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Climate Change Impacts in the Mediterranean Region
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Can we use regional climate simulations for energy applications?

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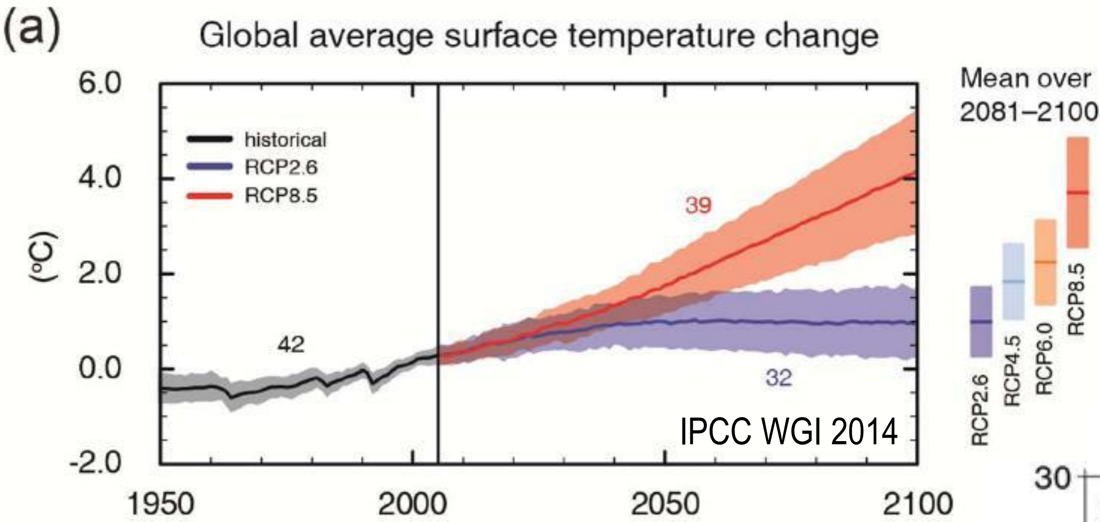
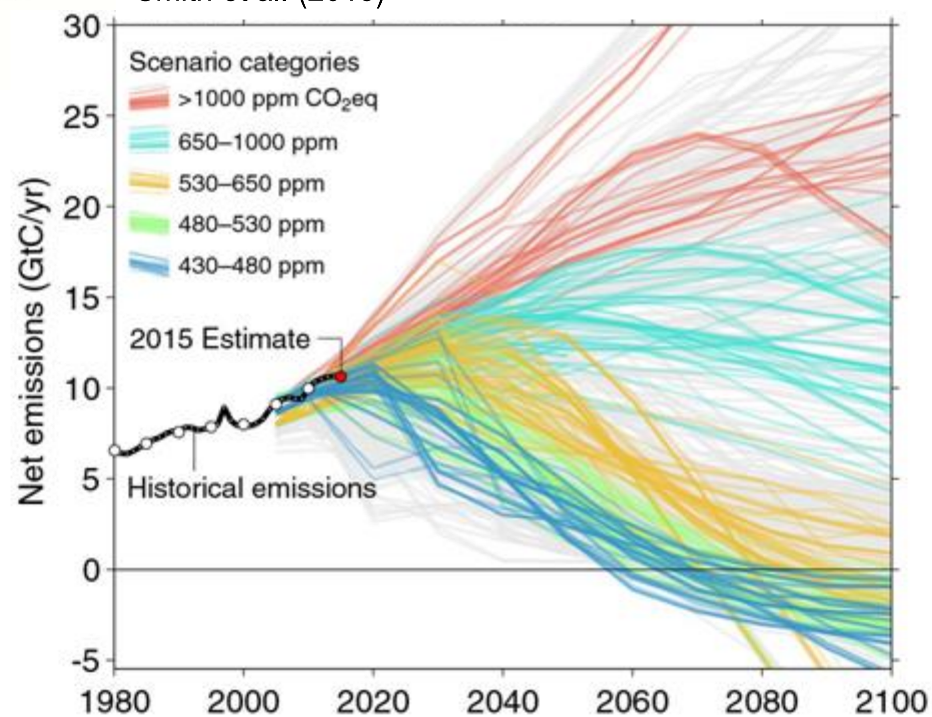
Stakes from an IPCC perspective

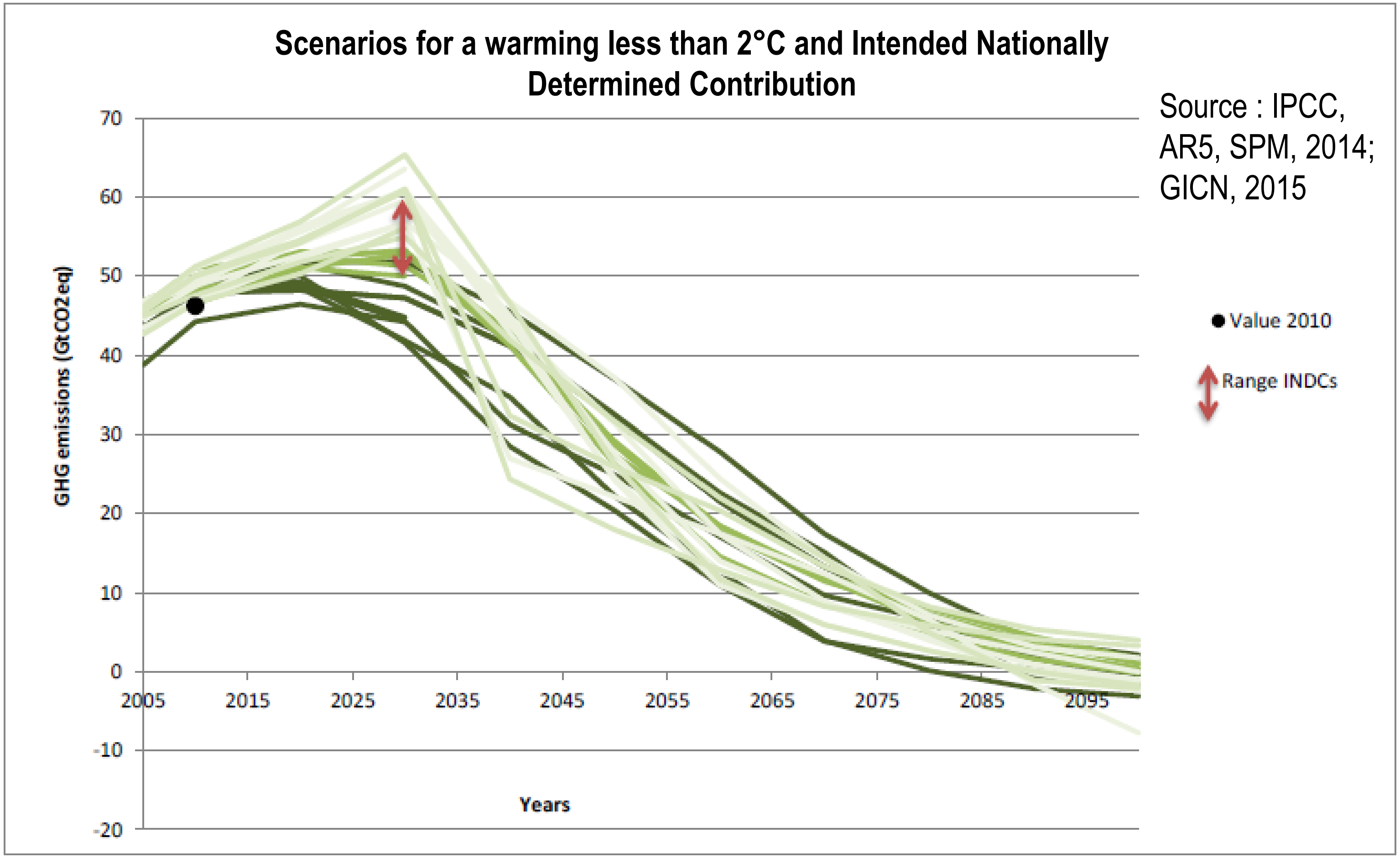
A greenhouse gaz emission issue



Smith et al. (2015)



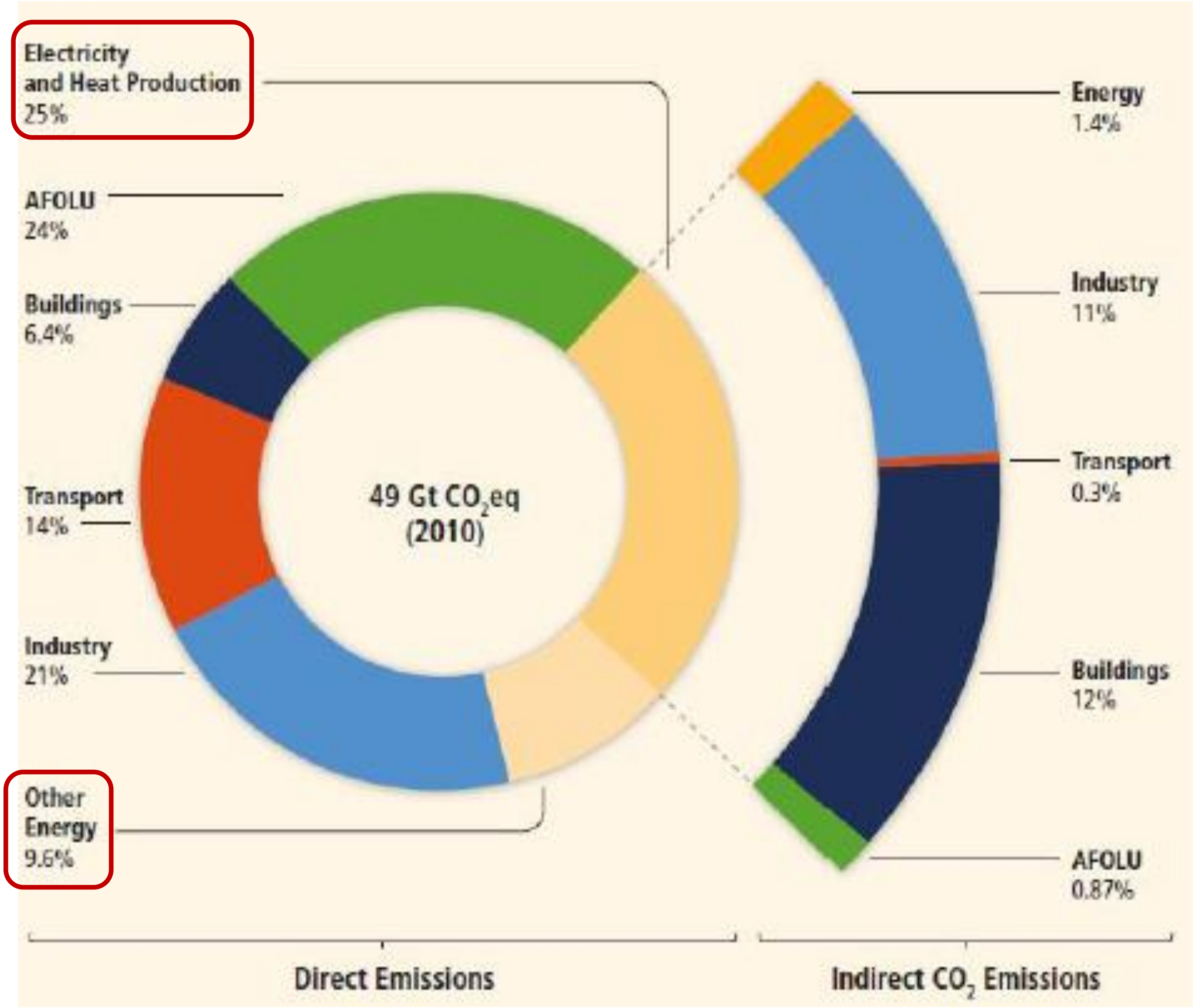
Stakes from an IPCC perspective



Only a few scenarios consistent with INDCs
All involve negative emissions

Stakes from an IPCC perspective

Greenhouse gaz emissions by economic sectors



Energy sector is responsible for 35% of GHG emissions

IPCC WG3 2014

Stakes from an IPCC perspective

Transition required for the energy sector in 2050

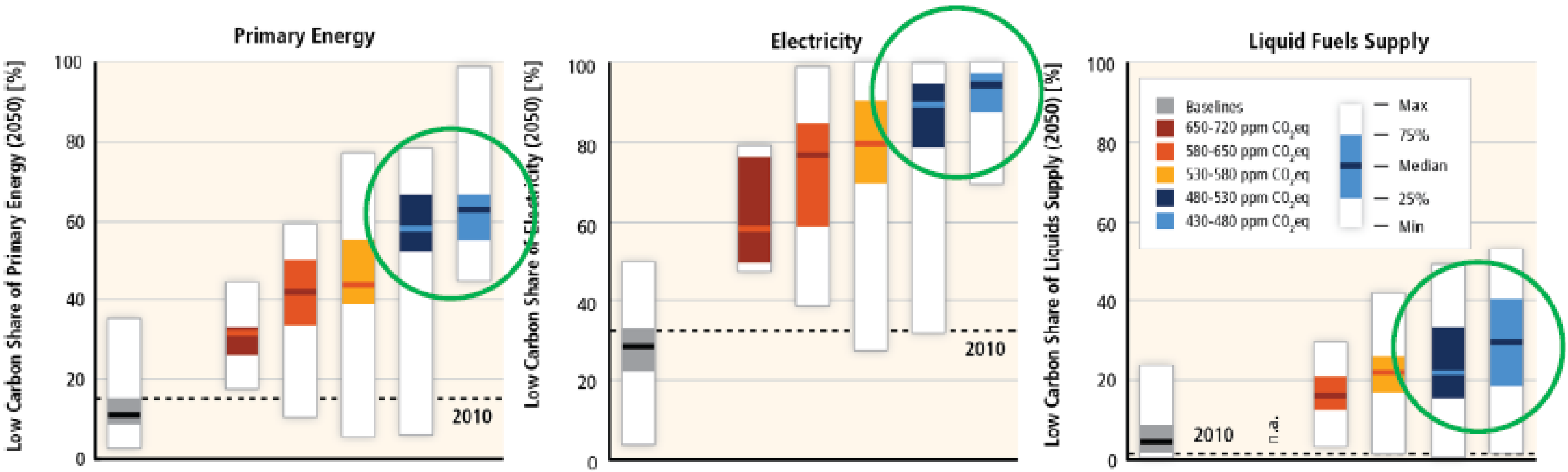


Figure 7.14. Share of low-carbon energy in total primary energy, electricity and liquid supply sectors for the year 2050. Bars show the interquartile range and error bands the full range across the baseline and mitigation scenarios for different CO_2eq ppm concentration levels in 2100 (Section 6.3.2). Dashed horizontal lines show the low-carbon share for the year 2010. Low-carbon energy includes nuclear, renewables, and fossil fuels with CCS. Source: AR5 Scenario Database. Scenarios assuming technology restrictions are excluded.

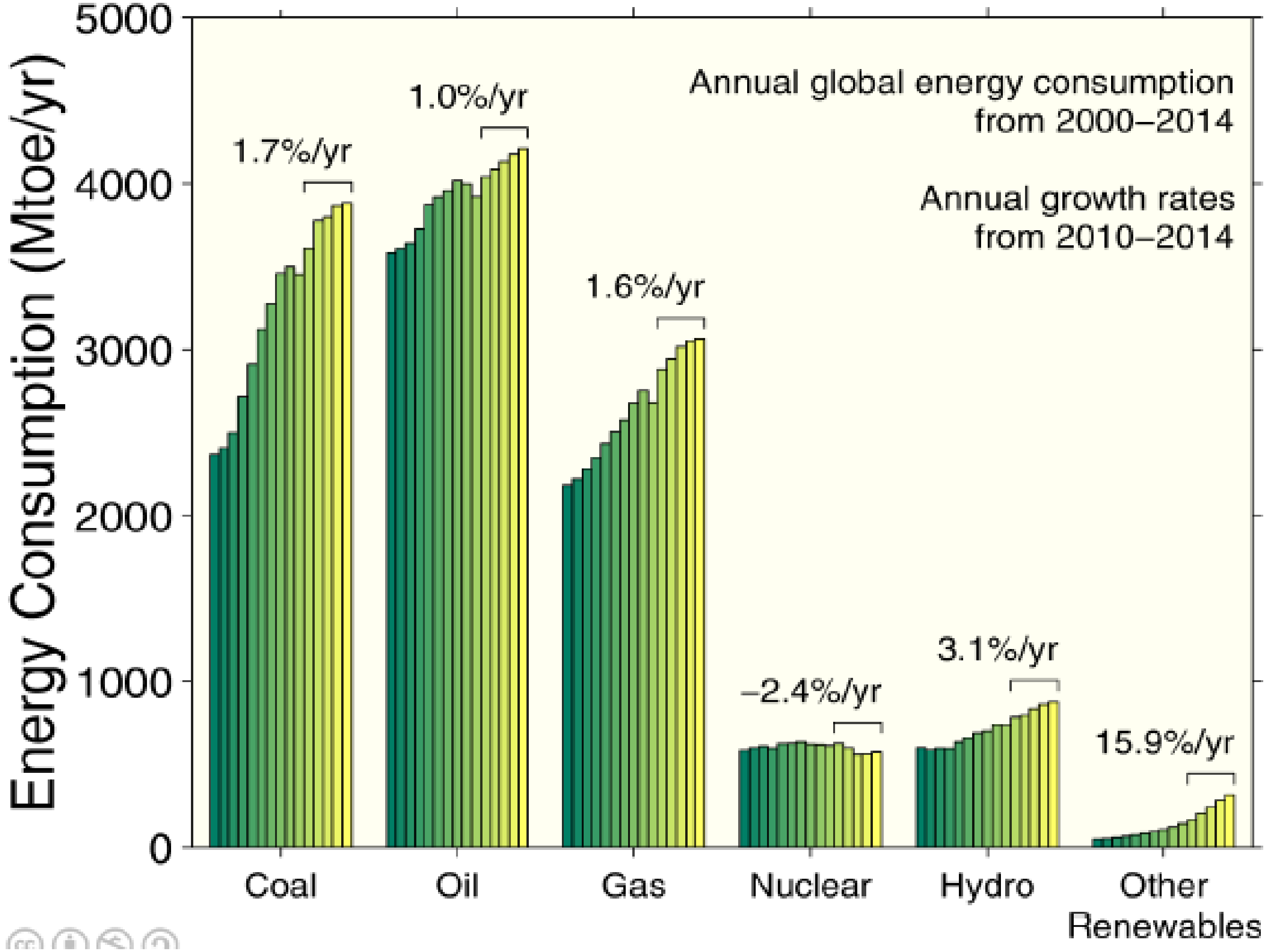
Scenarios leading to a « more likely than not <2° C warming »

IPCC WG3 2014

Stakes from an IPCC perspective

Recent evolutions in energy consumption by technology

BP 2015



Stakes from a EU policy perspective

The problem

"The challenges of transforming Europe's energy system remain urgent and daunting: the EU currently imports approx. 55% of its energy – and might reach 70% in the next 20 to 30 years. In 2030 the EU will be importing 84% of its gas, 59% of its coal and 94% of its oil. In these circumstances, it is obvious that the challenge to satisfy our energy needs is big."

The European Renewable Energy Council, "RE-Thinking 2050: A 100% Renewable Energy Vision for the European Union"

EU directive promoting the use of energy from renewable sources (2009)

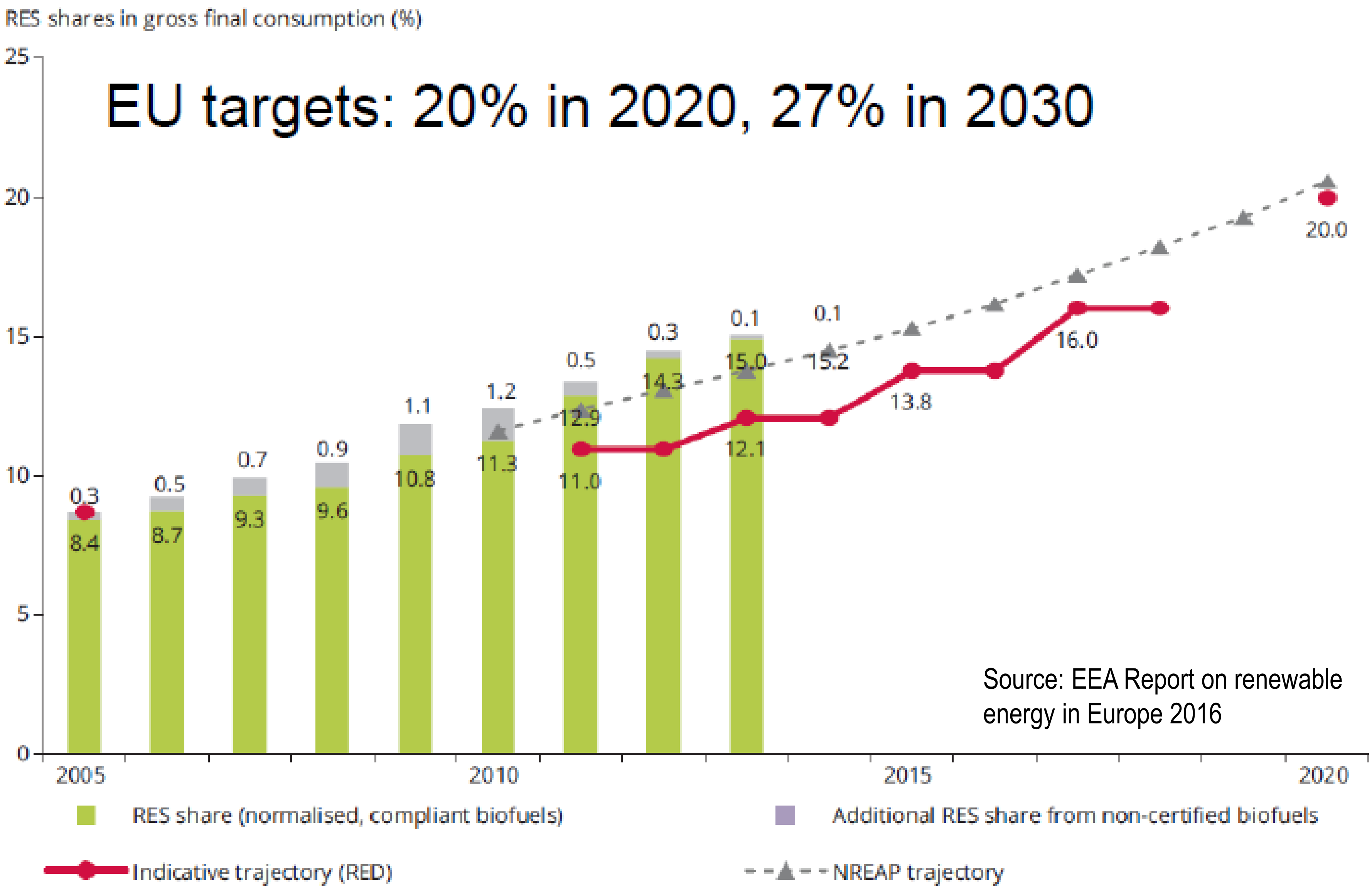
- Reduce greenhouse gas emissions and comply with the Kyoto Protocol
- Promote energy security
- Promote technological development and innovation
- Create job opportunities and regional development, especially in rural and isolated areas

3 objectives

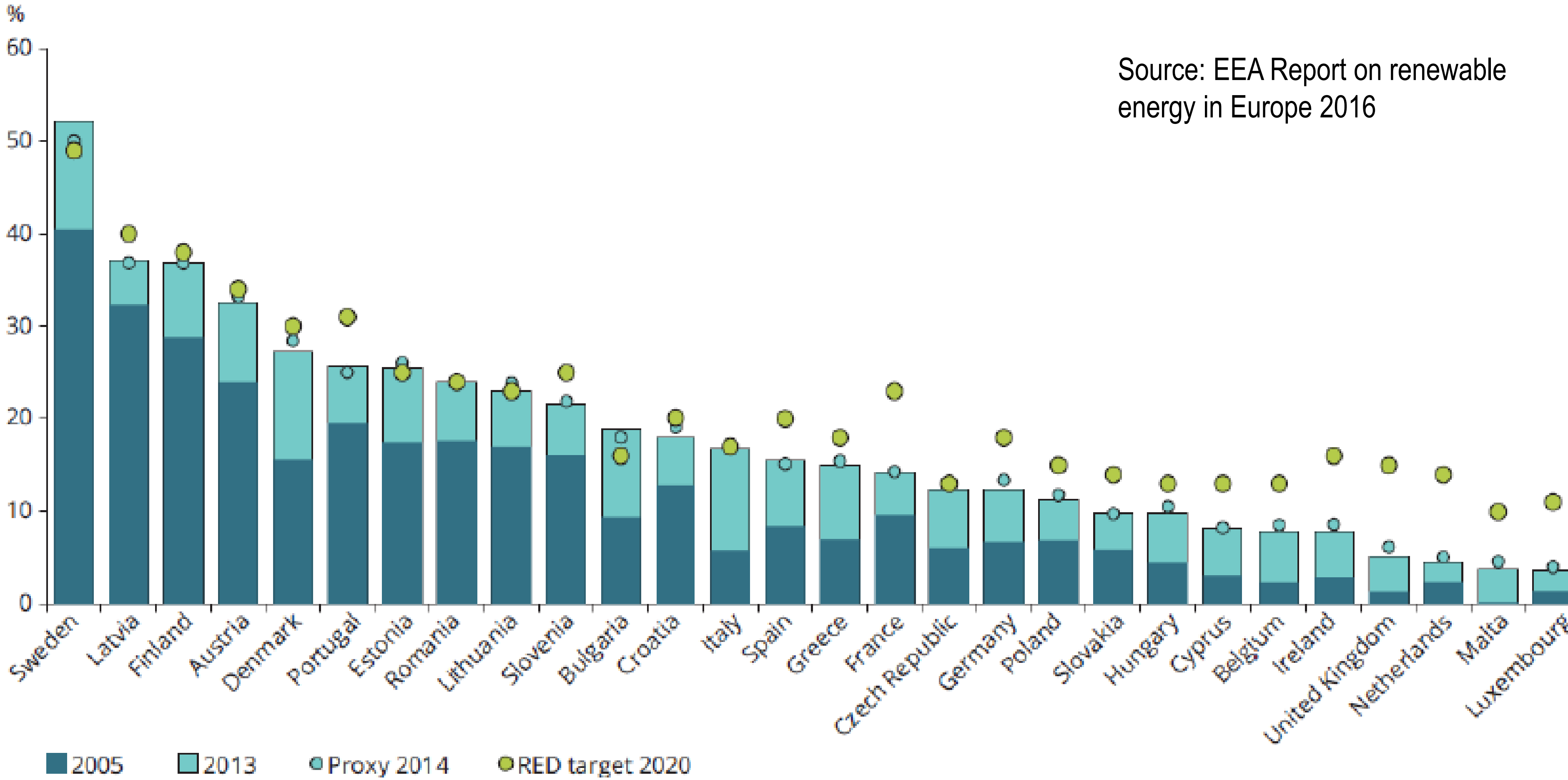
- Reduce GHGs 20% below 1990 levels
- Reduce emissions by 20% by improving energy efficiency, and
- Increase the share of energy derived from renewables to 20%

Stakes from a EU policy perspective

EU-28 actual and approximated progress to interim and 2020 targets



Stakes from a EU policy perspective



Source: EEA Report on renewable energy in Europe 2016

How can regional modeling help for energy applications?

- **Intensity and frequency of extreme events (heat/cold waves, frost and snow storm, windstorms)**
  - Energy demand variability
  - Cooling water availability
  - Power outage

- **Renewable energy resources and their variability**
  - Water resources (if routing is accounted for in the regional climate model)
  - Wind and solar resources

- **Impact of renewable energy production on regional climate**

- **Evolution in the context of global change**

- **Prospective scenarii (e.g. energy mix,…)**
  - Production/consumption modelling from regional climate model
  - Technology deployment (optimization model, economic model, …)

This overview

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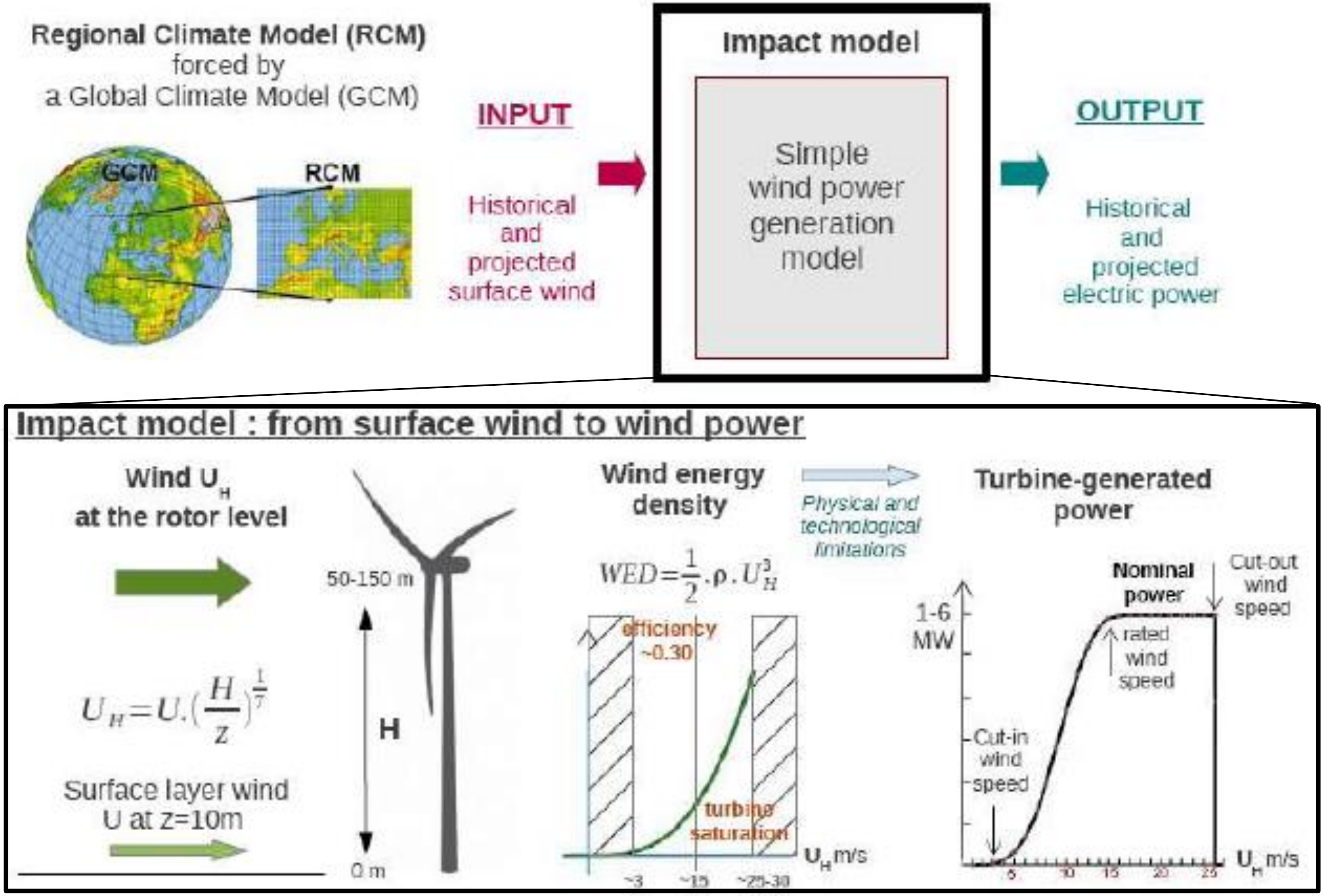
Renewable energy resources and their variability

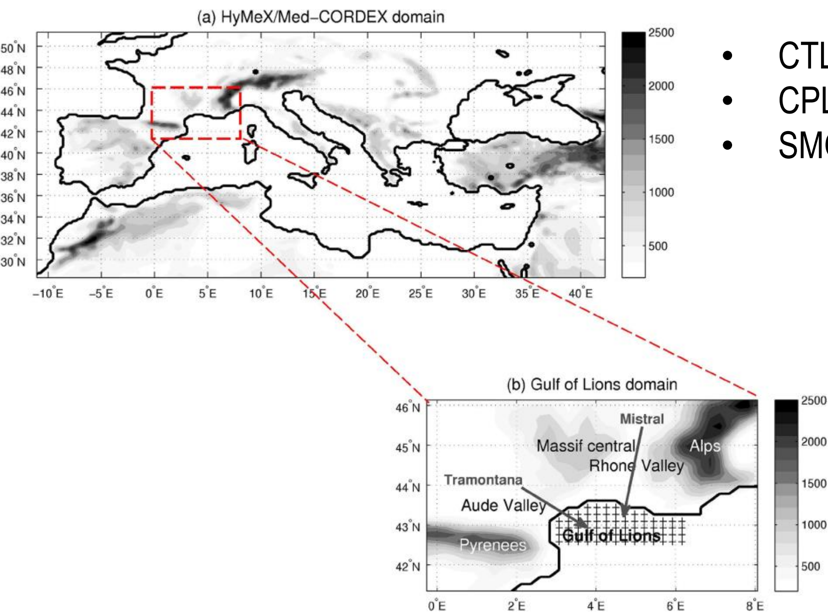
Methodology



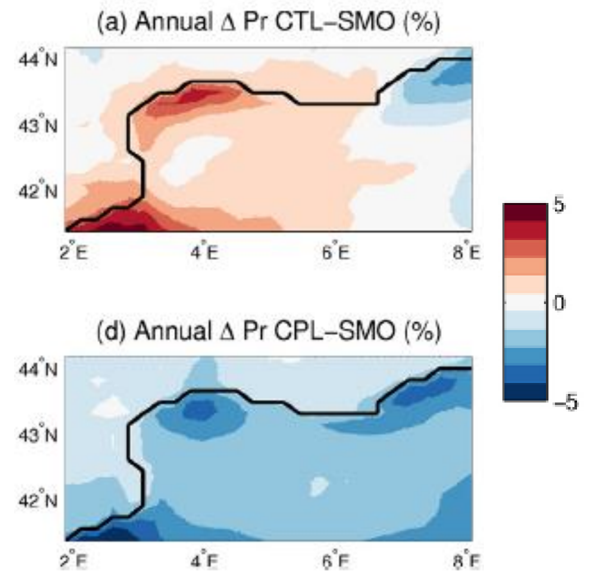
Calculation for each wind farm and national fleets

Renewable energy resources and their variability

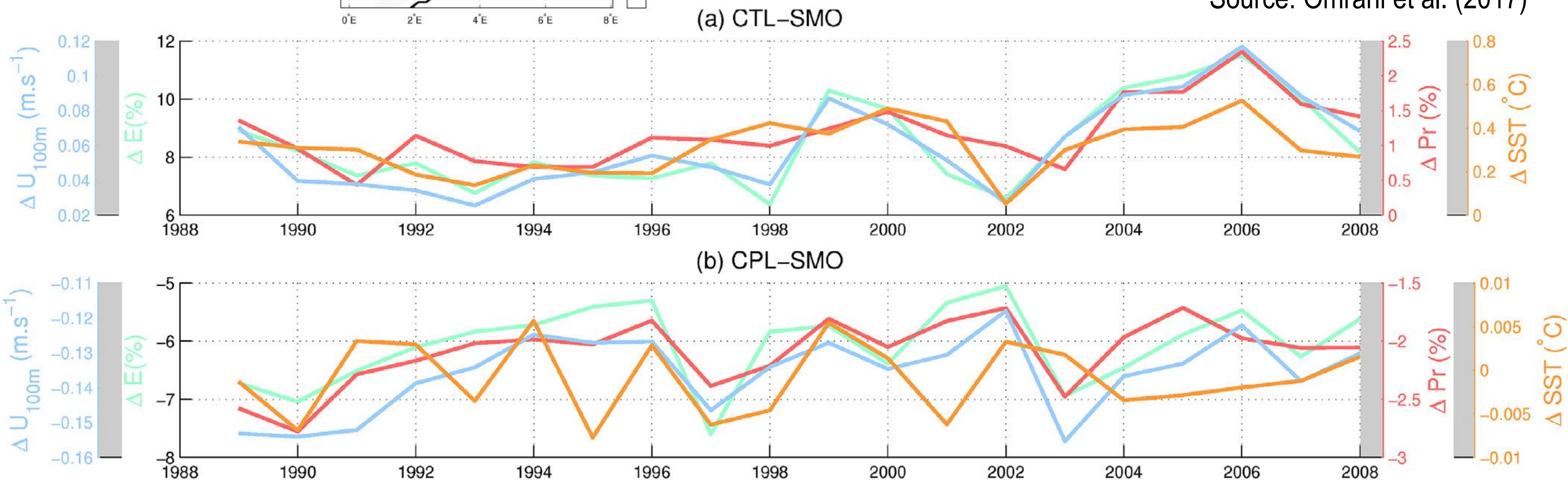
Wind production potential in a RCM and AORCM



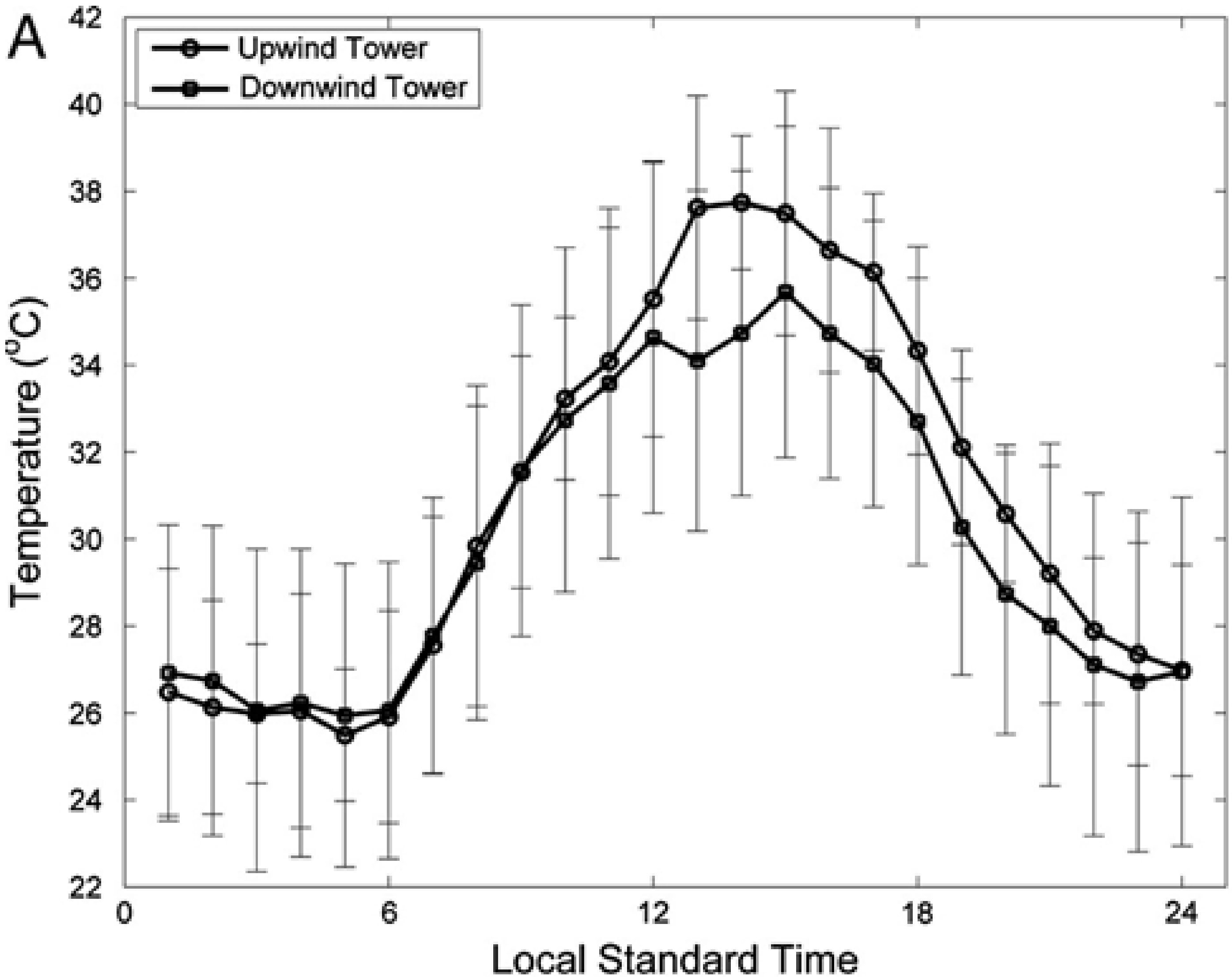
- CTL: 20-year simulation wih ERA-I SST
- CPL: same in O/A coupled mode
- SMO: same with smoothed CPL SST



Source: Omrani et al. (2017)

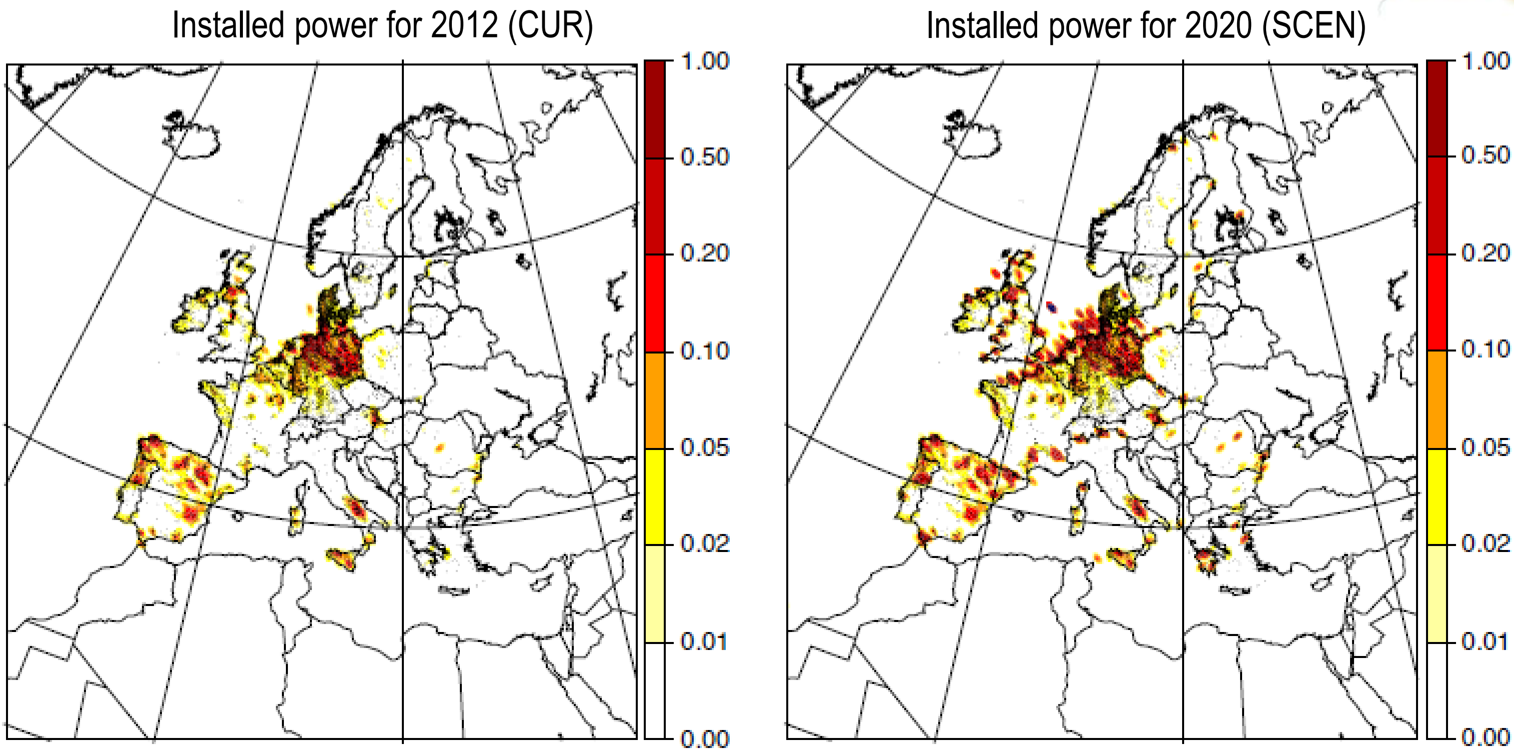


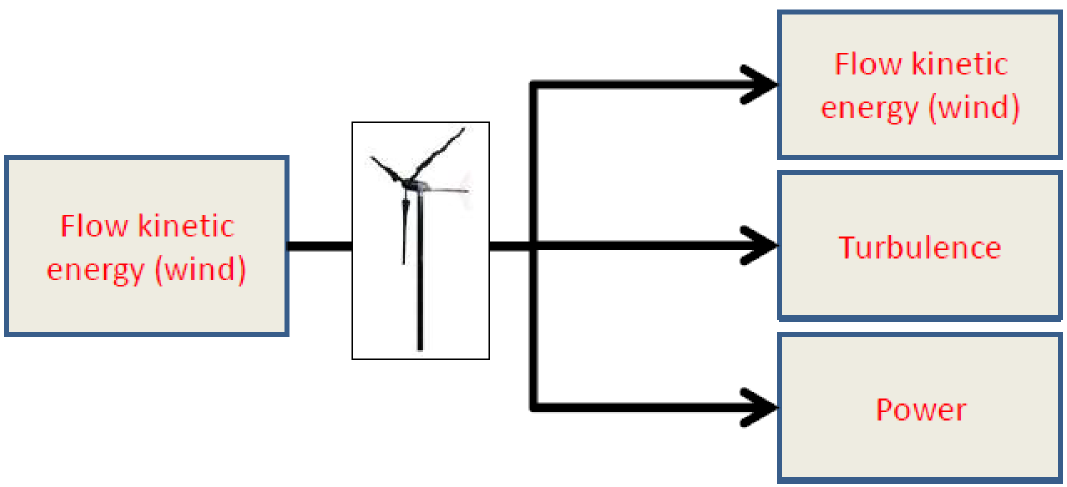
Impact of renewable energy production on regional climate



Source: Roy and Traiteur (2014)

Impact of renewable energy production on regional climate

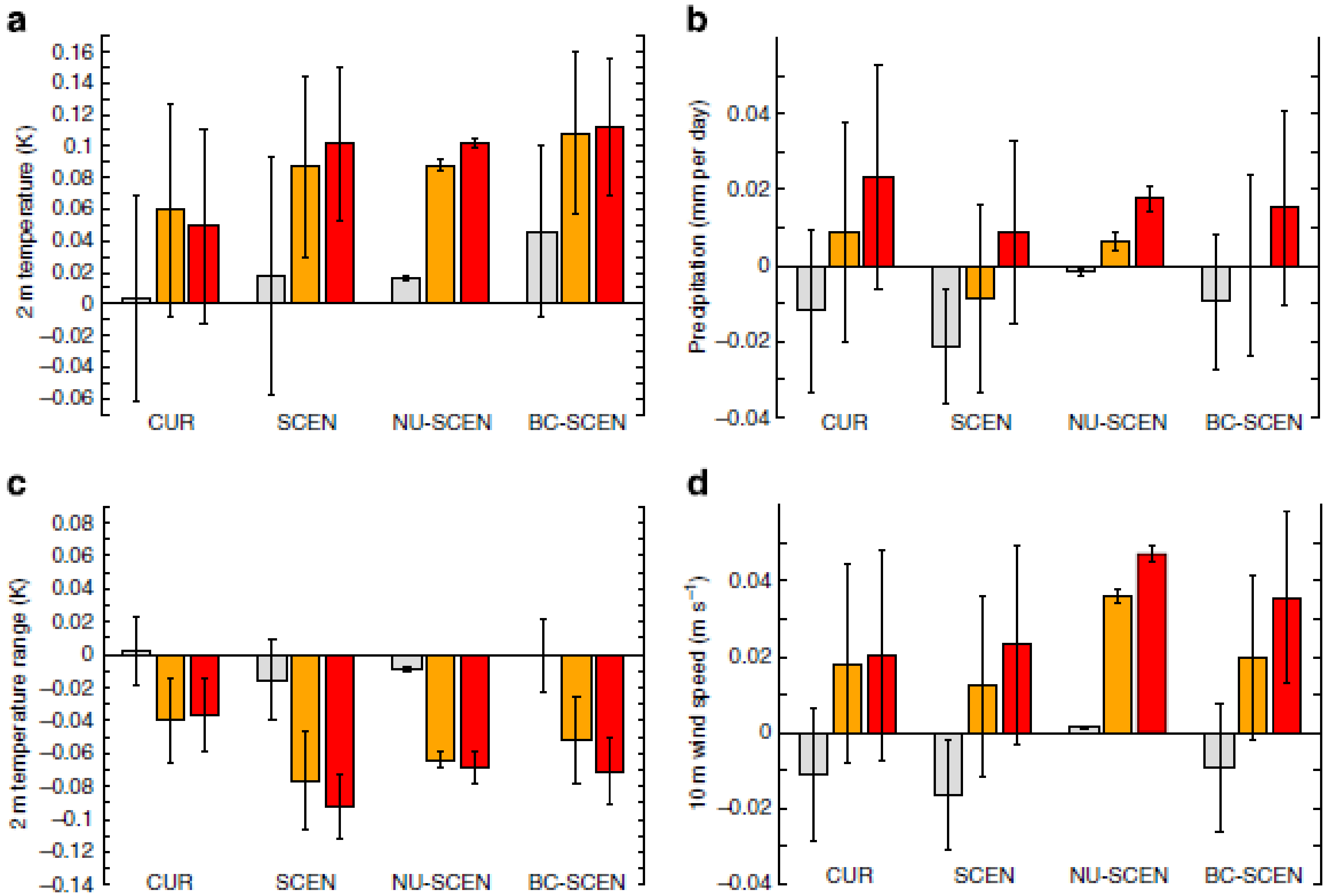




- Use of Fitch et al (2012) formulation in WRF
- Use of Climate & Energy package for 2020
- Simulations over 33 years with and without wind farms

Source: Vautard et al. (2014)

Impact of renewable energy production on regional climate

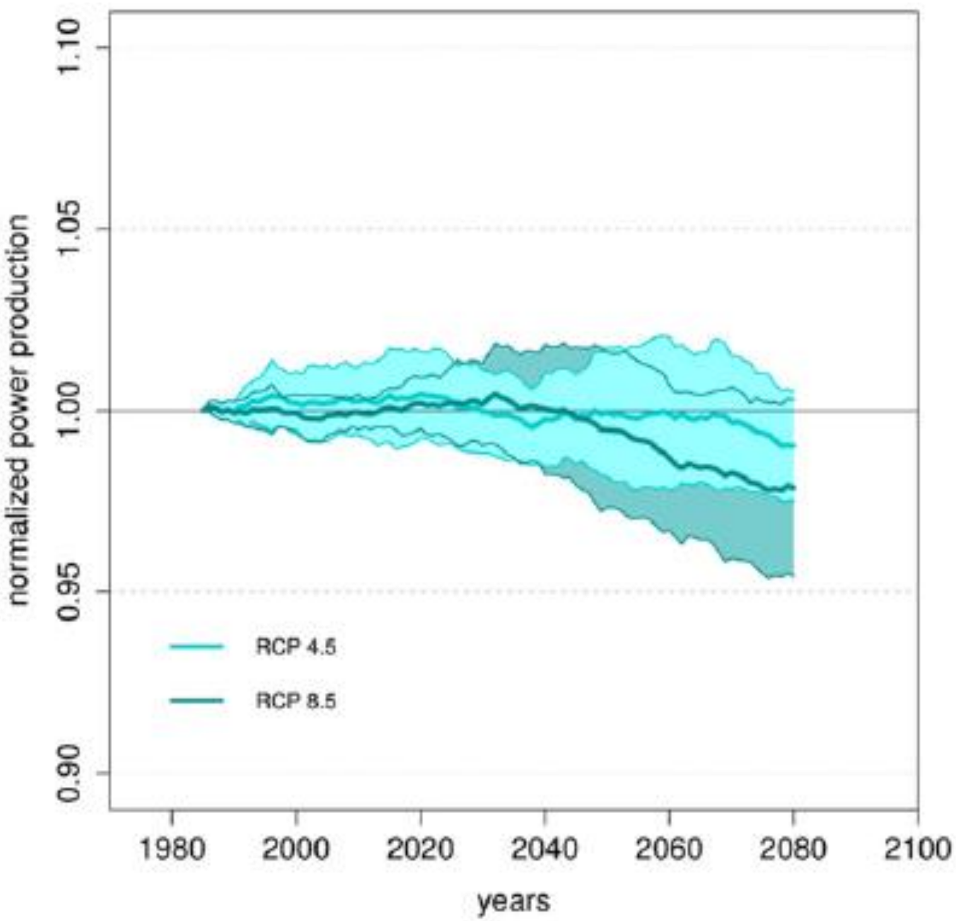


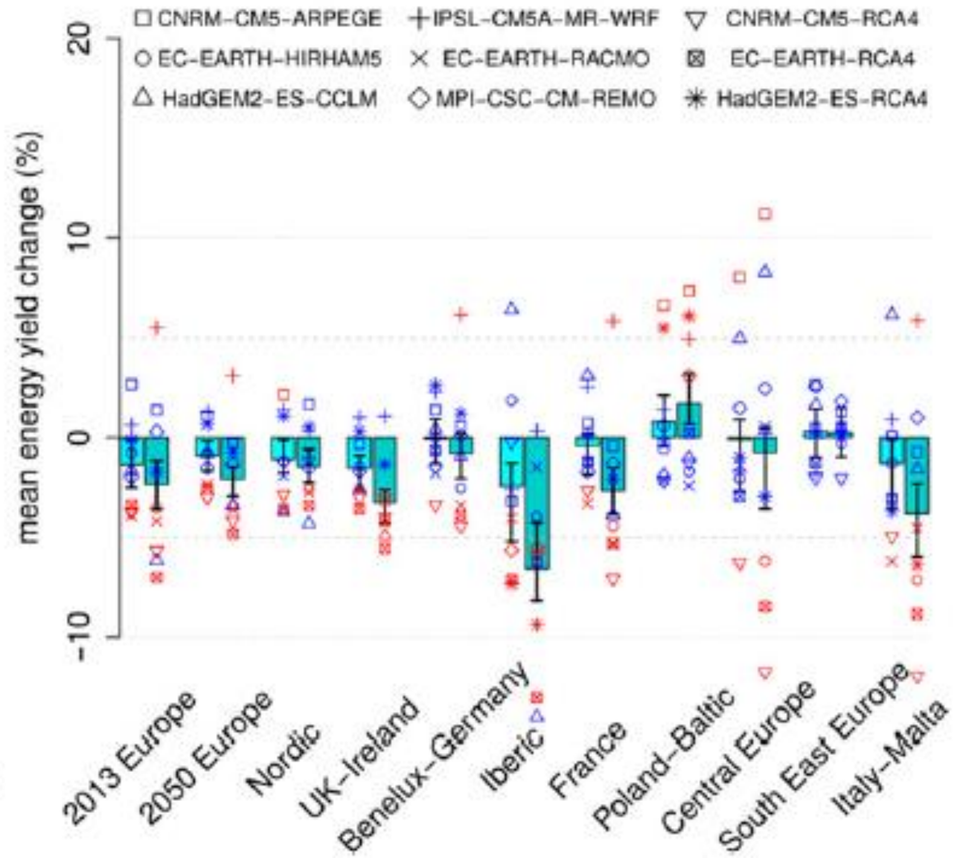
- Weak threats of interactions between climate and wind energy for near-term scenarios
- Evaluation of environnemental consequences necessary with energy deployment scenarios

Source: Vautard et al. (2014)

Evolution in the context of global change

Impact of climate change on wind power potential and production

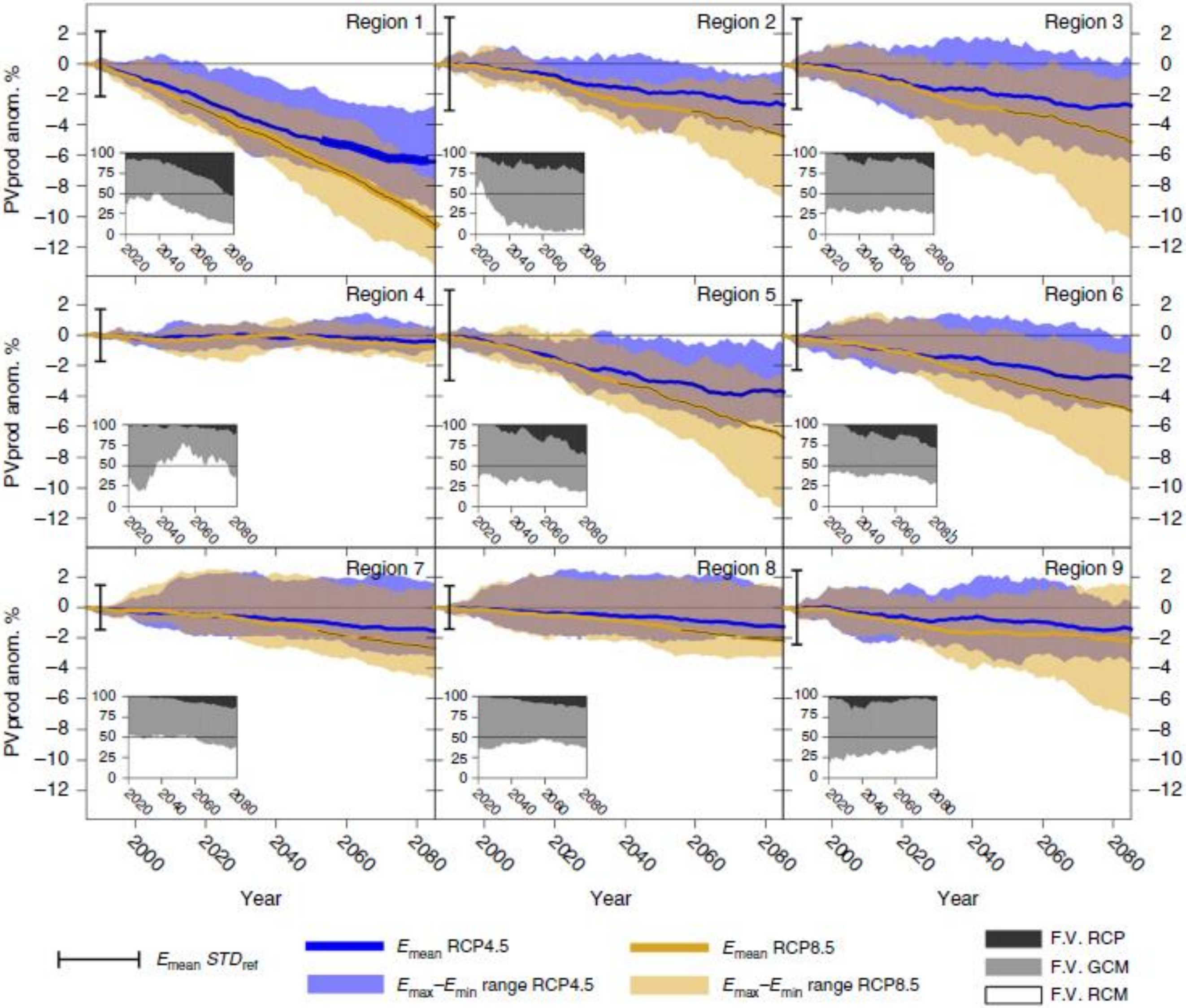


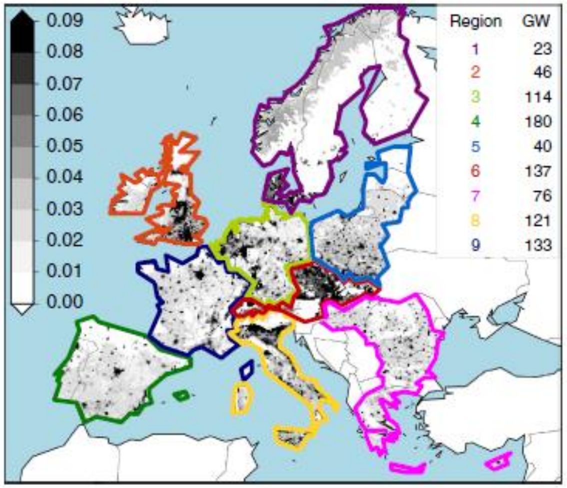


Source: Tobin et al. (2016)

Evolution in the context of global change

Impact of climate change on wind solar potential and production

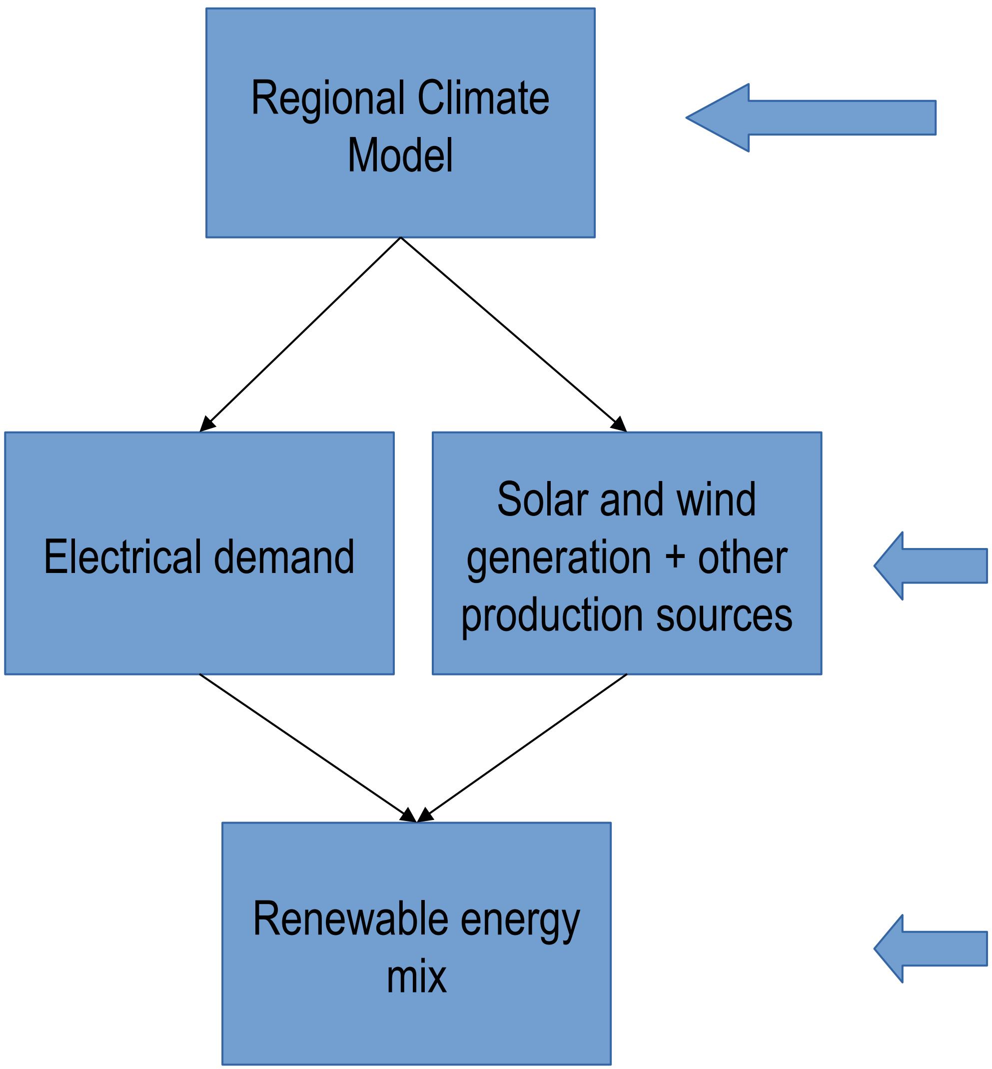




Source: Jerez et al. (2015)

Prospective scenarii

Methodology



Climatic dataset

MED-CORDEX regional climate simulations (with WRF)

Numerical integration :

- 20km resolution
- 1989-2012
- ERA-Interim B.C

Electrical dataset

GSE and GRE dataset

« Optimization » of solar and wind production wrt electrical demand

Prospective scenarii

Electrical demand

$$D = A_1 \sin\left(w\frac{2\pi}{53}\right) + A_2 \cos\left(w\frac{2\pi}{53}\right) + A_3 \sin\left(w\frac{4\pi}{53}\right) + A_4 \cos\left(w\frac{4\pi}{53}\right) + A_5 \sin\left(w\frac{10\pi}{53}\right) + A_6 \cos\left(w\frac{10\pi}{53}\right) + B \quad (1)$$

$$A_x = off\,(a_0 + a_1 tx + a_2 fdd) + sat\,(b_0 + b_1 t_x + b_2 fdd) + work\,(c_0 + c_1 t_x + c_2 fdd) \quad (3)$$

Calendar — Daily max temperature — Frost duration days

Electrical Production

- PV energy
  - Partitioning solar radiation into direct and diffuse components, projected onto a 25° plan with a south orientation
  - Conversion of solar radiation takes into account of the air temperature, clearness index and several load loss factors (Rahman et al, 2009).
- Wind energy
  - Wind interpolation at hub height (100m)
  - Transfer function using the power curve to compute electrical production from windspeed
- Conventional + hydro
  - 90th quantile of the annual electrical demand

Prospective scenarii

Technology deployment optimization: mean-variance portfolio theory

Process of assessing risk (variance) against an expected (mean) yield → penetration rate (mean) versus the spatial variance of the different types of renewable energy production (also called portfolios)

$$\min \left| \sum_{i=1}^{N} \omega_i \mu_i - \mu_{Target} \right|$$ Maximizes the penetration in all regions

$$\min \sum_{i=1}^{N} \sum_{j=1}^{N} \omega_i \omega_i \sigma_{ij}$$ Minimizes the variance between regions (aggregation)

$$\mu_i \omega_i \leq D_i(t) + T_i$$ Forbids congestion

$$\min \sum_{i=1}^{N} \omega_i (CAPEX_i + 24 \cdot OPEX_i - \mu_i \omega_i \cdot EPrice)$$ Maximizes the profitability

with $\mu_i = \frac{1}{T} \sum_{t=1}^{T} \frac{P_i(t)}{D_i(t)}$ the penetration in region i, $\sum_{i=1}^{N} \omega_i = \overline{\omega}$ the total installed capacity

$$0 \leq \omega_i \leq \overline{\omega}$$

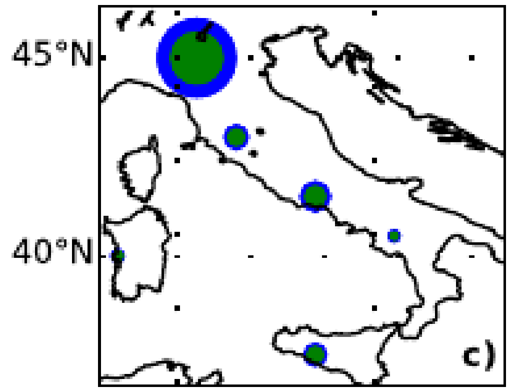
Prospective scenarii

A trade off problem which minimizes critical situation occurrence:

- *power shortage*
- *grid saturation with renewables (network instability, negative prices)*

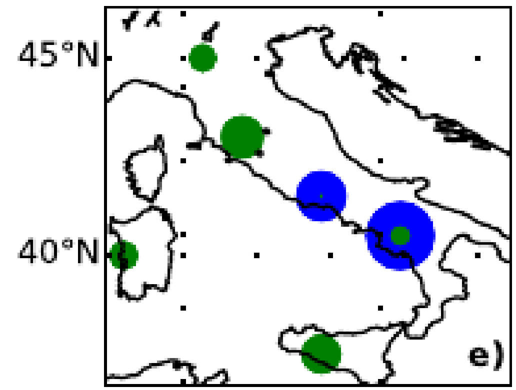
Based on resources only

70% PV - 30% WD



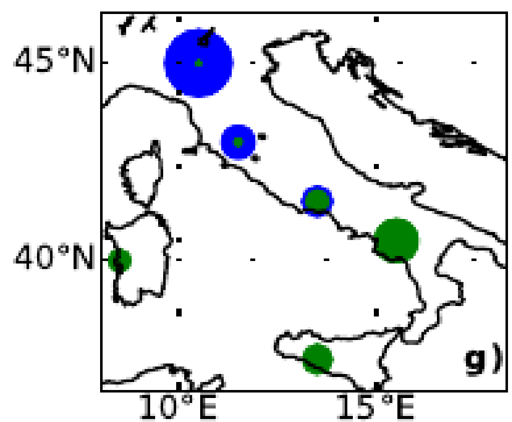
Accounting for profitability

60% PV - 40% WD



Actual mix in Italy

69% PV - 31% WD



Source: Stéfanon et al. (sub.)

Conclusions

- Regional climate model simulations of practical interest for energy production infrastructure safety and for resilience analysis

- Regional climate model simulations of practical interest for renewable energy resource assessment in a present and future climate using simple resource to production model

- Regional climate model simulations of practical interest for management strategy if including additional component (technology deployment optimization, economic model, electricity distribution in the grid, electricity market,…).

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Thank you for your attention
… questions?

Credit Dave Yoder

Tocco da Casauria, in central Italy, produces more electricity than it uses, making money off the surplus.