The converging Energy-Mobility System needs an integrated Approach for the Sustainability Transition

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Technological and societal advances are driving the energy and mobility systems toward increasingly interdependency ("convergence" or "sector coupling"), so that they will ultimately become what we call the "energy-mobility system". The energy-mobility system will need an integrated approach to policy and governance, especially for successful management of the sustainability transition.

Convergence of the energy and mobility systems

The mobility and energy sectors are subject to the same macro-economic megatrends, which is leading to their institutional and technological convergence into what we will call the 'energy-mobility system'. There are several reasons for this convergence. First, deregulation, here meaning the stimulation of competition in regulated network industries, is a powerful institutional enabler of convergence, by allowing and incentivising companies to innovate with new products, services, and business models. Second, digitalisation is a technological enabler of convergence, by joining the sectors in a 'data layer' on top of their physical infrastructure. Lastly, decarbonisation is an accelerator of convergence, by positing the electrification of all forms of mobility as a solution to this pollution. One of the clearest examples of this electrification can be found in batteries, which are a fundamental technology for the decarbonisation of mobility, but also, an essential technology for integrating and managing more renewables into electricity grids. They can even serve both purposes at the same time, using decentralised electric vehicles as flexible load to balance the electricity grid. Similarly, battery-free electric vehicles that are continuously fed power, such as trains, trams, metros or trucks on so-called 'e-highways' can also be used as an operable load for grid management.

The convergence of energy and mobility is creating a new type of system, where electricity demand itself will become mobile. This will represent a new challenge for the grid: conventional electricity load is mostly static. Flexible supply and demand will become very important in order to maintain a balanced grid and prevent (local) bottlenecks. Transportation services will make up a considerable part of the load on the electricity grid, which, in turn, will change the way electricity and mobility networks are planned, built, and operated. The electrification of mobility will make it difficult, if not impossible, to manage the electrical grid unless the load can be actively modulated.

Coherence of policies and institutions

The coherence framework (see: Crettenand & Finger, 2013; Finger et al., 2005, 2015) tells us that institutions (policies, regulations) and technology co-develop and argues that institutions should, therefore, remain relatively aligned with the technological advancements, if they are to be enable rather than impede the efficient functioning (performance) of a socio-technical system. However, some degree of incoherence between technology and the prevailing institutions can also spur innovation as the associated problems of the misalignment allow for or require companies to find innovative solutions. Ultimately, however, only the alignment of the physical system with the institutional regime will lead to optimal performance. If one is to follow this coherence framework, it would be logical to develop institutions that are in line with the recent technological developments in matters of energy and mobility sector coupling, especially for the sustainability transition. Indeed, only a certain coherence between the new technological potential of such sector coupling on the one hand, and aligned institutions on the other, will contribute to decarbonisation and the sustainability transition, more generally. In other words, in order to effectively govern this converging energy-mobility system, policies should focus on broad social, economic, and environmental efficiency, rather than on optimising each sector individually.

Cross-sectoral policy ambitions

There are five broad policy ambitions that we can identify for such a sustainability transition. First, the reduction of energy consumption through efficiency and sufficiency measures. Energy use is the main cause of emissions in our economy and any reduction in energy use is a direct gain

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for climate change mitigation. Second, the electrification of energy demand currently met by fossil fuels. Electrification remains the only realistic option for immediate action in sectors such as transport. By changing the use of fossil fuels to electricity, immediate reductions in carbon emissions are rapidly attainable. Third, the decarbonisation of electricity generation. This obviously reduces the emissions of the electricity sector but becomes more beneficial and necessary in combination with the second policy area. Indeed, using electricity to replace fossil fuels only contributes to reducing overall greenhouse gas emissions if the electricity comes from a low-carbon source. Fourth, the promotion of resilience and security of supply. This is sometimes relegated to the peripheries of sustainability policy debates, or even forgotten altogether, but is absolutely necessary in order to securely and safely manage the first three policy ambitions (Sinn, 2017). Grid management and operational practices need to be reconsidered and made more resilient where necessary to manage the required new infrastructure facilities, assets, and loads in the energy and mobility sectors. Promoting the digitalisation of the demand-side can significantly contribute to increasing grid resilience. Fifth and last, the integration of green infrastructure management. Green infrastructure (agricultural land, forests, meadows, soils) next to mobility and energy infrastructure is generally managed for the purpose of reducing the natural hazards that can impact the system: falling trees, avalanches, mudslides, etc. Integrating green infrastructure management focused on stimulating natural carbon sinks (Wiesmeier et al., 2019) and biodiversity into the overall management of the energy-mobility infrastructure could provide a key contribution to the sustainability transition.

These five policy areas will, in their combination, lead to a successful energy transition. The ensuing policies and regulations should be applied to the converging energy-mobility system, ideally in a manner that favors an integrated governance of this system. Besides integrated policy and regulatory solutions, the convergence of the energy-mobility system will, at one point, require a system operator with intimate knowledge of both systems. We will now present the case of the Swiss national rail company, an integrated energy and mobility operator, which could further develop their system role if corresponding policies and regulations were to be put into place. Their successful advances in the sustainability transition showcases the potential for an integrated approach.

Swiss Federal Railways

The Swiss Federal Railways (Schweizer Bundesbahnen, SBB) was founded in 1902. Previously a branch of public administration, SBB has been a limited company since 1999, regulated by public law and fully owned by the Swiss state. SBB is not the only railway company in Switzerland but is, by far, the largest, retaining a legal monopoly on passenger transport on most long-distance domestic connections. SBB's railway network is almost entirely electrified, making the company the largest consumer of electricity in Switzerland, good for about 4% of the national electricity consumption.

The Swiss railway system operates at a frequency of 16.7 Hz, one third of the frequency of the main electricity grid. For this reason, the system has its own separate electricity grid, including nine hydro-electric power plants operating at 16.7 Hz and eight frequency convertor stations connecting it to the 50 Hz grid. About 90 percent of the electricity comes from renewable sources. The Swiss railway electricity infrastructure is owned and operated by SBB itself, making SBB the largest prosumer in Switzerland, vertically integrating power supply, transmission, and distribution up to and including power demand. SBB also provides electricity to the other railway companies in Switzerland and is regulated to provide its electricity activities at fair and competitive prices. In addition, SBB supplies some auxiliary services to Swissgrid, the TSO of the main 50 Hz grid.

Being a state-owned company, SBB is expected to be a role model of the sustainability transition and it has been successful during the past years in aligning its internal activities with the ambitions of the Energy Strategy 2050. It has set the internal goal to reduce its emissions by 50% by 2030, and by 92% by 2040 (SBB, 2020), which is more ambitious than the national target. SBB is active in all the five above described policy areas that contribute to climate change mitigation. It has implemented energy efficiency measures that have reduced its overall energy consumption in 2018 by about 10% as compared to forecasts in 2011, and aims to double these savings by 2025 (SBB, 2020). It has furthermore committed itself to electrifying the remainder of its fossil fuel consumption, including the heating of its buildings and replacing the remaining fleet of diesel locomotives. It has committed to having 100% of its electricity generated from renewable sources by 2025 (SBB, 2020). SBB is also investing significantly in the resiliency of the grid on the demand side so as to accommodate the significant capacity increases expected in the future. Here, SBB has the unique possibility to manage power demand from the power plant all the way down to the train. For instance, the company has implemented a demand response solution that can modulate train heating systems to prevent local bottlenecks in power supply and is developing a similar solution for the traction power of the trains. Another program similarly signals trains to slow

down when needed to prevent forced stops of trains, reducing the overall energy consumption and increasing the punctuality of the trains. A little known fact about SBB is that it is also the largest manager of forests and green infrastructures in Switzerland, considering that it oversees about 16'200 hectares of land consisting of forests and meadows adjacent to its railway infrastructures, of which it directly owns about a third (SBB, 2020). They have recently started considering the promotion and conservation of biodiversity in their management of these green lands.

Transport over rail is generally recognized as being the most efficient type of transport (Wee et al., 2005) with the least amount of emissions. Together with the advances described above, SBB is actively and successfully becoming one of the country's champions of the energy transition. The company is in a unique position to take on a more comprehensive role in the Swiss energy transition, on two accounts: on the one hand, SBB can provide the energy-mobility infrastructure that will be required for the electrification of road-based transport; on the other hand, SBB has the potential and the capabilities to become the system leader for this integrated energy-mobility system.

SBB already provides the electricity infrastructure for Switzerland's railway sector. However, as we have seen above, not just rail, but the entire mobility sector and, in particular, road-based mobility will need a dedicated electrical infrastructure to operate, namely a charging infrastructure as well as overhead lines for grid-connected electric vehicles. Mobile assets like cars, and trucks pose particular challenges, and SBB has many years of experience successfully operating such a system for the case of rail. SBB is also the only actor with the required scale to effectively integrate mobility and electricity at the Swiss national level. By providing the electricity infrastructure for rail-based and road-based mobility, SBB will be able to harness their synergies.

One of the largest potentials of electrifying mobility is not in marginal improvements of the already electrified railway sector, but by encouraging a modal shift-to-rail, both potential passengers and cargo. The railway electricity infrastructure will need to be upgraded to allow for the increased load, new infrastructure will need to be built, and new digital solutions and service offerings will need to be developed to integrate the various modes of transport so as to entice consumers to make the switch. Should SBB take on the role of energy-mobility infrastructure operator, the company will be in the unique position to optimize the entire energy-mobility system to become more sustainable. It would not only be infrastructure manager but also the largest consumer. Since sustainability-related activities have become clearly articulated inside the company, SBB has achieved remarkably fast results in implementing solutions. Because it owns and operates the entire value chain SBB can pilot and scale many technological innovations rapidly. Using its dominant position of infrastructure provider, it can standardise these innovations and the related operational knowledge. There is indeed a large potential for energy efficiency and system resilience, notably as a result of linking rail and road, energy and mobility, electrification of road-based transport, decarbonisation measures and land-use management.

Being the provider of the energy-mobility infrastructure, SBB can implement measures to reduce the energy consumption of the mobility sector as well as to promote the electrification and decarbonisation of road transport. SBB's demand-side innovations also contribute to the resilience of the mobility and energy systems simultaneously. The company can take their innovations and offer them to other companies on their network. The company can show a similar ambition to pilot and implementing new green infrastructure management practices, which can serve to promote such practices in adjacent green areas as well.

An energy-mobility system operator

We can derive several concrete recommendations for policymakers so as to allow a company like SBB to realize this new potential. In a first step, it should be given the role of managing the electricity infrastructure for roads as well as for rail. Road-side electricity infrastructure will include charging stations but also overhead cables for electric trucks on so-called 'e-highways'. The railway electricity grid is already conveniently located adjacent to the main highways in the country, and the operational expertise of powering moving assets is already developed at SBB. It should be encouraged to physically link the electrification of road and the electrification of rail, to harness the synergies between the planning, operation, and maintenance of the infrastructure. Building charging infrastructure next to stations will also somewhat ease the integration of private and public transport. Once such a system is built, SBB should be encouraged to further spearhead the development of an integrated mobility and energy management system, one that allows other mobility companies (other railway companies, charging operators, urban mobility companies, etc.) to join so that the overall system can be managed efficiently and optimised for resiliency and sustainability. In this new role, SBB should be empowered to accelerate the sustainability transition of this energy-mobility system by piloting and standardising its innovative

solutions and by providing them to the other mobility actors. It should be given the possibility to encourage, facilitate, and even incentivise a modal shift, prioritising rail for long-distance passenger and freight transport and electrified vehicles (cars, trucks, etc.) for short distances.

In a second step, the currently fragmented regulation of energy and the various transport modes of road and rail should evolve into a more coherent regulation of this integrated energy-mobility system. The regulatory competences for rail transport, road transport, and electricity are currently attributed to different offices in Switzerland. An integrated energy-mobility system requires a new and more innovative approach to regulation. In an ideal future scenario, a single regulatory authority will have the sole authority to govern the entire energy-mobility system. For now, to ensure that the interdependencies of the energy and mobility systems are adequately regulated, the regulatory authorities of road, rail, and electricity should at least work together and develop a common approach for dealing with the technological and societal developments that are leading up to this convergence and that must be put to work for the energy transition.

In a third step, also the national Energy Strategy 2050 should be revised: not only must the transport sector – rail and road – become an integral part, but so must the entire energy-mobility system. The role of SBB as a leader in fostering the energy transition in these two integrated sectors must also be acknowledged and made explicit.

Conclusion

This article introduced the concept of the energy-mobility system and the interdependent parts of the socio-technical systems of mobility and energy that are a result of convergence or sector coupling. Electrification of transport services provides the physical underpinning of the energy-mobility system. Electrified transport services represent significant electricity demand and storage and are increasingly being operated as flexible assets in the electricity grid. This demand-side inclusion is not only economically attractive but necessary for the resilience of a decarbonising, decentralising electricity grid, especially once electricity demand becomes mobile. Policymaking and governance have to evolve with the changing technological reality and can no longer treat mobility and energy as completely separate sectors. Effective governance of this new energy-mobility system requires assigning a system operator, in much the same way as such system operators already exist for the electricity system, for instance. In Switzerland, SBB is well on its way to becoming such an energy-mobility system operator. It is one of the few national rail companies in the world that is vertically integrated from the power plant down to the train, managing its energy and mobility infrastructure together for itself and other companies on its network. The Swiss case is unique but can serve as an example for other countries looking to develop their regulatory approach to the energy-mobility system.

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References

Crettenand, N., & Finger, M. (2013). The Alignment between Institutions and Technology in Network Industries. Competition and Regulation in Network Industries, 14(2), 106–129.

Finger, M., Crettenand, N., & Lemstra, W. (2015). The Alignment Framework. Competition and Regulation in Network Industries, 16(2), 89-105.

Finger, M., Groenewegen, J., & Künneke, R. (2005). The Quest for Coherence between Institutions and Technologies in Infrastructures. Competition and Regulation in Network Industries, 6(4), 227–259.

SBB. (2020). Personal interviews.

Sinn, H.-W. (2017). Buffering volatility: A study on the limits of Germany's energy revolution. European Economic Review, 99, 130–150.

Wee, B. van, Janse, P., & Brink, R. van den. (2005). Comparing energy use and environmental performance of land transport modes. Transport Reviews, 25(1), 3–24.

Wiesmeier, M., Urbanski, L., Hobley, E., Lang, B., von Lützow, M., Marin-Spiotta, E., van Wesemael, B., Rabot, E., Ließ, M., Garcia-Franco, N., Wollschläger, U., Vogel, H.-J., & Kögel-Knabner, I. (2019). Soil organic carbon storage as a key function of soils—A review of drivers and indicators at various scales. Geoderma, 333, 149–162.