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Joint ICTP-IAEA Workshop on Vulnerability of Energy Systems to Climate Change and Extreme Events

19 - 23 April 2010

Impacts of climate change on renewable energy sources in Croatia

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Contents

Climate in Croatia

Climate in Croatia is divided into two predominant climate regions:

- Continental (Croatian interior which includes Zagreb and Slavonia)
- Mediterranean (from Istria until Dubrovnik in the south)
- During the 20th century, a decrease in precipitation and an increase in temperature in almost every season experienced
- In the future, Croatia is expected to be hotter and drier – especially in the summer

- Future climate change impacts will not be distributed evenly, but different regions in Croatia will have different influences
- Dynamical downscaling by a regional climate model is currently underway at the Croatian Meteorological and Hydrological Service where GCM is used named EH5OM

Power system planning

Power system planning demands long-term approach:

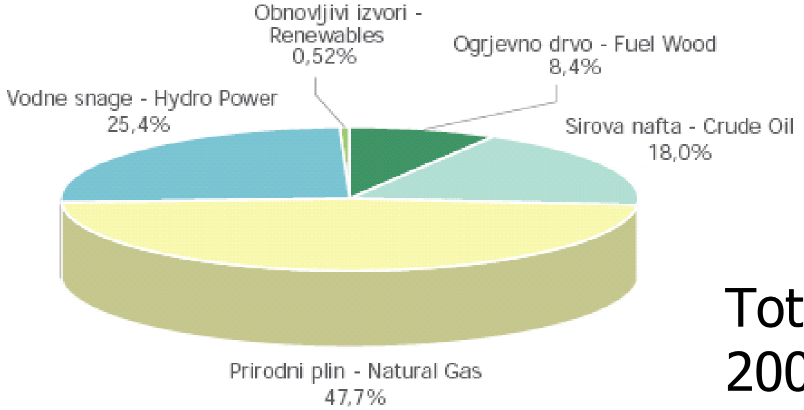
- long planning and construction process (1-12 years)
- long life time of new power plants (25-60 years or longer for hydro with revitalization)
- 5-10% loss of the future planned income can make a difference between economically justified and unjustified power plant – important to have good inputs!

Presentation questions:

- How will climate change influence generation from renewable energy sources in Croatia?
- Which climate variables influence electricity generation?

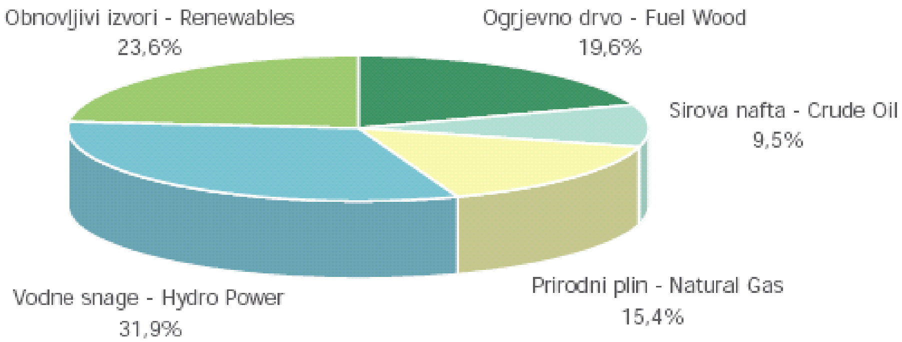
Domestic energy production

2008. godina
Year: 2008



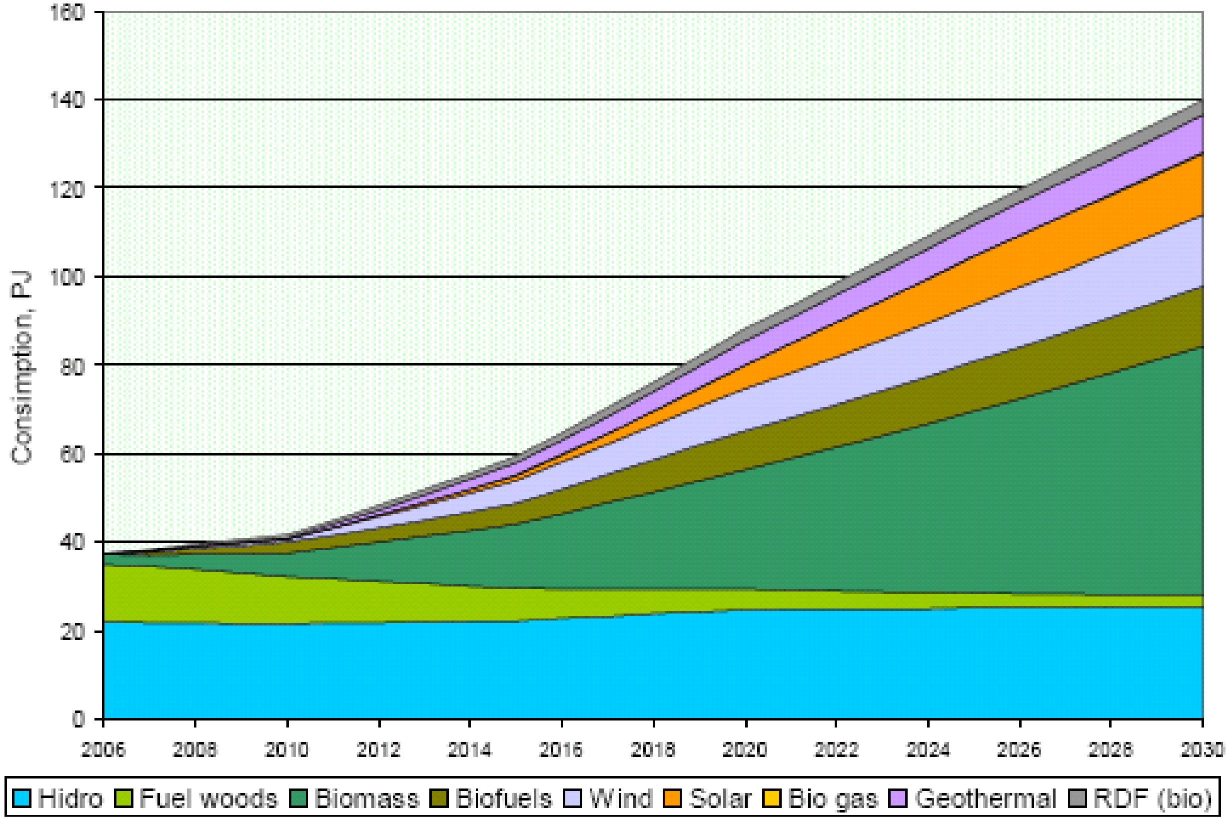
Total installed power capacity in 2008 - cca 4000 MW
Hydro capacity cca 2000 MW (50%)

2030. godina
Year: 2030

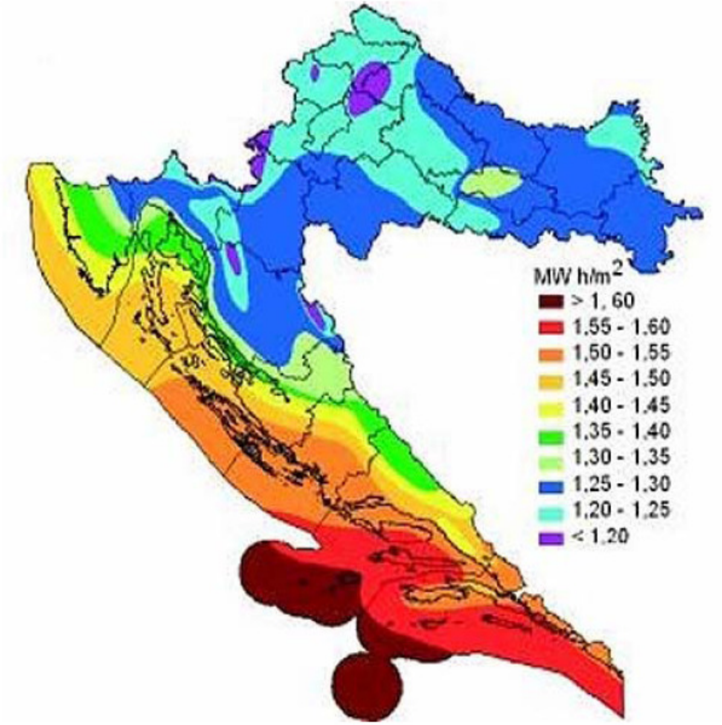


Energy strategy outlook to 2030

2000 MW in wind parks
420 MW in biomass power plants
60 MW in waste-to-energy plants
30 MW in geothermal power plants
250 MW in solar power plants
140 MW in small hydro



Photovoltaics – potential



Esg- an average annual irradiated solar energy per square meter

Location	Average annual irradiated solar energy per day (kWh/m^2d)
Croatia, Southern coast	5,0-5,2
Croatia, Northern coast	4,2
Croatia, continental part	3,4-4,2
Central Europe	3,0-3,2
Northern Europe	2,8-3,0
Southern Europe	4,4-5,6

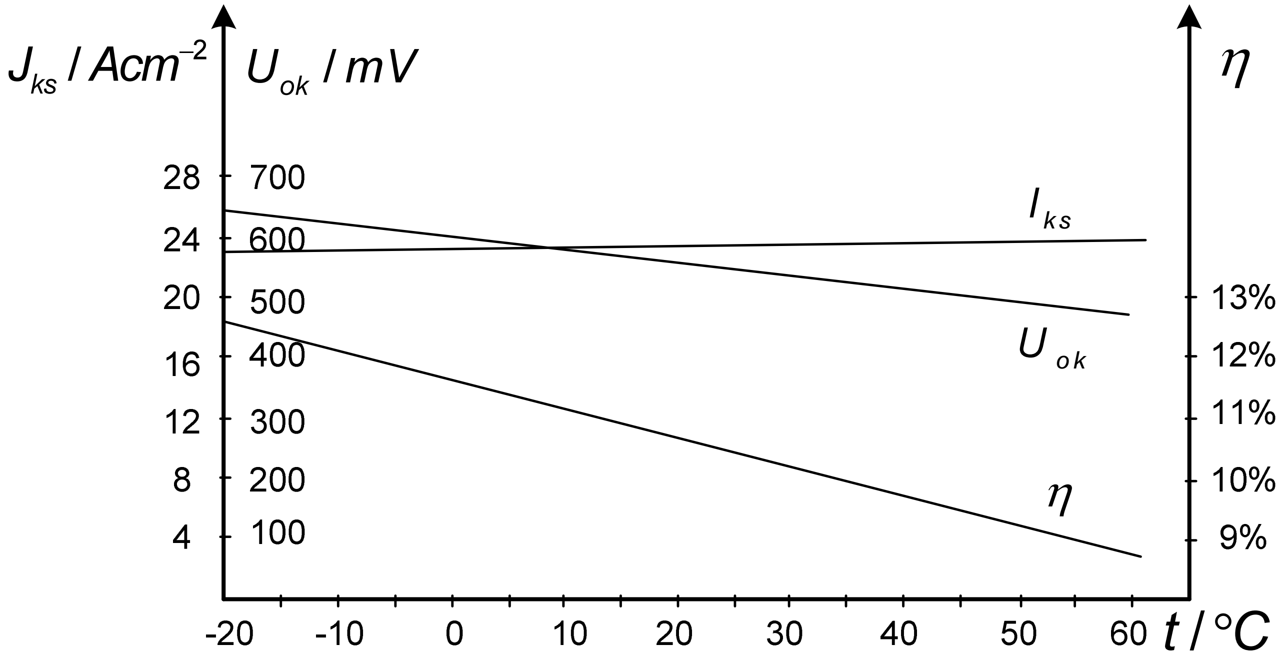
- Southern coast of Croatia is receiving as much solar energy as Greece or Northern Spain
- Some parts of Croatia have more then 2700 hours of sunshine/year!

Photovoltaics – impact from CC

- Temperature
- Number of days under snow cover
- Irradiated energy
- Extreme events

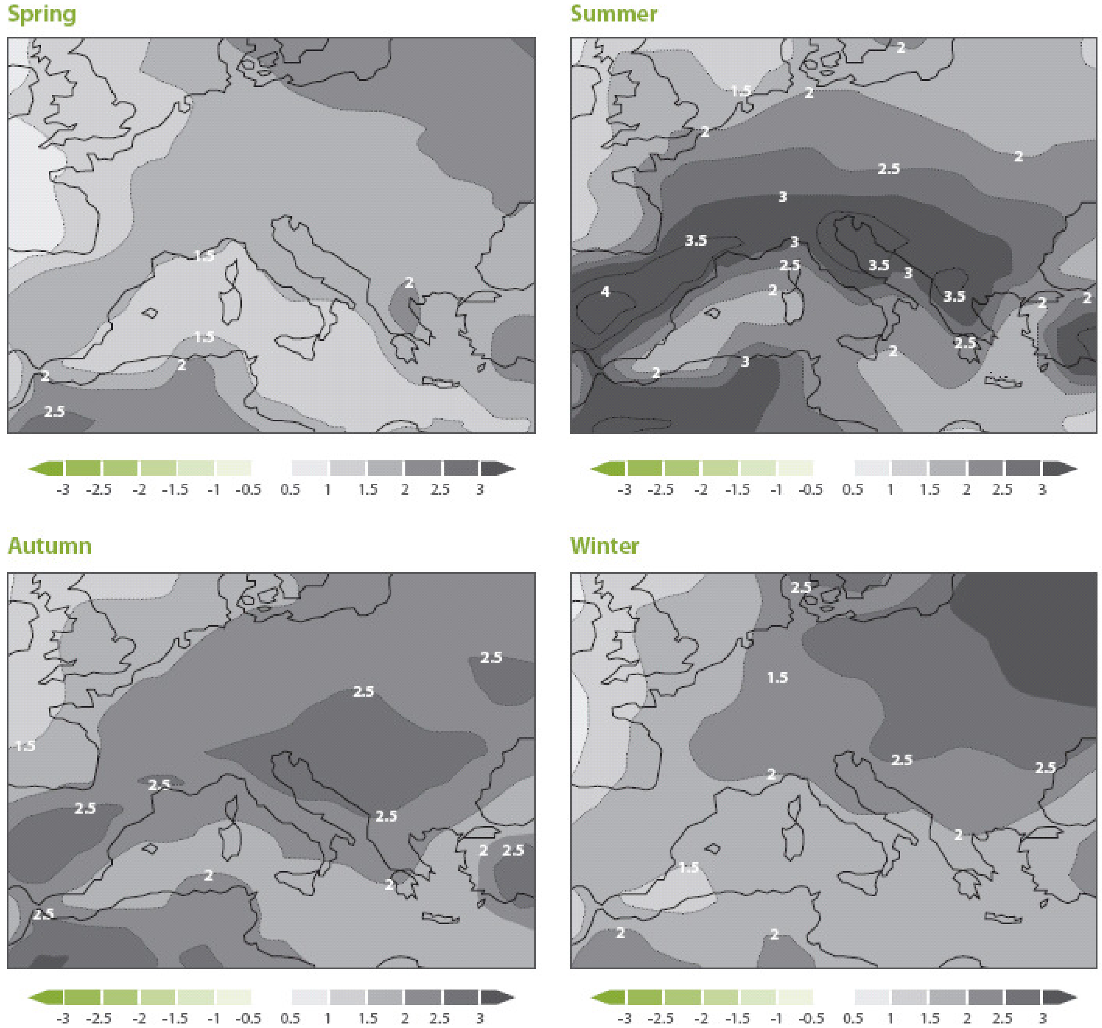
- Time horizon: 2041 -2050 (compared with 1981-1990)

PV – temperature impacts



- "Cell temperature coefficients" differ according to technology and producer (efficiency, power, current, voltage)
- For silicon based cells, for each °C temperature rise - efficiency lowers for 0,5%

PV – temperature change



- Average temperature increase in summer is 3.5 °C.
- With maximal temperature rise of 6 °C, efficiency drop from PVs is up to 3%!

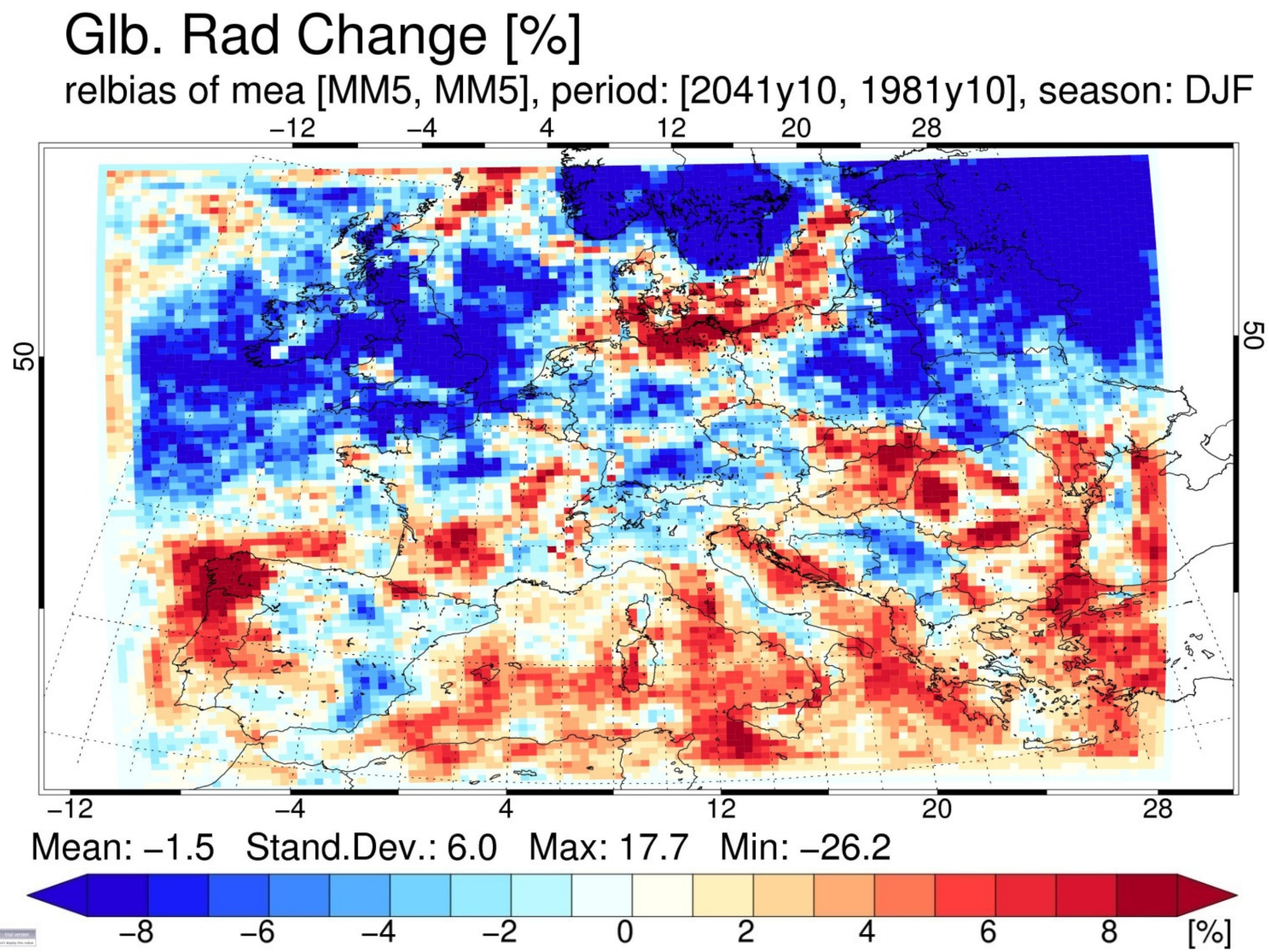
PV – total irradiated energy

Total irradiated energy

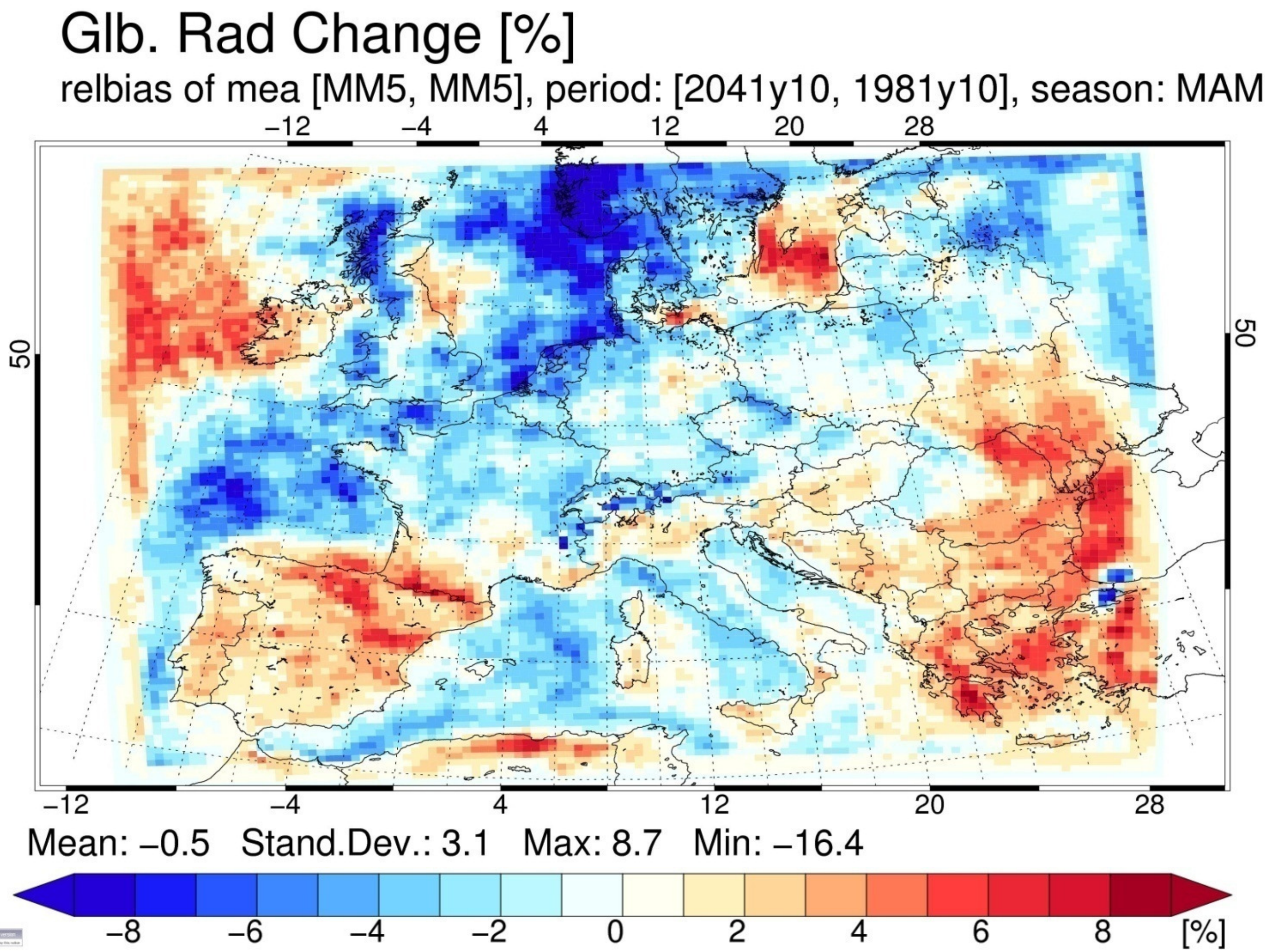
- A sum of direct and diffused irradiation
- Mostly influenced by cloudiness

- For the period 2041-2050 expected rise of total irradiation is the highest in summer and autumn (from 8% to 10%)
- Such increase means direct proportional increase of electricity production from PV panel by 8-10% in summer and autumn

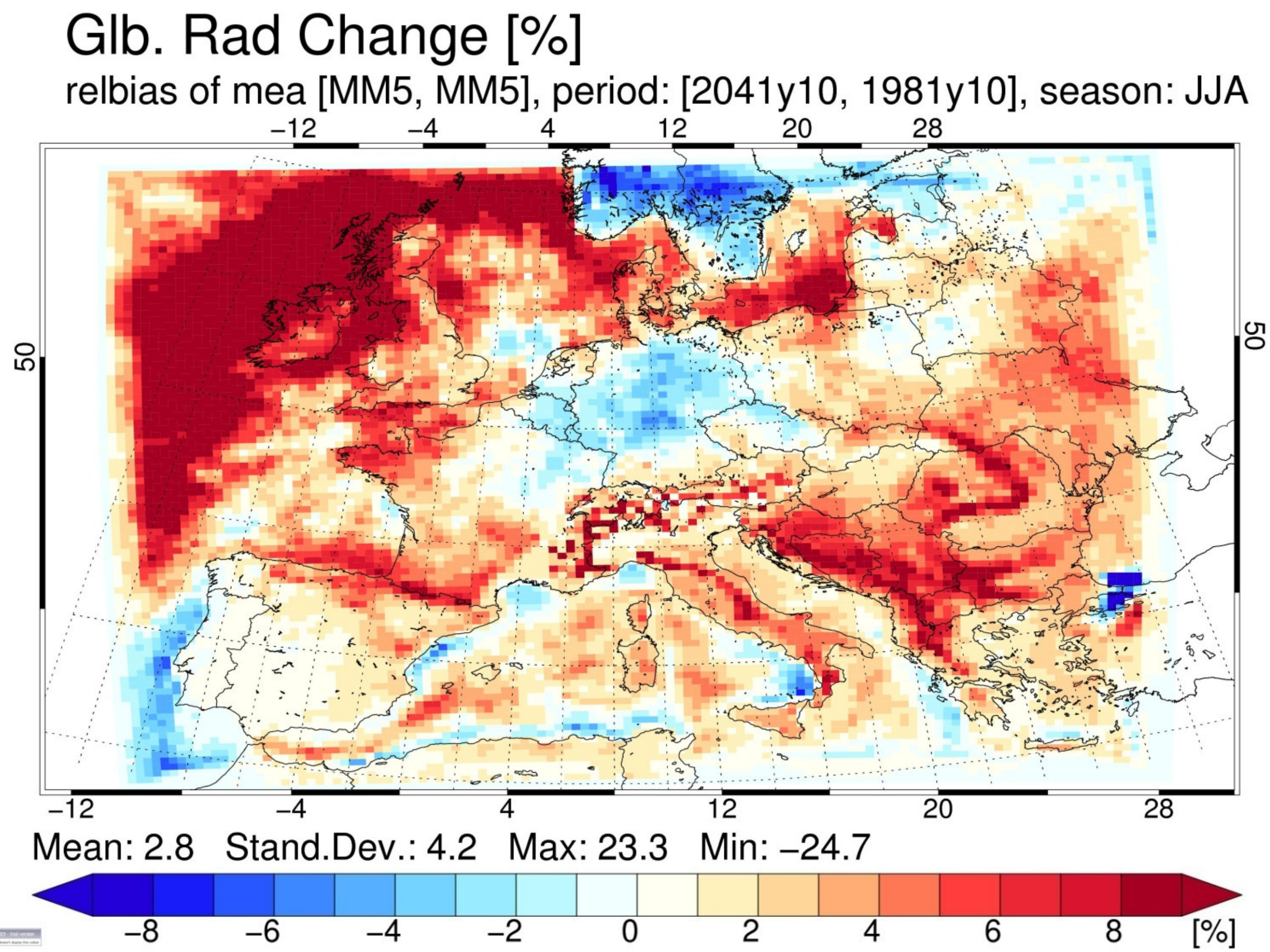
PV – irradiation change winter



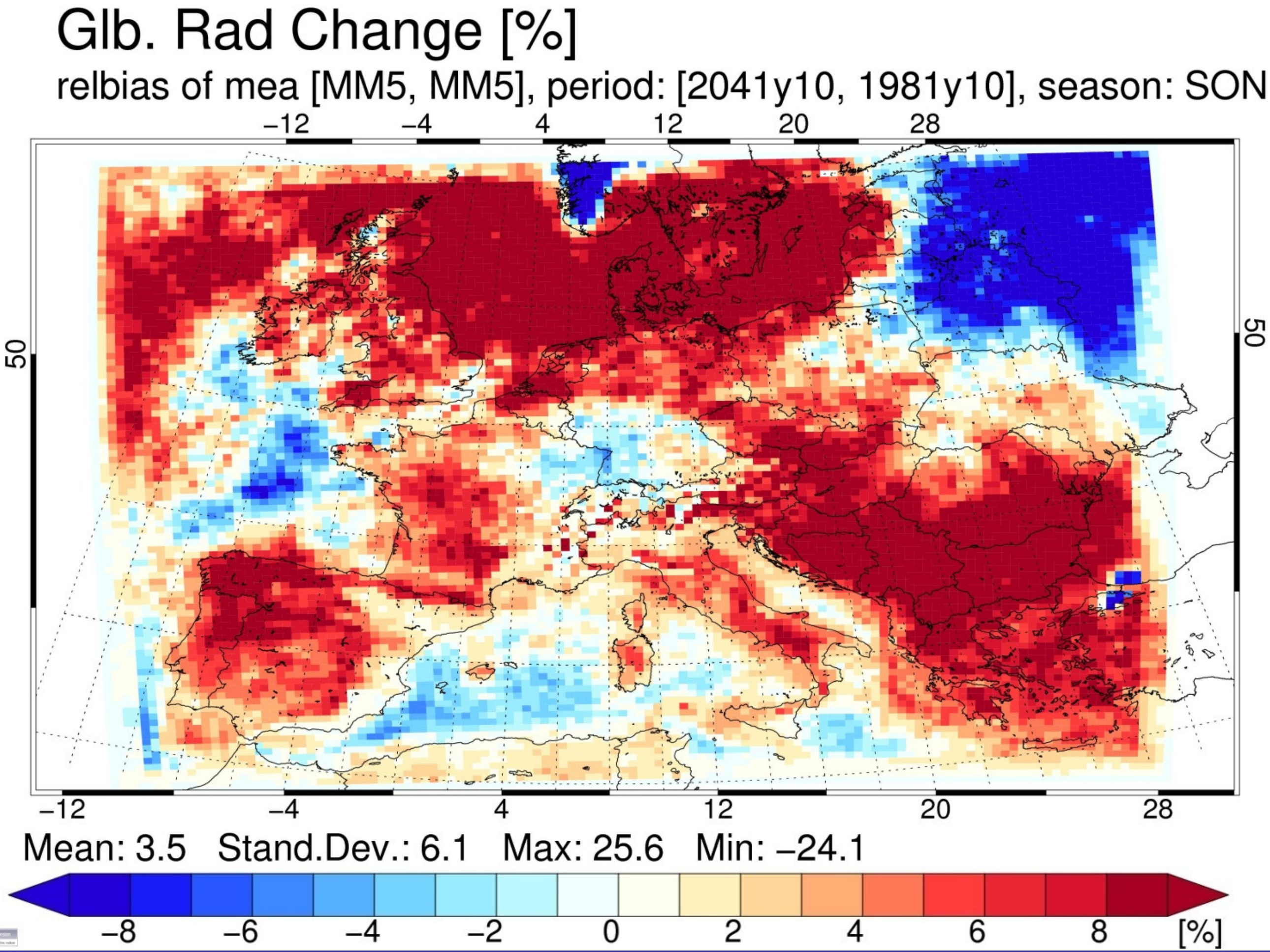
PV – irradiation change spring



PV – irradiation change summer



PV – irradiation change autumn



PV – other impacts

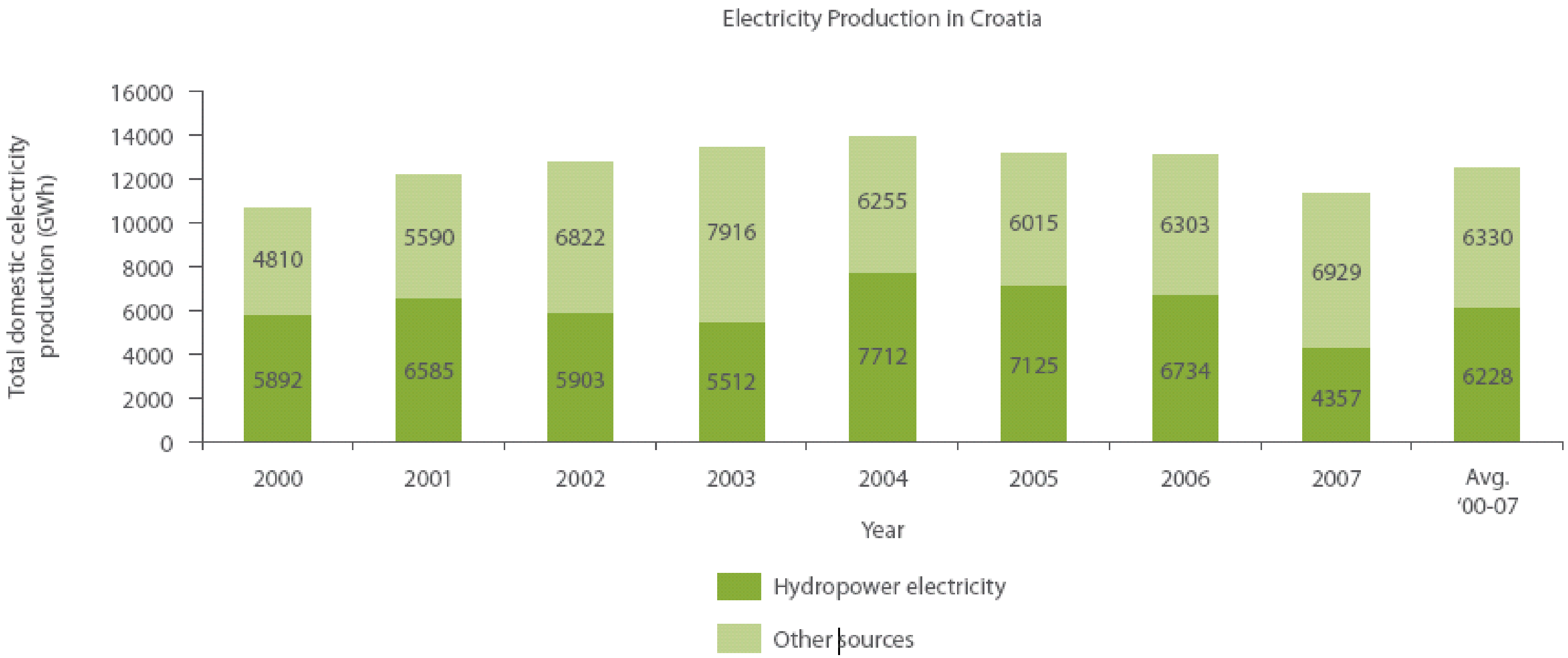
Number of days under snow cover

- Lower precipitation up to 10%
- Higher temperatures in winter mean less days with snow cover
- Result: more solar energy on PVs, with less need for snow removal

Extreme weather events

- Higher temperatures and less precipitation will result in more forest fires that can affect PV plant; risk hard to quantify, but can be reduced with choice of PV plant location
- Expected increase in strong winds and storm events can influence PV panels with stronger force than designed

Hydro



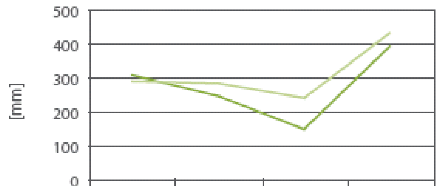
- Half of electricity produced in Croatia from 2000 – 2007 came from hydro power plants
- 50% of installed Croatian power capacities are in hydro
- Average annual share of hydro in total electricity consumption was 39%

Hydro

Most hydro power plants located in Southern Croatia, with water inflow depending on water situation in Bosnia and Herzegovina

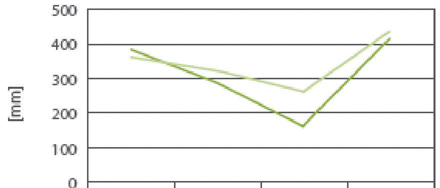
Hydro – less precipitation, 2080-2100

Northern Adriatic coastal area



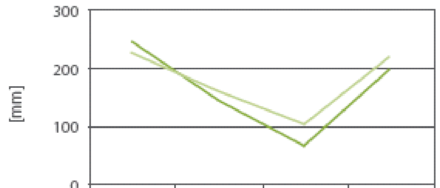
	Winter (Dec - Feb)	Spring (Mar - May)	Summer (Jun - Aug)	Autumn (Sep - Nov)
Precipitation Averages (Present 1961 - 1990) (mm)	290.5	283.7	237.5	434.1
Future Averages (2080 - 2100)	306.8	245.1	144.7	392.4

Mountainous area



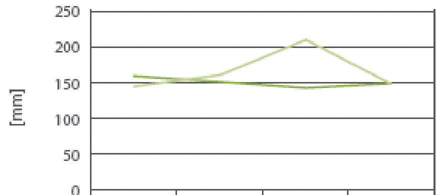
	Winter (Dec - Feb)	Spring (Mar - May)	Summer (Jun - Aug)	Autumn (Sep - Nov)
Precipitation Averages (Present 1961 - 1990) (mm)	360.2	319.3	259	433.6
Future Averages (2080 - 2100)	381.5	283.9	159.8	413.7

Dalmatian coastal area



	Winter (Dec - Feb)	Spring (Mar - May)	Summer (Jun - Aug)	Autumn (Sep - Nov)
Precipitation Averages (Present 1961 - 1990) (mm)	233.8	165.5	105.8	224.4
Future Averages (2080 - 2100)	252.3	151.3	66.9	202.9

Pannonian area



	Winter (Dec - Feb)	Spring (Mar - May)	Summer (Jun - Aug)	Autumn (Sep - Nov)
Precipitation Averages (Present 1961 - 1990) (mm)	138.5	157.1	211.2	143.4
Future Averages (2080 - 2100)	155	146	135.6	143.5

Hydro

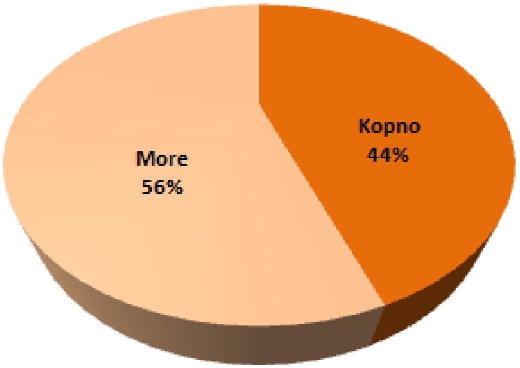
- Lower precipitation means less water inflow to hydro reservoirs
- Macro-scale hydrological models predict that production from Southern European hydros will decrease between 20-50% by the 2070s (CEC 2007, Lehner et al. 2005)
- Recent experience from new small HPPs in Bosnia and Herzegovina show in some cases 20-30% lower electricity generation than planned (water flow data used were mostly from 1970s)

Cost for replacing 35% loss of hydro production annually:

-65 million € (if replaced with coal, 50 €/MWh)

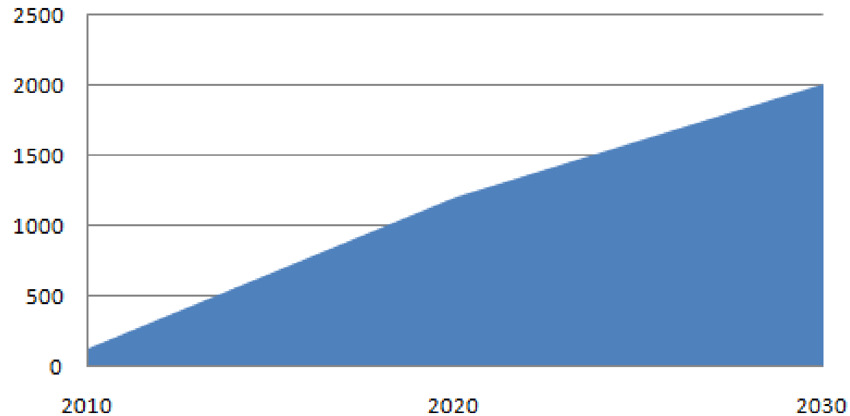
-117 million € (if replaced with imported electricity, 84 €/MWh)

Wind energy development

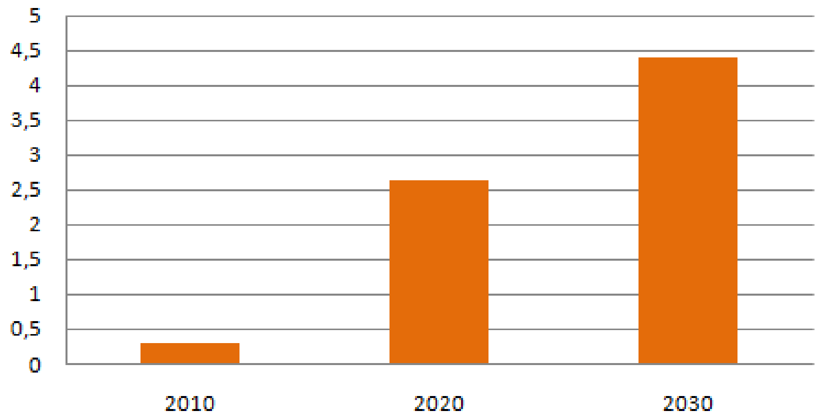


Economical potential – 9 TWh/year (with strong interconnection to neighboring power systems)

Installed wind capacity (MW)



Electricity generation from wind (TWh)



Goals:

- In year 2020 - 1200 MW;
- In year 2030 - 2000 MW.

Wind

- Increasing number of studies looking at changes in wind speed and impacts on electricity production
- Two main impacts from CC:
  - Change in wind speed (influence on quantity and timing of the wind resource and electricity produced)
  - Increase in maximal wind speed for which wind power plants are designed (influence on equipment robustness)

$$P = \frac{1}{2}\rho U^3$$

P – Power; U – wind speed, ρ – air density

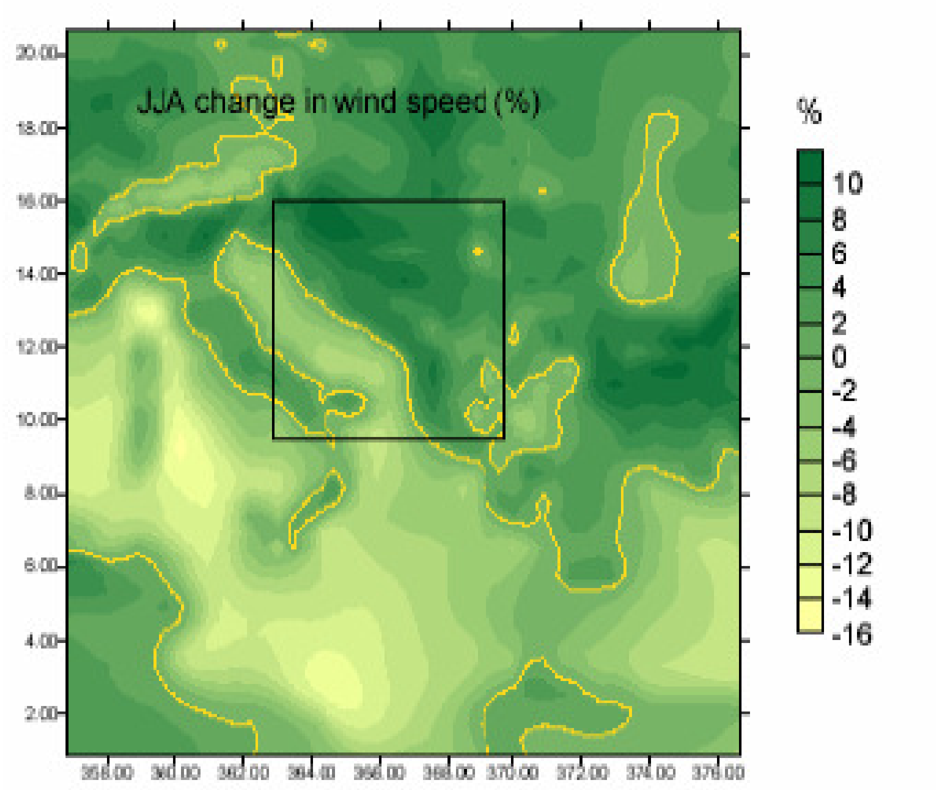
- Due to this cubic relationship, 10% change in wind speed could alter energy produced by 13-25% (Baker et al, 1990)
- Wind turbines can extract energy over a defined band of wind speeds, typically between 3 and 25 m/s
- Rise in 1°C changes air density and production by 0,3%

Wind

- Detailed wind downscaling model should be applied to analyze change in wind speed and direction (grid 15 -50 km)

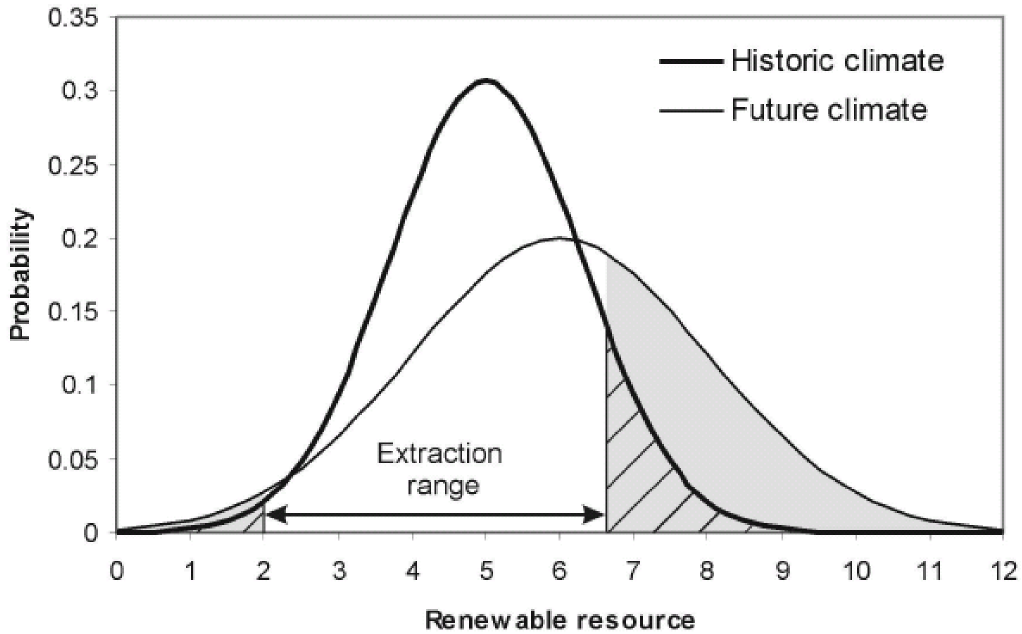
Rise in wind speed in summer in Croatia between 2-6 % expected in 2080s (MAGICC/SCENGEN v. 4.1) This could result in 6-19 % more electricity generated

Change in wind direction can also impact electricity generation from wind power plant



Wind speed variability

- can have significant impact on electricity production from wind power plants:
  - wind speed rises
  - due to the variability, most part of this wind speed rise is unexploited because it is out of the wind speed upper limit



Conclusions

- This work represents a first step in exploring the potential changes in production from PVs, wind and hydro in Croatia due to climate change
- Power planning demands detailed understanding of long term availability of these potentials
- PVs - positive correlation with CC – up to 5% higher electricity generation until 2050 (summer, due to lower cloudiness)
- Hydro – negative correlation with CC – between 10-40% lower electricity generation in 2070s (less precipitation)
- Wind – positive correlation with CC – between 6-20% higher electricity generation in 2080s (rise in wind speed)


Hvala!
Thank you!