IAEA
International Atomic Energy Agency

Webinar

Climate Risk and Vulnerability Analysis

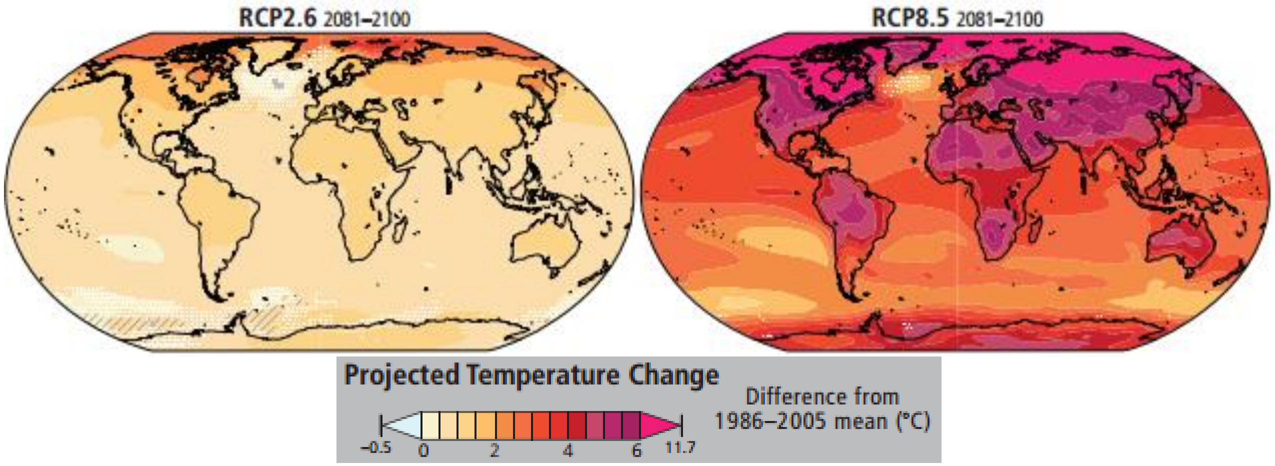
Climate Change Vulnerability and Adaptation in the Energy Sector

February 8, 2021

Loreta STANKEVICIUTE
PESS Section / NEPK Division
Department of Nuclear Energy

Gradual Climate Change (GCC) and Extreme Weather Events (EWEs)

- **Gradual climate change (GCC):** *Changes in mean and variability over decades*
  - Temperature
  - Precipitation
  - Wind patterns
  - Sea level rise

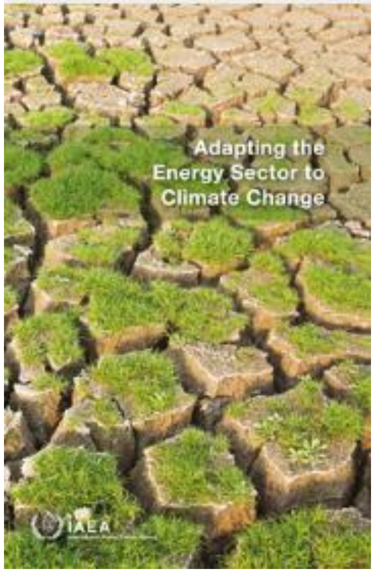


- **Extreme Weather Events (EWEs):** *occurrence of a value of a weather or climate variable above (or below) a threshold value near the upper (or lower) ends of the range of observed values of the variable*
  - Extreme high or low temperature and precipitation, extreme winds, storms, hail, lightning
  - Increasing frequency and intensity, affecting larger areas, prevailing longer

Impacts on energy system

Extraction/Resource → Transport → Conversion → Transmission & Distribution

IAEA Report: Adapting the Energy Sector to Climate Change



https://www.iaea.org/publications/12338/adapting-the-energy-sector-to-climate-change

Extraction / Resource

- Coal and Uranium:
  - flooding open-pit mines
  - dust from coal stockpiles
- Oil & gas:
  - melting permafrost -> destabilizing equipment
  - sea level rise: inundating coastal and offshore sites
  - see level rise + winds: damage to onshore wells and offshore platforms
- Hydro:
  - higher evaporation losses
  - changes in water availability (including indirect changes due to need for more irrigation and water cooling for thermal plants)
- Wind:
  - changes in wind resource
- Solar:
  - changes in insolation

Transportation to conversion

- Ocean-going ships:
  - Less sea-ice = more opportunities for passage
  - Sea level rise may affect ports and limit options for large vessels
- Inland ships:
  - Difficult passage for extreme low and extreme high water levels
  - Extreme low temperatures: ice
- Rail & roads:
  - Freeze-thaw cycle leads to damage
  - High temp: tracks deform; roads soften
  - Low temp: RR switches freeze; roads crack
- Pipelines:
  - Low temp: can weaken/damage pipelines
  - High temp: increased corrosion and greater energy requirements for compression

Conversion: thermal (coal, gas, nuclear) - Gradual CC

- temps increase
  - thermal efficiency decreases by 0.1 - 0.5% per 1 C° increase
  - cooling efficiency decreases: capacity loss of 1 – 2% per 1 C° average temperature increase
- changes in rainfall patterns
  - can reduce the availability of water from rivers and lakes, leading to potential reductions in output or even shutdowns with low water levels
- increased windiness near coasts and dry areas
  - salt sprays from sea → corrosion, short circuit of exposed electrical equipment; dust and sand → equipment malfunction
- sea level rise
  - flooding of low lying coastal sites

Conversion: thermal (coal, gas, nuclear) – Extreme Weather Events

- Extreme heat: if water for cooling is too hot, can reduce generation or force shutdown; reduce effectiveness of cooling;
- Extreme cold: ice clogging water cooling intake;
- Precipitation: excessive rain or snow can collapse unreinforced structures; excessive snow can inhibit plant access;
- Drought: low water levels can force plants to reduce generation output or shutdown
-
- Flooding: coastal plants vulnerable to storm surge; inland plants vulnerable to river flooding; safety systems can be damaged
- Lightning: can short-circuit instrumentation, back-up gen connection, grid connection
- High winds: wind-generated missiles can damage buildings, back-up gen, knock out grid connection

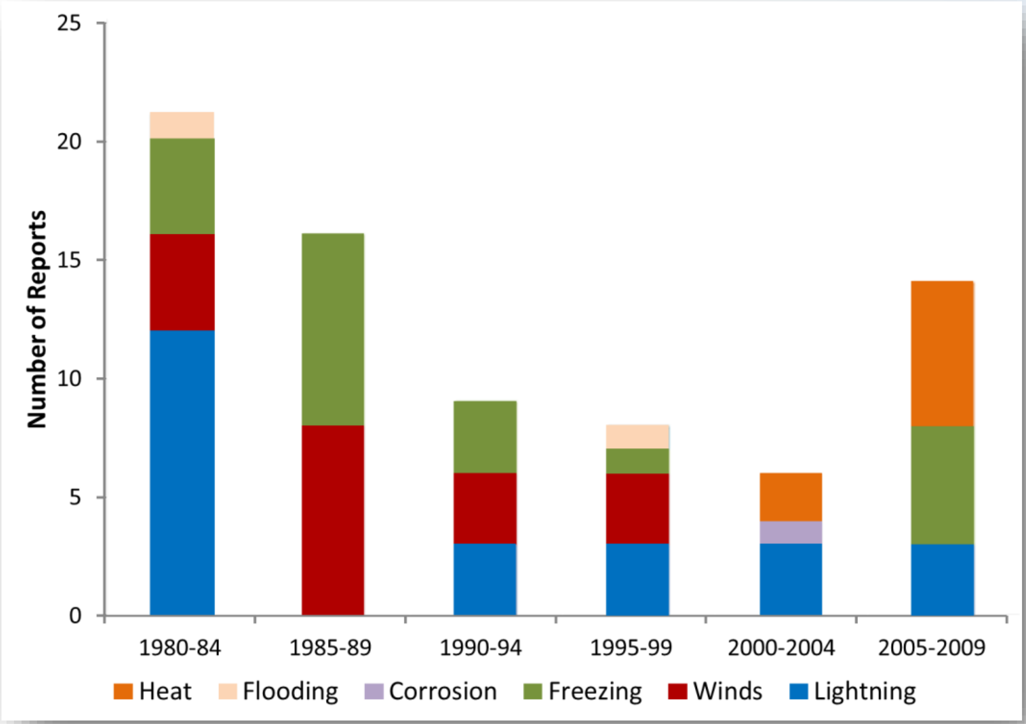
CC and EWEs impacts on Nuclear Energy

Key: Nuclear - lots in common with all thermoelectric plants, but **special**:

- Physical protection and security
- Diverse, independent, redundant safety systems (to prevent common cause failures – later)
- Need for long-term core cooling
- Need for reliable electric grid

Vulnerabilities to extreme weather in the past

- IAEA's International Reporting System (IRS)
  - 88% of weather related events affect 3 major systems
    - Water cooling: 28%
    - Electrical control systems: 27%
    - Transmission grid: 32%
    - Remainder of events were general (e.g. flooding)



- From 1980 – 1999, events are equally distributed between lightning (33%), winds (33%), and freezing (30%)
- In the 2000s, heat related events began to appear

Conversion: oil & gas refineries

- Gradual CC: sea level rise inundating coastal refineries
- Gradual CC + EWE:
  - Precipitation: flooding refineries
  - Winds: physical damage
  - Lightning: structural damage; fires

Conversion: hydro

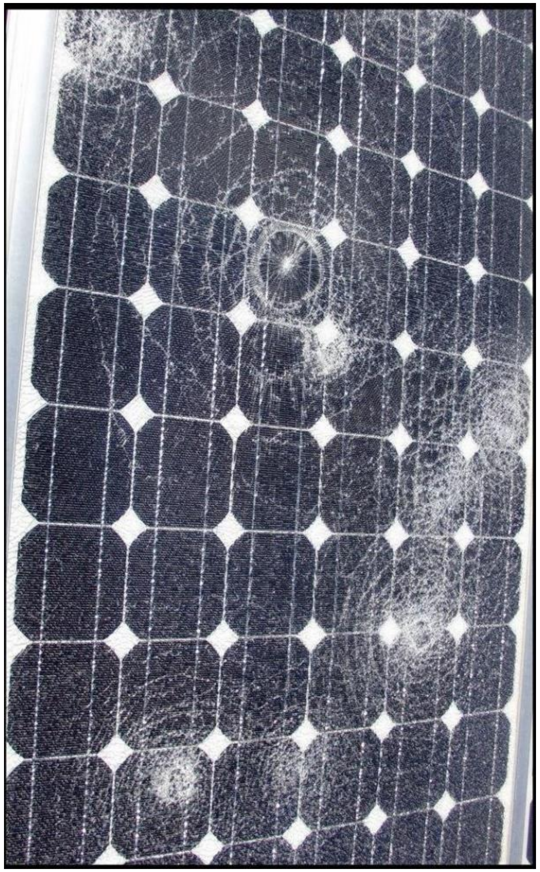
- Gradual CC:
  - Lower precipitation = lower long-term capacity and output
- Gradual CC + EWE:
  - Flooding: structural damage to dam wall or turbines from water force and debris
  - Flooding + winds: waves causing dam overflow

Conversion: wind

- Gradual CC:
  - Changes in the spatio-temporal wind resource distribution; mean wind power densities over Europe and NA likely within ±50% of current values
  - Less frequent icing with increasing temp
  - Lower precipitation: more dust deposition
  - Sea level rise: inundating coastal and offshore sites
- Gradual CC + EWE:
  - Winds: structural damage
  - Low temps + precipitation: ice formation on blades reducing efficiency; structural damage
  - Lightning: structural damage

Conversion: solar

- Gradual CC:
  - Increasing temp: lower PV and CSP efficiency
  - Changes in cloudiness and average insolation
- Gradual CC + EWE:
  - Increased precipitation, high winds, hail and high temperatures can each damage PV and CSP
  - Drought + winds: more sand and dust deposited on collectors, reducing efficiency of PV and CSP



Transmission & Distribution

- Rail, road, inland waterways, pipelines: same issues as transport from source to conversion
- Electric grid:
  - Gradual CC: decreasing transmission efficiency of 0.4% per 1 C° increase
  - Gradual CC + EWE:
    - High temp: lines and transformers overheat, capacity declines & outages
    - Low temp: ice -> damage & outages
    - Lightning: damage & outages
    - Winds: damage & outages
    - Flooding: damage & outages

Costs of not adapting

- Direct costs:
  - Physical damage to infrastructure
  - Reduced output and outages
    - e.g. every 24 hours a 1 GW unit is shut down costs the owner $1.2 million (assuming $50/MWh)
- Indirect costs:
  - Outages that lead to wider blackouts can impose substantial indirect costs
    - Value of lost load in developed countries ranges from 200 to 960 million euros for a 24 hour blackout (based on lost output for a 1 GW plant) (Nooij et al. 2007, Tol 2007)
  - Cumulative macroeconomic costs from physical damage, need for additional capacity, outages, etc.

Adaptation Options

- Numerous
- General approaches fall within 2 categories
  - Physical protection, *e.g.*
    - building sea walls and other earthworks to protect coastal energy infrastructure from sea-level rise and storm surges
    - route heated water from cooling system to inlet area to prevent ice clogging;
    - Install tornado missile shields; Ensure that circuits are insulated and grounded
  - Alternative technologies
    - alternative cooling options (C/BA): reuse wastewater, recover evaporated water in recirculating systems, dry cooling

Main messages

Gradual CC: mostly affects the resource base of renewables

Gradual CC + EWE: the impacts can be severe throughout energy supply chain

- Special case: Nuclear sector is exposed and vulnerable, but adaptive and resilient. Future CC and changing EWEs→ new challenges

  – Adaptation existing: feasible, but C/BA
  – Adaptation new: revised design bases, site selection

IAEA support to Member States:

- Safety Standards and Guides: continuous updates
- Nuclear and other energy sector: CRPs for joint work
- Energy System Assessment within CLEW Framework

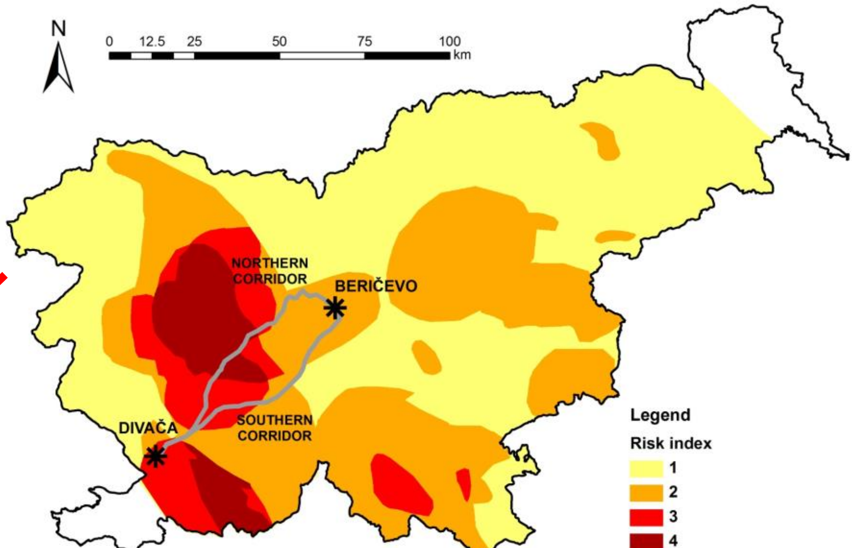
CRPs – Coordinated Research Project

CRP on Adaptation of nuclear and non-nuclear energy infrastructure (2013-2016)
Example of Slovenia's case study

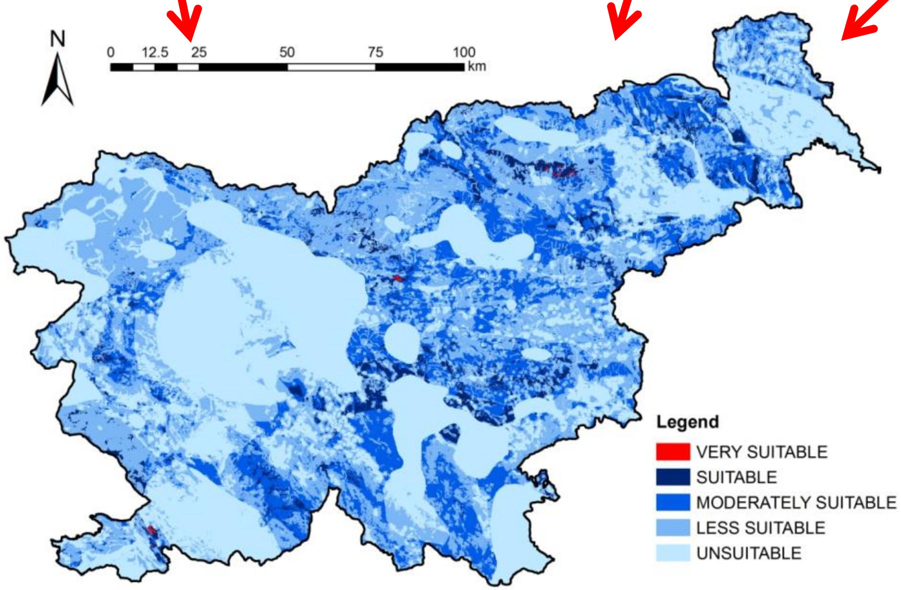
- GIS supported vulnerability evaluation
- Risks to power grids due to ice storms
  - Siting of transmission line
  - Siting of windfarms

Spatial Attractiveness

Environmental Vulnerability



Risk-assessed siting for two alternative power lines



Risk-assessed spatial suitability for windfarms

Windfarms

⇒ Very suitable area: 31 km^2

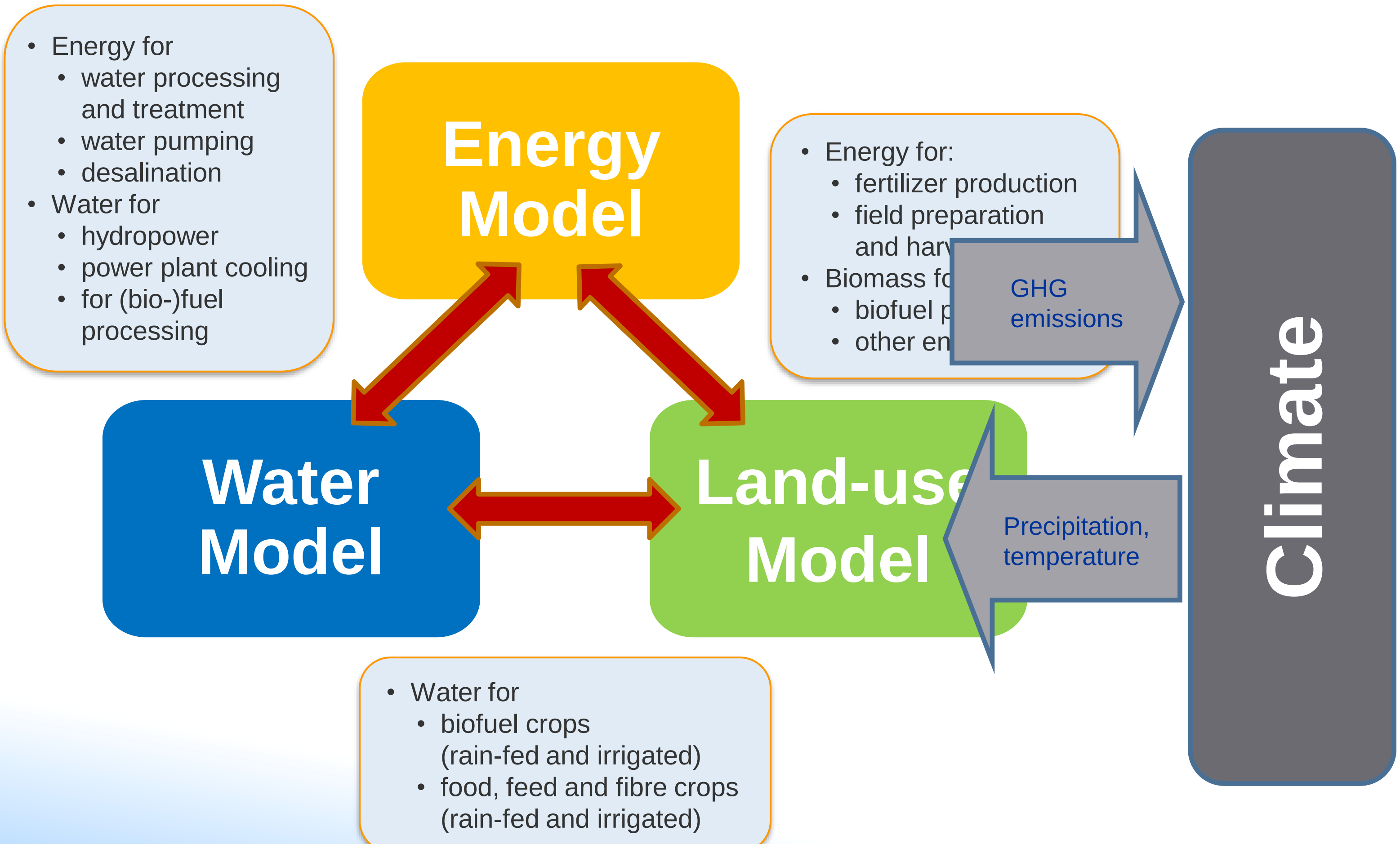
⇒ Potential capacity: 930 MW

⇒ Potential annual energy production: 1.68 TWh

Source: Matko, et al., 2016

Climate, Land and Water Use and Energy Systems Interactions

Basic concept: land, energy and water resource systems are highly integrated and any assessment of these resources should ideally treat them as such



Thank you!

PESS.Contact-Point@iaea.org