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The effects of carbon taxes on investments in Smart-Grids and consumer engagement

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Main theme

❑ **Economics of Climate Change and the Electric sector**

- Anthropogenic emissions are among the main causes of CC + growing public concern
- Why the electric sector?
    - Most carbon intensive sector
    - Increasing demand
    - Long lived capital
    - Availability of low-carbon technologies

  Though now it is subject to strong external constraints**:**
    - Fossil fuels
    - Nuclear power
    - Renewable energy

  → need for a profound change/qualitative innovation

❑ **Sustainable Innovation** (Environment, Economics, Society)

❑ **Innovation of the electric power grid**

Innovation of the electric power grid

Innovation of the electric power grid

❑ Drivers:

- climate change
- quality of service
- cost reduction
- energy independence/security

❑ Options: Super-Grids and Smart Grids

Super-grids:

- connect inter-regional electric power systems **facilitating trade** among regions
- allow to take **advantage of distantly located energy sources** to minimize the costs of electricity.

Smart-grids:

- exploit **local electricity production possibilities** by engaging with **"empowered" consumers**
- increase the use of **distributed** renewable sources
- Improve **grid operations**, management and quality & reliability of service and possibly change the architecture of the system (from distributive to integration of local self-sufficiencies)

Both technologies entail a modernization of the electric grid and allow an increase in the electricity share of renewable sources, even if they have very **different implications, organizational dynamics and cultures**:

- Super: deal with a centralized setting, large investment projects, no interaction with the end user;
- Smart: favour decentralization and end-user involvement and empowerment.

→ they need to be addressed and analysed with **different methods and tools** that allow to capture all relevant dimensions.

Aim

- **General Objective:** Analyse the role of in the innovation of the power system via both Super and Smart Grids in climate policies.

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- **Specific focus on Smart-Grids**

  - Four dimensions of Smart-Grids:
    Technological improvements
    1. Management efficiency gains
    2. Larger share of renewable sources is manageble
    Consumer as a new generation source
    3. "tangible" household production (PV, micro-wind)
    4. "intangible" household production through demand management (behavioural change)

  - CSP powered Super-Grids (Massetti and Ricci, 2013);

Methodology

METHODOLOGY: Integrated assessment model + Multi-Criteria Analysis

- **WITCH:** World Induced Technical Change Hybrid model

  To evaluate optimality of investments of Super and Smart Grids in a unique platform able to compare them also with other mitigation options.

SUPER-GRIDS

- CSP Electricity generation

- Long distance transmission

- Electricity trade Europe-MENA

SMART-GRIDS

- Investments in ICT-zation of the grid

- Customer relation management cost reduction

- “real” electricity generation by households

- “virtual” electricity generation by households

- Relaxation of the penetration limit for renewables

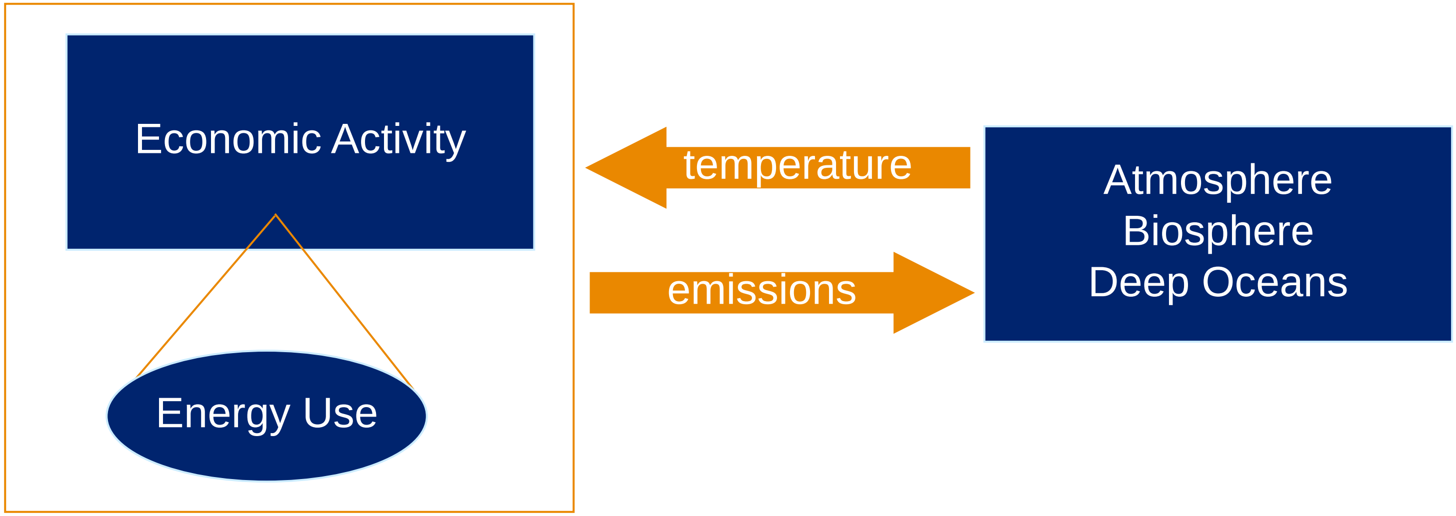
- **MCA**

  Extend the analysis to include also other **evaluation criteria** in order to have a multidisciplinary approach that takes into account the different impacts that different energy strategies may have on that important for **policy** decisions.

The WITCH model

METHODOLOGY: extention of the WITCH Model (Bosetti *et* al., 2006)

- **Hybrid I.A.M.:**
  - **Economy:** Ramsey-type optimal growth (inter-temporal)
  - **Energy:** Energy sector detail (technology portfolio)
  - **Climate:** Damage feedback (global variable)



SCOPE: Specific focus on Europe and USA

Smart–Grids in WITCH

Investments in the innovation of the grid (I_{SMART}) accumulate as follows:

$$CUM\_I_{smart}(n,t+1) = CUM\_I_{smart}(n,t) + I_{smart}(n,t)$$

For each region and at each time step, the level of innovation of the power system is evaluated with an index:

$$INNOV(t,n) = CUM\_I_{smart}(t,n) / SGI(t,n)$$

with SGI being the cost for a complete "smartening" of the grid

once a certain level of investments is reached, it is possible to make:

- Investments in "home production systems" (I_{hp})
- Investments in "behavioural triggers" (information) (I_{bc})

$$K_{PV}(n,t+1) = K_{PV}(n,t)(1-\delta_{PV}) + \frac{I_{PV}(n,t)}{SC_{PV}(n,t)}$$

The level of electricity generated depends on investment costs, O&M costs, capital and efficiency and "SWITCH"

$$EL_{PV}(n,t) = min\{\mu_{PV,n} \cdot K_{PV}(n,t); \theta_{PV} \cdot O\&M_{PV}(n,t)\}$$

$$EL_{DSM}(n,t) = \{\mu_{DSM,n} \cdot K_{DSM}(n,t)\}$$

All three investments and $O\&M_{hp}$ costs are subtracted from consumption at time t, that influences utility

Simulation scenarios

- **Business as usual** (“Bau”)
  no climate policy, i.e. no restriction on GHG emissions

- **Unconstrained Stabilization** (“U-Stab”);

- **Constrained Stabilization with limit on Nuclear Power** (“NC-Stab”),
  expansion of Nuclear Power that cannot exceed 2005 levels;

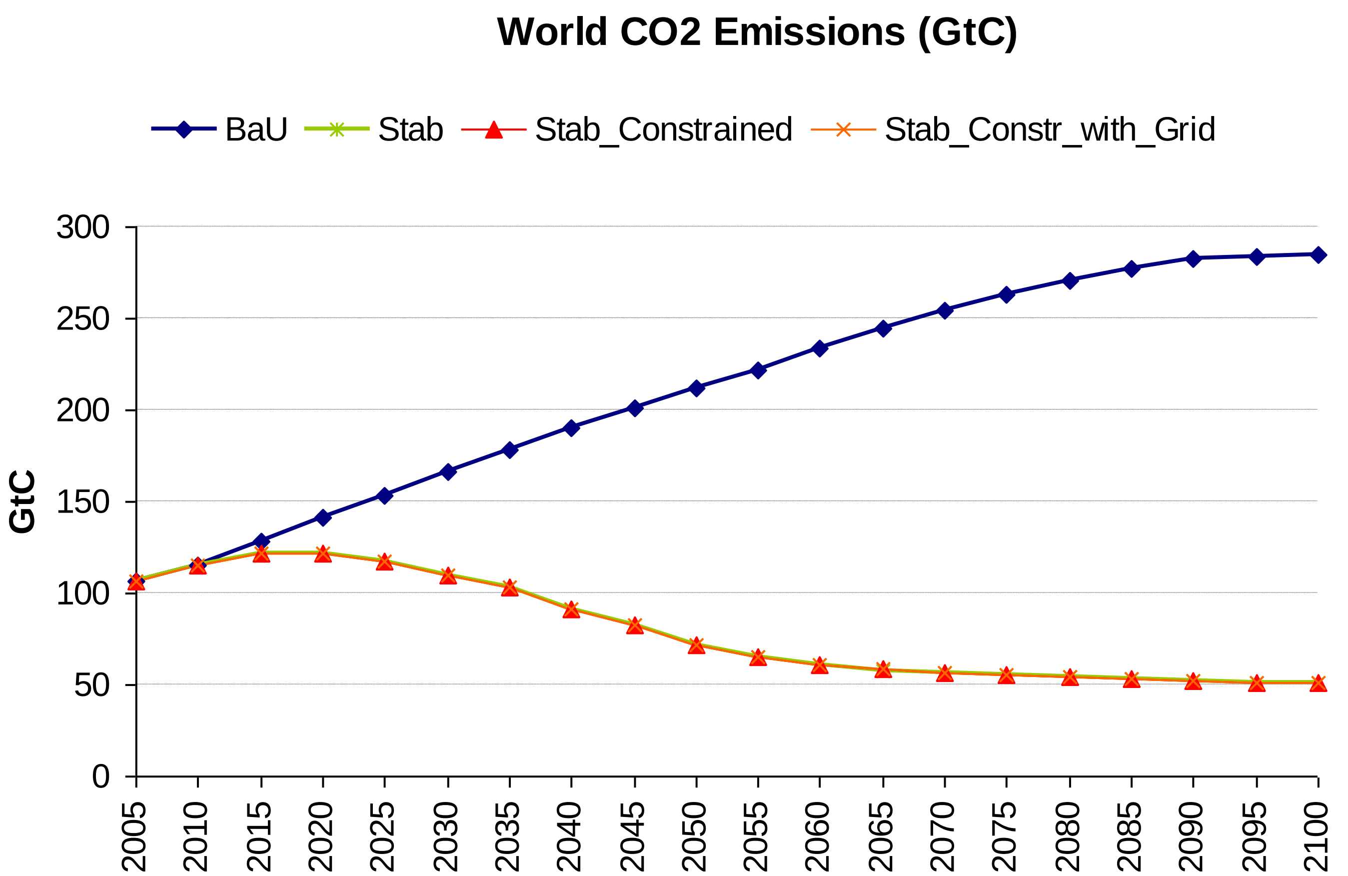
- **Constrained Stabilization with limit on CCS** (“CC-Stab”),
  there is no possibility of Capturing and Storing CO_2 (CCS);

- **Constrained Stabilization with penetration limits on Nuclear power and CCS and on the import of CSP from MENA** (“INCC-Stab”),
  import constraints (15% of electricity consumption)
  plus constraints on Nuclear power and CCS activities.

<u>Policy Scenarios:</u>

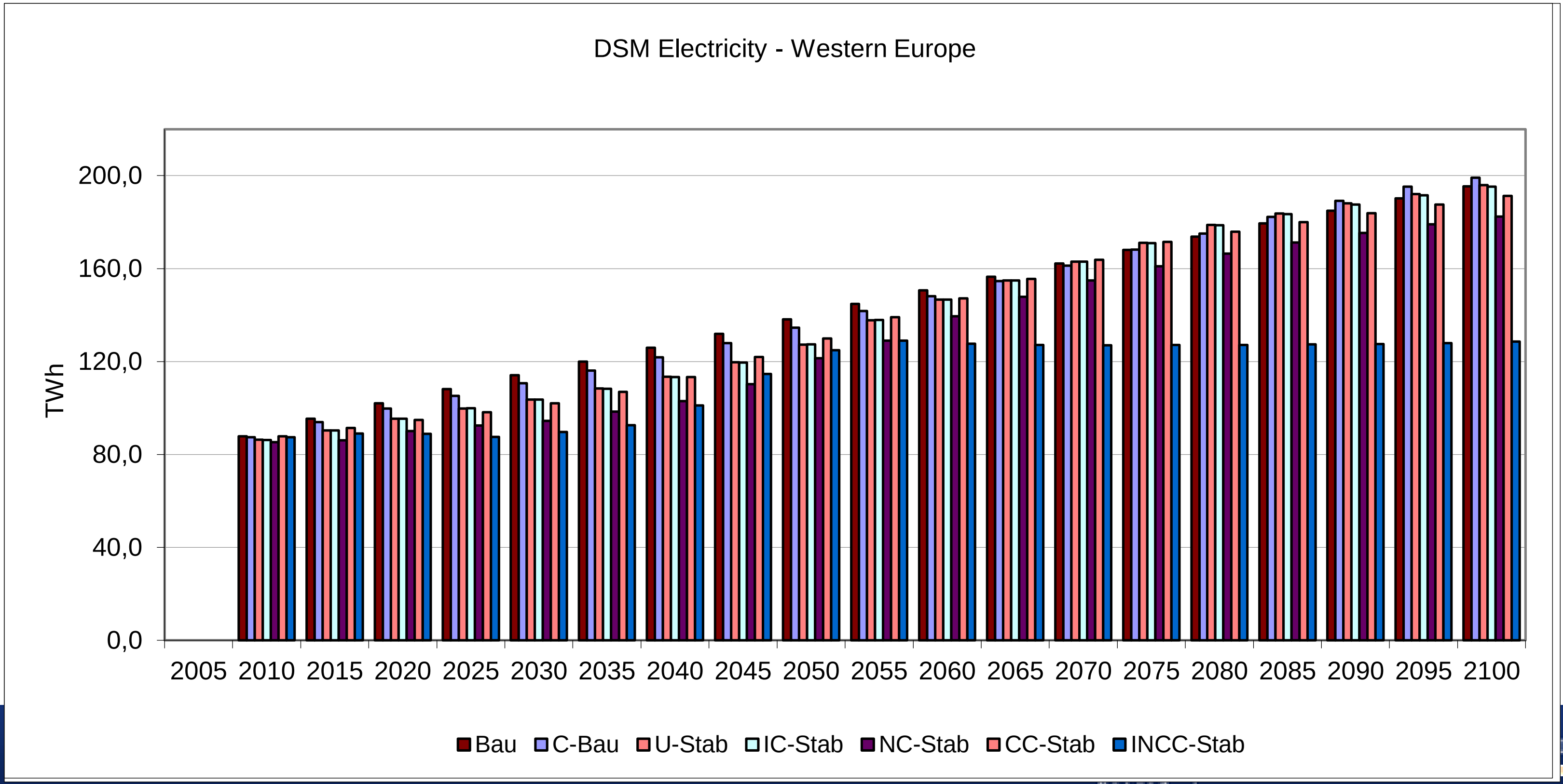
- **Stabilization target:** All GHG atmospheric concentration stabilised at 535ppm-CO_2eq by 2100
- **Stabilization instrument:** a world carbon market that equalizes marginal abatement costs worldwide. Carbon allowances are allocated according to the “Contraction and Convergence" scheme.

Carbon emissions

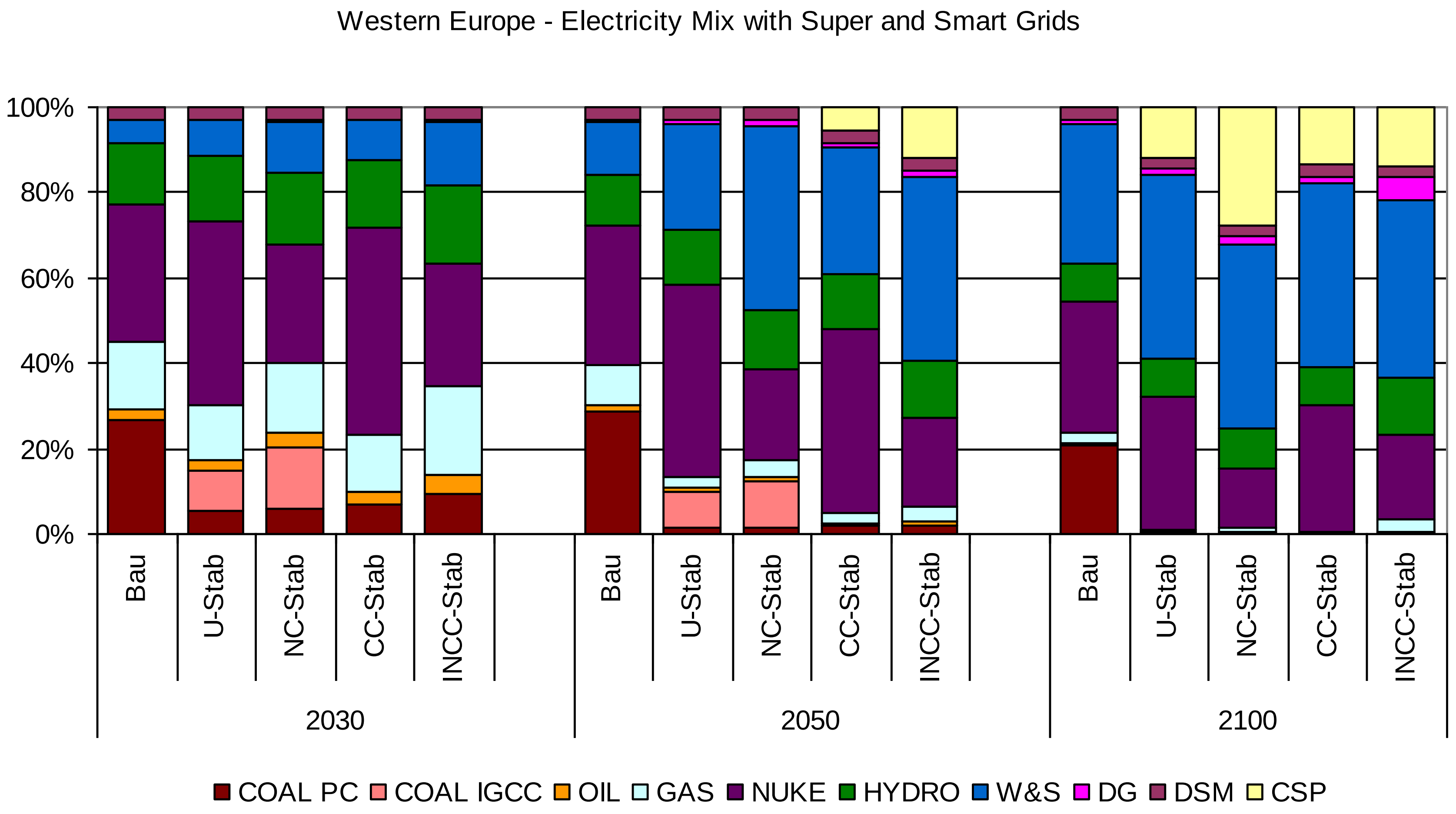


Investments

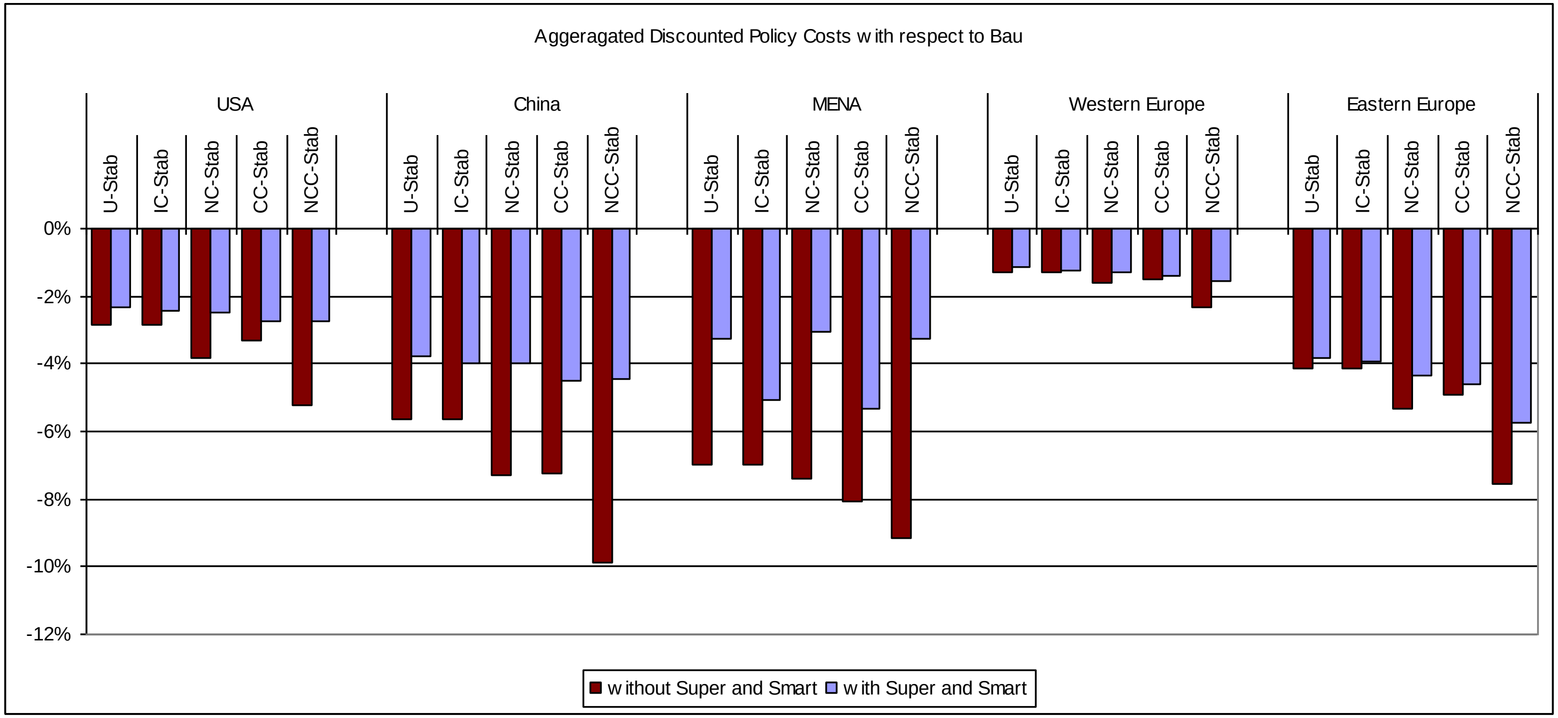
- Investments in Smart-Grids from 2010 all scenarios (full 2020) – in Super Grids in 2035-2050
- Management gains, investments in DSM and in residential PV start early; limit on renewables is extended in 2035-2050
- Even if we exclude the benefits, investments in Smart-Grids, DSM & residential PV start in 2010 (slower)



Simulation results



Policy costs



S+S Grids: main results (1)

Quantitative analysis:

We have integrated both Smart and Super in a **unique platform** to compare them, and assess their integrated **economic potential with respect to other mitigation options**, under different scenarios.

To find that:

» for Smart Grids, the **time** to invest is **now**: the managing gains are large with respect to costs and generation by consumers, although at quite low levels, is optimal. The impact the electricity mix by allowing a greater use also of medium and large scale renewable domestic plants.

» for Super Grids the timing seems to be different (around 2035-40) but **shares** become very large.

» the **stabilization option value** of the innovation of the network is very large (up to 23-64%)

Multi-dimensional analysis

Construction of a multi-criteria sustainability function that takes into account the different impacts that the energy strategies can have on many aspects important for policy-makers (here we focus on Super and Smart Grids):

Sustainability Function = f (Env, Tech, Energy, Econ, Organiz, Society, Geop)

- Environment
  (Large plants and transmission lines vs. already covered surfaces or local opportunities)
- Technology
  (Engineering challeges vs. engineering + ICT)
- Economy and Finance
  (Small number of large players vs. large number of different sized players; new market opportunities also for non energy-related business and for consumers!; new sources of financing; optimization of local opportunities)
- Organizational relevance
  (Centrally planned system vs. integration of local 'ecosystems')
- Society
  (small impact vs. new role/empowement of citizens, new opportunities to diffuse environmental and energy culture both with potential spillovers to other sectors)
- Geopolitical relevance
  (large vs. Impact, depending on the level of diffusion)

For now the analysis is qualitative, we will though extend it to identify performance indices for each argument

S+S Grids: main results (2)

Qualitative analysis:

- **Super-Grids** belong to a **more traditional** energy management context/culture.
- **Smart-Grids** instead open towards a **more complex context/culture**, closer to the concepts of **Knowledge Economy** and the related Knowledge Society, where the role of the consumer is changing from passive to active. Smart-Grids, in fact, facilitate a smart energy use and the **consumer/citizen empowerment**.
  - →New roles and relations in the market for “old” players (consumers may become producers)
  - →New players are able to enter the market and offer more sophisticated goods and services.
  - →More players and of different sizes, that can also find innovative ways of interacting.

  This has effects also on the structure of system, on society.
- The **complexity of the system** assessment and management is increased because the variable of human behaviour is introduced in the picture **→NEW TOOLS FOR ASSESSMENT** that consider new dimensions **explicitly**
- **Potential conflict**: innovative policies for reward system and system integration (regulatory agency)

Final Remarks

- Our results seem to confirm the structural importance of the innovation of the power network for all possible future scenarios, in a carbon constrained world.

- What emerges to be particularly interesting is the timing

- To exploit their full potential these technologies should interact synergically. The fact that they are characterised by very different actors and organizational structures and cultures may induce the risk of one prevailing on the other.
In particular, if Super-Grids prevail over Smart Grids, the opportunity of engaging with the end-users could be lost. The potential of a more distributed empowerment – that is spreading in many sectors especially services – is, also in this case, very important as consumer involvement is necessary to tackle the issues of climate change.

- The importance of a multi-dimensional analysis capable of capturing many aspects of a complex phenomena. A first step has been to extent the quantitative analysis of the economic and CO_2 mitigation potentials to consider also additional aspects even if in a qualitative way.

Future Steps

Next Steps:

- evaluate other policies

- extend the simulation in the WITCH model of the effects of Smart-Grids to consider for example demand response and other consumption management options (data);

- include in all the analysis commercial activities, public buildings and non-electricity related industries.

- extend and operationalize the multi-disciplinary analysis

Sost. Function = f (Env, Tech, Econ, Organiz, Society, Geop).

Thank you

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