The economic consequences of Maladaptation

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ECRAN/TAIEX Workshop on risk and vulnerability assessment and adaptation planning in the energy sector.

Tirana (Albania), 16-17 April 2015

1. A primer on (energy) economics

> What is the goal of a **responsible** (energy) public policy?

> > ***Welfare***

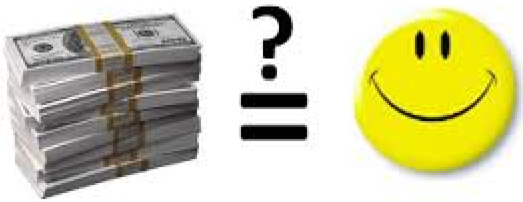
> **Economics**: maximize welfare with limited resources

> Welfare can be **measured** through utility

> > But utility can only be ranked

> Solution: use a proxy!

> > GDP



> Focusing on GDP risks ignoring intangible, relevant sources of welfare (e.g. environment)

> Creating GDP may have negative **byproducts**

> > We know one very well: ***Climate change***

2.

Energy policy: climate and environment and economics, oh my

> Mitigation

"reduce GHG emissions and enhance sinks"

> **Adaptation**

"adjustment in natural or human systems to a new or changing environment"

Intertwined

> **'20-20-20' goal**. By 2020:

> 20% increase in energy efficiency

> 20% reduction of CO_2 emissions

> **and 20% renewables** (national targets 2009/28/EC)

> Climate variability and uncertain *resource endowments*

> ↑ *Extreme events* –focus on critical infrastructures

> Incidence on *demand*

> **Europe 2020** strategy for smart, sustainable and inclusive (green) growth

> 20% renewable energy => 417 000 jobs

> 20% increase in energy efficiency => 400 000 jobs

> *It all depends on **how** we mitigate and **adapt***

Climate change impacts on energy systems (Schaeffer et al., 2012

Energy sector	Climate variables	Related impacts
Thermoelectric power generation (natural gas, coal and nuclear)	Air/water temperature	Cooling water quantity and quality
	Air/water temperature, wind and humidity	Cooling efficiency and turbine operational efficiency
	Extreme weather events	Erosion in surface mining
		Disruptions of offshore extraction
Oil and Gas	Extreme weather events	Disruptions of offshore extraction
	Extreme weather events, air/water temperature, flooding	Disruptions of on-shore extraction
	Extreme weather events, flooding, air temperature	Disruptions of production transfer and transport
	Extreme weather events	Disruption of import operations
	Flooding, extreme weather events and air/water temperature	Downing of refineries
		Cooling water quantity and quality in oil refineries
Biomass	Air temperature, precipitation, humidity	Availability and distribution of land with suitable edaphoclimatic conditions (agricultural zoning)
	Extreme weather events	Desertification
	Carbon dioxide levels	Bioenergy crop yield
Hydropower	Air temperature, precipitation, extreme weather events	Total and seasonal water availability (inflow to plant's reservoirs)
		Dry spells
		Changes in hydropower system operation
		Evaporation from reservoirs
Demand	Air temperature, precipitation	Increase in demand for air conditioning during the summer
		Decrease in demand for warming during the winter
		Increase in energy demand for irrigation
Wind Power	Wind and extreme weather events	Changes in wind resource (intensity and duration), changes in wind shear, damage from extreme weather
Solar Energy	Air temperature, humidity and precipitation	Insolation changes (cloud formation)
		Decrease in efficiency due to decrease in radiation
		Decrease in efficiency due to ambient conditions
Geothermal	Air/water temperature	Cooling efficiency
Wave Energy	Wind and extreme weather events	Changes in wave resource

3.

The economic consequences of *maladaptation*

> We live in a complex socioecological system

> Resources have been put to the limit

    > **Tradeoffs** are at the core

> *Ex-ante*, comprehensive **economic** (i.e. welfare) assessment necessary to prevent maladaptation

    > This has not been always the case

Maladaptation*: adaptation initiatives that actually harm socio-ecological systems, e.g. promoting adaptation in the short-term but increasing long term vulnerability*

4. Variability in resource endowments & energy supply

> Renewables have in common an uncertain resource endowment

> sunshine hours; wind; water availability; etc.

> Conventional solution: diversify installed capacity

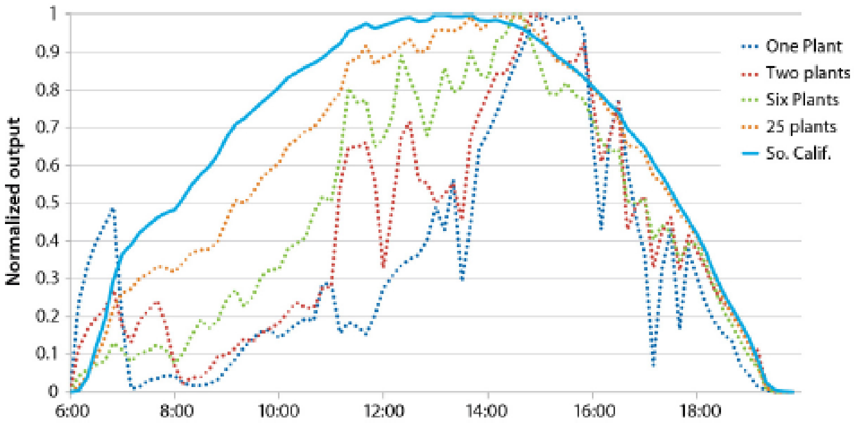


Figure 1. As the number of PV plants increases, their normalized, aggregate output becomes smoother. This is an example of normalized power output for increasing aggregation of PV in Southern California for a partly cloudy day for modeled PV plants in the Western Wind and Solar Integration Study Phase 2 (Lew et al. 2013).

> But climate change is here to stay

> Permanent, systemic impact on resource endowments

> Temperature (affecting e.g. crops and biomass)

> Sunshine (through cloudiness)

> Wind (and wave formation)

> Melting permafrost (oil, gas)

> Rainfall

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Hydropower: the water-energy nexus

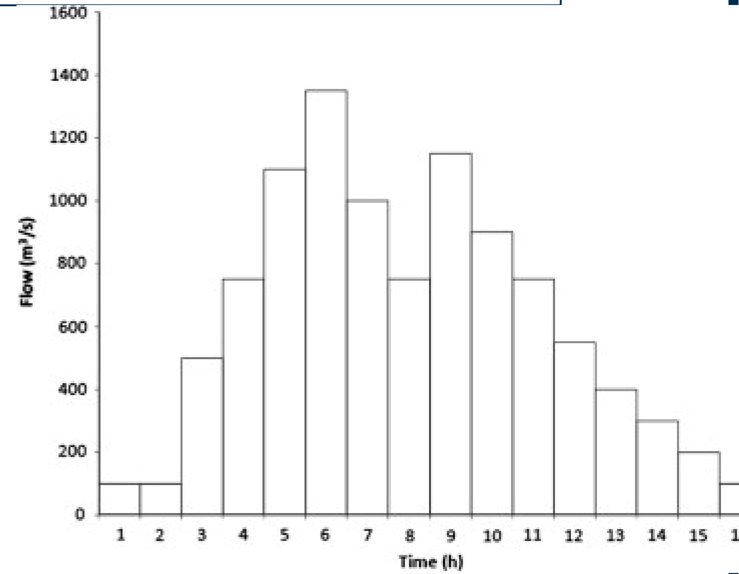
If average rainfall decreases -shall we increase hydropower capacity to ensure a stable energy supply?

> **Pros**: hydropower is renewable, carbon dioxide emission-free and easily exploitable

> **Cons**: modifies the structure of water courses and may need large water impoundments

> Hydropower may impair the integrity of water courses and river health

> **Tradeoff**: renewable energy (EC, 2009) vs. river restoration (EC, 2000)



Adaptation options

> Carefully assess the **nexus** (**tradeoffs**): market vs environmental income

> Hydropower Sustainability Assessment Protocol (Tollefson 2011); "sustainability assessment framework for hydropower development and operation"

> Minimize tradeoffs (e.g. *Pulse flows)*

It’s all about smart engineering (or it isn’t?)

> Hydropower is one of the most affected sectors by climate change

    > Reduced water flows

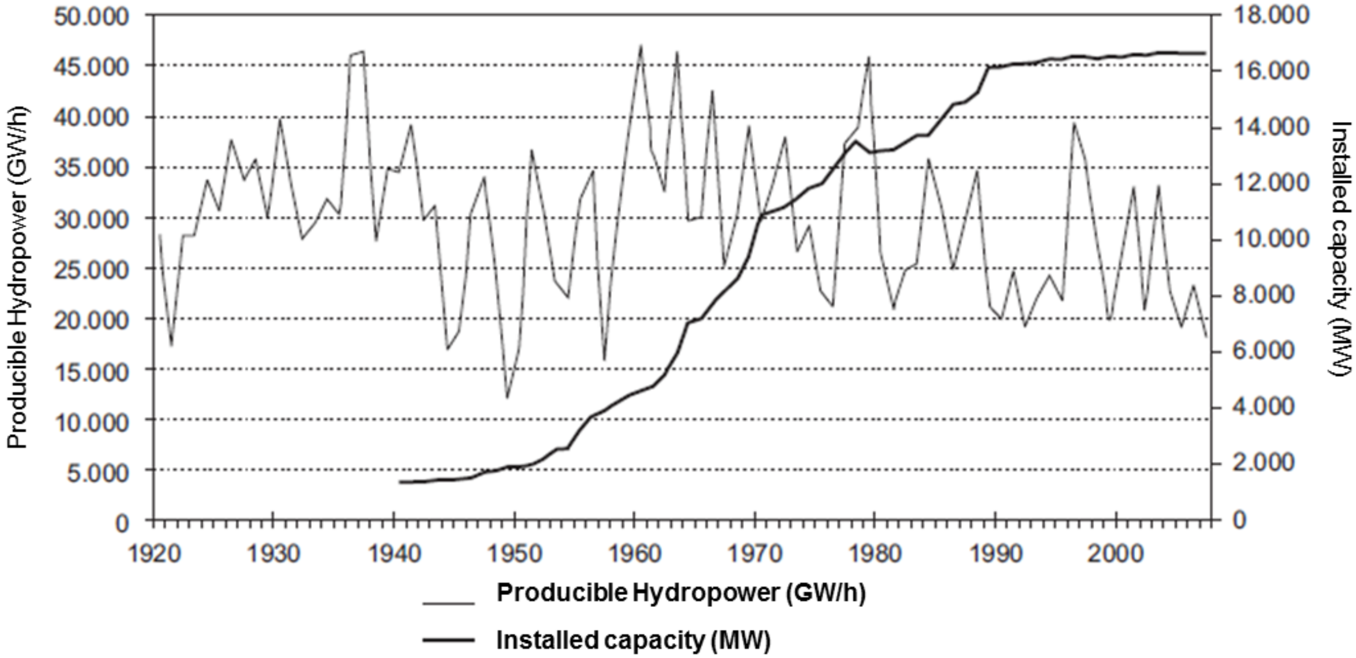
> Also in competition with other uses (e.g. agriculture)

> Solution? *Increase supply!*

> And Spain did

    > The most regulated rivers in the EU

    > About the same producible hydro now and in the ‘20s



Corollary:

> Renewable does not mean infinite

> Acknowledge the limits of nature

Sea level rise

> Flooding and erosion => supply & transportation disruptions

> 158 major oil/gas/LNG/tanker terminals + 71 operating nuclear reactors on the coast

> Adaptation options:

> Hard engineering (dikes, seawalls, breakwaters, raising port areas)

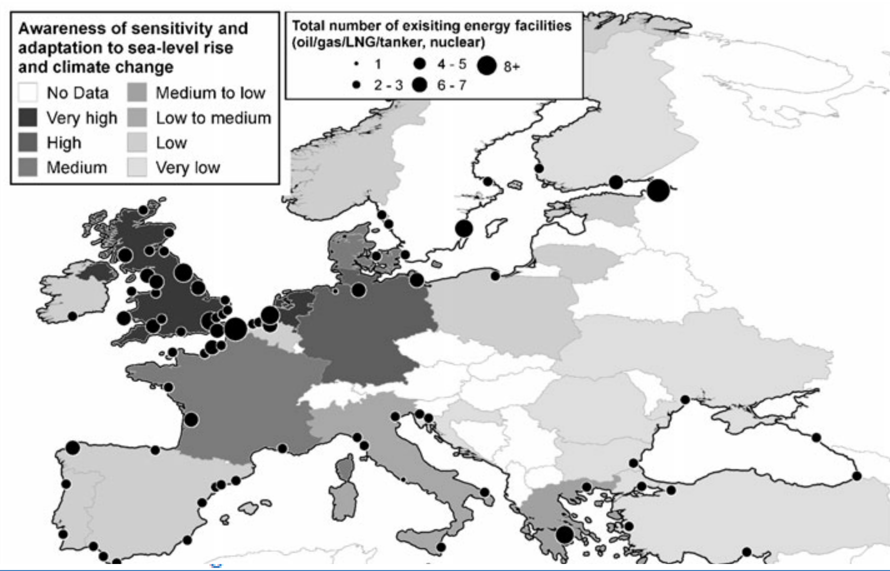
> Soft engineering (shore nourishment, dune building)

> And what if we neglect adaptation?

> The economy loses

> Asymmetric impact

> E.g. sea level rise impacts on Italy (Standardi et al., 2015)



	A1B	A1FI	A1T	A2	B1	B2
Piedmont	**2.32**	**2.80**	**1.84**	**3.43**	**1.71**	**1.80**
Aosta Valley	2.51	3.03	1.99	3.65	1.85	1.95
Lombardy	**1.80**	**2.18**	**1.42**	**2.61**	**1.32**	**1.39**
Trentino Alto Adige	1.51	1.86	1.17	1.85	1.07	1.14
Veneto	-5.13	-5.94	-4.53	-12.06	-4.41	-4.41
Friuli V. G.	-2.01	-2.94	-1.63	-5.41	-1.48	-1.56
Liguria	0.27	0.30	0.17	0.89	0.13	0.15
Emilia Romagna	-11.93	-13.95	-9.53	-14.54	-8.72	-9.33
Tuscany	-2.44	-3.38	-1.60	-2.70	-1.41	-1.57
Umbria	1.81	2.18	1.45	2.73	1.36	1.42
Marche	0.36	0.54	0.24	0.93	0.22	0.23
Lazio	-2.04	-2.72	-1.36	-2.19	-1.15	-1.32
Abruzzi	1.11	1.39	0.84	1.91	0.47	0.81
Molise	1.15	1.40	0.91	1.95	0.82	0.88
Campania	-0.72	-1.06	-0.18	-0.55	-0.18	-0.18
Apulia	-1.71	-2.09	-1.31	-1.66	-1.18	-1.29
Basilicata	1.05	1.26	0.84	1.69	0.78	0.82
Calabria	-1.45	-1.34	-1.53	-1.27	-1.54	-1.54
Sicilia	-0.43	-0.34	-0.52	-0.14	-0.55	-0.54
Sardinia	-0.85	-1.71	-0.74	-1.18	-0.72	-0.80
Italy	-1.51	-1.83	-1.20	-2.16	-1.11	-1.17

5.

Incidence on demand

> Global warming impacts heating and cooling demand

> Northern and central EU: decrease in heating demand dominates

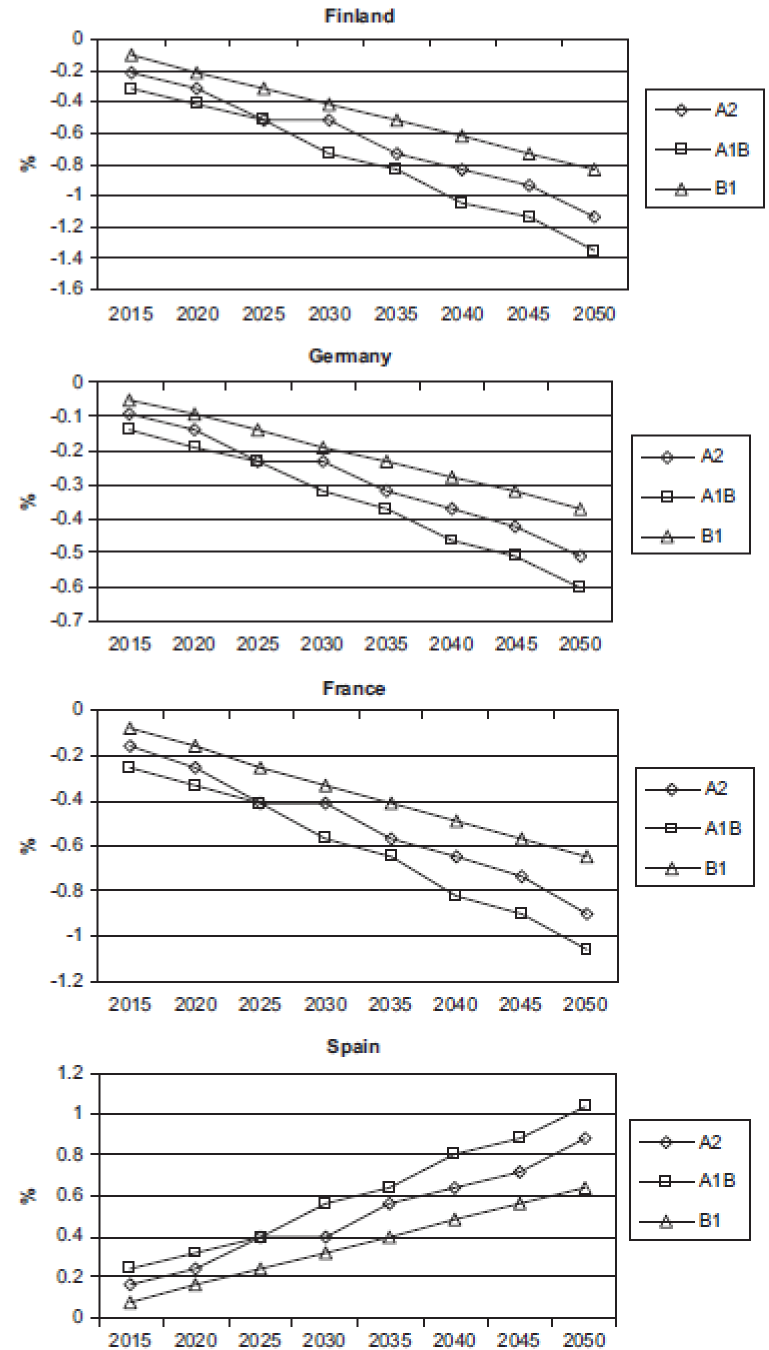
> Southern EU: Increase in cooling demand dominates

> Adaptation is **critical for mitigation** (vicious/virtuous circle)

> > Hard engineering (new investments, interconnections with other power systems, energy saving programmes, etc.)

> > Economic instruments

		Price-driven	Quantity-driven
Regulatory	Investment focused	• Investment subsidies • Tax credits • Low interest/Soft loans	• Tendering system for investment grant
	Generation based	• (Fixed) Feed-in-tariffs • Fixed Premium system	• Tendering system for long-term contracts • Tradable Green Certificate system
Voluntary	Investment focused	• Shareholder Programs • Contribution Programs	
	Generation based	• Green tariffs	



6. Extreme events and critical infrastructure

> Climate change increases the likelihood of **extreme events** and **demand peaks**

> > Heat waves and droughts will negatively affect the cooling of thermal power plants
>
> > Floods, extreme winds, ice loads and other extreme events may shut down important components of the grid
>
> > Increasing summer peaks for cooling may disrupt energy supply

> Extreme events sometimes have long-lasting effects

> > Most analysis focus on *direct costs*
>
> > The *indirect costs* may be even more relevant

> White Paper on adapting to climate change (EC 2009b):

> > ensure climate-proofing of existing and planned infrastructure TEN-E (EC, 2013)
>
> > climate risk assessment conditional for public investments
>
> > assess the practicality of assimilating climate impacts into construction standards.

> This may be too narrow of an approach

> > **Disasters are going to occur**
>
> > Promoting resilience is not only about infrastructures

> Also: i) spread information; ii) complementary prevention (e.g. Land use codes); iii) institutional quality

5. Concluding remarks

> Climate change is expected to have considerable impacts

> Energy systems often do not incorporate these impacts in their planning and operation

> **Climate change is here to stay**

> Even if mitigation succeeds above expectations

> Adaptation is necessary against:

> Variable resource endowments & demand

> Extreme events

> Adaptation strategies should be assessed on site

> No silver bullets

> Maladaptation/neglecting adaptation may have significant, negative impacts on Southern European countries

Modelling a blackout in Italy

> Local failures may rapidly **escalate** in modern *interconnected networks*

> > *Catastrophic cascade of failures*

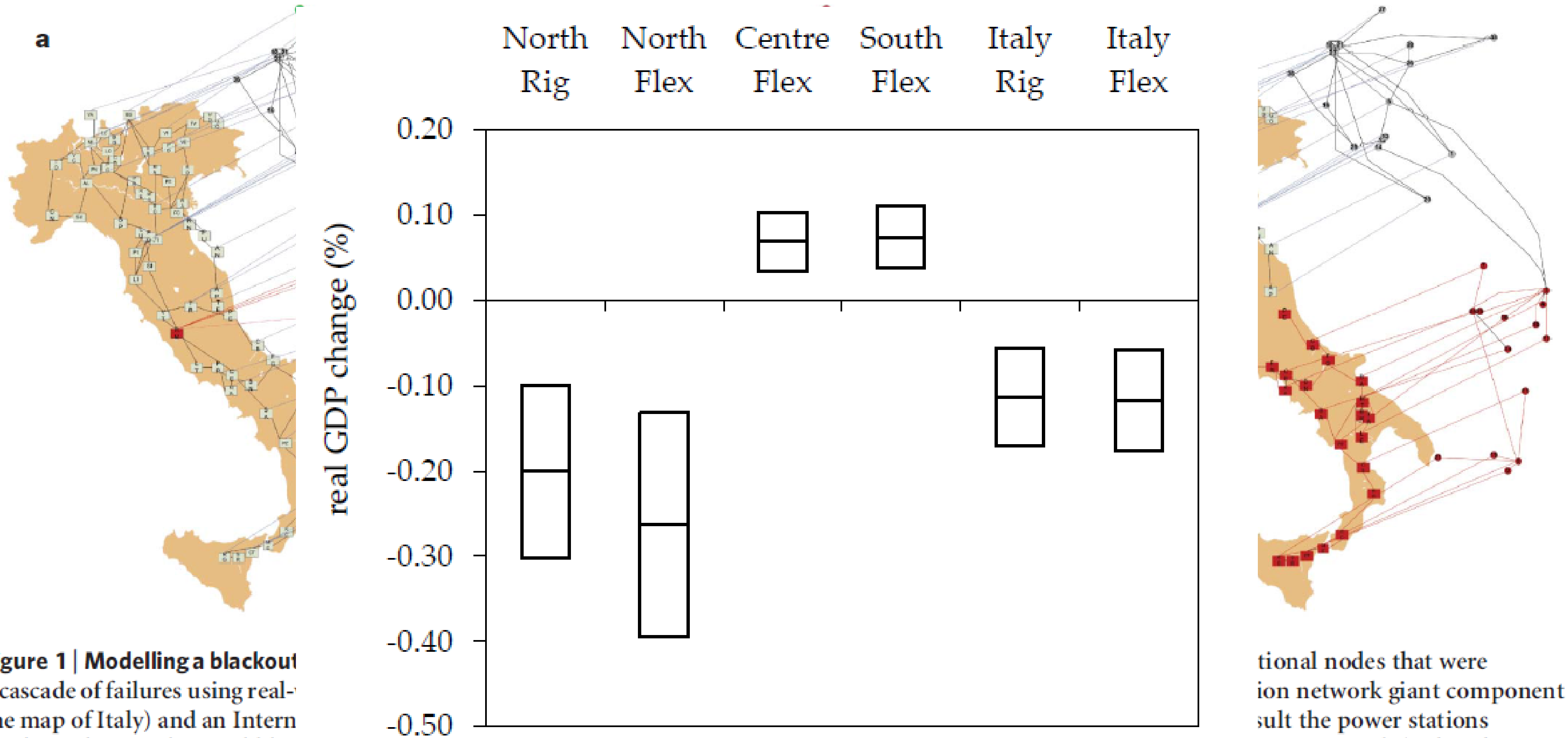


Figure 1 | Modelling a blackout … tional nodes that were
a cascade of failures using real- … ion network giant component
the map of Italy) and an Intern … sult the power stations
implicated in an electrical blac… … ower network (red nodes on
2003[20]. The networks are drawn using the real geographical locations and every Internet server is connected to the geographically nearest power station. **a**, One power station is removed (red node on map) from the power network and as a result the Internet nodes depending on it are removed from the Internet network (red nodes above the map). The nodes that will be disconnected from the giant cluster (a cluster that spans the entire network) … map). Again, the nodes that will be disconnected from the giant cluster at the next step are marked in green. **c**, Additional nodes that were disconnected from the giant component of the power network are removed (red nodes on map) as well as the nodes in the Internet network that depend on them (red nodes above map).

Thanks for your attention

Annex

Biomass: the water-food-energy nexus

> Increasingly relevant

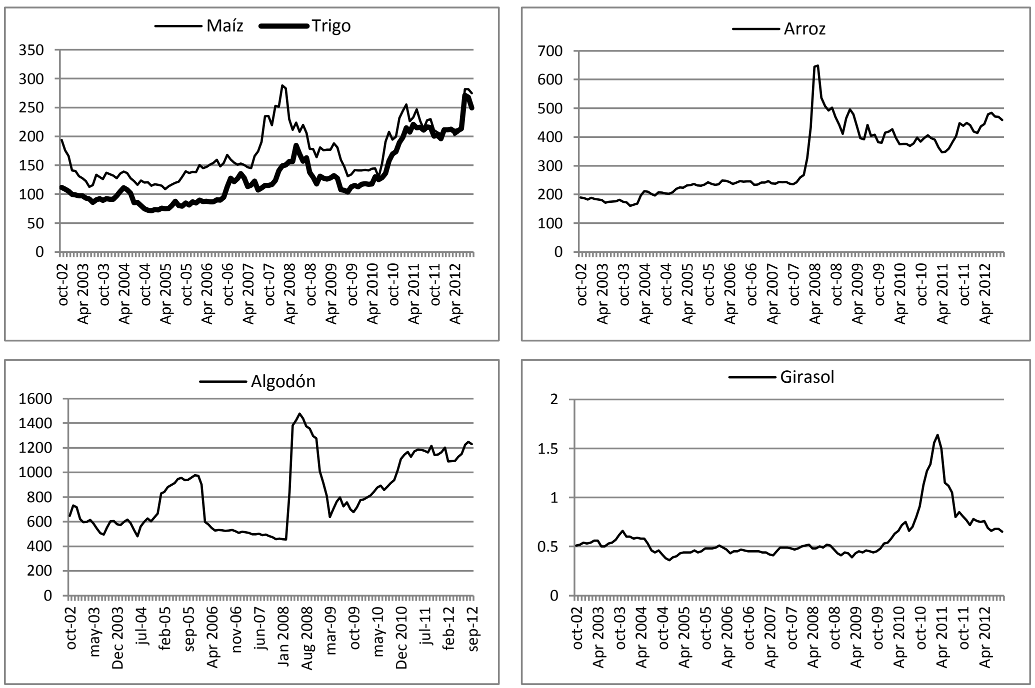
> Mobile; widespread; proper planning => resilient to climate change

> Possible negative feedbacks:

> land-use change (deforestation, invasive alien species)

> Environmental impacts (↓ water availability; CO2?)

> Distortions in food production and prices (FAO hunger map)



Source: World Bank (2012)

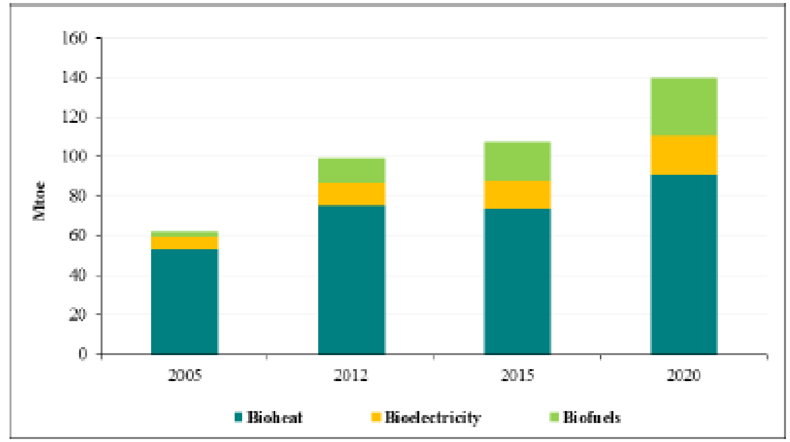


Figure 1: EU biomass consumption in electricity, heating, and transport (Mtoe, 2005-2020).
Source: National renewable energy action plans (NREAPs) and 2011 progress reports[23].

EC recommendations

> ban biomass from land converted from forest, high carbon stock areas, highly biodiverse areas

> greenhouse gas emissions: 35% (50% in 2017 and 60% in 2018) less than EU's fossil energy mix

> support high energy conversion efficiencies

> monitor biomass origin