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The Sustainable Smart/Super Grid: Recent INSEAD Research

Paul R. Kleindorfer

Paul Dubrule Professor of Sustainable Development & Distinguished Research Professor, INSEAD
Anheuser-Busch Professor of Management Science, Emeritus, The Wharton School, University of Pennsylvania

22nd Sustainability Roundtable
November 16-17, 2009

Outline of Discussion

The GRID is everywhere: Three Illustrative Case Studies

- Energy Conservation at Pfizer Freiburg Facility
- Technology choice in the low-carbon economy
- Fleet replenishment at La Poste

Some discussion points associated with changing energy policies

- Policy challenges
- Business challenges
- Research challenges

Pfizer Goes Green at its Freiburg Facility

- Focus on Sustainability Strategy
- Research Interest on Performance-based Contracting
- Interesting interactions of carbon-grid-energy conservation
- Early History
  - Lots of low-hanging fruit identified, but not much progress for several years
  - Cost pressures and sustainability pressures finally push the “Becker Portfolio” to the top

Pfizer's Freiburg Facility has launched a sustainability program to reduce energy costs and CO^2 emissions

Introduction

Context

- Concerns with **Global Warming** caused by CO^2 emissions that are created throughout the production and consumption of carbon-heavy natural resources such as oil, gas and coal is at the forefront of the public debate.
- Companies have started to consider excessive **CO^2 emissions** not only as a driver of significant costs but also as a potential root cause of an unfavourable public image.
- At the same time, companies have recognized that reducing an organization's reliance on natural resources is a sizeable **business opportunity**. With the emergence of a trading market for regulator issued emission rights an investment that reduces a company's CO^2 footprint can be partly funded through the sale of excess emission certificates to other players who face a higher CO^2 output.

Project

- **Pfizer** as a global player in the Pharmaceutical Industry was driven by exactly these motivations:
  - Reduce primary energy **costs**
  - Enhance public image through balancing **economical, societal** and **environmental** issues
- As a consequence, Pfizer has launched a **sustainability program** consisting of a portfolio of activities to reduce and modify the company's energy footprint
- Pfizer's plant in **Freiburg can be seen as a role model** in this context having mobilized a series of sustainability projects.
- One particular project – an investment in a **Biomass plant, i.e. a Wood Pellet Boiler** – will be the subject of this Independent Study Project.

The Pfizer Freiburg Energy Efficiency Projects are Aligned with Pfizer's Broader Sustainability Agenda

Social Impact

- Beneficial reputation for both local and global community
- Increased employee motivation
- Increased legitimacy in dicussions with regulator

The impact of Pfizer Freiburg Portfolio of Energy Efficiency Projects

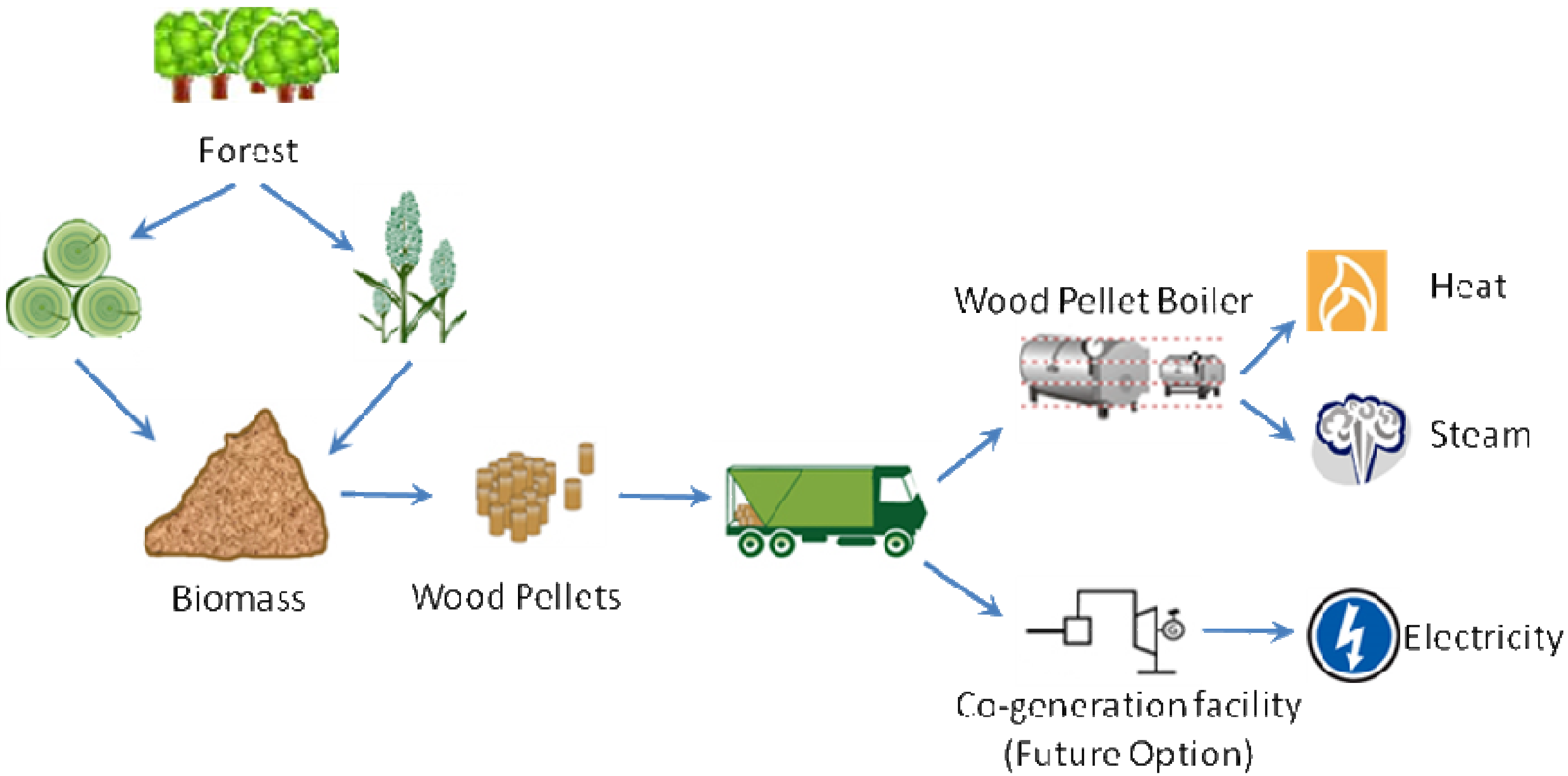
Economic/Profit Impact

- Reduced CO^2 emissions as potential revenue generator via JI credits
- Energy savings
- Potential attractiveness for sustainable portfolios

Environmental Impact

- Reduced CO^2 emissions
- Energy efficiency increase
- Spread of best practices on boilers and process heat to other Pfizer facilities and alignment with Pfizer's sustainability strategy

The Wood Pellet Boiler Project



Phase I: Boiler to Heat and Steam
Phase II: Install Absorption Cooler to augment Geothermal
Phase III: CHP Co-generation (Pellet Manufacture & Grid Integration)

The Wood-Pellet Boiler Project is one of may elements of the "Freiburg goes green" initiative

Sustainability Agenda in Freiburg

Freiburg goes Green

- Photovoltaic system
- Geothermal heating and cooling
- Wood Pellet Boiler
- Closure of energy inefficient buildings
- Waste management

Phase I

Scope

- Replacement of oil and gas fired boiler with biomass (wood pellet) boiler delivered by EC Bioenergie
- Commitment to 5 year maintenance and wood pellet supply deal with EC BioEnergie

Investment

- € 1.05 mio Capex

Outcome

- 23600 MWh oil and gas heat replaced with biomass
- 5000 t CO^2 reduction

Phase II

Scope

- Absorption Cooling to smooth summer-winter load
- Couple Pellet manufacturing with power cogeneration and resale of power to GRID

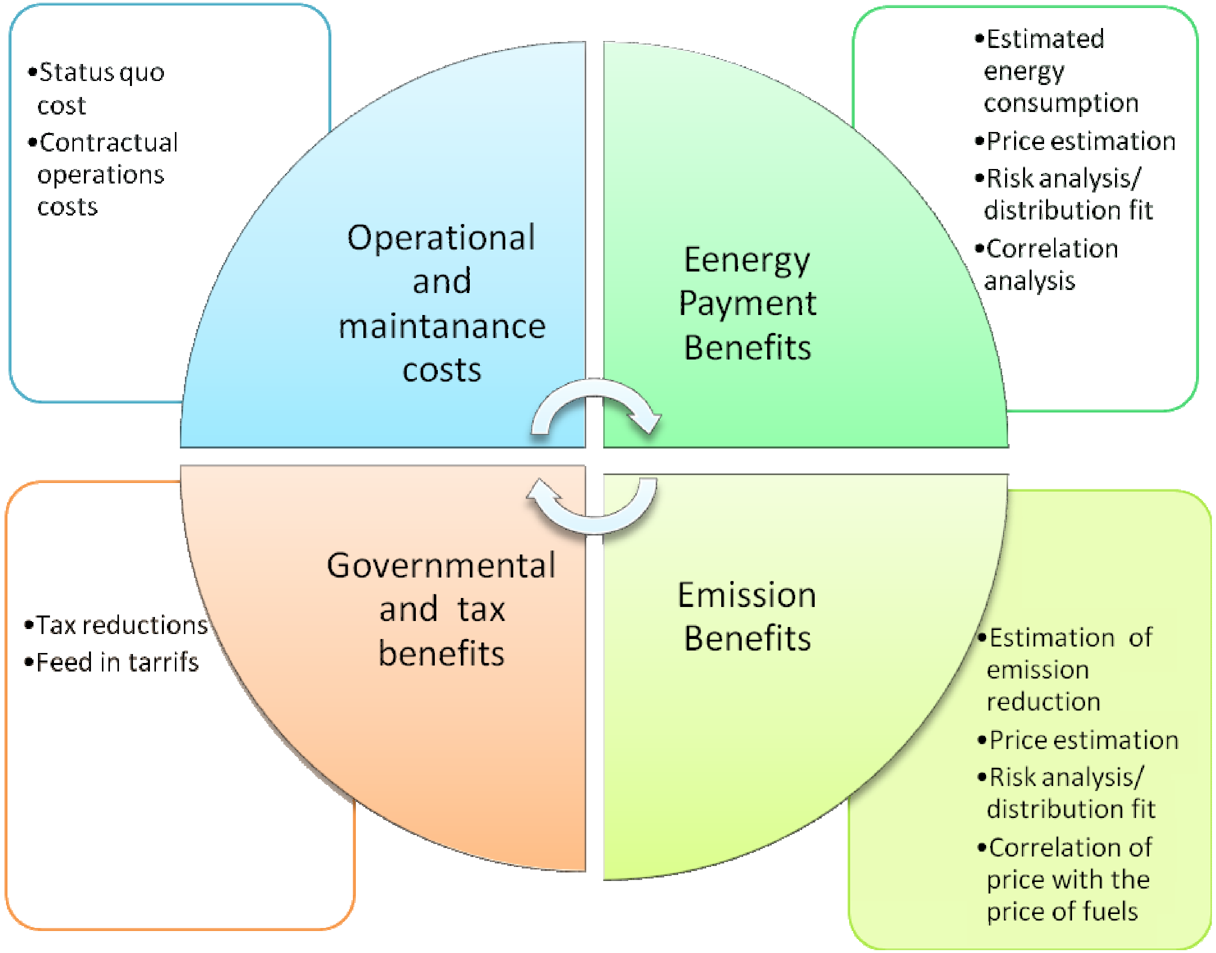
Investment

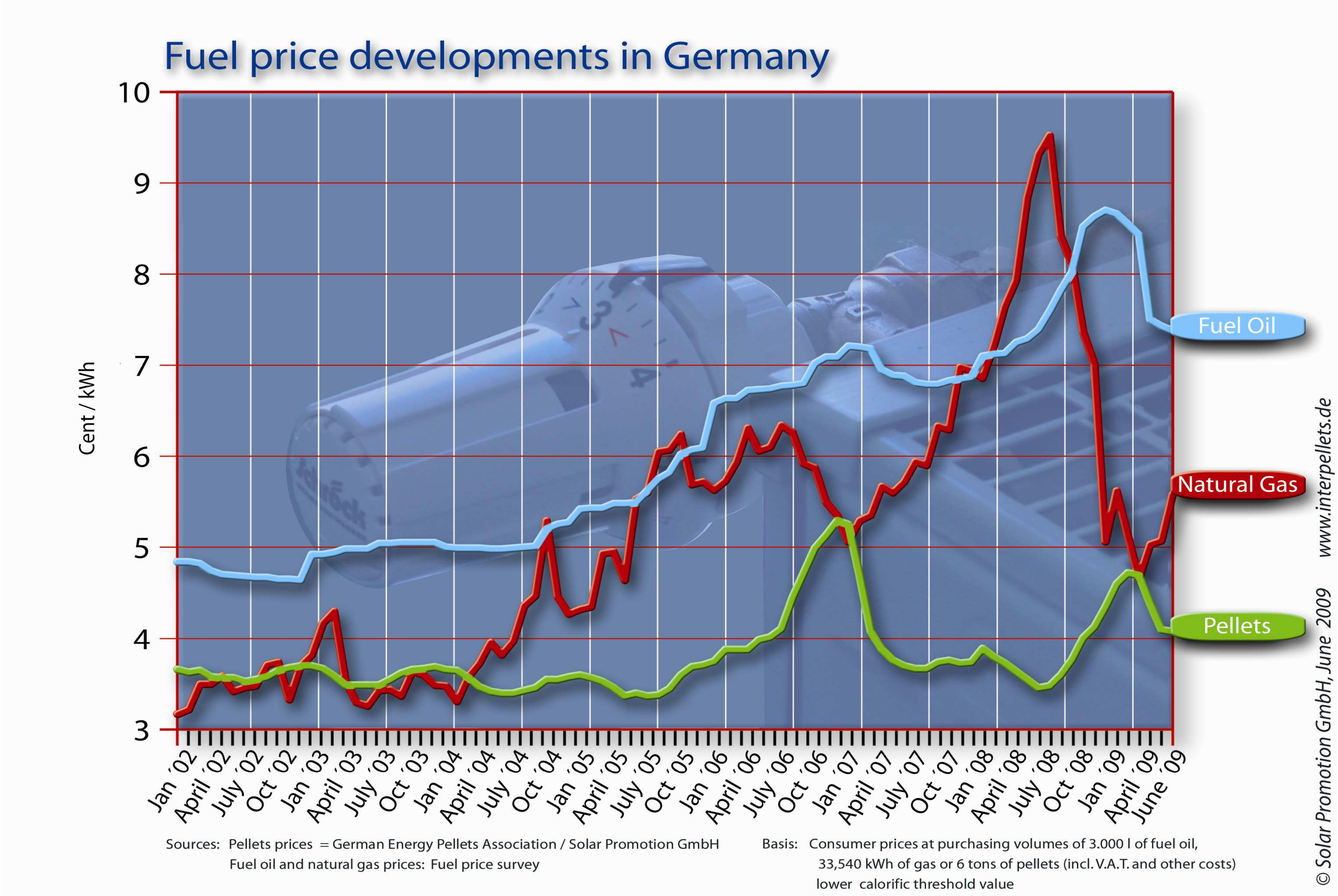
- € 4 mio Capex

Outcome

- Additional 20000 MWh biomass heat and 1600 MWh power generated
- Approx additional 5000 t CO^2 reduction

Evaluation Framework




Fuel price developments in Germany
Cent / kWh
10
9
8
7
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4
3
Fuel Oil
Natural Gas
Pellets
Jan '02
April '02
July '02
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April '09
June '09
Sources: Pellets prices = German Energy Pellets Association / Solar Promotion GmbH
Fuel oil and natural gas prices: Fuel price survey
Basis: Consumer prices at purchasing volumes of 3.000 l of fuel oil,
33,540 kWh of gas or 6 tons of pellets (incl. V.A.T. and other costs)
lower calorific threshold value
www.interpellets.de
© Solar Promotion GmbH, June 2009

Key Drivers of Project NPV

- Gas/Oil Price (base and as driver for electric power price) vs. Pellet Price in Phase I
- Buy-back revenues from CHP self-generation (Big Deal!!!) in Phase II
- Carbon Price through JI brokerage credits (5-10K tons/annum)
- Basic approach (valuation under several alternative scenarios)
  - Smoothing summer & winter loads via absorption cooling
  - Performance-based contracting on Pellet Price
  - Government regulation of Feedin/Buyback tariffs

- Outcome: Very positive on all dimensions (NPV, CO_2, Image …)

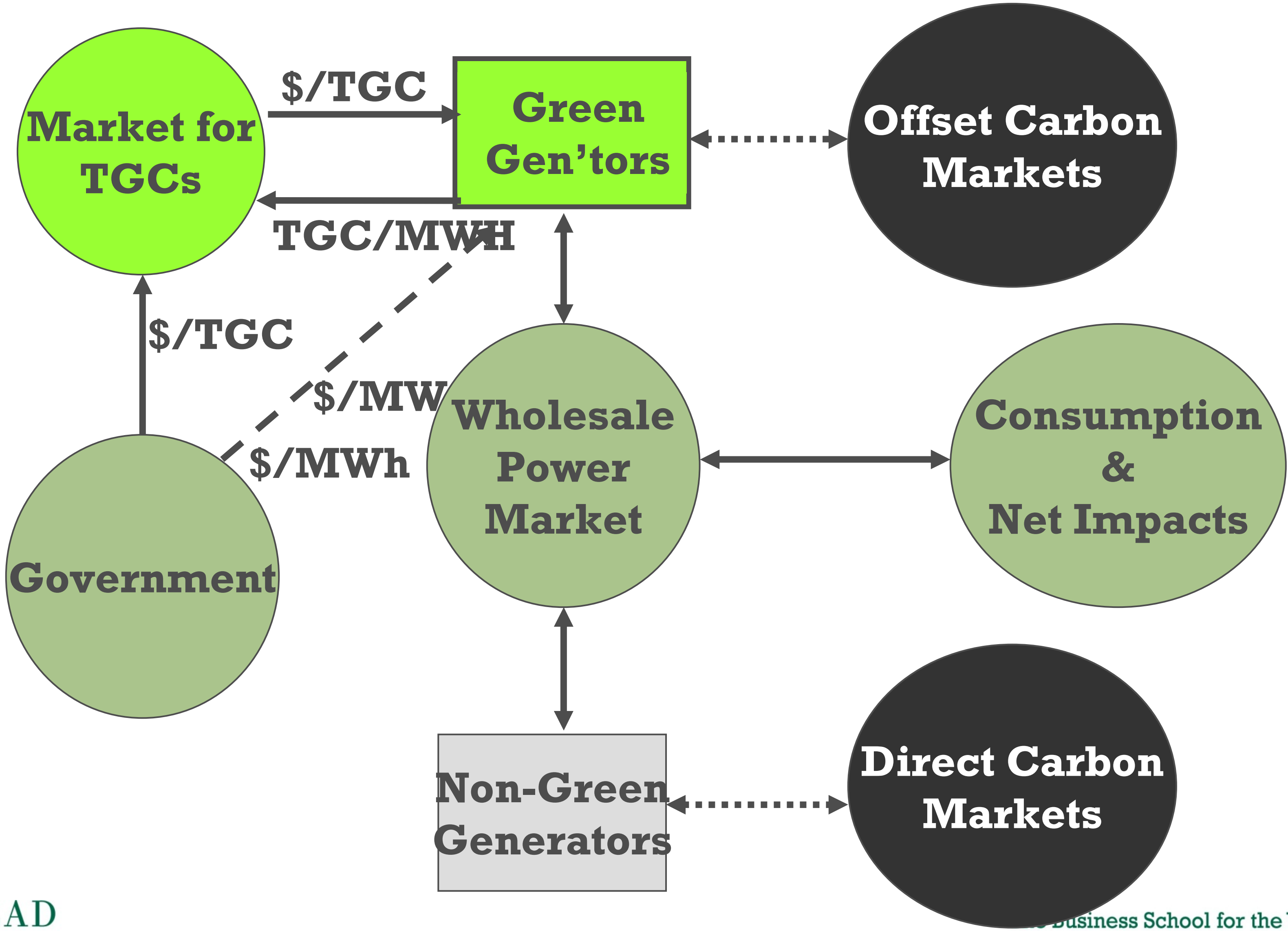
Electric Power and Grid Operations

- Early history of the GRID
  - Edison and Westinghouuse: from DC to AC
  - Purposes of (high-voltage) GRID
    - Connection of major resources such as hydro for long distances
    - Connection of regional generators to load center and DISCOs
    - Connection of adjacent Operational Control Areas for pooling, emergency response and sharing of excess power
- Characteristics of this incredibly complex, moving machine
  - Tens of thousands of tons of spinning steel
  - Totally synchronized for given frequency
  - Instantaneous balance of supply and demand required
  - Non-linear and loop flows determined by physical laws

Electric Power
Expectations and Reality

- Expectations for large growth in supply over the next 20 years, both in absolute terms and as a percent of total energy consumed
- Expectations :
  - Large amounts of Renewable Energies
  - Large amounts of decentralized energies/add-ons
  - Free Market shall reign!
- Realities
  - Grid investment in many countries has lagged
  - Many open problems on the technical side regarding integration of decentralized power sources
  - Problems of Balkanization and rights, roles and responsibilities have yet to be clarified regarding who has responsibility for paying for grid reinforcements

Electric Power and Carbon Markets



Electric Power Portfolio*

Long-run technology planning problem: Determine "optimal" investments in a portfolio of technologies having differing characteristics concerning:

Capital costs per MW (€/MW/hr)

Running costs per MWh (€/MWh)

To maximize expected profits s.t. risk constraints and capital availability.

Short-run dispatch problem: Determine optimal bidding or dispatch structure into a market to cover demand and maximize short-run profits (with additional hedge instruments added).

What's different when facing carbon/GHG liabilities?

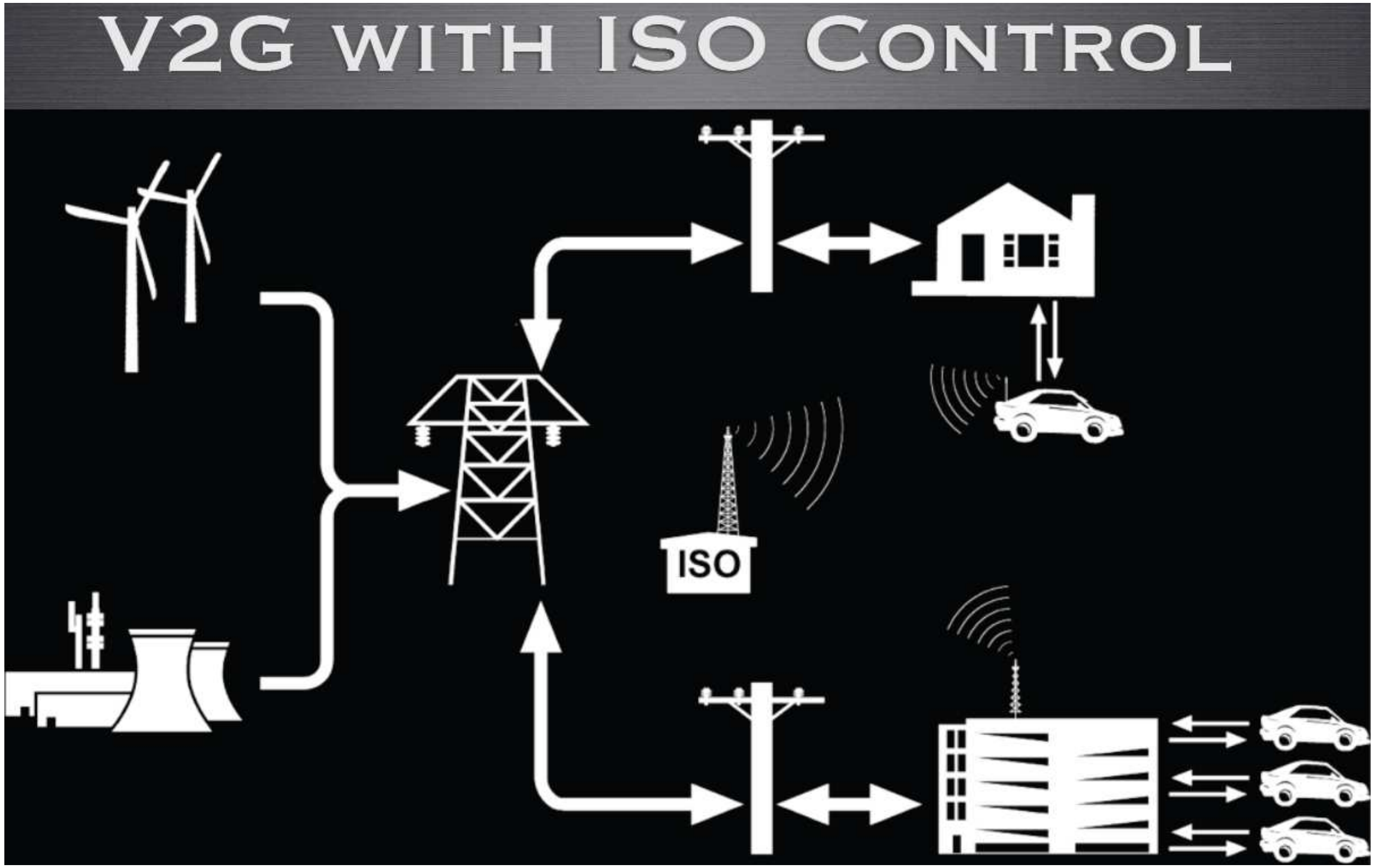
$$C_{i\tau} = c_{i\tau} + U_{s\tau} f_i = F_{s\tau} h_i + v_i + U_{s\tau} f_i$$

See Kleindorfer: http://opim.wharton.upenn.edu/risk/library/WP2008-05-11_PRK_Integrating.pdf

Research Results

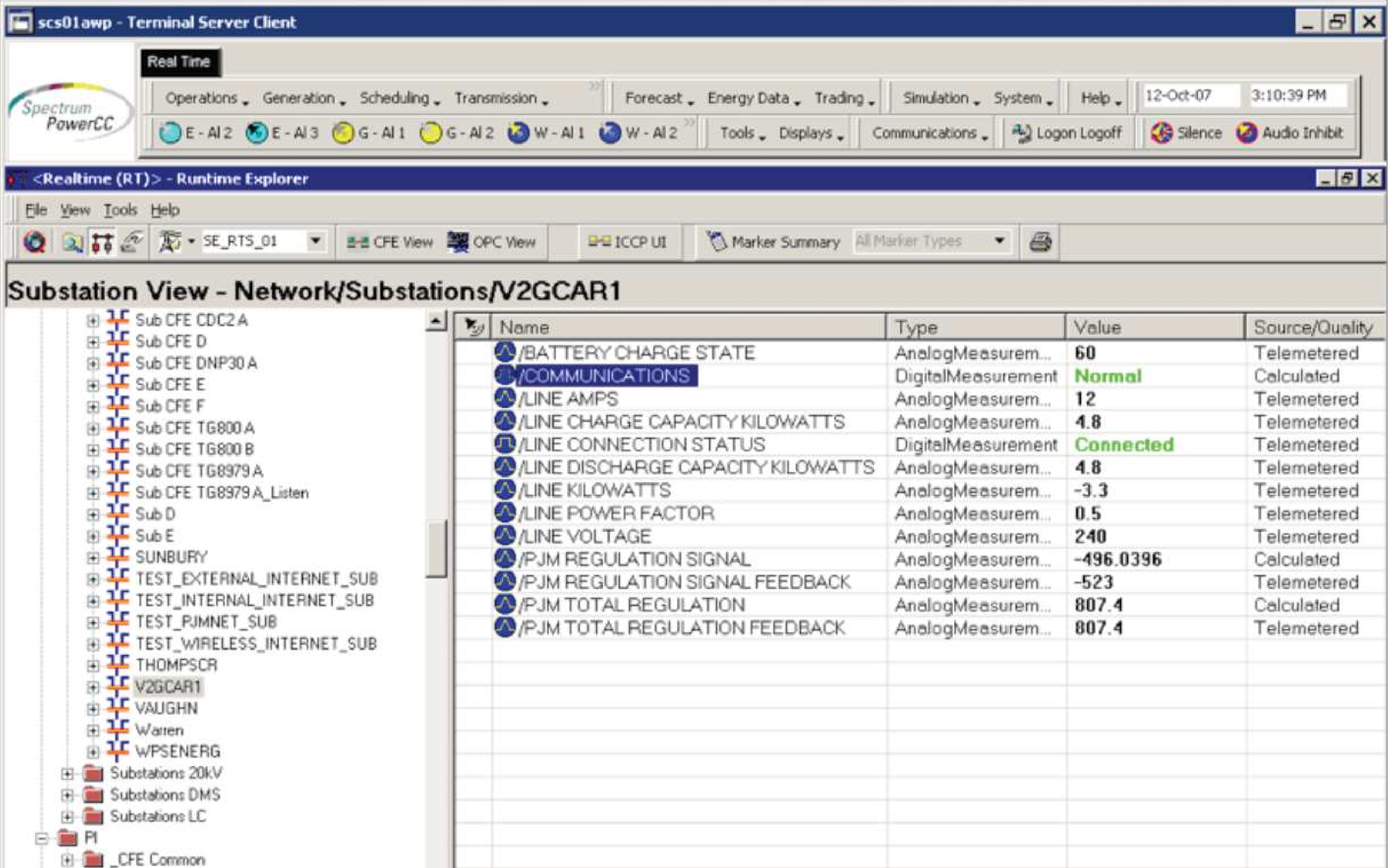
- Basic results trade off increased capital and operating costs that impact on technology mix choices as a result of CO_2 prices
  - Characterizing optimal dispatch and bidding procedures for electric power companies
  - Characterizing associated optimal carbon certificate (EUAs in ETS) risk hedging procedures, accounting for banked and allocated certificates
  - Characterizing long-term technology choices as a function of descriptions of the unfolding market for EUAs/CERs
- Note that the standing assumption here is that GRID operations are independent of these choices. However, the GRID will be fundamentally affected by expected increases in renewable energy resources, primarily because of fluctuating supplies
- Typical problem is V2G

Vehicle to Grid (V2G) and Commercial Fleets: The INSEAD - La Poste Project*

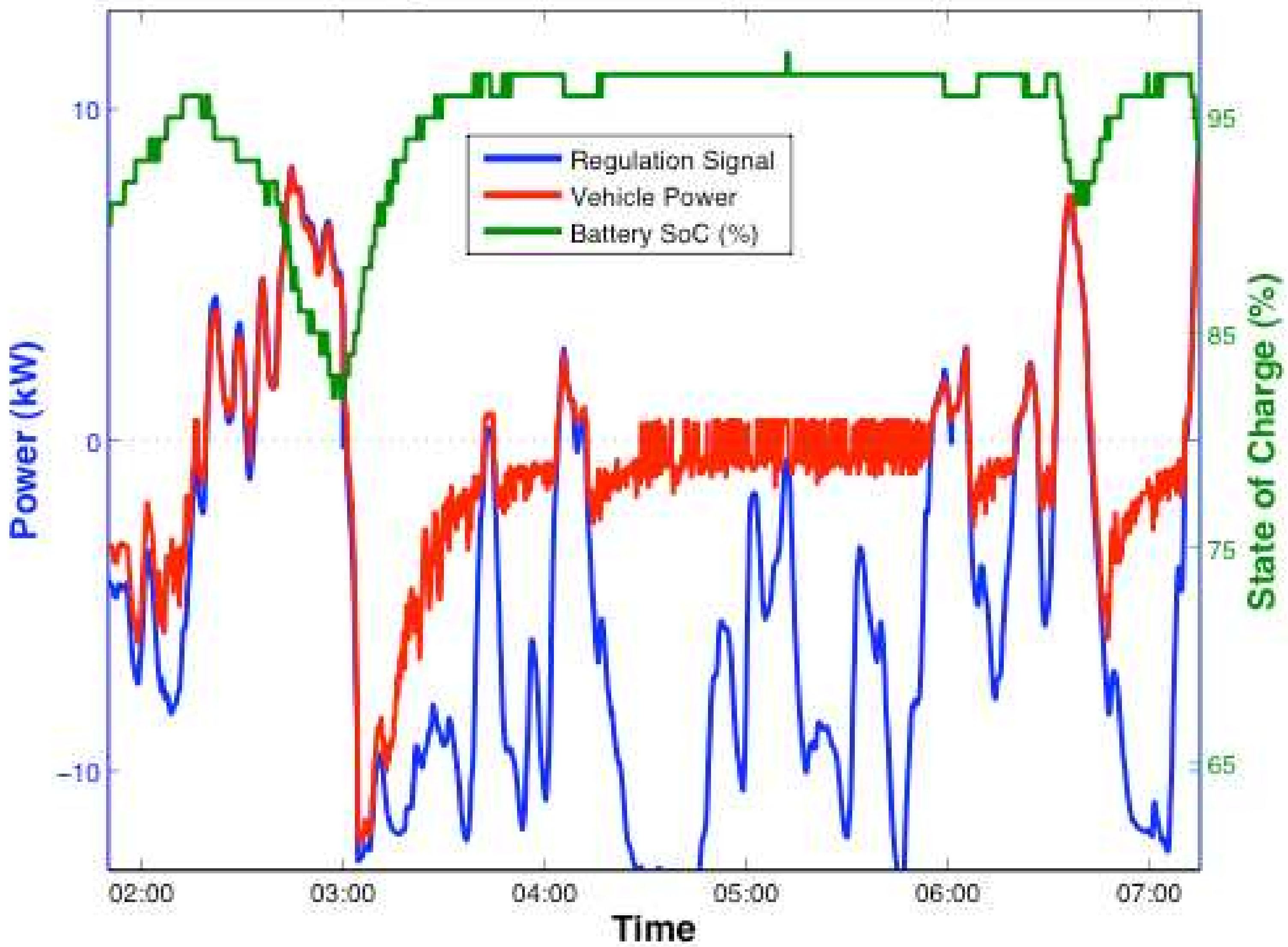


*For an introduction to V2G issues from a GRID perspective., see
http://www.magicconsortium.org/_Media/test-v2g-in-pjm-jan09.pdf

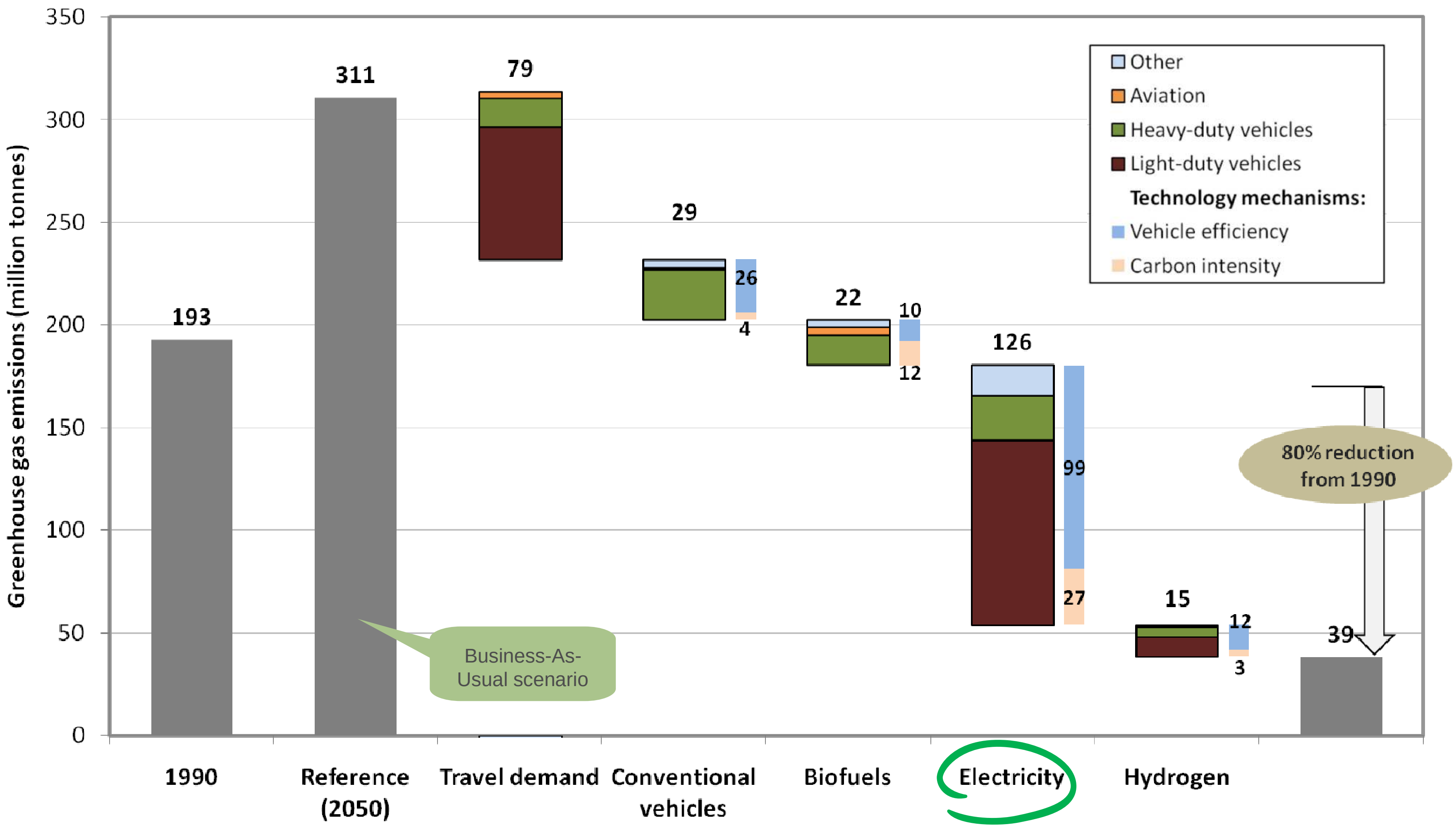
WHAT THE ISO SEES



Regulation Limited by Full Battery



Why EV's? 80% GHG reduction by 2050 possible with radical changes in transportation sector



Source: Daniel Sperling, "Transforming Transportation: two billion cars and climate-energy policy", 2009

EV initiatives prevailing in the world

- In 2008 Australia started producing its first commercial all-electric vehicle. Originally called the Blade Runner, its name was changed to Electron, and is already being exported to New Zealand. The Electron is based on the Hyundai Getz chassis and has proven popular with governmental car pools;

- In British Colombia it is legal to drive a LSV EV on public roads, although it also requires low speed warning marking and flashing lights. Quebec is allowing a three year LSV pilot project;

- Chinese government adopted a plan with the goal of turning the country into one of the leaders of all-electric and hybrid vehicles by 2012. It provides subsidies for EV research and up to 8,000USD subsidy for each EV or hybrid vehicle purchased by taxi or governmental agency;

Only 19% CO2 pollution would be reduced by replacing ICEVs with EVs, since 75% of Chinese electricity is generated with coal;

- Infrastructure provider “Betterplace” (started in 2007), together with the government, begin first efforts to make Israel the world’s first mitigated EV network. An infrastructure of 500,000 charging points and 200 battery exchange stations are planned. By 2011, 150,000 charging stations are planned;

- Ireland has reached agreements with Renault and Nissan to boost the use of EVs. EVs will be a feature on Irish roads within next time before 2011;

- UK’s prime minister Gordon Brown suggested that by 2020 all new cars sold in Britain could be electric or hybrid with less than 100g/km CO2 emissions; Large subsidies planned (3000 to 4000 Euros)
- Nissan’s Sunderland plant – the largest car factory in the UK – has been granted a £380mil EU-backed loan to develop EV technology;
- Plans announced to deliver 25,000 EV charging places across capital by 2015, in order to make London the “electric car capital of Europe”;

Source: Internet Research material (www.wikipedia.org)

The industry is responding to the trend

Following EVs are available in the sub-100 km/h class

City speed

Cars capable of at least 60 km/h (37 mph), but not 100 km/h (62 mph)

Model	Top speed	Capacity (Adults)	Charging time	Nominal range
Kewet Buddy	80 km/h (50 mph)			40 to 80 km (25 to 50 mi)
Citroën C1 ev'ie	97 km/h (60 mph)[99]	4[99]	6-7 hours[99]	100 to 110 km (60 to 70 mi)[99]
CityEl	63 km/h (39 mph)	1		80 to 90 km (50 to 56 mi)
MyCar	64 km/h (40 mph)	2	5 to 8 hrs	64 to 110 km (40 to 68 mi)
NICE Mega City	64 km/h (40 mph)[100]	4[100]		96 km (60 mi)[100]
REVA i	80 km/h (50 mph)	2 + 2	8 hrs (80% in 2 hrs)	80 km (50 mi)
REVA L-ion	80 km/h (50 mph)	2 + 2	6 hrs with onboard charger 1 hrs with external charger	120 km (75 mi)
Stevens Zecar[101]	90 km/h (56 mph)[101]			80 km (50 mi)
ZAP Xebra SD and PK	64 km/h (40 mph)	PK 2 person - SD 4	4 hours 120 volt 20 amp 220 volt compatible	40 to 64 km (25 to 40 mi)

Source: WHU Research and Internet Research material (www.wikipedia.org)

The industry is responding to the trend

Following EVs are available in the super 100 km/h class

Highway capable

Cars capable of at least 100 km/h (62 mph)

Model	Top speed	Acceleration	Capacity Adults+kids	Charging time	Nominal range	Market release date
Tesla Roadster[102]	217 km/h (135 mph) (limited)[102]	0 - 97 km/h (60 mph) in 3.9 sec	2	3½ hours	320 km (200 mi)[102]	Available
Th!nk City	100 km/h (62 mph)		2 (+ 2 optional)		170 km (110 mi)	Available
Nissan EV-02[103]	100 km/h (62 mph)		2 (+ 2 optional)		160 km (99 mi)	2010 in US
Venturi Fétish[104]	170 km/h (110 mph)[104]				300 km (190 mi)[104]	
BEV, 'Electron' [74]	110 km/h (68 mph)	0-60 in 7 seconds	4 Adults	9 hrs with onboard charger 1.5 hrs with external charger	120 km (75 mi)	Available

Source: WHU Research and Internet Research material (www.wikipedia.org)

Alternative charging methods to "home plug" are evolving

Propositions and ideas for infrastructure, storage and charging methods

better place

- On a charging station, a robot replaces discharged battery of the car with a charged one in about 40 seconds solving the problem of long charging time. 100 of such stations are planned for 2011 in Israel;
- Ambitious goals of 150,000 charging points (e.g. parking lots) by 2011 set as an attempt to ease country's the dependence on crude oil and solve political problems;
- Solar energy should be primarily used later;
- Introduction of battery leasing contracts, similar to mobile phone contracts with included km's. However, problem to find the structure, financing this, since none of the car producers would be able to give away a car "for free";
- Apart from Israel, the concept is to be implemented in Denmark, Australia, etc. in cooperation with car producers;

- **Refilling** zinc-bromine flow batteries or Vanadium redox batteries, instead of recharging;
- **Flywheel** offers an alternative storage capacity (long life-time, energy densities 0.36-0.5 MJ/kg);
- **Super-capacitors** offer an another alternative storage capacity (fast (re-) charging times). EEStor claims to have developed one with 1MJ/kg energy density (compared to 0.59-0.95 MJ/kg of a Li-Ion battery) – this would allow to charge an EV for 5 minutes sufficient to drive for 400 km;
- **Induction** coils under the road to provide battery charging while driving or on a parking lot (Project "Vision Elektromobilität 2050"). This would provide protection against vandalism of charging stations and allow transmission of control signals over the charging network. The efficiency of such methods lies at 95%;

Source: Press Research material (zeit.de)

Too few energy puffers exist to cope with the energy surplus at off-peak times in Germany

Problem

- There is more electricity produced by wind farms than it is actually used;
- Subsidized excess electricity from wind farms is exported;
- Further giant wind farms are planned at Nord- and Ostsee;

Existing Puffers

e·on — Huntorf: Compressed air energy storage (CAES) efficiency 54%. During off-peak time, the air is pumped into a cavern (about 300.000 qubic meters). At peak time, the air is released, together with natural gas to power the generator. Released air needs to be warmed to avoid freezing. This CAES is able to take up 60MW for about 8 hours and able to deliver a maximum of 290MW for two hours. A similar CAES power station is located in the USA;

EnBW — New project for 2011: Adiabatic compressed air puffer has a higher efficiency of 70% since the warmth from compressing the air is recycled;

- In Germany, there are about 30 pump-water puffers which usually have an efficiency of 75%. During off-peak time, water is pumped into a higher placed reservoir and released back through turbines at peak-time. This could be e.g. used to export the off-shore wind electricity of Bremerhafen to Scandinavia to store it there in hydropower stations;
- However for most it is more economical to fire a gas powered station to compensate for the peak-time;

Source: WHU Research & Press Research material (zeit.de)

EVs may play significant role in buffering energy peaks

- During about 90% of the time, cars (PKW) are not driven;
- Additional earning potential for car owners when using their EVs as energy buffers. Cheaper night-time electricity can be sold during day-time in the power market at a higher price;

Vehicle to Grid (V2G)

Using H2 as energy carrier

- During night-time, when the electricity is cheap, cars electrolyze H2 with their fuel-cells from water;
- At day-time, when the car is not used, fuel-cells generate electricity from stored H2 and feed it to the network;
- Provide power plants with the H2 generation capability in order to fire it later with CH2 at peak times to run the turbine/generator;

Using batteries

- During night-time, when the electricity is cheap, cars charge their batteries;
- At day-time, when the car is not used, batteries feed the electricity to the network;
- Given 2.5 million EVs in 2020, an additional storage capacity of about 25GWh would be available, enough to provide half of Germany with electricity for half an hour;

Decentralized solar and wind power production is highly complementary to decentralized energy storage facilities

Emissions from various energy & EV power systems

Energy Source	Motive Energy for Automobile	Power System	Liters of Gas Eqv./100 km *	Gr of CO2 Eqv./km *	Gr of CO2 Eqv/km- Auto Alone
Oil	Gasoline	Internal Combustion	6.7	164	140
Oil	Diesel	Internal Combustion	6.4	156	131
Oil	Diesel	Internal Combustion	5.2	129	108
EU Elect Mix **	Electricity	EV with LI–Ion Battery	6.0	87	0
Wind	Electricity	EV with Li-Ion Battery	2.2	0	0

This calculation is for a VW Gulf-sized auto

* Includes energy/CO2 for all upstream activities

** Electric Power Mix based on EU-15 use of nuclear, coal, gas, oil & renewables 2008

German Data 2008.
Source: WHU Research & Press Material (zeit.de)

Cooperating Organizations

Academic Centers

INSEAD Social Innovation Centre

Prof. Paul R. Kleindorfer

Dr. Renato Orsato

David Drake, Ph.D. student

Paul Dubrule Chair for Sustainable Development

Kuehne Foundation Chair in Logistics Management (WHU)

Prof. Dr. Stefan Spinler

Andre Neboian, Ph.D. student

WHU - Otto Beisheim School of Management

Potential Research Partners

La Poste, DPWN, …

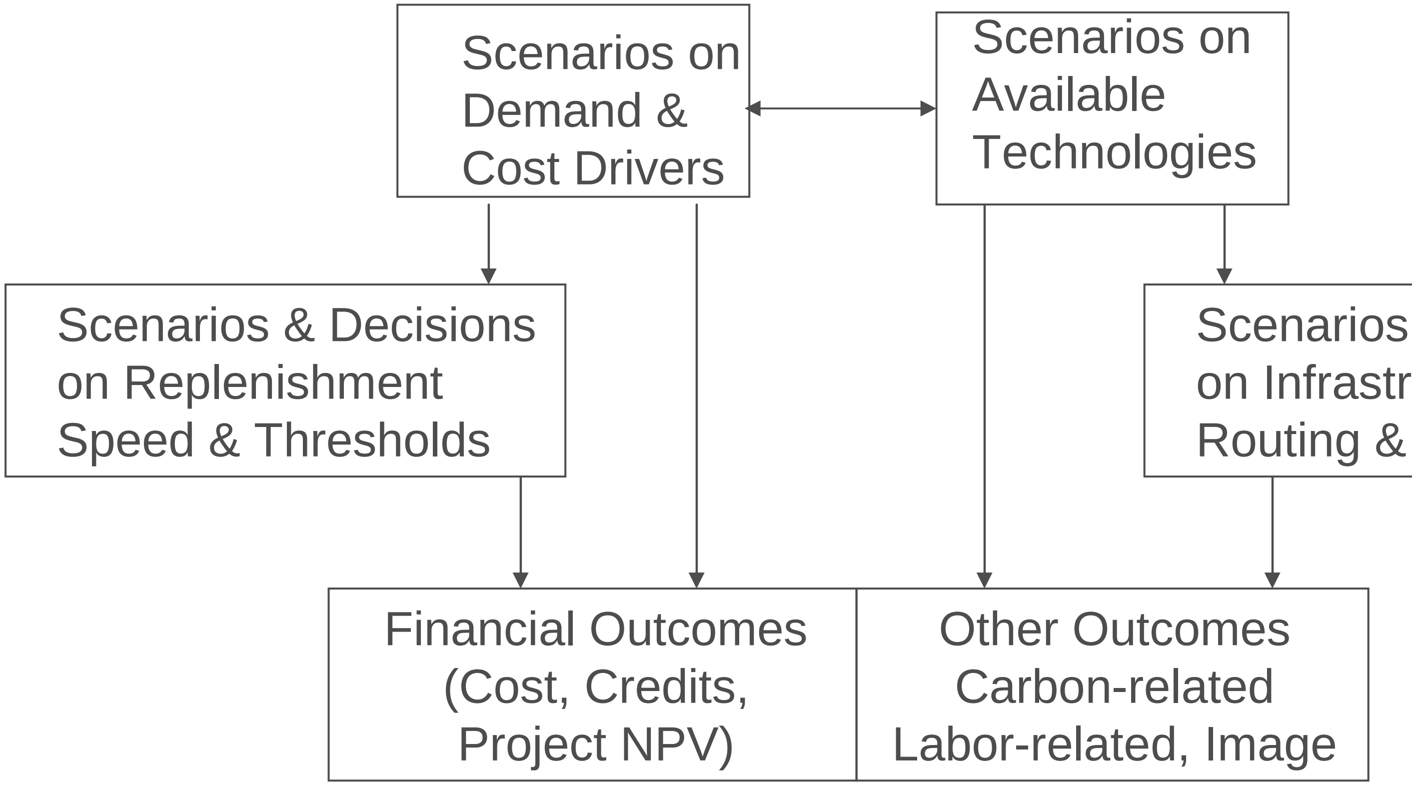
Automotive Sector: Renault, Peugeot, VW, …

Electric Power Sector, EdF, RWE, ENEL, …

Carbon Sector: Caisse des Depôts, BMWi (Germany)

The following slides on Real Options are based on on-going research with Andrei Neboian and Professor Stefan Spinler, WHU, 2009, who are academic partners on this research project

Macro-Structure of Fleet Replenishment Valuation Model



5 Poles of the Problem & Related Research Tasks

- Operator (PO)
  - Real-options framework to evaluate alternatives
  - Multiple objectives (financial, carbon, labour, …)
- Automotive Manufacturer
  - Sustainable mobility strategies and related technology scenarios
  - Interacting economies of scale with overall EV market penetration and EV pricing/design/infrastructure
- Electricity supplier
  - Basic tariff structure central to the evaluation
  - Externalities (G2V synergies)
- Carbon accounting, financing (JI) and markets
  - Impact on total PO value chain
  - Transport-specific activities
- Government
  - Taxes on oil (revenue)
  - Subsidies and regulations

Valuation Problem in Real Options Terms

Basic alternatives/options in vehicle replacement with EVs

option value

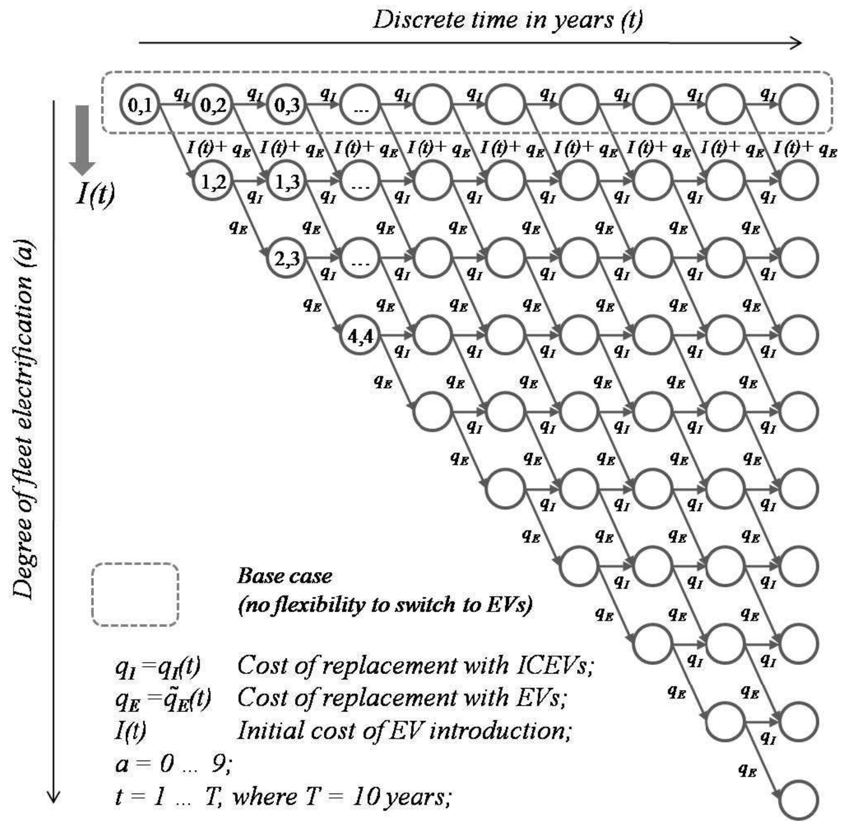
Continue using ICVs	Combination	Refurbish with EVs

- Find a practical solution to transfer investment situation into option terms;
- Identify relevant stochastic processes;
- Derive relationships to calculate present value for investment setting;
- Allow for modification possibilities to introduce more sophisticated and detailed assumptions;

Objective: Identify and value various renewal strategies under the option to replace with EVs using ROs

Representation of Decisions/Options

- Every year of operation, the fleet operator can decide on either replacing disused vehicles with ICVs or EVs – i.e binomial decision; It would seem natural to replace the entire cohort (of same age vehicles) whenever a replenishment decision is made.
- Each state corresponds to a year of operation and fleet composition (ICVs and EVs);
- Movement to the right on the option map corresponds to time progression, movement down – to increasing proportion of EVs in the fleet, represented by the degree of electrification (***a***);
- Initial movement down is afflicted with a one-time outlay of ***I(x, t)***;
- Base case (BAU scenario) could exclude the possibility to introduce EVs – i.e. every year, the fleet operator replaces retired ICVs with new ICVs;
- Each state transition is afflicted with acquisition costs of new vehicles (q_I and q_E respectively for vehicle type I and E);
- Over 10 years of operation, option map yields 512 potential paths, giving rise to option value;



The challenge is to calculate the flexibility (option) value of the setting - i.e. the option premium over the BAU case

Source: Nebojan and Spinler, WHU, 2009 (unpublished)

Model Development

Detailed Assumptions

Sensitivity Analysis
- Identify key parameters with strongest influence on option value and provide the model with more detailed assumptions governing these;

Additional stochastic variables
- E.g. Electricity price, JI-credits

Fleet age and growth/decline rate
- Log-normal distribution of the fleet age
- Alternative assumptions (possibly stochastic, reflecting uncertain demand) on fleet growth/decline rate

Battery & Vehicle Assumptions

Battery and vehicle leasing models
- Coordinate with contract structure of existing fleet operators and battery providers;
- Connect to models like Better Place to transfer some risk to 3rd Parties
- Alternative Assumptions on interface with Automotive Supplier on price drivers

Expanded Option Map

•Short-cuts to higher EV amount
- Allow for possibility to introduce more EVs than the amount of ICVs needing replacement over a single year;
- Salvage value of retired ICVs needs to be considered; Could be influenced by government subsidies

Combinatorial replacement plans
- Introduce the opportunity to replace retired ICVs with EVs and ICVs; Need to discuss also alternative vehicle types for different postal operations

Additional replacement options
- Biofuel, LNG, LPG, and Hydrogen fueled vehicles and underlying stochastic variables. PHEVs may be even simpler to introduce then other options, requiring additional stochastic parameters;

Studies on other Poles: Central to Efficiency

Automotive Sector

- Develop strategy, technology and infrastructure support map for EV space based on Orsato (2009)
- Market and production economies of scale between fleet replenishment and other vehicle sale
- Chassis and traction systems interactions across fleet and other vehicle sales

Electricity Supplier

- V2G issues and interruptible tariffs (note daytime operations, but integration with wind power troughs and evening peaks are still very relevant)
- Locational and transmission issues related to wind parcs and battery reserves are key grid issues

Carbon Credits

- JI credits and brokerage
- Simple modeling (e.g. per Kleindorfer & Li framework on carbon credits for electric power)
- Possible governmental subsidies
- Confluence with PO carbon footprint targets (Buc et al. framework paper on USPS approach is relevant)

Potential results/interests of this research?

- Multiple-stakeholder risk sharing: Structuring of the interorganizational risk and benefit profiles and determination of total benefits and instruments for risk sharing (e.g. in pricing of initial leased vehicles, tariff setting with EdF, CO2 credits, …)

- Evaluating the possibility of jump-starting move to sustainable transportation by conversion of major fleet owners to electric vehicle fleets

- Note: A significant part of the payoff could arise from V2G operations, integrated with renewables/wind--Making good on this will require significant investments in the grid to allow load-following battery reserves to function properly.

Reflections on Research Case Studies

- These three case studies indicate the central role of a "smarter grid" in the next few years
  - Pfizer: Major part of the value proposition is resale of CHP power to the grid—this is one of many decentralized energy projects
  - Electric Power Technology and Dispatch: Carbon drivers are pushing hard for growth of renewable energy sources and for increased dispatch sensitivity to carbon intensity of power sources
  - La Poste: Synergies with wind power are significant IF they can be profitably harnessed… the grid will be a major aspect of determining this
- Discussion Points and Challenges
  - Policy
  - Business/Investment
  - Research

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