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Model-Based operational analysis for complex systems - A case study for electric vehicles

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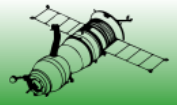
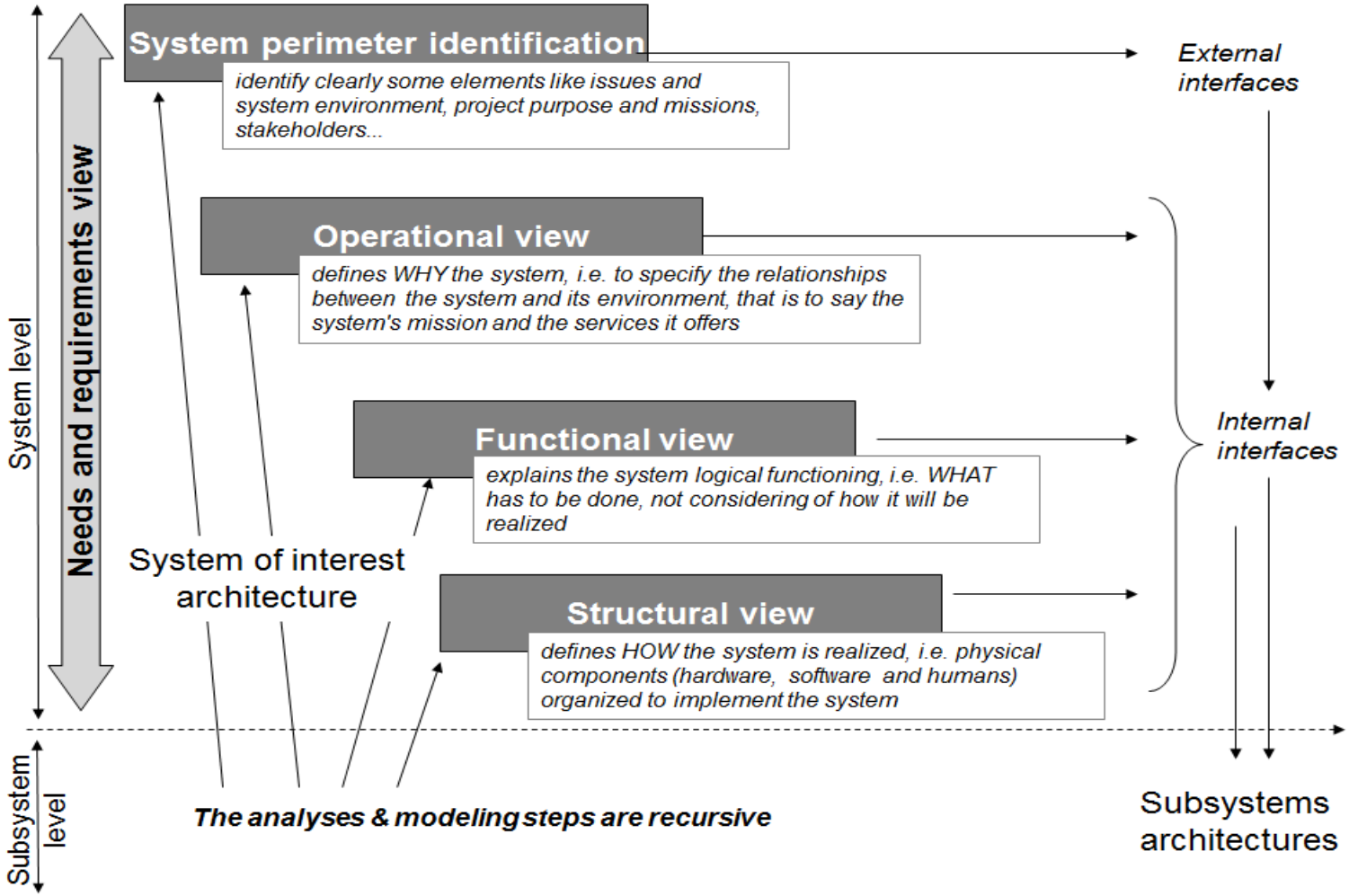
Outline

- Introduction
- Complex Systems Architectural Deign Framework
- Electric Vehicles – Case Study
- Conclusion & Perspectives


Architectural Design Framework

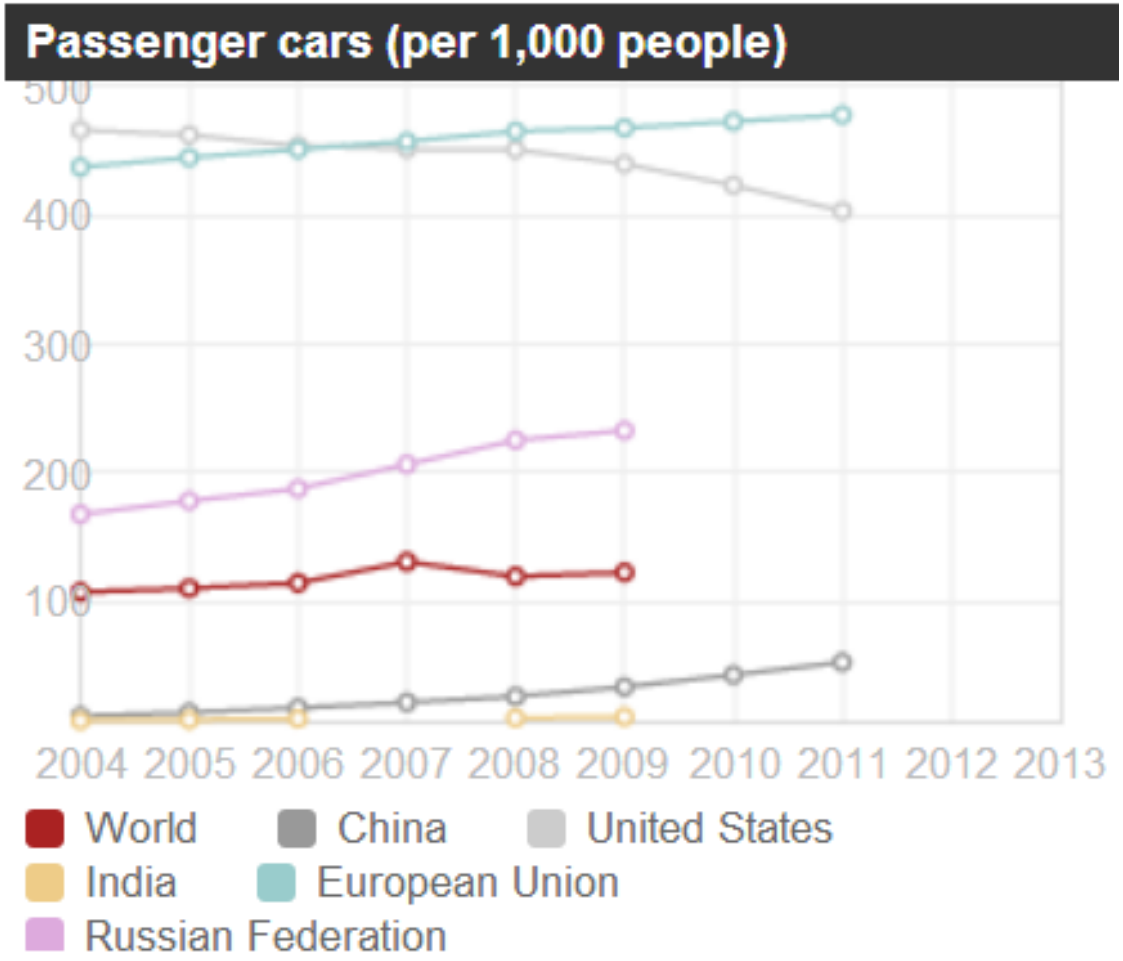


These views are refined by a behavioral perspective, modeled using SysML

Renault / CEA efforts ?

NO
Out of scope and inconsistent with the paper

Why Electric Vehicles – Context (1/3)

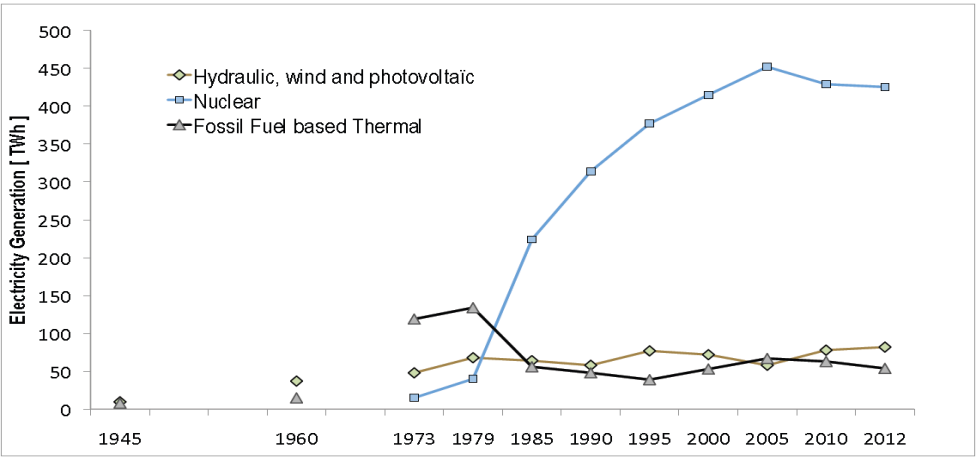


ECO2 - Economic & Ecologic

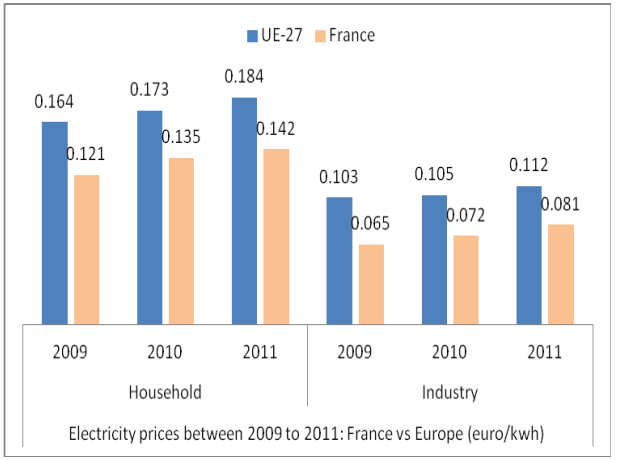
- Road transport consumes more than 72% of the total transport energy consumption.
- Internal combustion engine vehicles are responsible for 10% of CO2 emissions.
- 1.6 billion vehicles in the world in 2030 and 2.5 billion vehicles in 2050. *Source: EC*

Source: data.worldbank.org

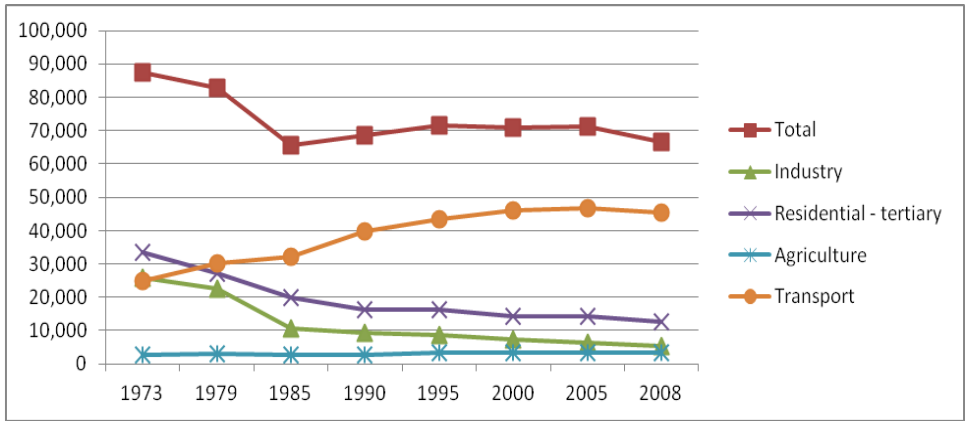
Why Electric Vehicles – Context (2/3)



Electricity generation [TWh] by fuel type in France from 1945 to 2012



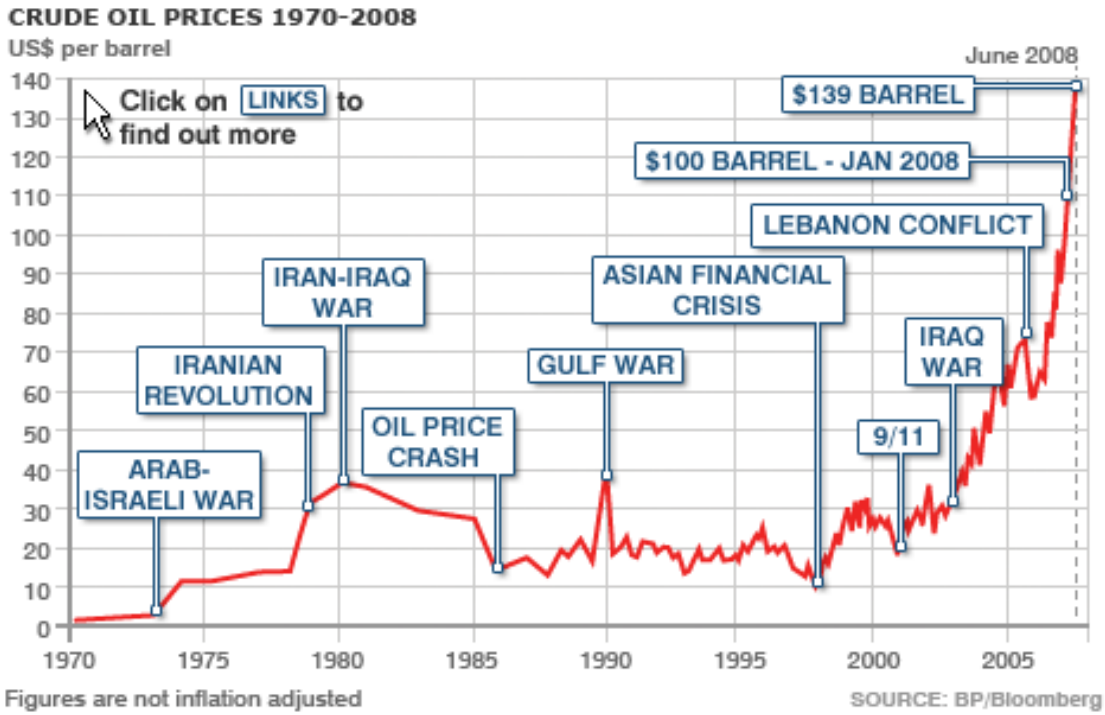
Electricity prices France vs Europe



Final energy consumption of refined oil by sector (in thousand tonne)

Why Electric Vehicles – Context (3/3)

Urgency for adopting EVs

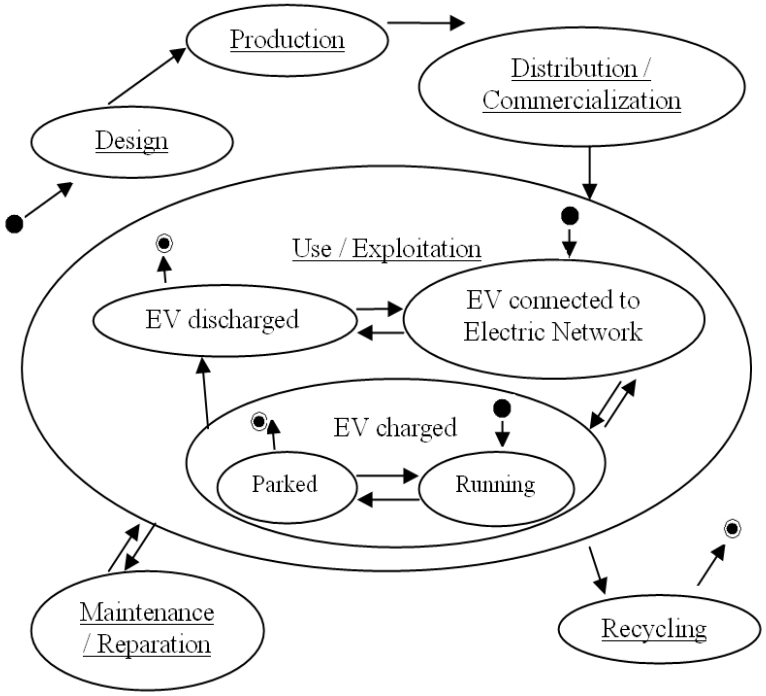


- 2003 National plan by Prime Minister for large-scale industrial production
- 2008 New funds for accelerating R&D
  - ➢ €250 million in soft loans
  - ➢ Subsidy of € 5,000 for purchasing Evs
  - ➢ Coordinating public purchase orders of EVs

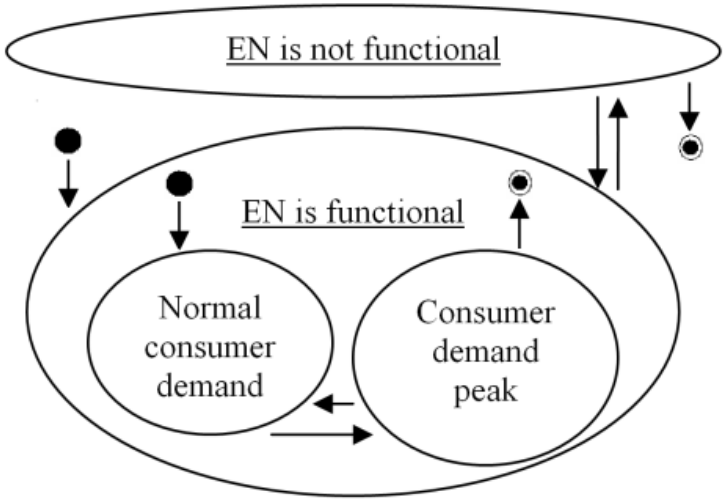
Environment Modeling

New disruptive technologies - New ecosystems

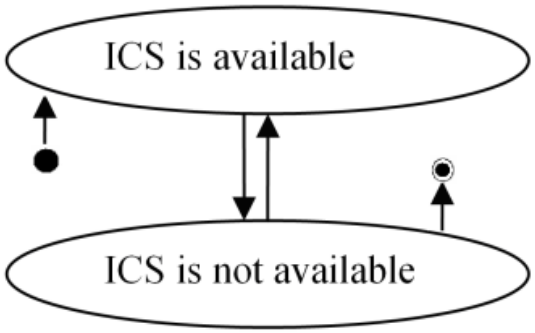
Context Operational Analysis



EV`s operational contexts.

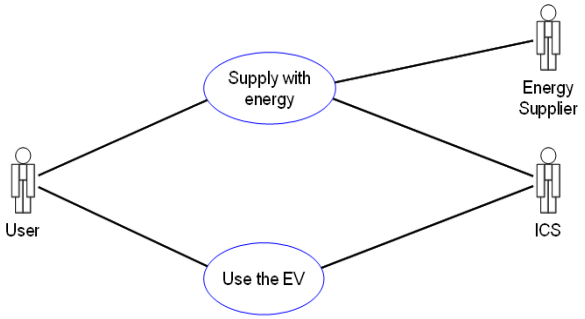


EN`s operational contexts.

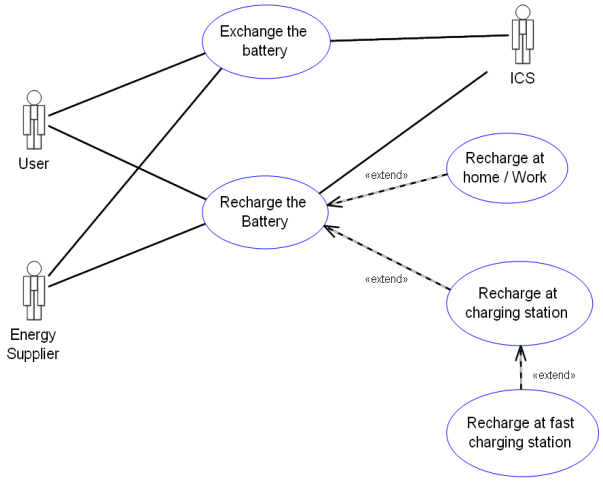


ICS`s operational contexts.

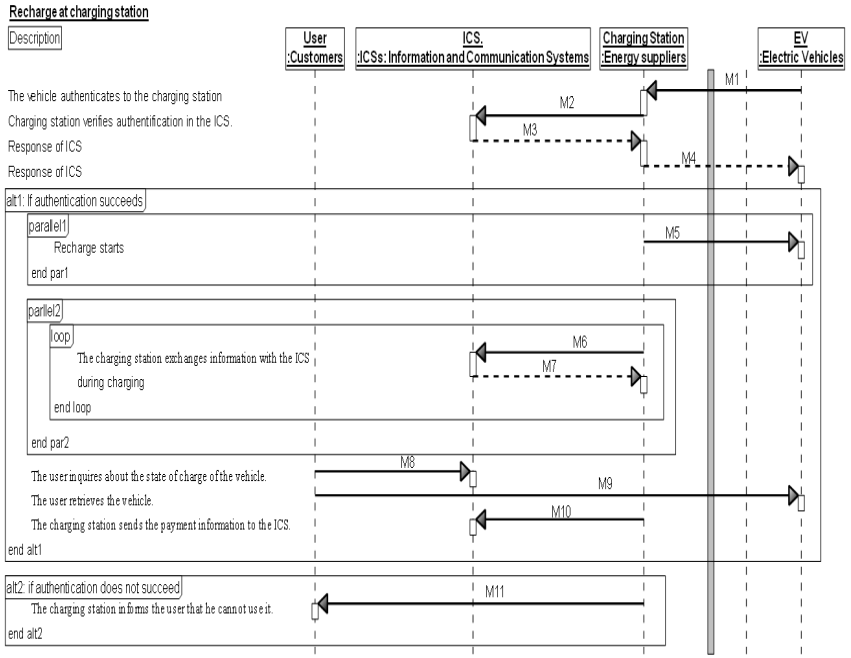
Use case / scenarios to elicit new functions



Use cases of an EV.



Details of the use case “Supply with energy.”



Example of scenarios associated with the use case “Recharge an EV at charging station.”

SysML Diagrams to support MBSE

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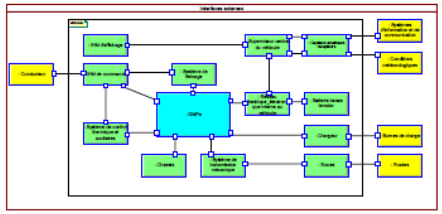
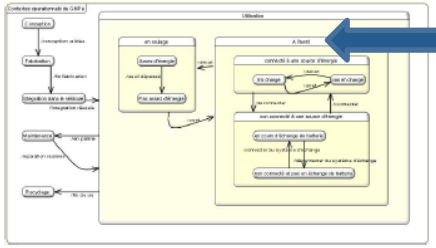
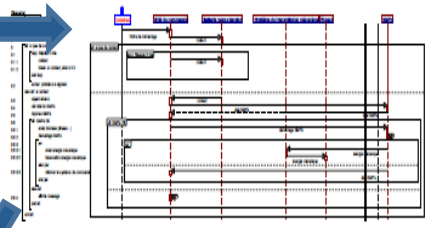
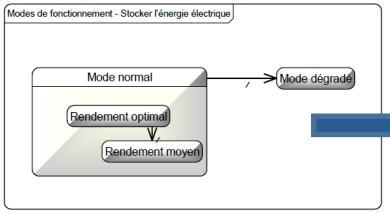
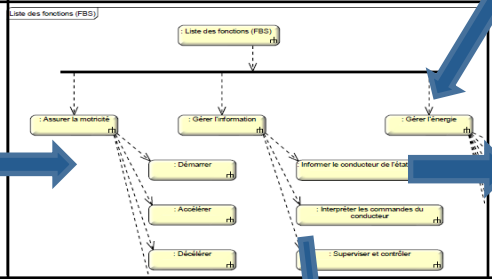
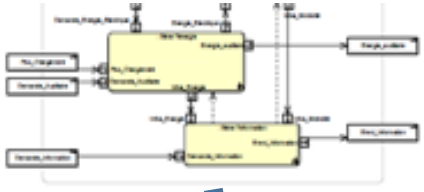
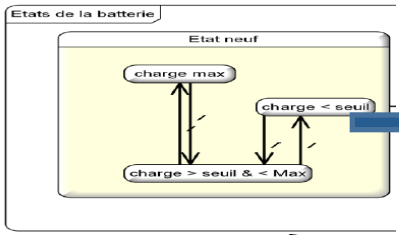
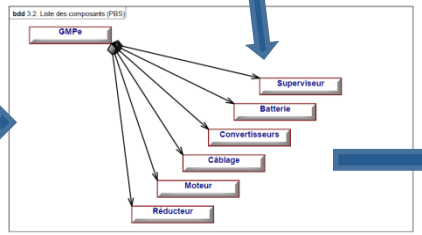
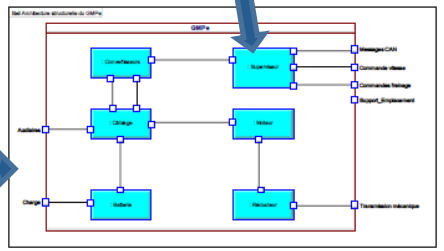
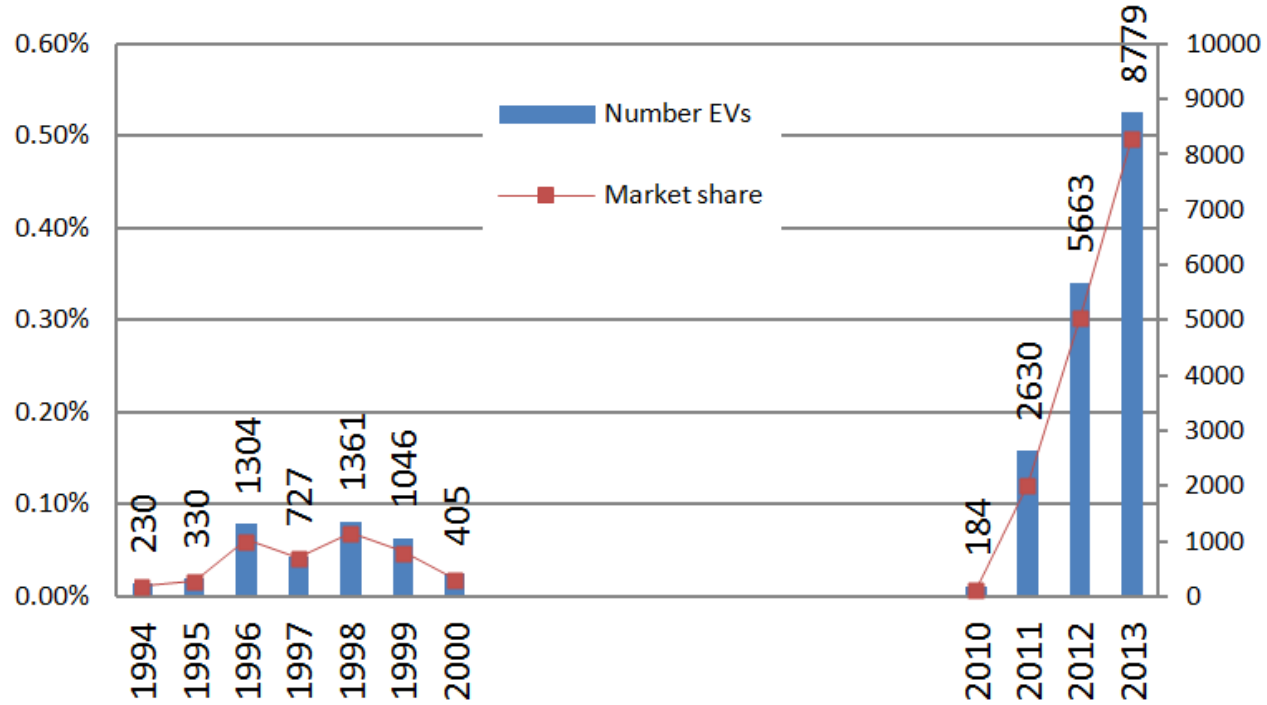


	States	Static views	Dynamic views
Operational Analysis			
Functional Analysis			
Structural Analysis			

An ongoing transition?



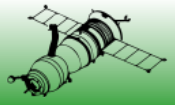
Number of registered new individual electric vehicles and market share in France

Impact on the infrastructure
Charging stations:
2 239 terminals (2013) → 97 000 terminals (2020)

Impact on labor market
15,000 to 30,000 new direct jobs by 2030

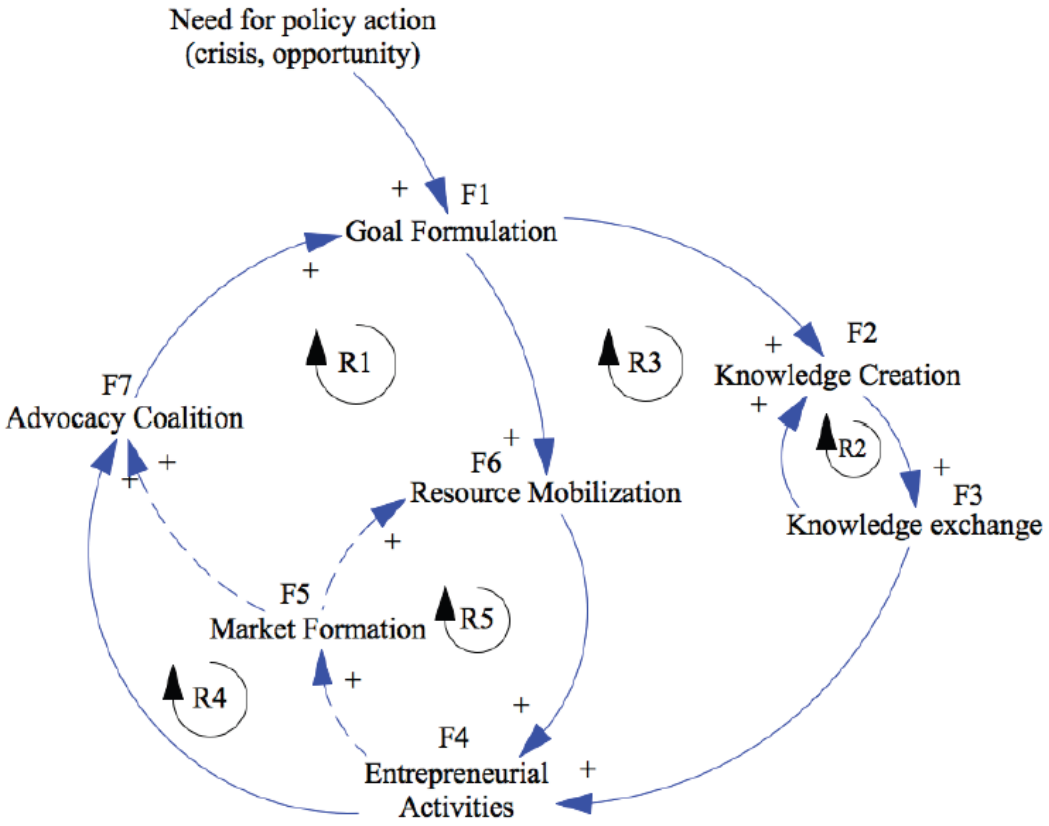
Conclusions

- Importance of Operational Analysis over the whole system lifecycle
- Modeling the system environment is crucial
- Need to maintain these two models
  - Relevance of the environment w.r.t. an evolving context
  - Examples related to our case study
    - EV development in Japan (given the impacts of Fukushima) and in USA (considering the shale gas context)
    - Ongoing energy transition in Germany
- Usefulness of an architecture design framework to perform pertinent analyses


Future work / ideas

- Link System Modelling with Business Modelling, in a Product Line Engineering perspective
- Innovation Dynamics for Development & Expansion of Electric Vehicles



Thank you!

Questions?

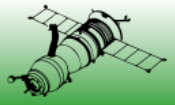
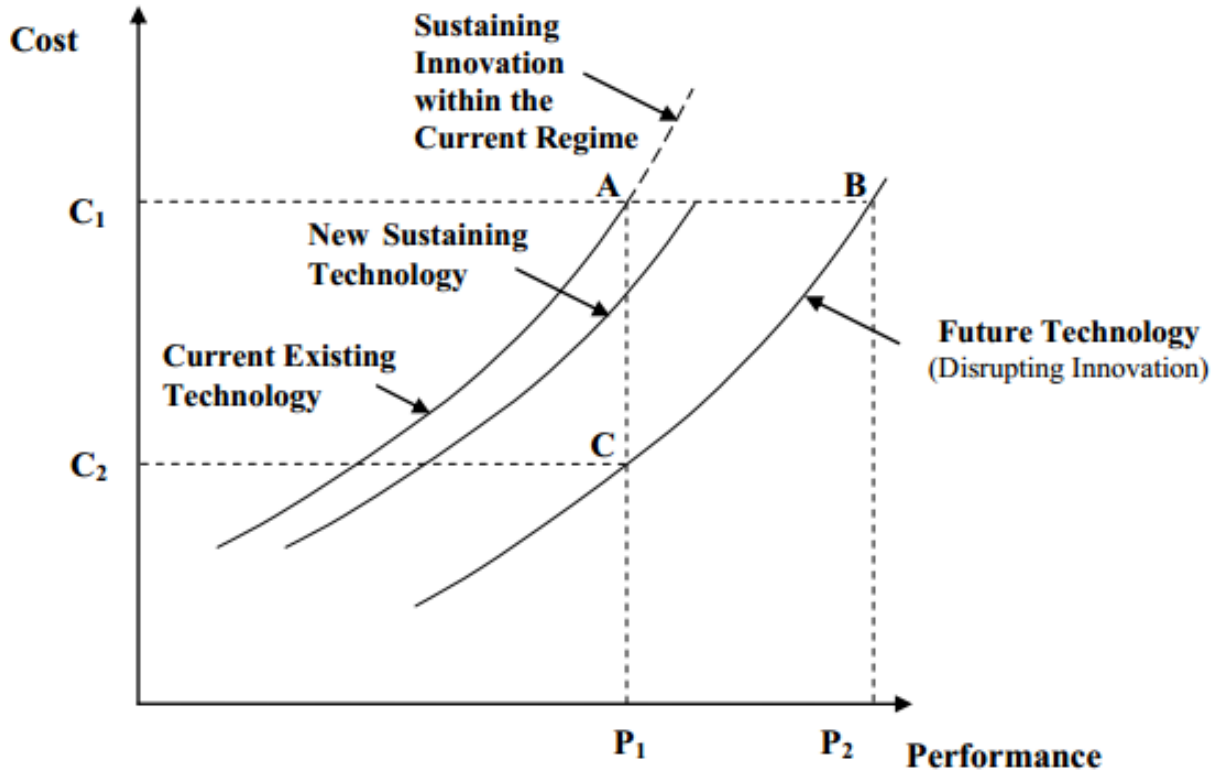




Figure 1. The efficient frontier for current and future technology contrasting sustaining and disrupting innovation.



Source: The Importance of Regulation-Induced Innovation for Sustainable Development . Nicholas A. Ashford and Ralph P. Hall, in Sustainability 2011, 3, 270-292; doi:10.3390/su3020270