

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

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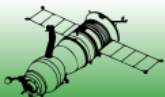
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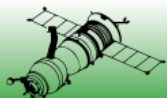
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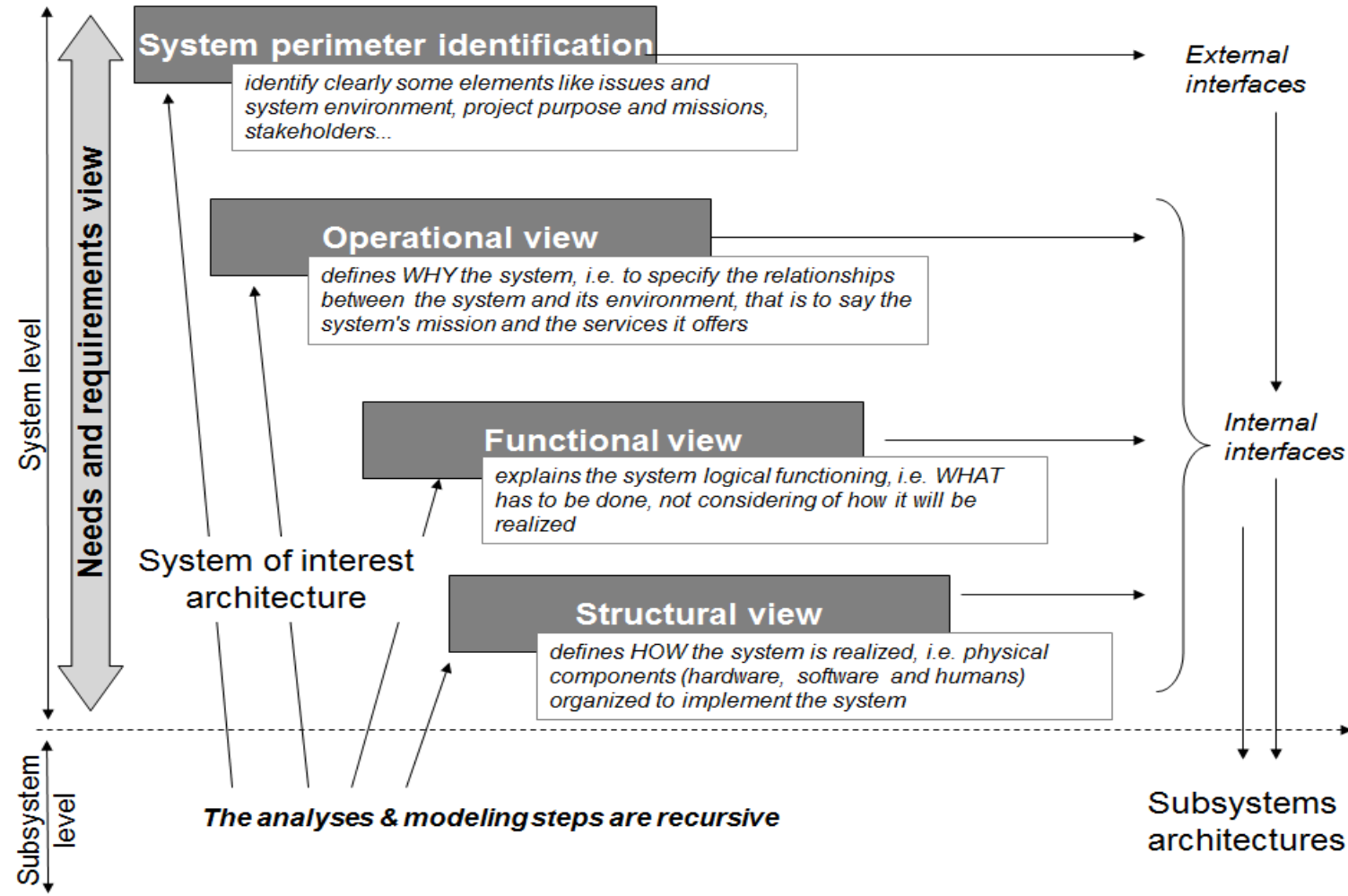


Outline

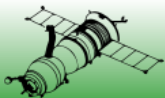
- Introduction
- Complex Systems Architectural Design Framework
- Electric Vehicles – Case Study
- Conclusion & Perspectives



Architectural Design Framework

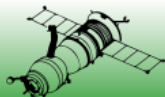


These views are refined by a behavioral perspective, modeled using SysML

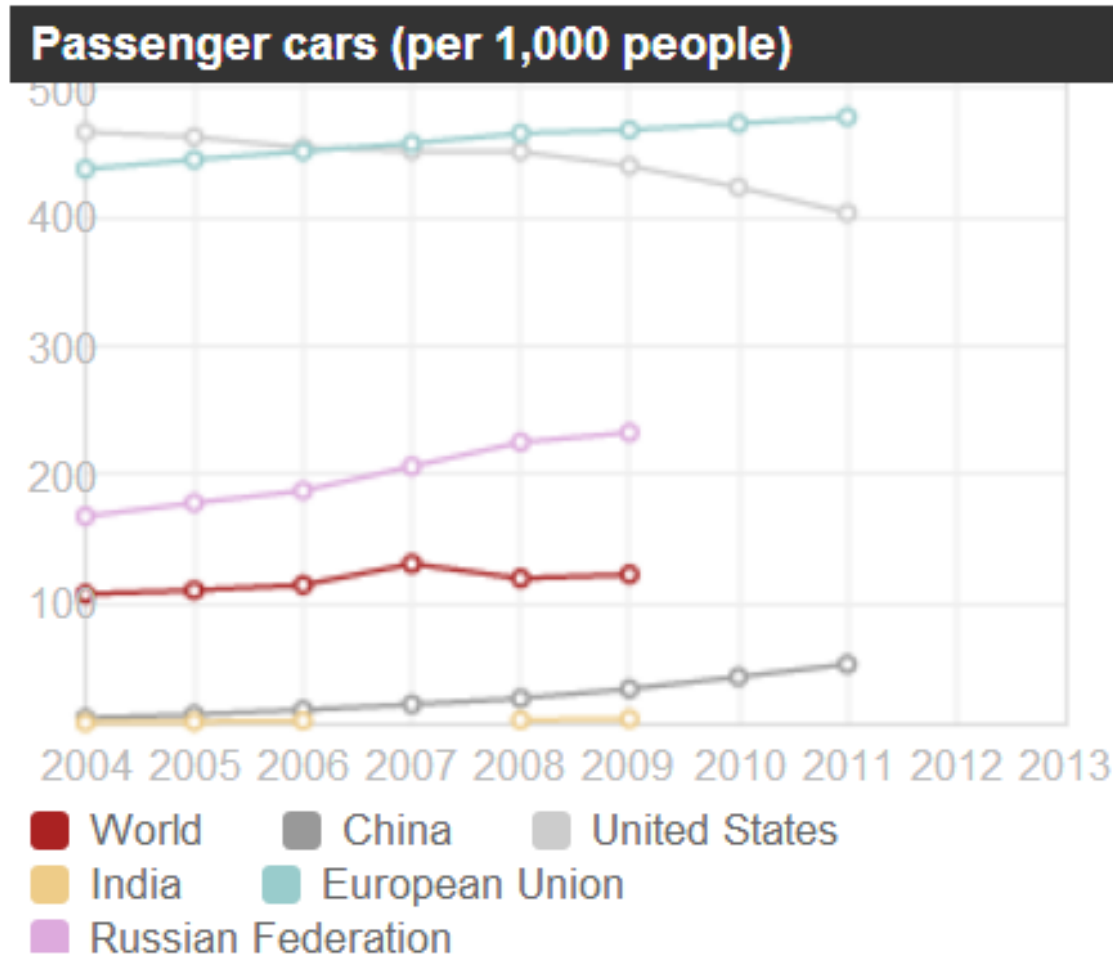


Renault / CEA efforts ?

NO
Out of scope and inconsistent with the paper



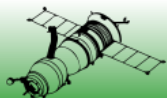
Why Electric Vehicles – Context (1/3)



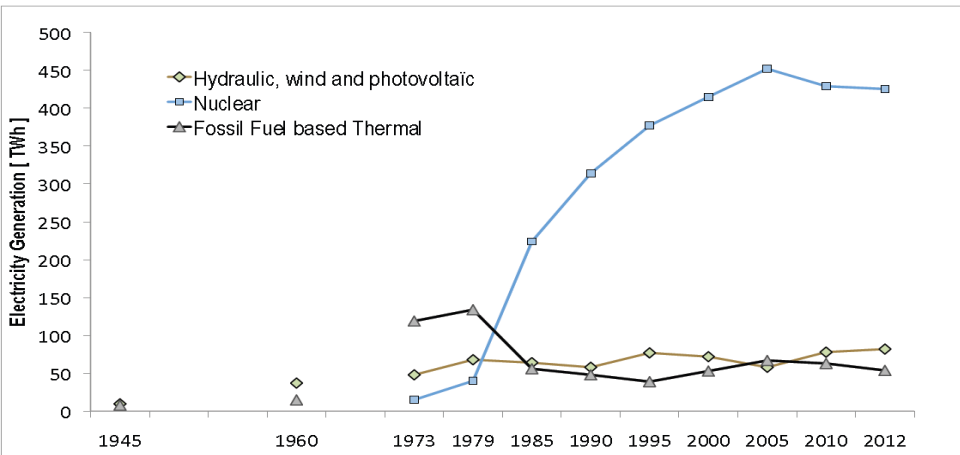
ECO2 - Economic & Ecologic

- 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*

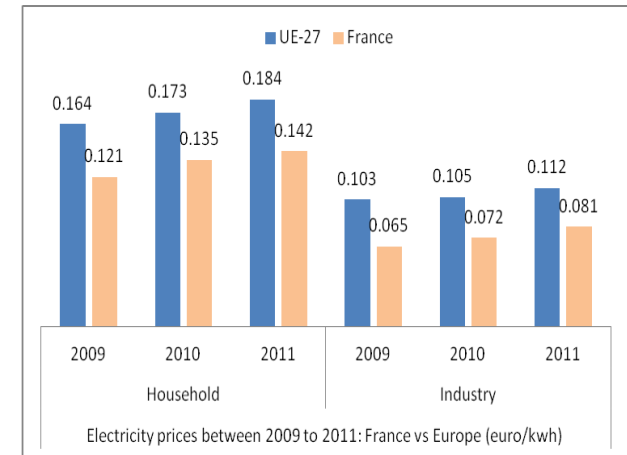
Source: data.worldbank.org



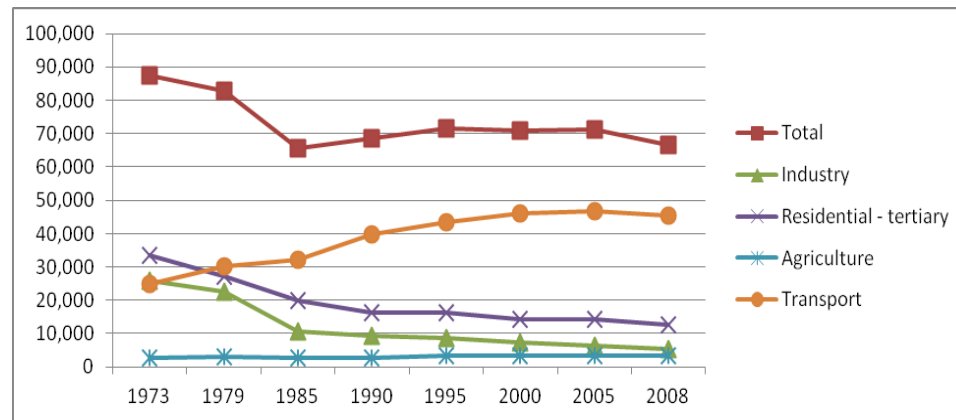
Why Electric Vehicles – Context (2/3)



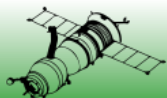
Electricity generation [TWh] by fuel type in France from 1945 to 2012



Electricity prices France vs Europe



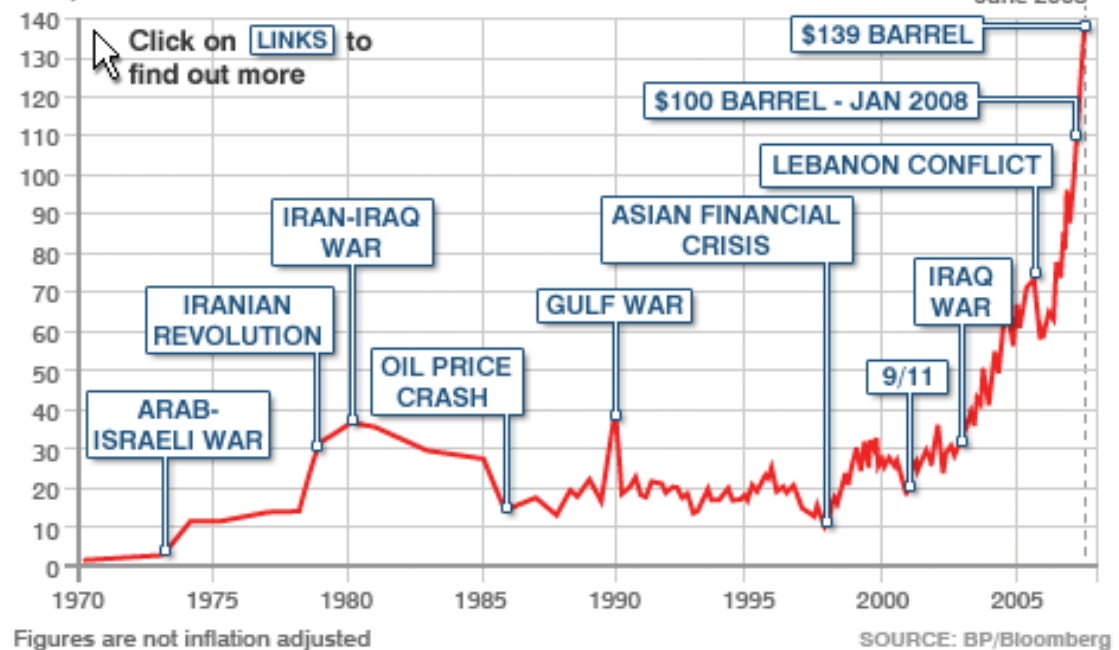
Final energy consumption of refined oil by sector (in thousand tonne)



Why Electric Vehicles – Context (3/3)

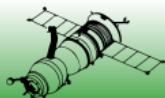
CRUDE OIL PRICES 1970-2008

US\$ per barrel



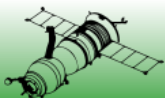
Urgency for adopting EVs

- 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

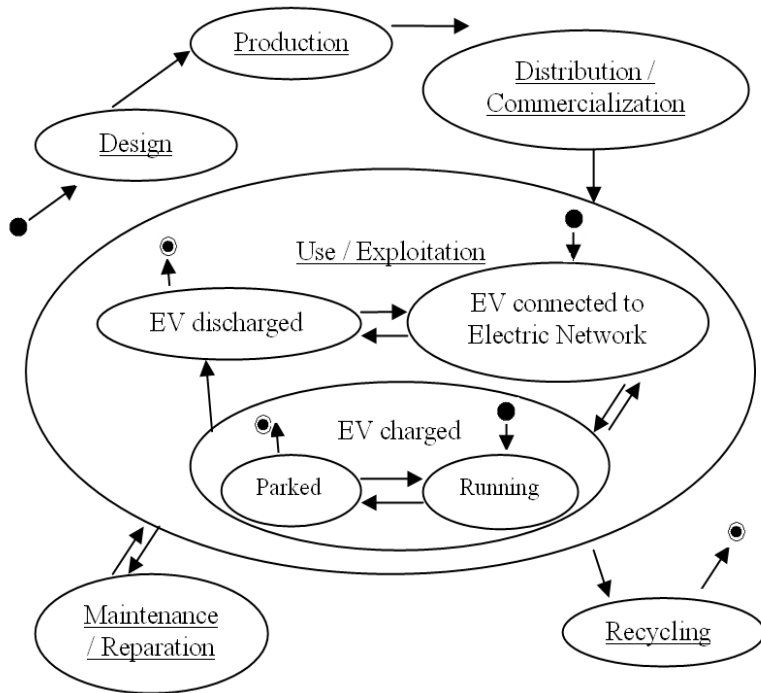


Environment Modeling

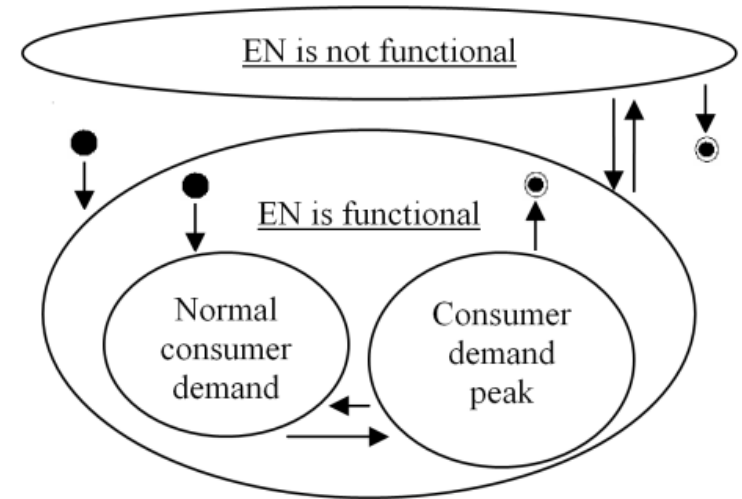
New disruptive technologies - New ecosystems



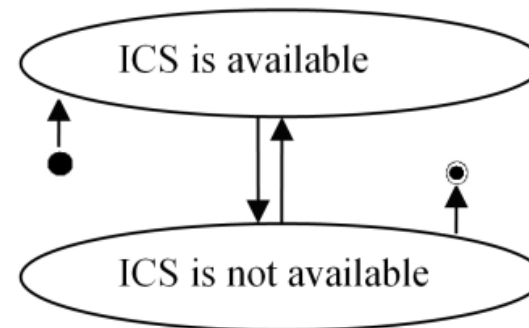
Context Operational Analysis



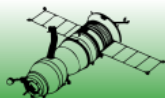
EV's operational contexts.



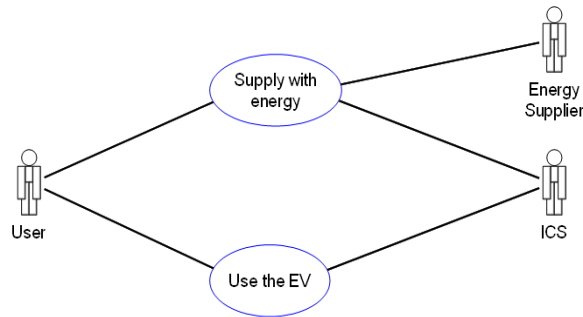
EN's operational contexts.



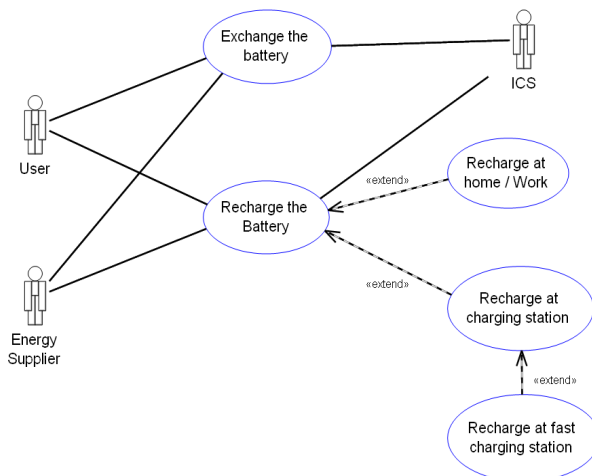
ICS's operational contexts.



Use case / scenarios to elicit new functions



Use cases of an EV.



Details of the use case “Supply with energy.”

Recharge at charging station

Description

The vehicle authenticates to the charging station
Charging station verifies authentication in the ICS.
Response of ICS
Response of ICS

alt1: if authentication succeeds

parallel1

Recharge starts

end par1

parallel2

loop

The charging station exchanges information with the ICS during charging

end loop

end par2

The user inquires about the state of charge of the vehicle.

The user retrieves the vehicle.

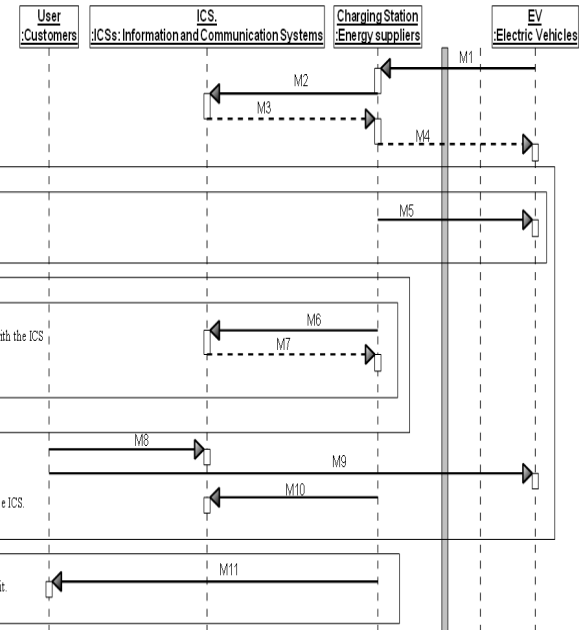
The charging station sends the payment information to the ICS.

end alt1

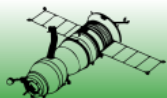
alt2: if authentication does not succeed

The charging station informs the user that he cannot use it.

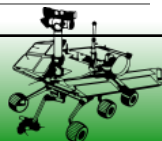
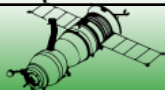
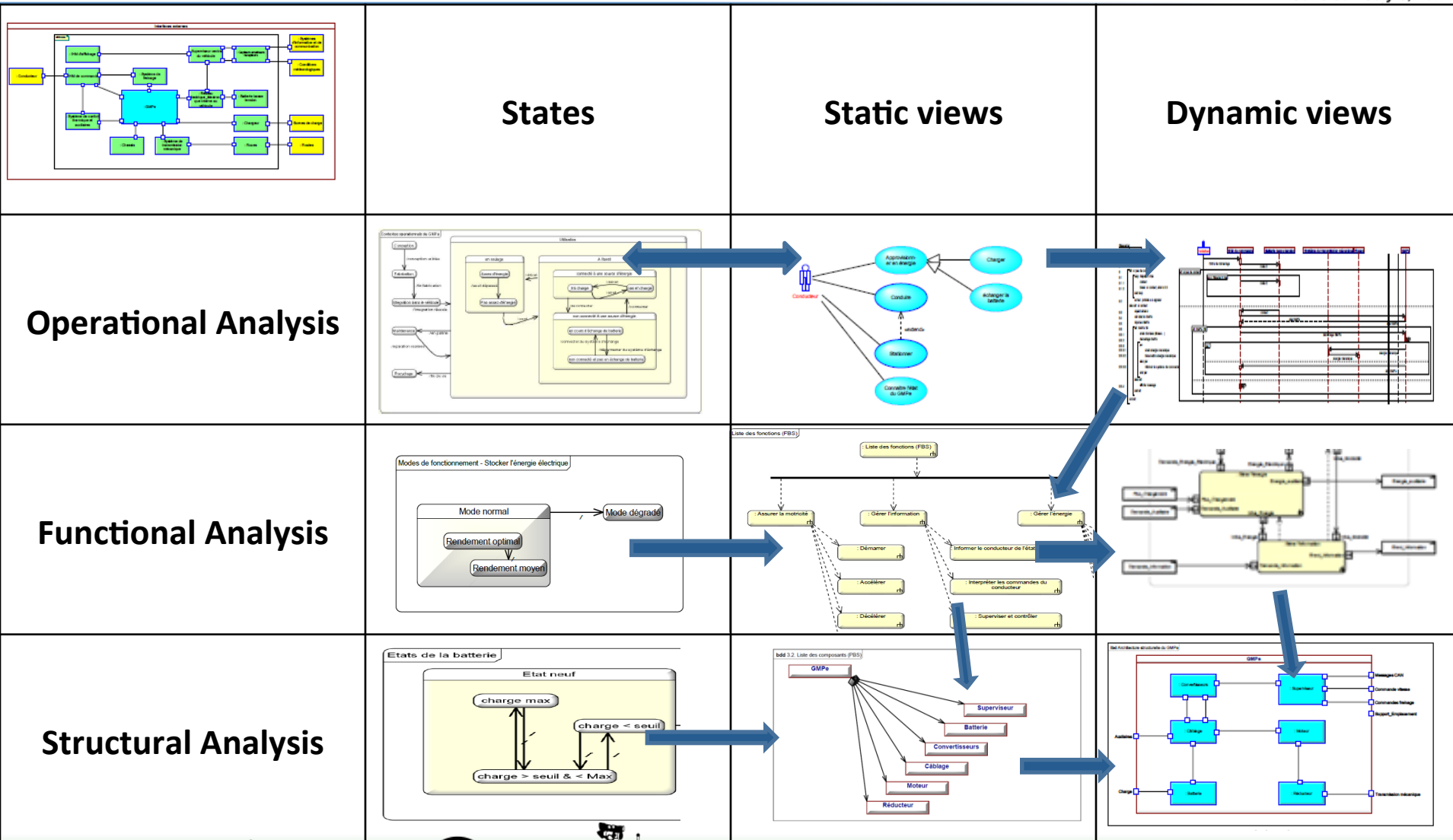
end alt2



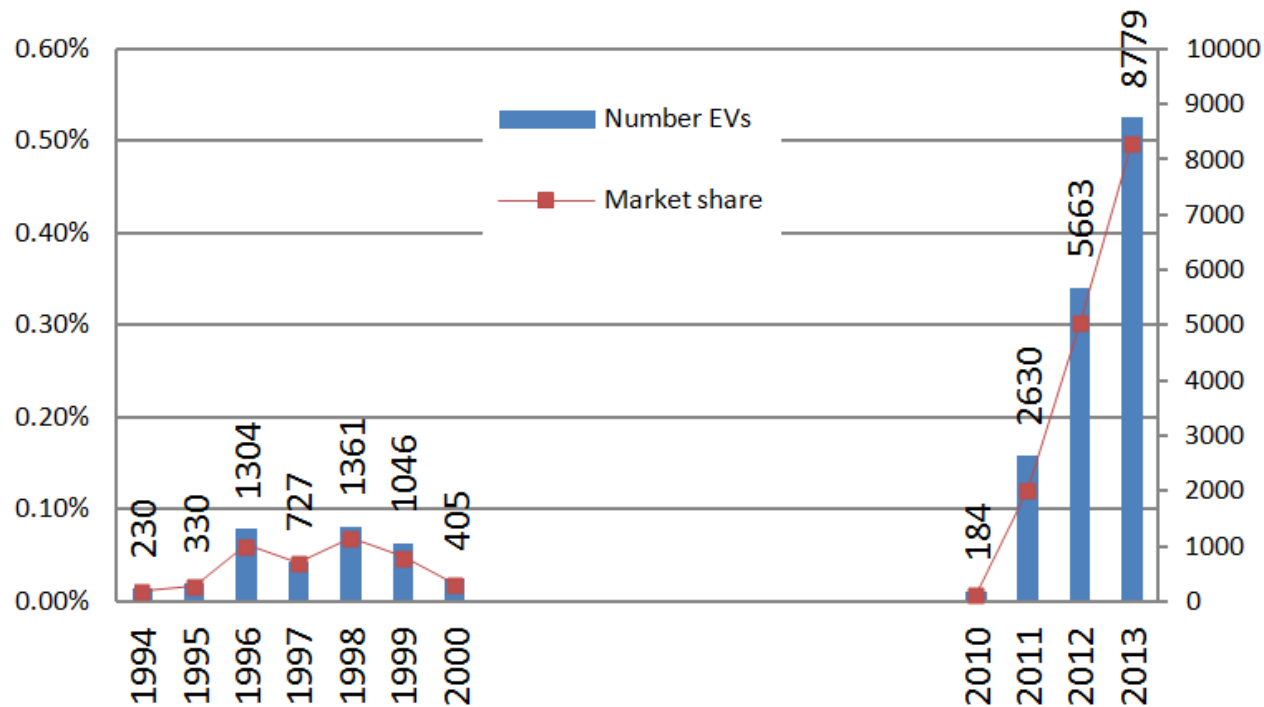
Example of scenarios associated with the use case “Recharge an EV at charging station.”



SysML Diagrams to support MBSE



An ongoing transition?



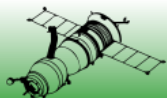
Impact on the infrastructure

Charging stations:
2 239 terminals (2013) →
97 000 terminals (2020)

Impact on labor market

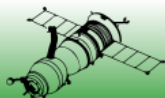
15,000 to 30,000 new direct
jobs by 2030

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



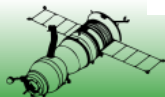
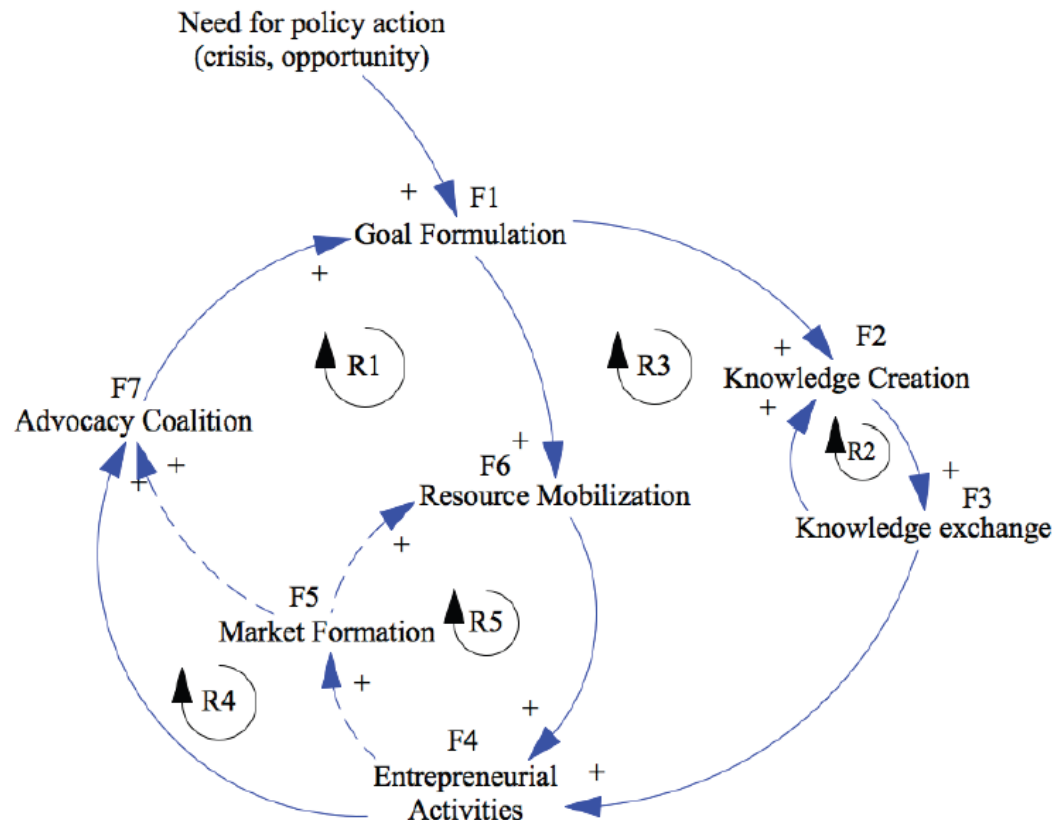
Conclusions

- 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?

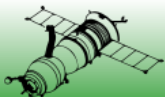


Figure 1. The efficient frontier for current and future technology contrasting sustaining and disrupting innovation.

