Towards Optimization of Renewable Energy Deployment for Nature-Based Solutions

Osamu Saito

Program Director, Institute for Global Environmental Strategies (IGES)

Visiting Professor, Institute for Future Initiatives (IFI),

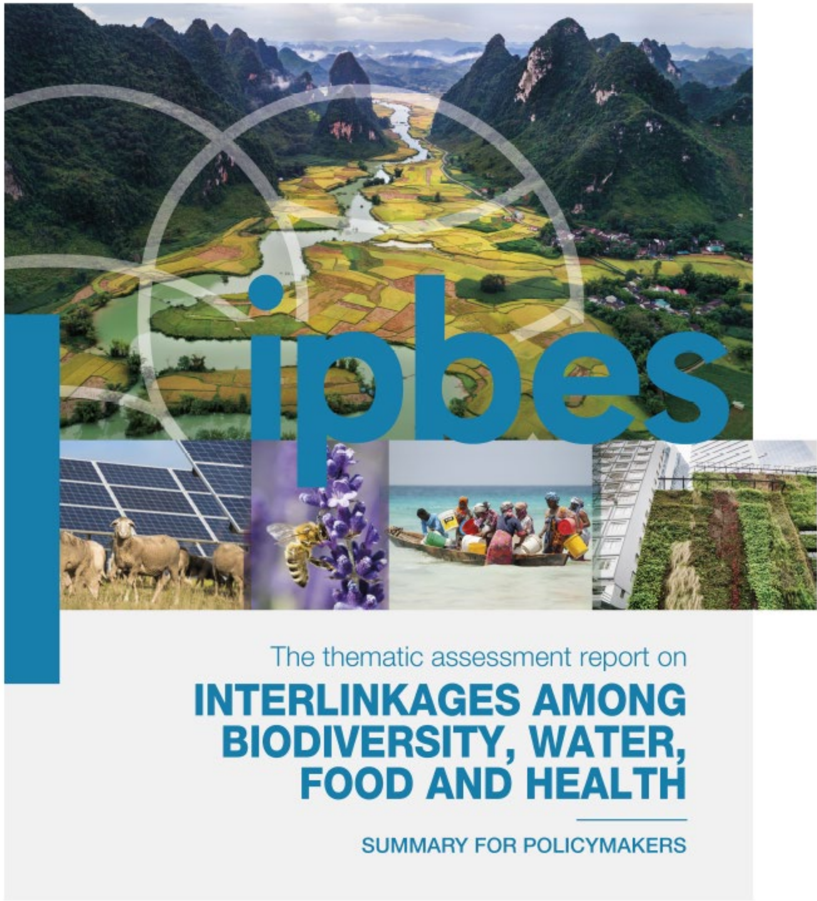
The University of Tokyo

IGES Institute for Global Environmental Strategies

東京大学未来ビジョン研究センター
Institute for Future Initiatives

Production of the IPBES Nexus Assessment

- Produced over a period of three years
- 165 selected experts:
  - ✓ Co-chairs: 2
  - ✓ Coordinating lead authors: 27
  - ✓ Lead authors: 110
  - ✓ Review editors: 13
  - ✓ Fellows: 13
- Contributing authors over 70
- Draws on 6,500 sources of knowledge, including peer-reviewed literature, grey literature and Indigenous and local knowledge



ipbes

The thematic assessment report on

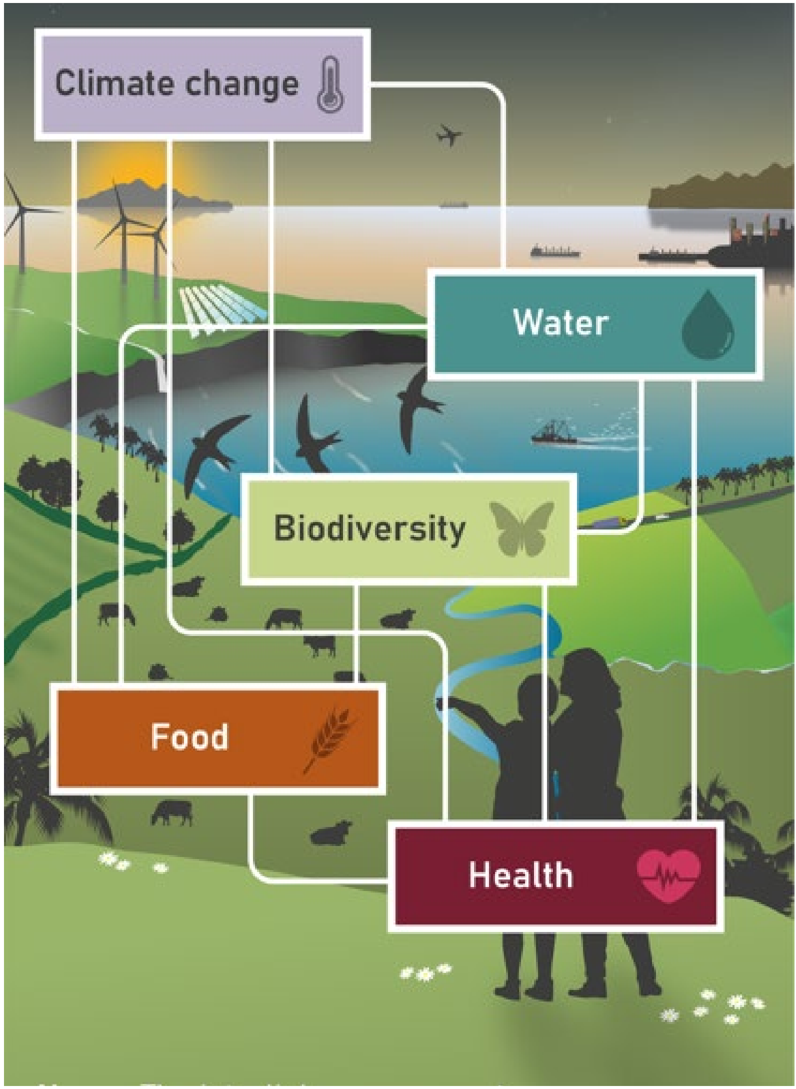
INTERLINKAGES AMONG BIODIVERSITY, WATER, FOOD AND HEALTH

SUMMARY FOR POLICYMAKERS

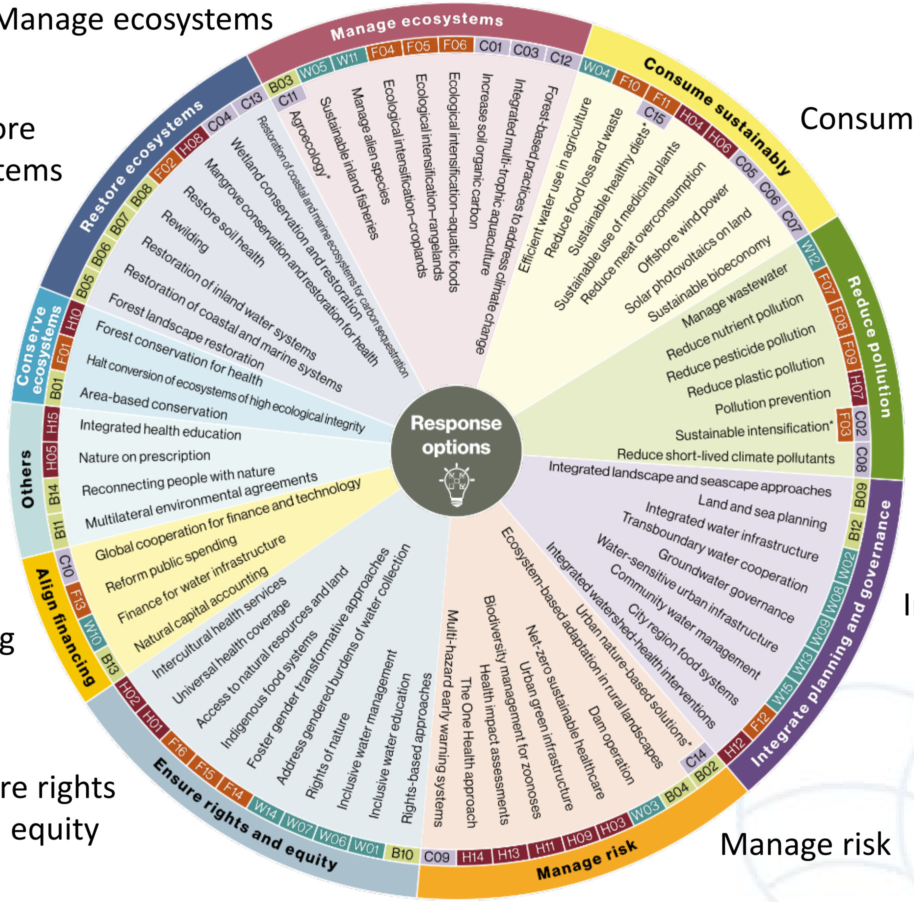
ipbes

IPBES Nexus Assessment

- 5 crises are interlinked
  - Our responses are not
- Solutions already exist
  - > 70 response options assessed
- Role for everyone
  - Collaboration required



Response options already exist that address nexus interactions



Manage ecosystems

Consume sustainably

Restore ecosystems

Conserve ecosystems

Reduce pollution

Others

Integrate planning and governance

Align financing

Ensure rights and equity

Manage risk

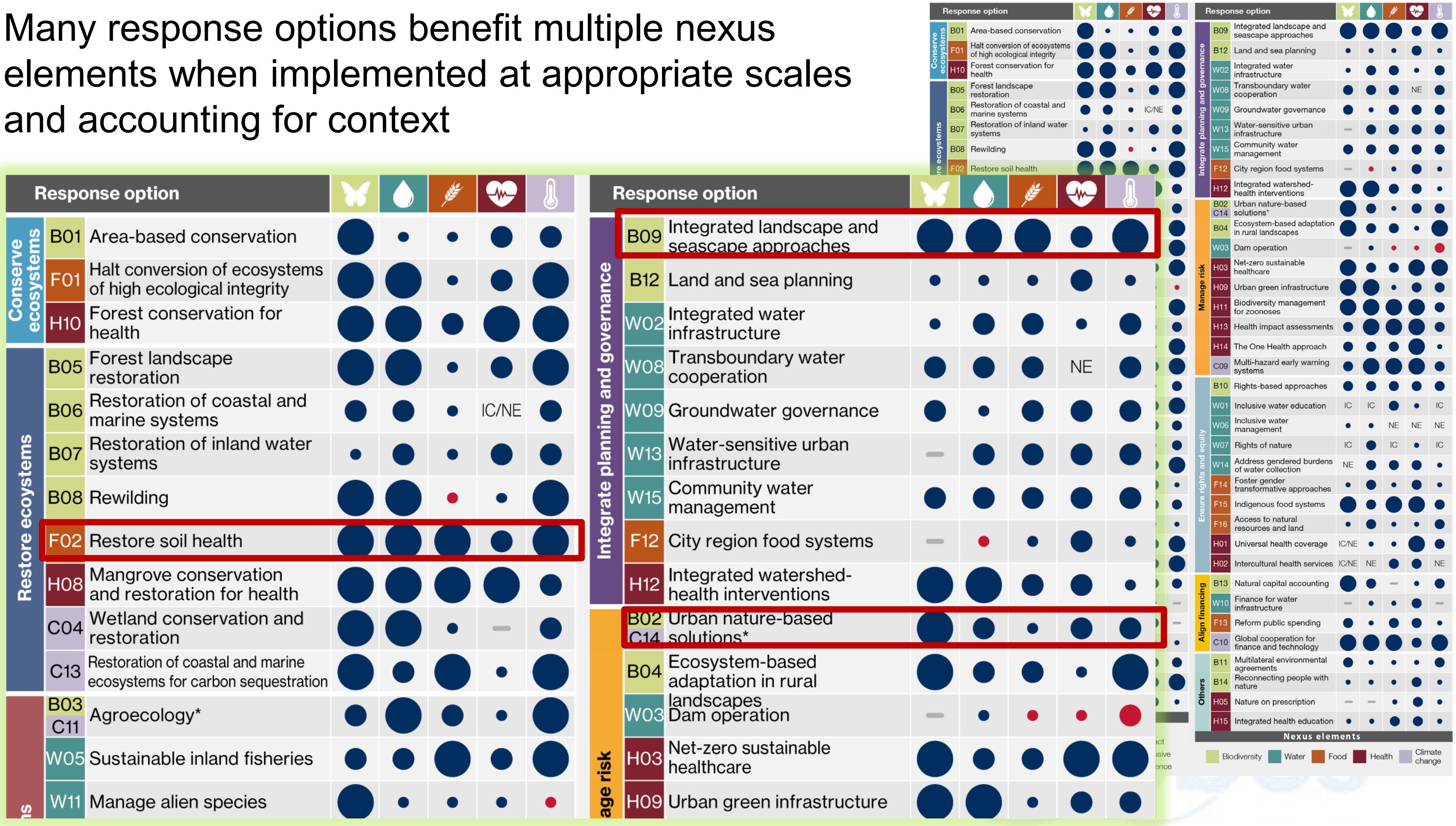
Nexus elements 🟩 Biodiversity 🟦 Water 🟧 Food 🟥 Health 🟪 Climate change

IGES Institute for Global Environmental Strategies

東京大学未来ビジョン研究センター Institute for Future Initiatives

Many response options benefit multiple nexus elements

- Many response options benefit multiple nexus elements when implemented at appropriate scales and accounting for context



Response option			🦋	💧	🌾	❤️	🌡️
Conserve ecosystems	B01	Area-based conservation	⬤	•	•	●	●
	F01	Halt conversion of ecosystems of high ecological integrity	⬤	⬤	•	●	⬤
	H10	Forest conservation for health	⬤	⬤	●	⬤	⬤
Restore ecosystems	B05	Forest landscape restoration	⬤	⬤	•	●	⬤
	B06	Restoration of coastal and marine systems	●	●	•	IC/NE	●
	B07	Restoration of inland water systems	•	●	•	●	●
	B08	Rewilding	⬤	⬤	🔴	•	⬤
	F02	Restore soil health	⬤	⬤	⬤	●	⬤
	H08	Mangrove conservation and restoration for health	⬤	⬤	⬤	⬤	●
	C04	Wetland conservation and restoration	⬤	⬤	•	—	●
	C13	Restoration of coastal and marine ecosystems for carbon sequestration	⬤	●	⬤	•	⬤
ns	B03 C11	Agroecology*	●	⬤	●	•	⬤
	W05	Sustainable inland fisheries	●	●	⬤	●	⬤
	W11	Manage alien species	⬤	•	•	•	🔴

Response option			🦋	💧	🌾	❤️	🌡️
Integrate planning and governance	B09	Integrated landscape and seascape approaches	⬤	⬤	⬤	●	⬤
	B12	Land and sea planning	•	•	•	●	•
	W02	Integrated water infrastructure	•	●	●	•	●
	W08	Transboundary water cooperation	●	●	●	NE	●
	W09	Groundwater governance	●	•	●	●	●
	W13	Water-sensitive urban infrastructure	—	●	●	●	●
	W15	Community water management	●	●	●	●	●
	F12	City region food systems	—	🔴	•	●	•
	H12	Integrated watershed-health interventions	⬤	⬤	●	●	•
age risk	B02 C14	Urban nature-based solutions*	⬤	●	•	●	●
	B04	Ecosystem-based adaptation in rural landscapes	⬤	●	●	•	⬤
	W03	Dam operation	—	•	🔴	🔴	🔴
	H03	Net-zero sustainable healthcare	⬤	●	●	⬤	⬤
	H09	Urban green infrastructure	⬤	⬤	•	●	●

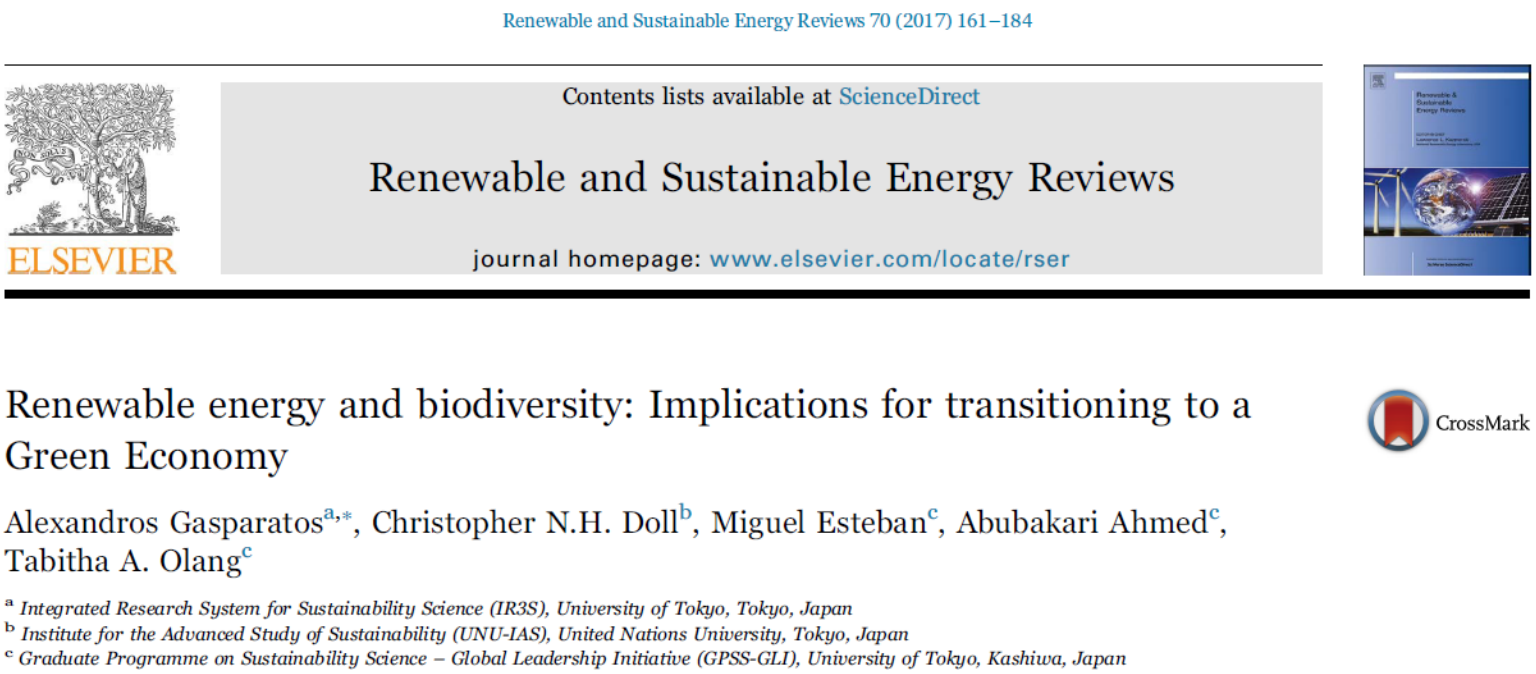
Response option			🦋	💧	🌾	❤️	🌡️
Integrate planning and governance	B09	Integrated landscape and seascape approaches	⬤	⬤	⬤	●	⬤
	B12	Land and sea planning	•	•	•	●	•
	W02	Integrated water infrastructure	•	●	●	•	●
	W08	Transboundary water cooperation	●	●	●	NE	●
	W09	Groundwater governance	●	•	●	●	●
	W13	Water-sensitive urban infrastructure	—	●	●	●	●
	W15	Community water management	●	●	●	●	●
	F12	City region food systems	—	🔴	•	●	•
	H12	Integrated watershed-health interventions	⬤	⬤	●	●	•
Manage risk	B02 C14	Urban nature-based solutions*	⬤	●	•	●	●
	B04	Ecosystem-based adaptation in rural landscapes	⬤	●	●	•	⬤
	W03	Dam operation	—	•	🔴	🔴	🔴
	H03	Net-zero sustainable healthcare	⬤	●	●	⬤	⬤
	H09	Urban green infrastructure	⬤	⬤	•	●	●
	H11	Biodiversity management for zoonoses	⬤	⬤	⬤	⬤	●
	H13	Health impact assessments	●	⬤	⬤	⬤	●
	H14	The One Health approach	●	●	●	⬤	•
	C09	Multi-hazard early warning systems	●	⬤	⬤	⬤	●
Ensure rights and equity	B10	Rights-based approaches	●	●	●	●	●
	W01	Inclusive water education	IC	IC	●	•	IC
	W06	Inclusive water management	•	•	NE	NE	NE
	W07	Rights of nature	IC	●	IC	•	IC
	W14	Address gendered burdens of water collection	NE	●	●	●	•
	F14	Foster gender transformative approaches	•	●	•	●	•
	F15	Indigenous food systems	⬤	●	⬤	⬤	●
	F16	Access to natural resources and land	•	●	•	•	●
	H01	Universal health coverage	IC/NE	•	•	⬤	●
	H02	Intercultural health services	IC/NE	NE	●	●	NE
Align financing	B13	Natural capital accounting	⬤	●	—	•	●
	W10	Finance for water infrastructure	—	•	•	●	—
	F13	Reform public spending	●	•	●	●	•
	C10	Global cooperation for finance and technology	⬤	⬤	⬤	●	⬤
Others	B11	Multilateral environmental agreements	●	•	•	•	●
	B14	Reconnecting people with nature	•	•	•	●	•
	H05	Nature on prescription	—	—	•	●	•
	H15	Integrated health education	•	•	●	●	•

Nexus elements

🟩 Biodiversity 🟦 Water 🟧 Food 🟥 Health 🟪 Climate change

Contribution of nexus response options to global policy goals

- Nexus response options can support the achievement of global goals and targets such as the Sustainable Development Goals, the Kunming-Montreal Biodiversity Framework targets and the Paris Agreement long-term goals for mitigation and adaptation
- Nexus response options enable integration across these global policy frameworks



Renewable and Sustainable Energy Reviews 70 (2017) 161–184

Contents lists available at ScienceDirect

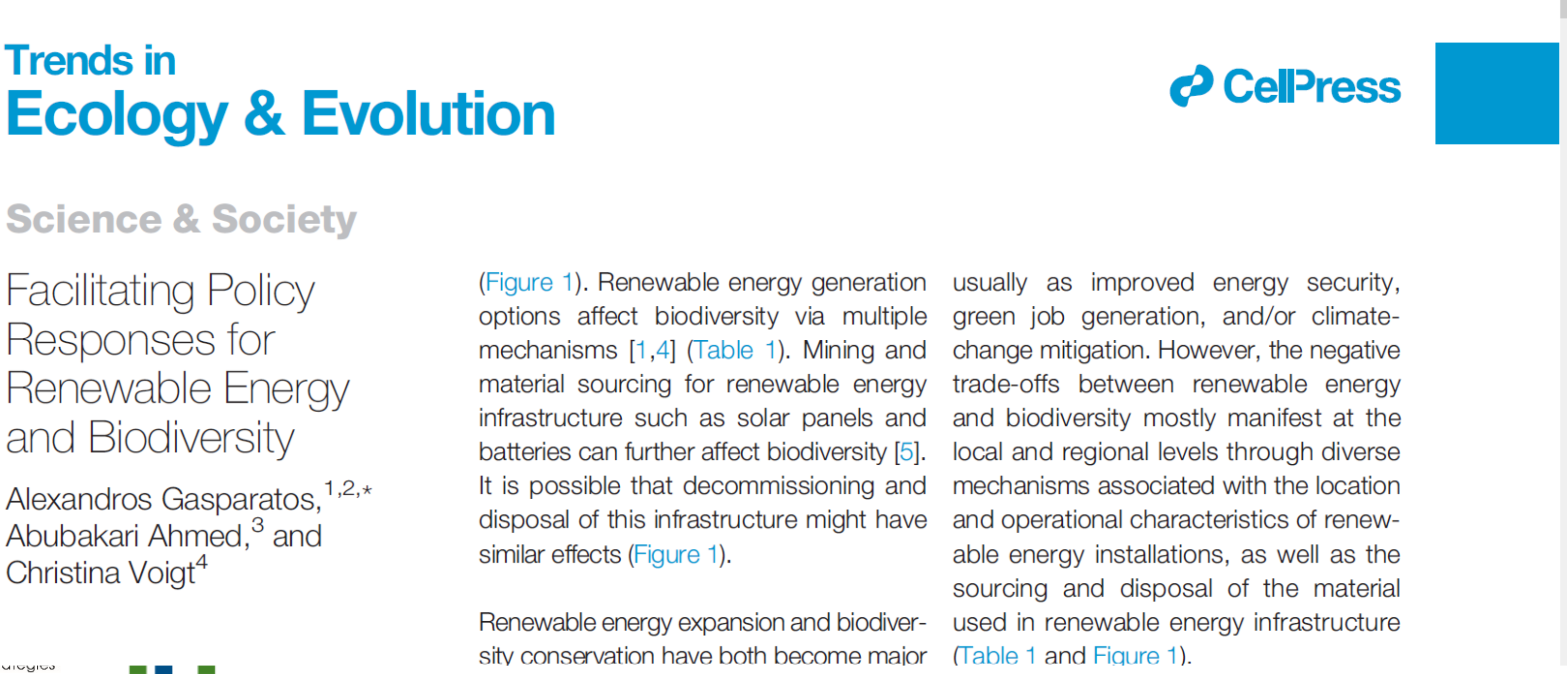
Renewable and Sustainable Energy Reviews

journal homepage: www.elsevier.com/locate/rser

Renewable energy and biodiversity: Implications for transitioning to a Green Economy

Alexandros Gasparatos[a,*], Christopher N.H. Doll[b], Miguel Esteban[c], Abubakari Ahmed[c], Tabitha A. Olang[c]

[a] *Integrated Research System for Sustainability Science (IR3S), University of Tokyo, Tokyo, Japan*
[b] *Institute for the Advanced Study of Sustainability (UNU-IAS), United Nations University, Tokyo, Japan*
[c] *Graduate Programme on Sustainability Science – Global Leadership Initiative (GPSS-GLI), University of Tokyo, Kashiwa, Japan*



Trends in
Ecology & Evolution

CellPress

Science & Society

Facilitating Policy Responses for Renewable Energy and Biodiversity

Alexandros Gasparatos,[1,2,*] Abubakari Ahmed,[3] and Christina Voigt[4]

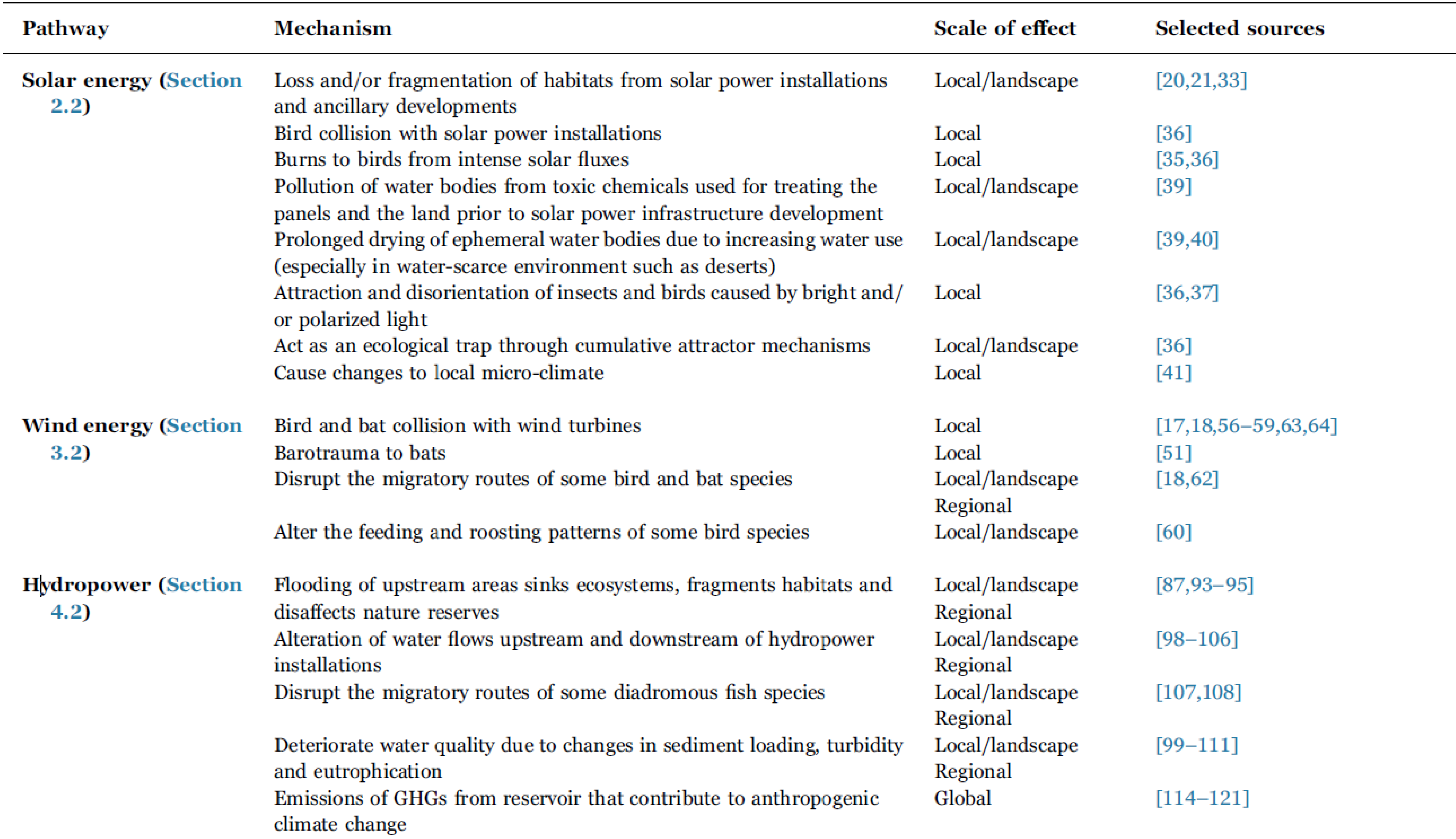
(Figure 1). Renewable energy generation options affect biodiversity via multiple mechanisms [1,4] (Table 1). Mining and material sourcing for renewable energy infrastructure such as solar panels and batteries can further affect biodiversity [5]. It is possible that decommissioning and disposal of this infrastructure might have similar effects (Figure 1).

Renewable energy expansion and biodiversity conservation have both become major usually as improved energy security, green job generation, and/or climate-change mitigation. However, the negative trade-offs between renewable energy and biodiversity mostly manifest at the local and regional levels through diverse mechanisms associated with the location and operational characteristics of renewable energy installations, as well as the sourcing and disposal of the material used in renewable energy infrastructure (Table 1 and Figure 1).

MA drivers of biodiversity loss for different renewable energy pathways

(Gasparatos et al. 2017)

Mechanisms of the negative effects of different renewable energy pathways on ecosystems and biodiversity (Gasparatos et al. 2017)



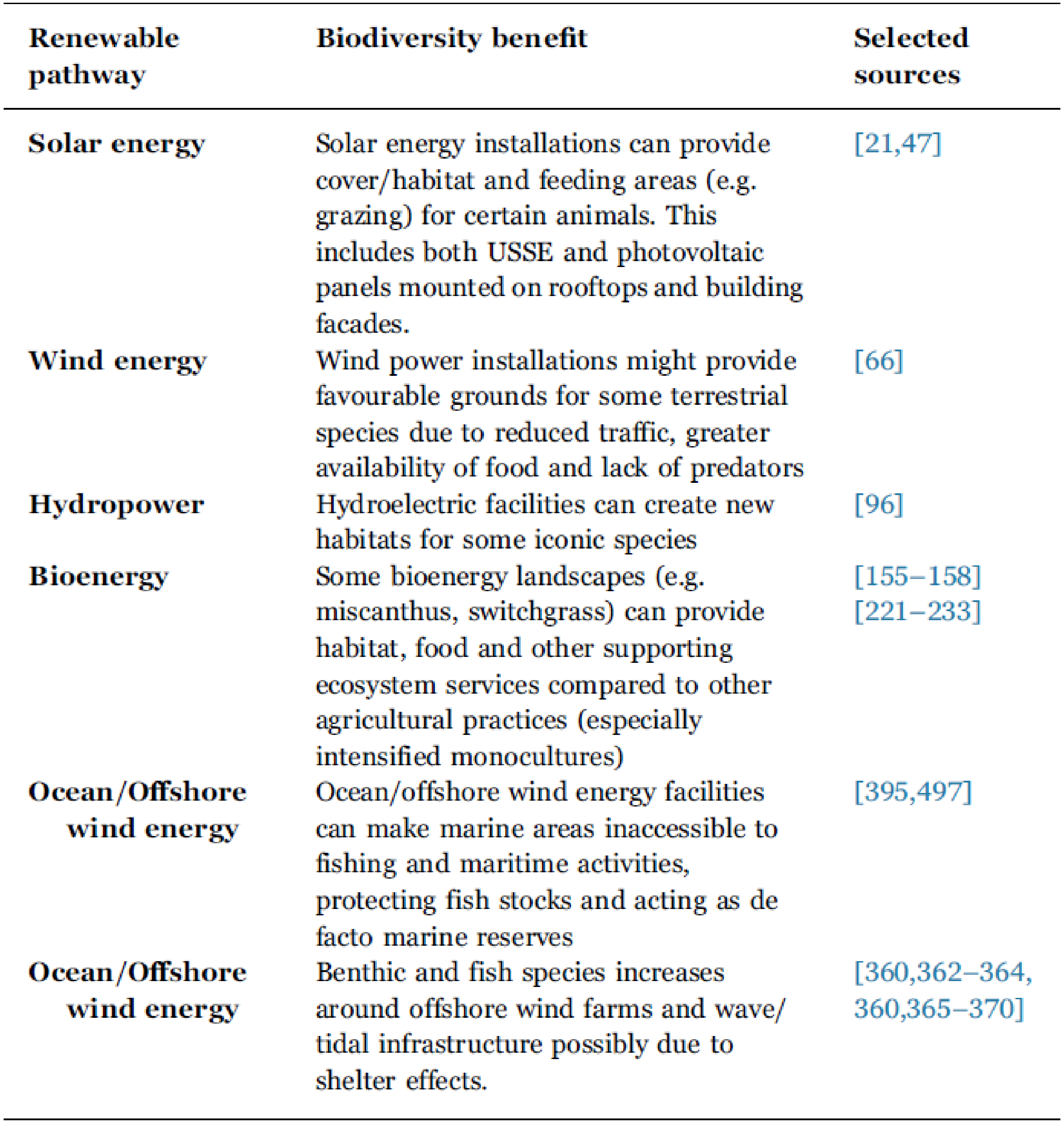
Pathway	Mechanism	Scale of effect	Selected sources
Solar energy (Section 2.2)	Loss and/or fragmentation of habitats from solar power installations and ancillary developments	Local/landscape	[20,21,33]
	Bird collision with solar power installations	Local	[36]
	Burns to birds from intense solar fluxes	Local	[35,36]
	Pollution of water bodies from toxic chemicals used for treating the panels and the land prior to solar power infrastructure development	Local/landscape	[39]
	Prolonged drying of ephemeral water bodies due to increasing water use (especially in water-scarce environment such as deserts)	Local/landscape	[39,40]
	Attraction and disorientation of insects and birds caused by bright and/or polarized light	Local	[36,37]
	Act as an ecological trap through cumulative attractor mechanisms	Local/landscape	[36]
	Cause changes to local micro-climate	Local	[41]
Wind energy (Section 3.2)	Bird and bat collision with wind turbines	Local	[17,18,56–59,63,64]
	Barotrauma to bats	Local	[51]
	Disrupt the migratory routes of some bird and bat species	Local/landscape Regional	[18,62]
	Alter the feeding and roosting patterns of some bird species	Local/landscape	[60]
Hydropower (Section 4.2)	Flooding of upstream areas sinks ecosystems, fragments habitats and disaffects nature reserves	Local/landscape Regional	[87,93–95]
	Alteration of water flows upstream and downstream of hydropower installations	Local/landscape Regional	[98–106]
	Disrupt the migratory routes of some diadromous fish species	Local/landscape Regional	[107,108]
	Deteriorate water quality due to changes in sediment loading, turbidity and eutrophication	Local/landscape Regional	[99–111]
	Emissions of GHGs from reservoir that contribute to anthropogenic climate change	Global	[114–121]

Pathway	Mechanism	Scale of effect	Selected sources
Bioenergy (Section 5.2)	Loss and fragmentation of habitats due to land conversion into agricultural landscapes dominated by a single crop (usually associated with large-scale monocultural modes of feedstock production)	Local/landscape	[144,146,147,195,196,198,203–205,209,210,216–220]
	Simplification and homogenization of habitats due to the extensive modification of landscape elements and ecosystem processes (usually associated with large-scale monocultural modes of feedstock production)	Local/landscape	[195,196,198,203,204,210,216]
	Pollution of soil and water from fertiliser/pesticide use that causes toxicity and eutrophication (usually associated with large-scale monocultural modes of feedstock production)	Local/landscape, Regional	[203,290–301]
	Emission of ambient air pollutants that contribute to acidification and tropospheric ozone formation	Local/landscape Regional	[159–182,203,237–248,274–276,278,279,280,281] Table 1
	Emission of GHGs during the entire life-cycle of bioenergy generation (including from direct and indirect land use change) that contributes to anthropogenic climate change	Global	
	Effects to local micro-climates due to changes in albedo and evapotranspiration	Local/landscape, Regional	[183,234,254–259]
	Invasive behavior of some feedstock species (e.g. eucalyptus, miscanthus) that compete with native vegetation	Local/landscape, Regional	[302–306,311]

Pathway	Mechanism	Scale of effect	Selected sources
Ocean energy (Section 6.2)	Fish/benthic species composition changes due to habitat loss from scour pits at the foundations of offshore wind generators and ocean energy devices installed/anchored in the seabed	Local	[355]
	Loss/change of habitat from the permanent inundation of the upstream portions of estuaries from tidal barrages.	Local/landscape	[344]
	Habitat change due to the alteration of hydrodynamic and sedimentation processes	Local/seascape	[26,353,381,382]
	Avoidance of underwater areas close to ocean energy installations by some species (especially during construction)	Local/seascape	[354,356,357]
	Species entrapment at tidal barrages	Local/landscape	[342]
	Collision of birds (with offshore wind generators) and aquatic species (with wave energy devices)	Local	[18,26,349,371,374,375]
	Interference with navigation and feeding patterns of local and migratory species	Local/seascape	[358,359,376]
	Excess mortality of tropical fish due to temperature shocks from upwelled cold water at OTEC projects	Local	[386]
	Increased turbidity at water column due to distrurbances in the seabed	Local	[387]
	Changes in salinity, water turbidity and exchange between flushing of oxygenated water in tidal barrages	Local	[370,377]
	Noise pollution during the construction and operation affects some aquatic species (particularly aquatic mammals)	Local	[355,388,389]
	Electromagnetic pollution from underwater cables can affect sensitive species	Local	[26,384,387]
	Chemical pollution from toxic lubricants and paints	Local	[26,359,374]
Geothermal (Section 7.2)	Habitat loss during the conversion of natural areas into geothermal facilities	Local/landscape	[402–405]
	Habitat change during site clearing, road construction, well drilling and seismic surveys that affects the breeding, foraging and migration patterns of certain species	Local/landscape	[401]
	Emission of toxic pollutants such as H_2S, arsenic and boric acid which can defoliate plants or be uptaken by biota	Local/landscape	[411–415]
	Noise and heat pollution from geothermal facilities	Local/landscape	[408,416,417]

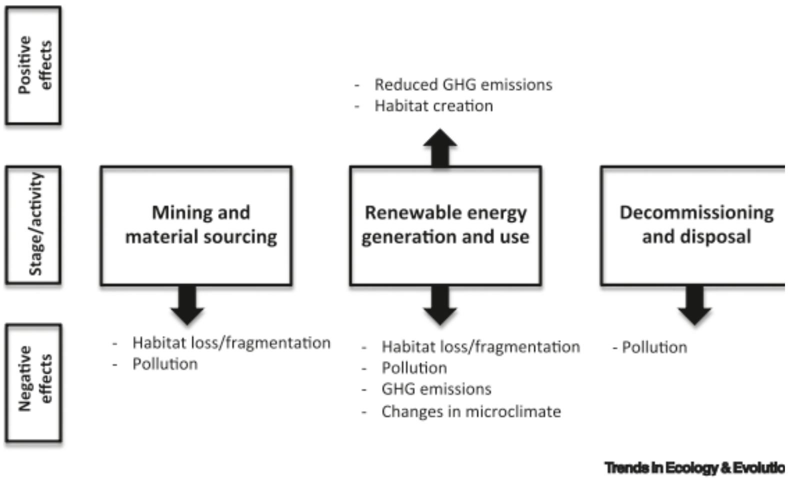
Biodiversity benefits of different renewable energy pathways

(Gasparatos et al. 2017)

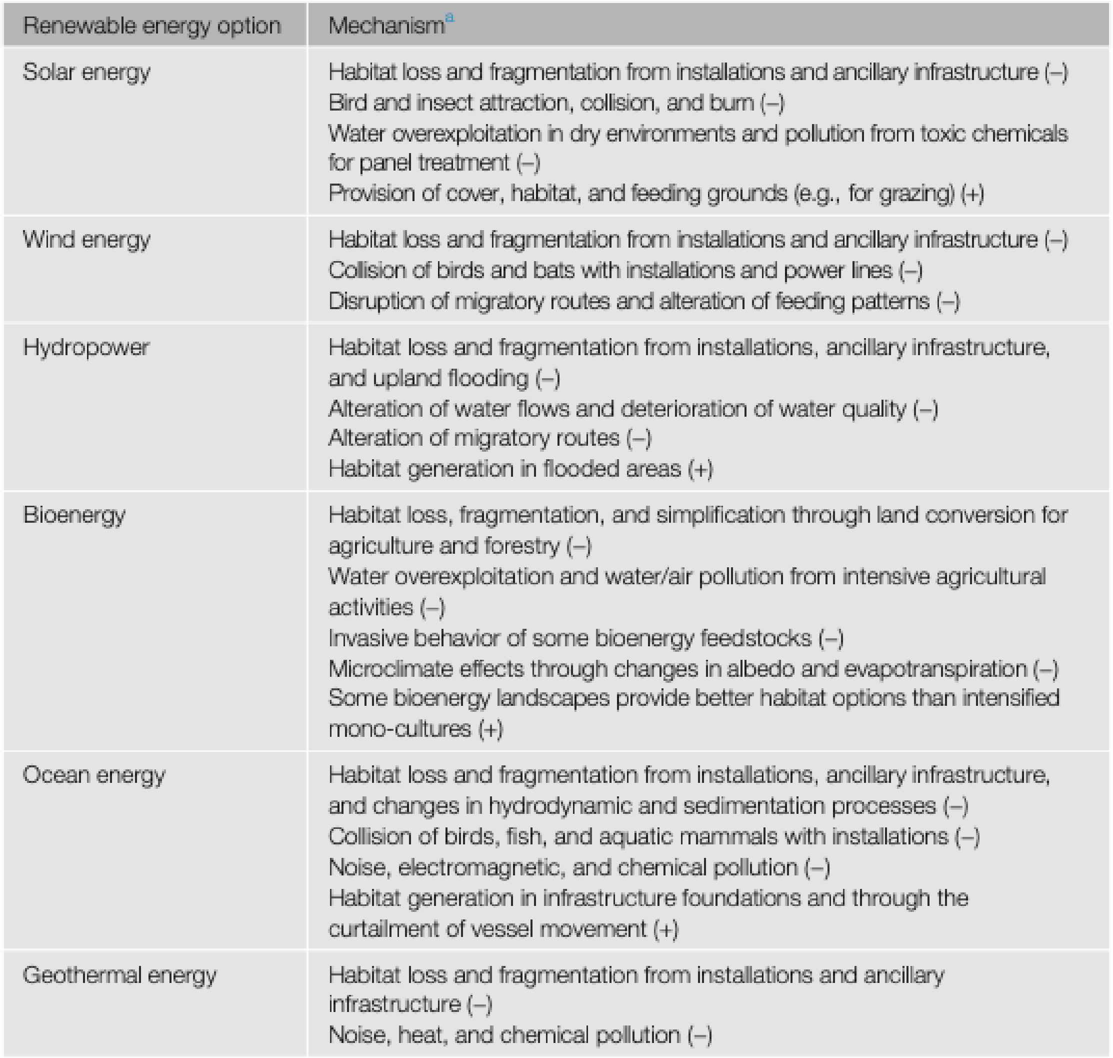


Renewable pathway	Biodiversity benefit	Selected sources
Solar energy	Solar energy installations can provide cover/habitat and feeding areas (e.g. grazing) for certain animals. This includes both USSE and photovoltaic panels mounted on rooftops and building facades.	[21,47]
Wind energy	Wind power installations might provide favourable grounds for some terrestrial species due to reduced traffic, greater availability of food and lack of predators	[66]
Hydropower	Hydroelectric facilities can create new habitats for some iconic species	[96]
Bioenergy	Some bioenergy landscapes (e.g. miscanthus, switchgrass) can provide habitat, food and other supporting ecosystem services compared to other agricultural practices (especially intensified monocultures)	[155–158] [221–233]
Ocean/Offshore wind energy	Ocean/offshore wind energy facilities can make marine areas inaccessible to fishing and maritime activities, protecting fish stocks and acting as de facto marine reserves	[395,497]
Ocean/Offshore wind energy	Benthic and fish species increases around offshore wind farms and wave/ tidal infrastructure possibly due to shelter effects.	[360,362–364, 360,365–370]

Main Interactions between Renewable Energy and Biodiversity



Main Mechanisms of the Effects of Renewable Energy Generation on Biodiversity (Gasparatos et al. 2021)



Renewable energy option	Mechanism[a]
Solar energy	Habitat loss and fragmentation from installations and ancillary infrastructure (–) Bird and insect attraction, collision, and burn (–) Water overexploitation in dry environments and pollution from toxic chemicals for panel treatment (–) Provision of cover, habitat, and feeding grounds (e.g., for grazing) (+)
Wind energy	Habitat loss and fragmentation from installations and ancillary infrastructure (–) Collision of birds and bats with installations and power lines (–) Disruption of migratory routes and alteration of feeding patterns (–)
Hydropower	Habitat loss and fragmentation from installations, ancillary infrastructure, and upland flooding (–) Alteration of water flows and deterioration of water quality (–) Alteration of migratory routes (–) Habitat generation in flooded areas (+)
Bioenergy	Habitat loss, fragmentation, and simplification through land conversion for agriculture and forestry (–) Water overexploitation and water/air pollution from intensive agricultural activities (–) Invasive behavior of some bioenergy feedstocks (–) Microclimate effects through changes in albedo and evapotranspiration (–) Some bioenergy landscapes provide better habitat options than intensified mono-cultures (+)
Ocean energy	Habitat loss and fragmentation from installations, ancillary infrastructure, and changes in hydrodynamic and sedimentation processes (–) Collision of birds, fish, and aquatic mammals with installations (–) Noise, electromagnetic, and chemical pollution (–) Habitat generation in infrastructure foundations and through the curtailment of vessel movement (+)
Geothermal energy	Habitat loss and fragmentation from installations and ancillary infrastructure (–) Noise, heat, and chemical pollution (–)

Environment Research and Technology Development Fund
Strategic Research and Development Area Project（S-21: FY2023-2027）

Development of an Integrated Assessment Model linking Biodiversity and Socio-Economic Drivers, and its Social Application (IAM-B)

Project website: https://iam-b.jp/en/

Lead P.I.: Osamu Saito (Institute for Global Environmental Strategies)

Theme 1 P.I.: Hiroya Yamano (The Univ. of Tokyo/NIES)
Theme 2 P.I.: Osamu Saito (IGES)
Theme 3 P.I.: Katsue Fukamachi (Kyoto University)
Theme 4 P.I.: Shizuka Hashimoto (The Univ. of Tokyo)
Theme 5 P.I.: Takehito Yoshida (The Univ. of Tokyo)

IGES Institute for Global Environmental Strategies

東京大学未来ビジョン研究センター
Institute for Future Initiatives

Post-PANCES: Development of an Integrated Assessment Model linking Biodiversity and Socio-Economic Drivers, and its Social Application (S21)

Objectives

- Develop an integrated assessment model to quantify biodiversity, climate change, and associated socio-economic factors
- The integrated assessment model will be developed and applied at both national and local scales in Japan to provide scientific inputs for building sustainable societies
- Contribute to assessments by IPBES and IPCC, TNFD, SDGs and Kunming-Montreal Global Biodiversity Framework, and post-SDGs global goals

Theme 1:
Development of an Integrate Assessment Model of a Social-Ecological System

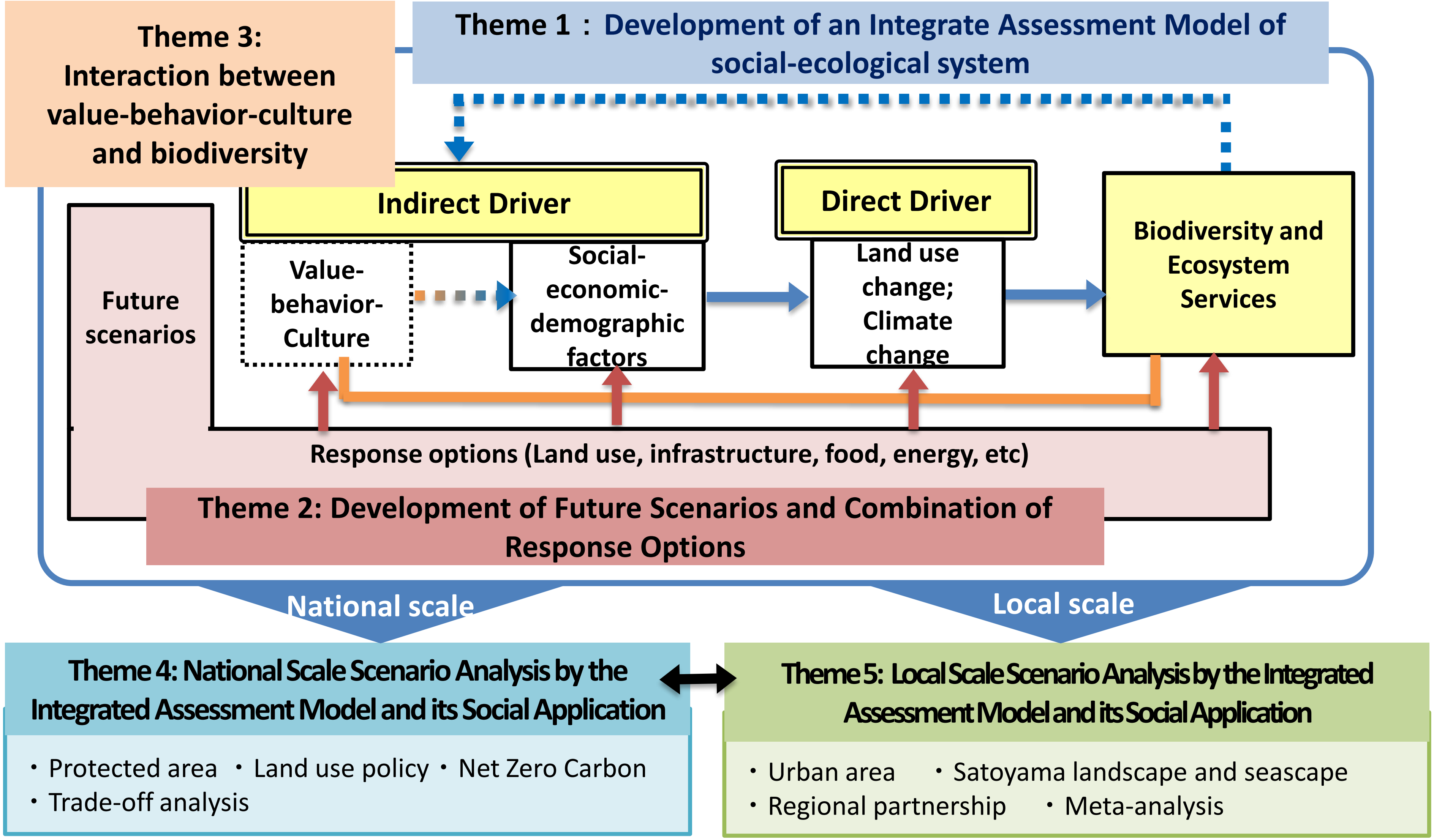
Theme 2:
Development of Future Scenarios and Combination of Response Options

Theme 3:
Interaction between Value-Behavior-Culture and Biodiversity

Theme 4:
National Scale Scenario Analysis by the Integrated Assessment Model and its Social Application

Theme 5:
Local Scale Scenario Analysis by the Integrated Assessment Model and its Social Application

Post-PANCES: Development of an Integrated Assessment Model linking Biodiversity and Socio-Economic Drivers, and its Social Application (S21) (FY2022-2027)



Theme 3: Interaction between value-behavior-culture and biodiversity

Theme 1：Development of an Integrate Assessment Model of social-ecological system

Indirect Driver

Direct Driver

Future scenarios

Value-behavior-Culture

Social-economic-demographic factors

Land use change; Climate change

Biodiversity and Ecosystem Services

Response options (Land use, infrastructure, food, energy, etc)

Theme 2: Development of Future Scenarios and Combination of Response Options

National scale

Local scale

Theme 4: National Scale Scenario Analysis by the Integrated Assessment Model and its Social Application

- Protected area
- Land use policy
- Net Zero Carbon
- Trade-off analysis

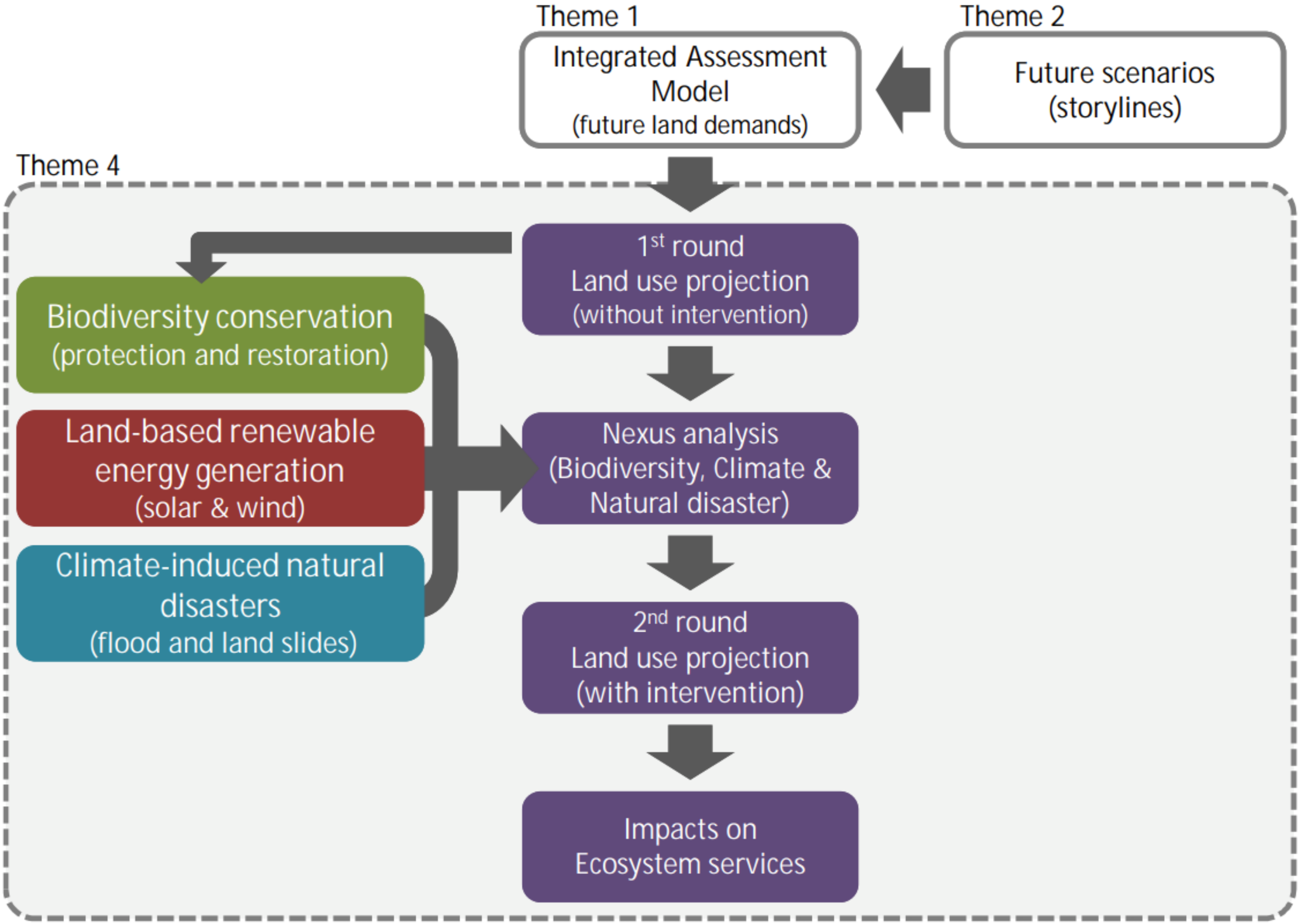
Theme 5: Local Scale Scenario Analysis by the Integrated Assessment Model and its Social Application

- Urban area
- Satoyama landscape and seascape
- Regional partnership
- Meta-analysis

IGES Institute for Global Environmental Strategies

東京大学未来ビジョン研究センター
Institute for Future Initiatives

Analyze synergies and trade-offs among biodiversity conservation, climate change mitigation, and natural disaster (Theme 4)

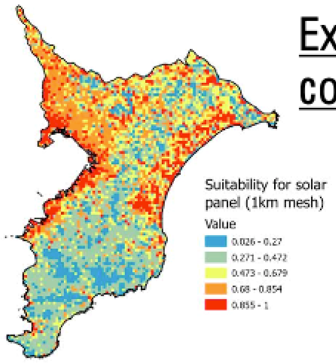


IGES Institute for Global Environmental Strategies

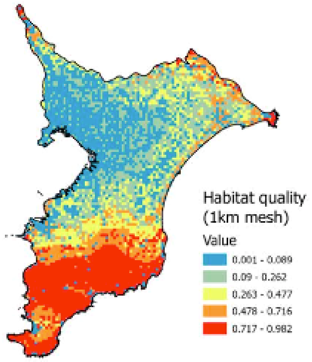
東京大学未来ビジョン研究センター
Institute for Future Initiatives

Nexus analysis framework of conservation, climate change mitigation & natural disaster risk (ongoing)

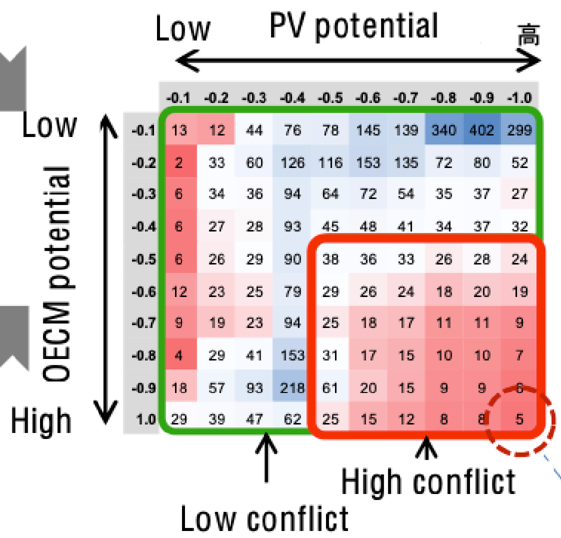
Example of the nexus analysis of RE development and biodiversity conservation potential



PV system installation potential

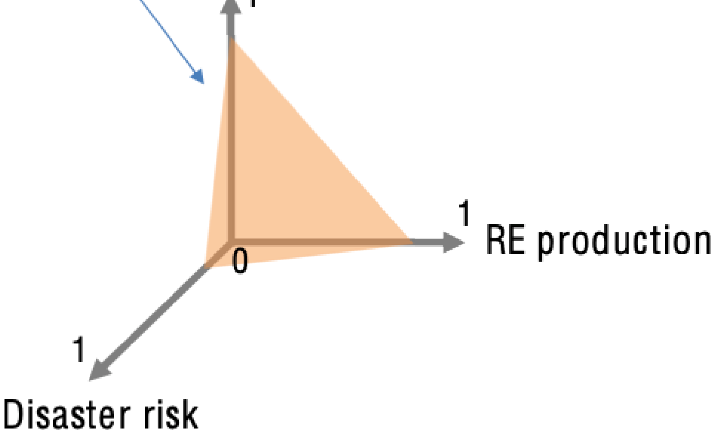


OECM introduction potential



	-0.1	-0.2	-0.3	-0.4	-0.5	-0.6	-0.7	-0.8	-0.9	-1.0
-0.1	13	12	44	76	78	145	139	340	402	299
-0.2	2	33	60	126	116	153	135	72	80	52
-0.3	6	34	36	94	64	72	54	35	37	27
-0.4	6	27	28	93	45	48	41	34	37	32
-0.5	6	26	29	90	38	36	33	26	28	24
-0.6	12	23	25	79	29	26	24	18	20	19
-0.7	9	19	23	94	25	18	17	11	11	9
-0.8	4	29	41	153	31	17	15	10	10	7
-0.9	18	57	93	218	61	20	15	9	9	6
1.0	29	39	47	62	25	15	12	8	8	5

All the meshes are evaluated from the biodiversity conservation perspective, renewable energy introduction, and natural disaster risk potentials



Summary

- IPBES nexus assessment (IPBES, 2024) identified 71 response options including urban nature-based solutions
- Renewable energy contributes sub-stantially to climate change mitigation, but its expansion can have trade-offs with biodiversity.
- These trade-offs could be reduced by building a strong evidence base, rationalizing the selection of sites and operational characteristics of renewable energy installations, and coordinating concerted policy efforts at the local, national and international levels.
- S-21 project has been working on nexus analysis across conservation, climate change mitigation & natural disaster risk.