). Suppliers of components are another relevant industrial actor of the individual car system; in particular, producers of batteries – and other electric and electronic components – play a more and more relevant role in the trajectory of electrification (Orsato et al., 2012): some of them are implementing autonomous strategies, such as Bollorè[10] – who developed the Parisian “Autolib” car-sharing scheme with Pininfarina (the Italian producer of the electric car “Bluecar”) – and BYD (Build Your Dreams), a private Chinese company producers of batteries for computers and cellular phones, who is now producing cars[11]. Some other car producers are trying – at very different scale of testing and marketing – to integrate some elements of the 'rent' and ‘manage’ business models into the car system (Zhou et al. 2011)[12]: Nissan-Renault already launched the mixed option of selling full-electric cars and renting batteries, in cooperation with Better Place, the emerging manager of

7 See, among others, Dennis and Urry (2009) and Sperling and Gordon (2009). Also see Marletto (2011) for a survey of the literature on this issue.

8 See Schipper (2011) for a worldwide analysis of the effects of such a strategy in terms of on-road fuel efficiency and CO_2 emissions.

9 By April 2012 Toyota (the largest automaker in world) hybrids had sold more than 4 million units (news.toyota.com.au, accessed 06/06/2012).

10 Is worth noticing that the Bollorè Group is a producer of batteries and ‘supercapacitors’ (a new type of energy storage components) for electric cars, buses and trams. (www.bollore.com, accessed 06/06/2012)

11 In China – which is today both the largest producer of cars and the greatest market for cars – most automotive companies are owned by the State or are joint ventures with major foreign car companies (such as BYD), with the relevant exception of Geely, an independent Chinese company (Sperling and Gordon, 2009, ch. 8; Wang, 2009).

12 For detailed and exhaustive analyses of electric car business models, see Kley et al. (2011) and Gomez San Roman et al. (2011). For an overview on traditional and innovative car business models, see: Wells (2010; ch. 5).

battery-charge and battery-swap stations[13]; Daimler (with its electric Mini) and BMW (with its electric Smart) are promoting two vehicle-to-grid (V2G) tests, in cooperation with two energy suppliers: the Italian Enel and the Swedish Vattenfall, respectively[14] (OECD et al., 2012). An increasing number of electric utilities is involved in partnership related to the diffusion of electric vehicles (Orsato et al. 2012).

b) ‘Public transport’
This is one of the two systems of urban mobility that are subaltern to the ‘individual car’ system (Frantzeskaki and de Haan, 2009; Kohler et al., 2009; Geels and Kemp, 2012). This system is mostly centred on the business model of ‘managing’ networks of transport infrastructures and services, but with a well rooted experience in the ‘rent’ business model thanks to taxi services – see the horizontal black arrow. Since its birth it has been able to plug-in vehicles (trolleys, tramways, trains, etc.) to the electric grid; again, this is the reason of a black vertical arrow covering all motorized propulsion technologies. Both most relevant actors of this system are local: public transport companies and urban and regional Authorities. Some capital cities are positioned on the map as examples of the several urban areas where different transport modes and technologies are effectively integrated (Pla and Segarra, 2008; Dennis and Urry, 2009; Sperling and Gordon, 2009; Buehler and Pucher, 2011; Hull, 2011, ch. 7).

c) ‘Individual bicycle’.
This is the other subaltern – if not marginal[15] – system of urban mobility; as the ‘individual car system’, it is centred on the ‘sell’ business model and – thanks to the increasing diffusion of electric bicycles (Rose, 2012)[16] – it is able to cover all propulsion technologies (except the internal combustion). In many pro-bike cities in Northern Europe this system is able to serve more than the 25% of total trips, thanks to the provision of cycling routes and parkings, that is a dedicated infrastructure, and other supporting measures (traffic calming, intersection modifications, integration with public transport, training and education, etc). (Pucher and Buehler (2008).

d) Sharing schemes
The map of urban mobility is completed by the dotted black rectangle representing the niche of ‘sharing schemes’. It must be stressed that such a niche, which is obviously centred on the ‘rent’ business model, it is now experiencing a rapid extension from cars to bicycles[17], that is, from motorized to non-motorized propulsion technologies. Established examples of car-sharing schemes includes: 'Mobility' in Switzerland, 'Cambio' in Germany and Belgium, 'Greenwheels' in the Netherlands, 'Zipcar' in the US and UK. Electric bikes and cars (see the already cited experiences of

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[13] The business model of battery rental (and, eventually, swap) not only reduces the price of electric cars, but also allows to install new technology batteries in old electric vehicles (Becker, 2009).

[14] With “E-mobility” 100 electric “Smart” and 400 recharging points will be provided in Rome, Milan and Pisa. With “Mini Berlin” 50 electric “Mini” and 100 recharging points are provided in Berlin; in the latter case, electric vehicle batteries are tested as storage capacity to help manage excess wind energy. For more details see: http://www.vattenfall.com/en/electric-cars.htm and http://www.enel.com/en-GB/innovation/ (both accessed 06/06/2012).

[15] Bicycle share of trips is significant (more than 15%) only in the Netherlands and Denmark. In most other Northern America and European countries (with the exception of Germany, Sweden and Finland) it is negligible, that is, less than 2%. (Pucher and Buehler, 2008).

[16] Not surprisingly the greatest market for these is China; Sperling and Gordon (2009) report a 2006 figure of 13 million e-bikes sold, but also – as of 2007 – the restriction of their use in many Chinese big cities, because of both safety and security reasons (electric bicycles were used by criminal gangs...).

[17] With the Parisian “Velib” bike-sharing scheme – managed by JC Decaux, an advertising company! – as the most relevant example.

Bollorè-Pininfarina 'Autolib' and Daimler 'Car2go'[18]) and innovative managers of large fleets are part of this niche too (Orsato et al., 2012).

(FIGURE 1 HERE)

4. Three scenarios of urban mobility for 2030

Three scenarios of urban mobility for 2030 emerge from the above map of ST systems and innovative actors as the result of different transformative and coalescing forces.

4.1. Scenario 1 – 'Automobility' (Figure 2)

This first scenario emerges from the reconfiguration of the existing individual car ST system and is generated by the integration in the car industry of new non-core industrial actors, in particular of producers of batteries and other electric/electronic components. The diffusion of electric cars – both as hybrid and full battery vehicles – is the technological reaction of the car system to the pressure of some "landscape" phenomena, such as: climate change, peak oil, degradation of urban space, etc. (Dennis and Urry, 2009; Zijlstra and Avelino, 2012).

In this scenario the business model remains focused on selling cars to individual consumers, but – if the emerging niche of car-sharing schemes is steadily integrated into the individual car ST system – it could be extended to the 'rent' option too. Manager of electric grids are relevant actors as suppliers of recharging utilities, but remains external to the car system. Other ST system of urban mobility – public transport, the individual bicycle – keep their subaltern position.

The "Automobility" scenario is the more probable because of pervasive – institutional, technological and economical – lock-in phenomena generated by the existing car ST system and strengthened by those national and federal (e.g., EU and US) policies providing relevant resources to its reproduction (Hull, 2011; Leurent and Windisch, 2011; Sheller, 2012; Wells et al., 2012).[19] But it is under dispute if its speed of change is fast enough to reach the ambitious targets of low-carbon urban mobility.[20]

(FIGURE 2 HERE)

4.2. Scenario 2 – 'Ecocity' (Figure 3)

In this scenario successful coalitions of urban enactors (public transport companies, local Authorities, providers of technologies, NGOs, etc.) – usually supporting a new vision for sustainable[21] cities – are able to create a new system of low-carbon urban mobility which is based

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[18] Car2go is now available in 20 cities, 5 in Northern America and 15 in Europe. Amsterdam and San Diego are the only two locations where the electric version of the 'Smart' is used. (www.car2go.com, accessed 06/06/2012).

[19] As noticed by Angela Hull (2011, p. 13) in her last book, automotive industries and Governments share a mutual convenience: the former benefit from public subsidies and infrastructures, the latter raise a large amount of tax revenues from car sell and use.

[20] The evaluation of the environmental sustainability of the three scenarios is based on the extensive literature on the subject; see among others: Rajan (2006); Bristow et al. (2008); Kendall (2008); Becker, 2009; Hacker et al. (2009); McCollum and Yang (2009); Fontaras and Samaras, 2010; Molocchi (2010); Rijkee and van Essen (2010); van Bree et al., 2010; Doucette and McCulloch (2011); Anable et al., 2012; Pasaoglu et al. (2012); Lutsey and Sperling (2012); Ma et al. (2012).

[21] Other synonimous may be used, such as: liveable, smart, green, etc.

on compact and mixed urban development, public and shared transport, and non-motorised mobility. Electric cars are integrated into this system, mostly as vehicles for car-sharing schemes and fleet operators.

The 'Ecocity' is the most sustainable scenario because of the effective combination of several actions for low-carbon urban transport

As stated above, some medium and big urban cities have already implemented the full integration of non-car transport modes. Even if some national transport policy scheme – e.g., in California, China, Denmark, Germany, Netherland, Sweden – support the 'Ecocity' vision, these local low-carbon systems co-exist with the car ST system, which mainly reproduces at a national/international level,

Two further levels of transformation may emerge: 1. the stable integration into this local coalitions of electric actors; 2. the diffusion of best-practices from pioneer to follower and laggard cities. The latter level of transformation strongly depends on the ability of the enactors of the new low-carbon system to “capture” national and federal policies.

(FIGURE 3 HERE)

4.3. Scenario 3 – ‘Electricity’ (Figure 4)

In this scenario the car becomes an element of a new integrated energy + transport system, with the electric industry as successful enactors. Local and national electric operators are interested in the diffusion of electric vehicles, not only because they already own – or manage – the essential facility of electric grids, but also because they aim at the new frontier of “smart grids”, that is, grids which are able to exchange electricity with distributed energy resources, also with the aims of increasing grid stability and reducing demand-supply unbalances, in particular in the case of renewable sources (Turton and Mourab, 2008)[22]. It must be noticed that it is still under dispute whether it is more profitable to connect smart grids to vehicles (V2G) or to battery-swap stations (B2G) (Andersen et al., 2009; Becker, 2009; Sovacool and Hirsh, 2009; Giordano and Fulli, 2012).

The emergence of this scenario strongly depends on the attraction of an increasing number of actors from the other urban transport systems and utilities, such as: managers of battery-swap stations, managers of sharing schemes, public transport operators, etc. Cities may play a relevant role as niches to test both technological/organisational innovations and coalition building (Wiederer and Philip, 2010), but the new energy + transport system will actually emerge only if the electric enactors are able to get an increasing influence on national and federal policies – that are now dominated by the 'individual car' system – in order to support the building of new infrastructures and exploit the latent economies of scale and network externalities on both demand and supply side (Turton and Mourab, 2008; Becker, 2009).

The environmental sustainability of this scenario will be conditioned by the energy mix used to run electric cars.

(FIGURE 4 HERE)

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[22] For an extensive report on European smart grid projects, see Giordano et al. (2011); details on grids+vehicles projects can be found at pp. 34-37 and in the Annex IV.

5. The future of urban mobility

The above mapping + scenarios exercise shows that the future of urban mobility could only emerge from one of three transformative processes: the reconfiguration of the existing 'individual car' system or the creation of the two new systems of 'low-carbon mobility' and 'energy + transport'. While the main features of the these three future systems are summarized in Table 1, what remains to be discussed is the likelihood of each of them.

As already stated, the reconfiguration of the 'individual car' system is the more probable; the main strength of this system is the ability to use its current dominant position to both: incorporate new innovative skills in order to hybridise its core technology (but not its business model), and benefit from “friendly” policy schemes, based on rich public incentives and loose environmental standards. The future dominant position of the 'individual car' system could only be threaten by an increasing attention to global issues (climate change, peak oil, etc.), by relevant changes in mobility behaviour, or by the implementation of a faster and more stringent policy approach (Urry, 2009; Davis et al., 2012; Sheller, 2012).

One could even doubt if one of the other two future systems of urban mobility may emerge without the support of specific policies; but – as already stressed – this in turn depends on the ability of enactors to influence the policy arena. This is way the likelihood of the systems alternative to the 'individual car' is strongly affected by the magnitude of their coalescing forces, that is, by the enrolling of new actors in coalitions for change and by the consequent self-reinforcing ability of enactors to achieve higher levels of power, resources and legitimacy.

From this point of view the 'low-carbon mobility' system seems to be in a better position than the 'energy + transport' system. Because its coalescing forces spans over all technologies and both the 'manage' and 'rent' business models; and because it benefits from the experience accumulated in the existing systems and niches of public transport, individual bicycle and sharing schemes. On the contrary, the 'energy + transport' system is focused on the single options of 'plug-in electric' propulsion and ‘manage’ integrated systems of grids+vehicles/batteries; thus its ability to enrol new enactors is more limited. The only strength of electric operators is that they own an essential facility for the diffusion of electric cars: the electric grid.

There is another relevant point in favour of the 'low-carbon mobility' system and against the 'energy + transport systems': while the former may (and do) reproduce at the local level, the latter – mostly because of the economies of scale and network externalities generated by the infrastructure – must reproduce at the national and international level, that is, it will emerge only after a takeover on the 'individual car' system. This is why 'low-carbon mobility' is already established as the dominant system of urban mobility in many cities around the world (with a wider diffusion in Europe), without confronting the world dominant position of the 'individual car' system. On the contrary, for the electric operators the local level is only useful to gain some more knowledge of the transport sector and to test the new technology of smart grids. Using a military metaphor: the 'low-carbon' system can use guerrilla in order to weaken a stronger enemy before the (eventually successful) final attack; the 'energy + transport' must face him in a traditional war, with to date limited chance of victory. The outcome of this “war” between current core-actors (the automotive industry) and enactors (local actors and electric operators) will also depends on producers of batteries and managers of sharing scheme: who will ally with? Today the former are more and more integrated into the ‘individual car’ system, while the latter seems more prone to be part of the local coalitions for ‘low-carbon mobility’. Will remain so in the future?

Even if this is an issue which deserves further analysis, it is apparent that the likelihood of scenarios for 2030 strongly depends on policy, in particular on policies implemented at a national and federal level: ‘Automobility’ will benefit from the continuation of supporting policies which – from the point of view of the automotive industry – are implemented at a bearable pace; ‘Ecocity’ will establish also thank to a multilevel policy which may accommodate the city-specific bottom-up initiatives for low-carbon urban mobility and foster their diffusion to urban areas that are less ready to radical change; ‘Electricity’ will emerge also because a new integrated energy-transport policy paradigm is adopted which provides new standards (on vehicles, batteries and grids), fosters the creation of old and new infrastructures (e.g., metropolitan railway networks and smart grids) and – last but not least – supports the integration of all relevant actors in a consortium for electric mobility, which may eventual transform in an entrepreneurial initiative.[23]

(TABLE 1 HERE)

5. Conclusions

The work presented in this paper was mainly aimed at checking if the socio-technical analysis of existing information on innovation for low-carbon urban mobility may provide new knowledge and hints for further research on the future of urban mobility.

Such a heuristic proved valid.

We have seen that ‘agency’ is a crucial variable. We have shown that different coalescing forces of innovative actors – featuring different innovative strategies – may lead to three alternative scenarios of urban mobility for 2030: ‘Automobility’ which is nothing but the technological reconfiguration of the existing ‘individual car’ system, led by the automotive industry; ‘Ecocity’ which integrates all alternatives to the car into a new system of ‘low-carbon mobility’, fostered by emerging coalitions of local enactors; ‘Electricity’ which is based on a new ‘energy + transport’ system, enacted by managers of (smart) grids.

We have also seen that ‘power’ is a crucial variable. The likelihood of all 2030 scenarios strongly depends on the ability of core-actors and enactors: a) to influence the policy arena in order to secure supporting policies. In particular, ‘Automobility’ is the more probable scenario because it benefits from the current dominant position of both the ‘individual car’ system and the ‘automotive industry’ core-actor; b) to enrol new actors in a coalition for (to resist) change. In particular, the positioning of both producers of batteries and managers of sharing schemes seems crucial to understand which system of urban mobility will actually achieve a dominant position in the future.

Finally, we have seen that ‘space’ is a crucial variable too. While both the ‘individual car’ and the ‘energy + transport’ system reproduce at a global level (mostly because of relevant economies of scale), the ‘low-carbon mobility’ system is already established in many cities around the world without confronting the ‘individual car’ system on the global level. Then, the emergence of the ‘Ecocity’ scenario crucially depends on the diffusion of this new system to a wider number of urban areas.

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[23] Something similar is already taking place on a local basis in Barcelona, Berlin, Brabanstad (NL), Goto Islands (J), Hamburg and on a national basis in Denmark, Finland and Israeli (Wells, 2010; Leurent and Windisch, 2011; OECD et al., 2012).

These results stimulate to further research. In particular there are three relevant questions about policy which deserve a well-founded answer: 1) Given the current dominant position of the 'individual car' system, will the 'Ecocity' and 'Electricity' scenarios ever emerge without a relevant public action? 2) Is the diffusion of the new 'low-carbon mobility' system possible without a multilevel policy which is able to mix bottom-up local initiatives and top-down (national and federal) support and funding? 3) The establishment of the 'Electricity' scenario also depends on the creation of new electric standards, infrastructures and industries; again: is this creative process possible without public support and funding?

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Fig. 1. A map of innovation in urban mobility: dominant system and core-actor; other systems and actors; competences

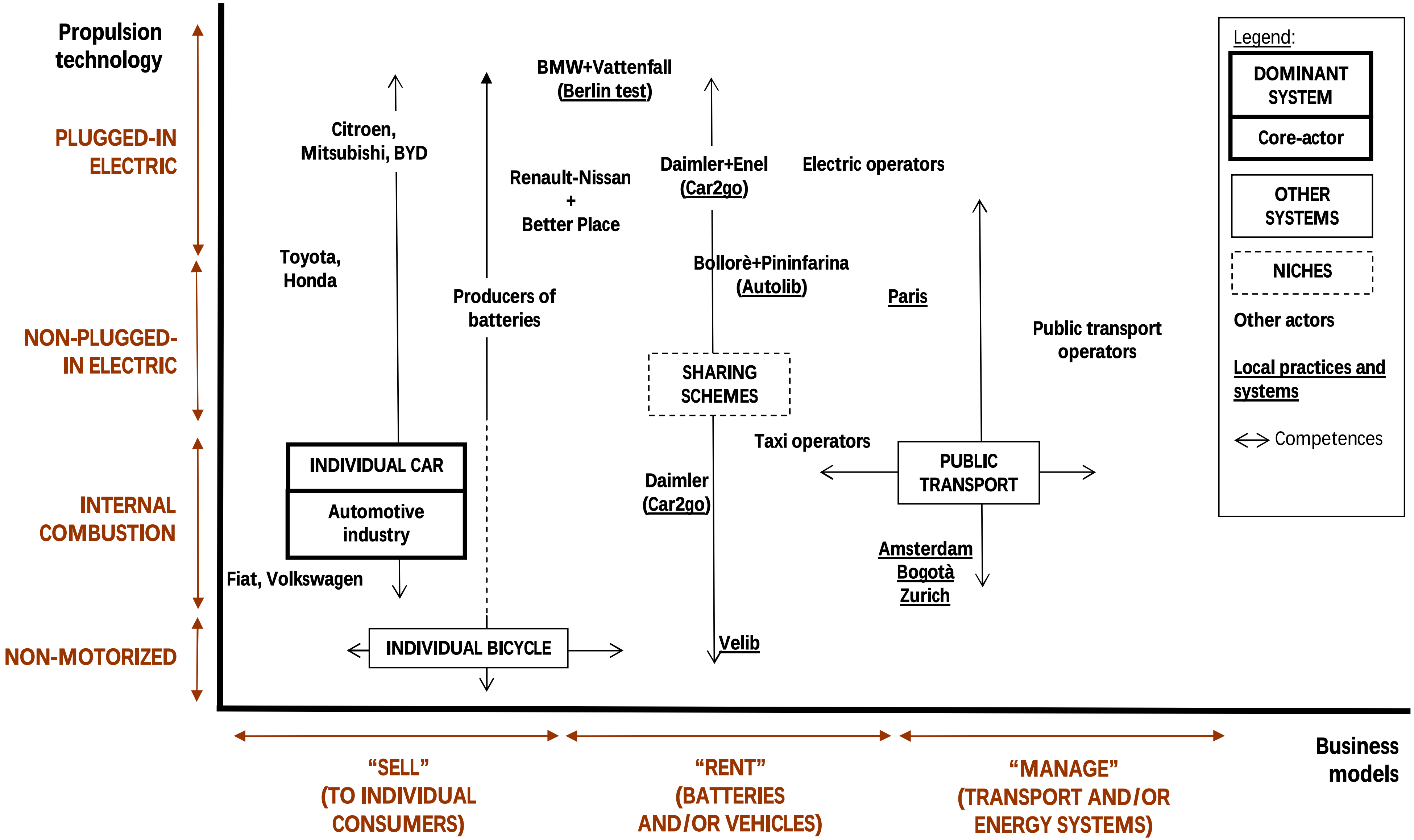

Fig. 2. ‘Automobility’ scenario: dominant system and core-actor; other systems and actors; coalescing forces

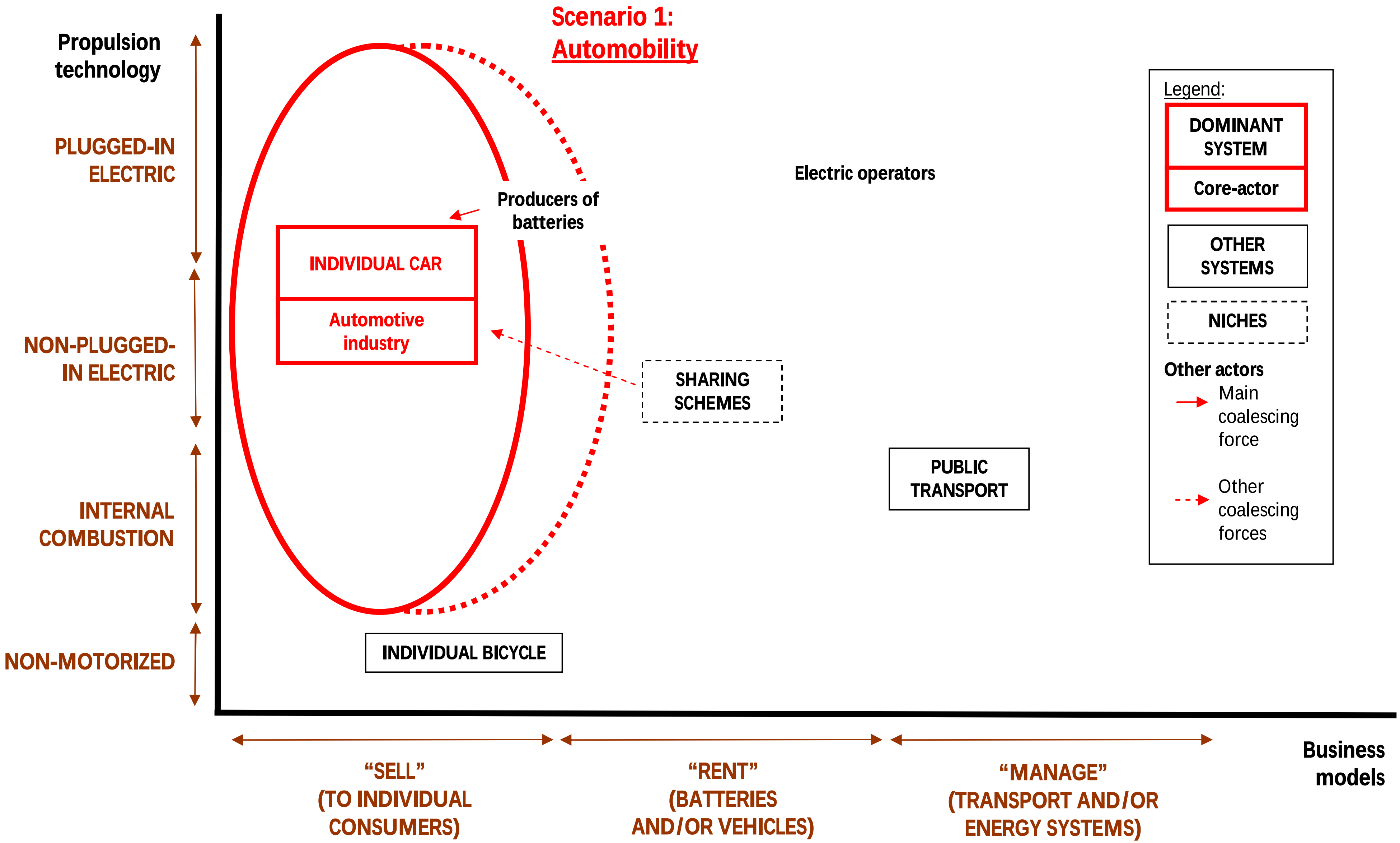

Fig. 3. 'Ecocity' scenario: dominant system and core-actor; other systems and actors; coalescing forces

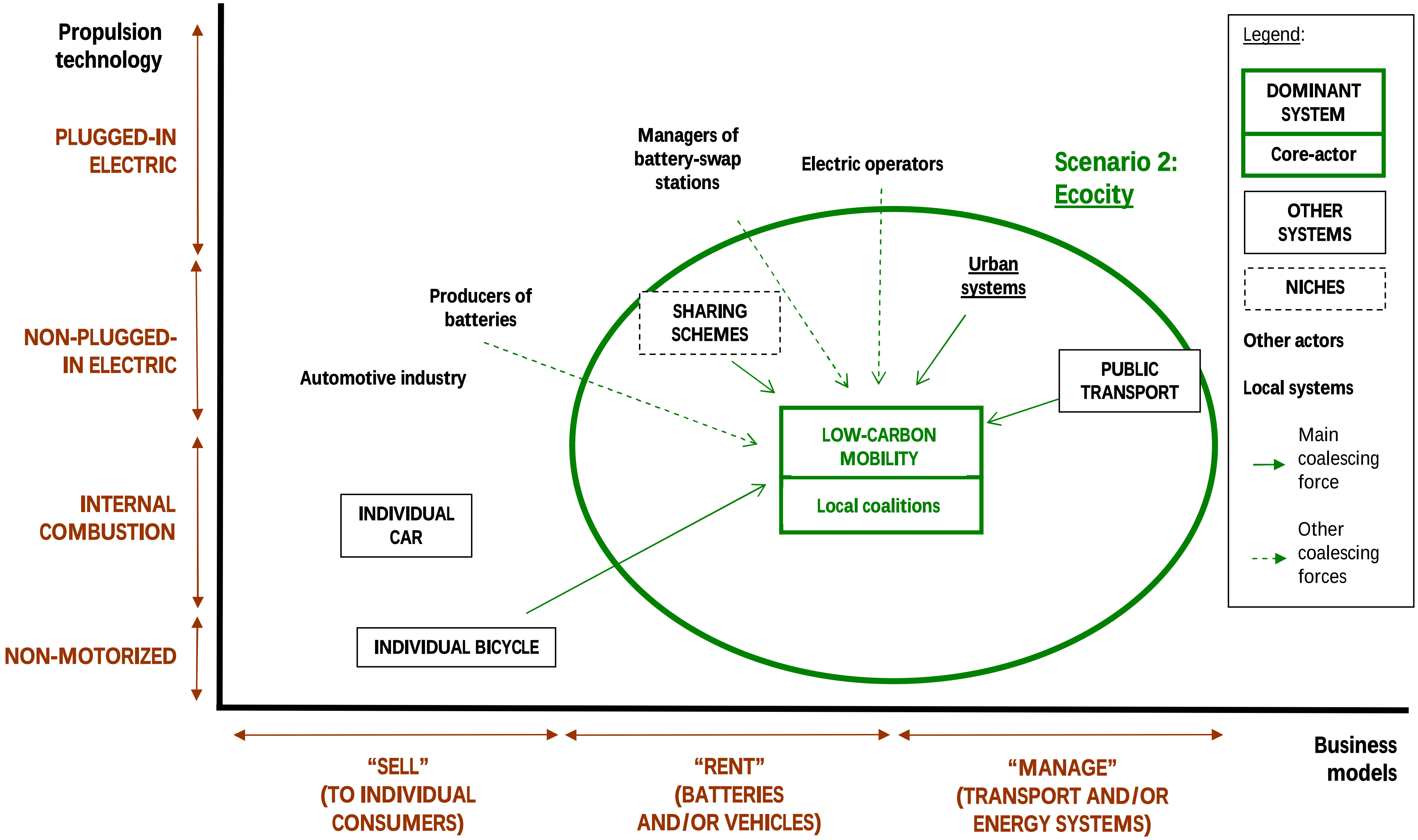

Fig. 4. ‘Electricity’ scenario: dominant system and core-actor; other systems and actors; coalescing forces

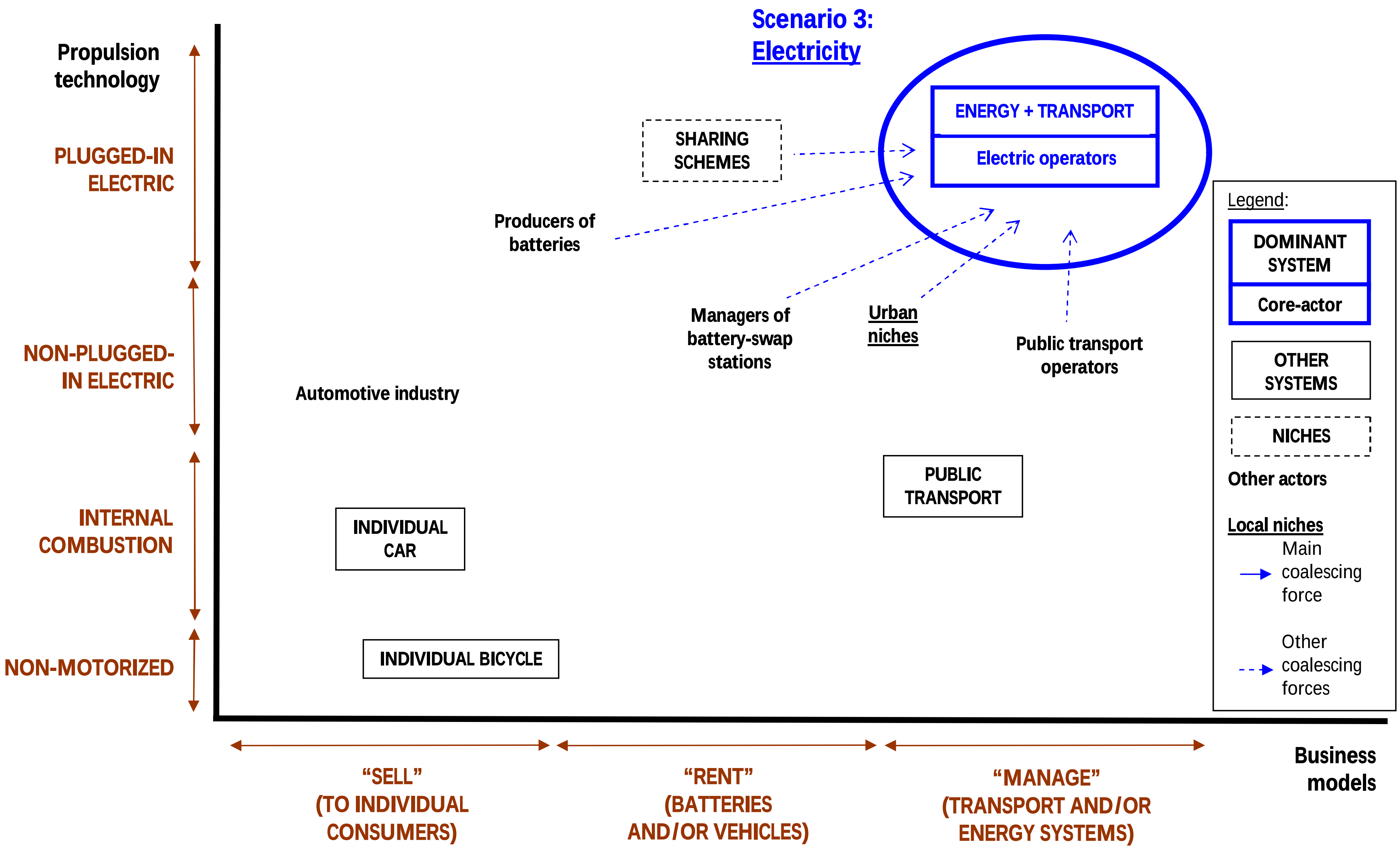

Table 1. Future systems of urban mobility: main features

	'INDIVIDUAL CAR'	*'LOW-CARBON'*	*'ELECTRICITY'*
Core-actor	Automotive industry	Local coalitions	Managers of electric grids
Transition pathway	Reconfiguration: Integration of producers of electric components into the already existing 'individual car' system	De-alignment and re-alignment: Local coalitions support the creation of a 'low-carbon mobility' system	Substitution: Managers of electric grids emerge as new core-actor after a "battle" with the automotive industry
Propulsion technologies	All, except non-motorised	All	Plugged-in electric
Business model	'Sell' cars (potential extension to sharing schemes)	'Manage' integrated systems of all sustainable modes of transport (including sharing schemes)	'Manage' an integrated 'energy + transport' system: smart grids + vehicles/batteries-to-grid
Role of the city	Not relevant: the 'individual car' system is reproduced at a national/international level	Some cities already host local 'low-carbon mobility' systems	Cities as niches for experimentation of the 'energy + transport' system, which is reproduced at a national and international level
Supporting policy	National and federal policies continue to support the innovative strategy of the automotive industry	A multilevel (top-down and bottom-up) national and federal policy is needed to envolve cities less ready to innovation and build a new dominant system	A national and federal integrated approach to transport + energy policies is needed to build a new dominant system