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Alternative climate scenario analysis on Energy-Food-Water and Health nexus in Bhutan

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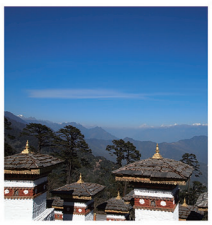
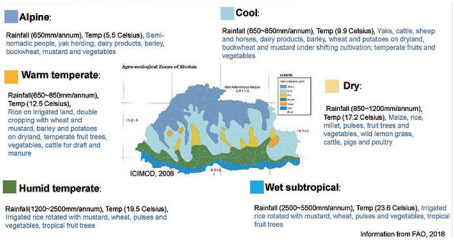
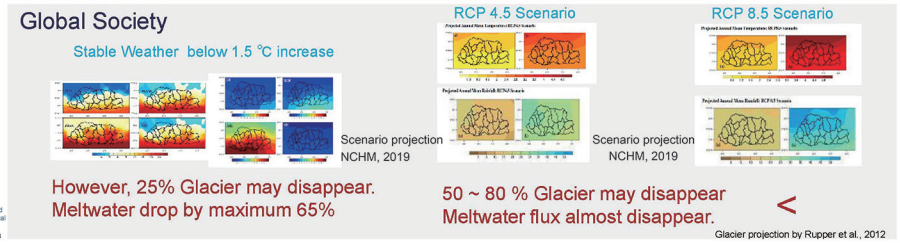
Background

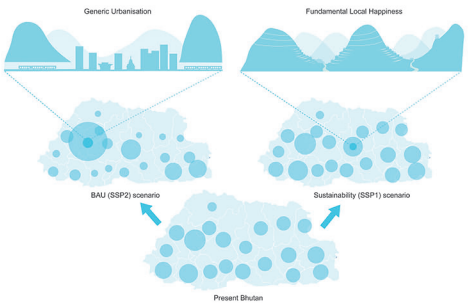
Bhutan is already facing significant impacts of climate change due to its mountainous and glacial terrain. Bhutan has six distinct climate zones, each with unique characteristics (see Fig.below). According to projections by the National Centre for Hydrology and Meteorology (2019), climate change may cause serious temperature and rainfall changes by the end of this century. The RCP4.5 scenario indicates a 0.8~1.6℃ increase by 2050 and 1.6~2.8℃ increase by 2100. The RCP8.5 scenario shows a 0.8~2.0℃ increase by 2050 and 3.2~5.6℃ increase by 2100. The most significant impacts are temperature increases in the southern part of the country and a decrease in rainfall causing dry weather in winter in northern Bhutan. In addition to these impacts, there are also more serious projections of glacial melt. If the temperature increase exceeds 1℃, then 25% of the glaciers may disappear, and meltwater will drop by a maximum of 65%. If the temperature increase exceeds 1.5℃ in RCP4.5 scenario, then 50~80 % of the glaciers may disappear and meltwater flux will almost completely disappear (see Fig below). These projections indicate that Bhutan needs to prepare for a catastrophic scenario as this may be caused by the global temperature rise and by the direction of global society.



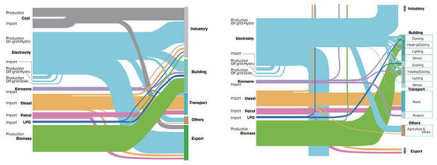




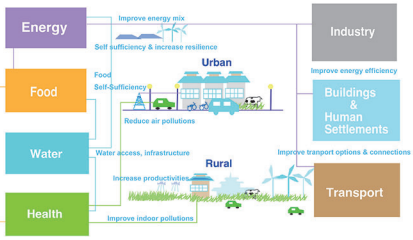
Analytical framework & scenario development



Bhutan SSP scenario (Kamei et al., 2021)



Energy flow dyagram (sectoral + detailed in building sector)
(Author made: data source Bhutan Energy Data Directory, 2015)



Bhutan nexus approach and key mitigation sectors

SSP1 - RCP 1.9 - Happy Bhutan

Energy

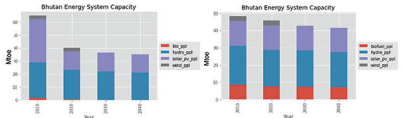
Hydro and solar are more utilized.
Rural biomass use is replaced by efficient appliances.
Small scale micro grid RE generations increase.

Food

Small scale agriculture are promoted.
Sufficient infrastructure for local small farmers.
Local supply chain becomes more utilized.

Water

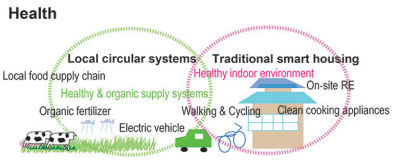
Water infrastructure are utilized for all residents.
Natural disaster risk management has been well-prepared.
Glacier and rainfall have balanced supply through all seasons.



Energy capacity (Urban- residential)
(Estimated by MESSAGEix model)

Energy capacity (Rural-residential)
(Estimated by MESSAGEix model)

- Overall, energy demand decreases thanks to the improved energy efficiency standard and sustainable consumption patterns with sharing economy.
- Small scale hydro increases as well as local-oriented PV installations with feasible mini-grid.



Health impact assumptions (based on GAINS Bhutan model analysis)

SSP1 - RCP 4.5 - Risks increase

Energy

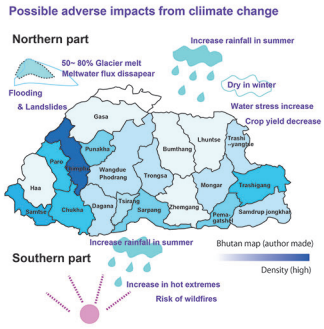
Hydro becomes more unstable sources.
Biomass still need to be used. The need for clean technology
Solar big farm can be developed in the northern part.

Food

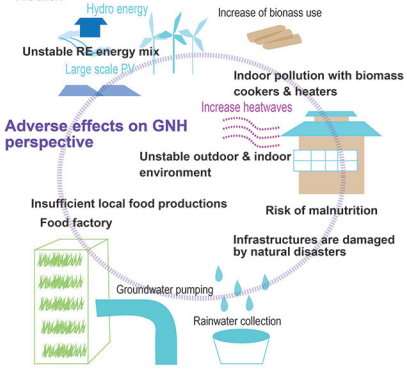
The feasible places for agriculture is limited.
Very limited crop species in different climate zones.
More artificial production system is needed.

Water

Water infrastructure have to be maintained.
Rain water becomes more important sources.
Water collection systems and local water storage tanks are more essentials.
Water recycling system is more important.

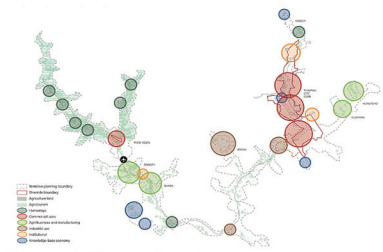


Climate impacts assumption based on NCHM, 2019

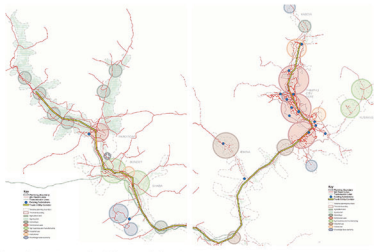


Health impacts assumptions in SSP1-RCP4.5 scenario
(Assumptions are based on Bhutan National Adaptation Plan, 2023)

Bhutan Urban - Rural sustainability, regional strategies (Thimphu + Paro), and Hydrogen deployment



Local structure plan/ Future employment *(Source: Ministry of Infrastructure & Transport)*



Local structure plan/Energy infrastructure *(Source: Ministry of Infrastructure & Transport)*

Population

Thimphu and Paro will promote a balanced distribution of the population with equal oppotunities: expect to increase 40 - 50% populations by 2047.

Integrated utility infrastructures

Adequate water, waste, energy, telecommunication infrastructures are well utilized across two regions.
Transport connection and green infrastructures are also well-connected as corridors' functions.

Local jobs

The target of creating +62,100 jobs by 2047 in Thimphu, mainly in the service sector.
The target of creating +15,900 jobs by 2047 in Paro, in the balanced mix sectors.

Potentials

The need for a strategic development of 'Energy communities' which share the larger scale PV installations as well as home based small scale PV on the rooftop.
Hydrogen and biogas are the high potentials for increasing the energy regilience.

Indigenous local supply

Large scale solar PV farm can take advantage of correctly oriented mountain faces.
Heat pumps can be utilised for electrifying space/water heating.
Ground source heat pumps (GSHP) provide better resilience to weather extremes.
Renewable gas generation and a renewable gas network is a promising opportunity for decarbonisation of heating and transport.

Bhutan green hydrogen perspective

SSP1 - RCP 4.5 scenario - hydrogen energy solution

Green hydrogen can be produced during the wet season (mainly in summer), which should be stored as hydrogen and used during the dry season (in winter) when hydroelectric power is not sufficient. This can also increase electrification and meet NDC principles.