

## Policies and implementation guidelines for data-driven, integrated, risk-based planning of sustainable infrastructure

Peter Head

Ryan Bartlett

Steven Crosskey

Anuj Malhotra

Rowan Palmer

November 23, 2020 | Last updated: December 10, 2020 *Tags:* [Infrastructure Investment and Financing](#)

---

We propose that Group of 20 (G20) countries create, within a robust enabling policy and institutional framework, a set of policies and actions to facilitate the use of a data-driven, risk-based, integrated systems planning and procurement approach in the “upstream” phases of sustainable infrastructure development. A focus on resource-efficient development, including nature-based solutions—with investment in natural capital and ecosystem services, supported by open data and systems planning—has the potential to reduce infrastructure costs by up to 40% when delivering the Sustainable Development Goals (SDGs). The approach can also address the drivers and vulnerabilities of increasing infectious disease incidences like COVID-19. The recommendations involve the use of metadata, data specifications, and network services as well as modeling to guide decision-making, monitoring, and reporting and collecting data. Specifically, this brief proposes that the G20: 1) develop funding programs explicitly designed to support more holistic, cross-sectoral landscape- or regional-scale planning in G20 countries and emerging markets; 2) develop integrated regional and local planning tools and standards; 3) expand and develop platforms for using open data and adopt data standards to improve transparency and accessibility; 4) create new performance-based procurement approaches for large-scale sustainable infrastructure, and 5) mobilize investment in linked global/local-scale climate risk and ecosystem service modeling tools.

---

### Challenge

Sustainable infrastructure is at the heart of multiple UN global agreements and agendas, including previous G20 agendas during the Argentine and Japanese presidencies. It has been defined by the Inter-American Development Bank (2018) as: “Infrastructure projects that are planned, designed, constructed, operated and decommissioned in a manner to ensure economic and financial, social, environmental (including climate resilience), and institutional sustainability over the entire lifecycle of the project.”

While agreement was achieved during previous G20 presidencies—including the adoption of the Principles of Quality Infrastructure Investment in 2018—there are still substantial gaps. Therefore, there are enormous opportunities to improve current planning practice to achieve sustainable infrastructure while delivering on key global sustainability and resilience goals. This includes the SDGs, Paris Agreement, Convention on Biodiversity Post-2020 Framework (CBD), and Sendai Framework, among others. The emergence of COVID-19 and the resulting public health and economic crises are a clarion reminder of just how significant these gaps still are. System-scale approaches to sustainable infrastructure planning and development are essential in addressing these gaps.

Integrated infrastructure and land use planning continues to evolve since its origins in the 1950s, combining ever more complex models and data across sectors to better estimate resilient and sustainable development trajectories and future scenarios (Waddell 2011; Mikovits, Rauch, and Kleidorfer 2018). Since 2005, more complex approaches have emerged that allow the optimization of short- and long-term holistic benefits and trade-offs of infrastructure “systems” development so that the system contributes substantially to delivering the holistic set of SDGs and leaving no one behind (United Nations Statistics Division 2016). This system includes energy, water, mobility, waste, communications, and natural and social infrastructure. As unending and increasingly intense climate shocks and interconnected stressors around the world demonstrate—alongside the current COVID-19 crisis—there is a clear need for an integrated multi-hazard approach to strengthen the capacity of people, communities, countries, and systems to withstand and recover from shocks, persist through stresses, and transform through crises (United Nations Office for Disaster Risk Reduction 2019). There is, therefore, an additional discipline needed within integrated planning—risk simulation—which is essential to finding the resilient development paths for delivering the SDGs.

It is estimated that trillions of US dollars of annual infrastructure investments, up to 8% of gross domestic product (GDP) per year, will be needed to reach the SDGs, and current spending projections fall short of the amounts required (Global Infrastructure Hub n.d.; Woetzel et al. 2017; OECD 2018). However, a recent assessment from the World Bank (Rozenberg and Fay 2019) shows that significant savings are possible through a policy mix that will enable countries to achieve them (this mix includes universal access to water, sanitation, and electricity; greater mobility; improved food security; better protection from floods; and eventually full decarbonization) while limiting spending on new infrastructure systems from an estimated 8% of GDP per year to 4.5% of GDP per year, a full 40% reduction. Through the exploration of thousands of scenarios, it shows that infrastructure system investment paths compatible with full decarbonization in the second half of the century are not just cheaper

than more-polluting alternatives but only possible through a holistic, upstream, systems planning approach.

The G20 can set the global agenda and guide countries in taking advantage of these substantial savings of up to 40% in total infrastructure investment costs through data-driven, integrated, risk-based planning approaches to delivering sustainable infrastructure. This approach will create enabling upstream planning conditions for a smart selection of project systems to go forward that are bankable, job-creating investments that simultaneously meet the objectives of the SDGs, Paris Agreement, CBD, and Sendai Framework, among others. The environmental drivers of the COVID-19 pandemic and associated global social and economic impacts provide additional powerful incentives to take smart integrated planning approaches that support improved balance between economic development and habitat conversion, biodiversity conservation, and resilience.

Unfortunately, integrated systems planning is still limited in implementation around the world (UNEP 2019). This is in part due to a lack of tools, standards, and certifications and weak technical planning and design capacity at the upstream of the planning and development cycle. This weakness especially applies to finding the right combination of projects at the right cost to meet long-term social and economic service needs, climate resilience, and support ecological preservation and regeneration rather than destruction. The global COVID-19 pandemic and associated global economic recession driven by the spread of yet another zoonotic disease (transmission from

wildlife to humans, following HIV, MERS, SARS, Zika, and Ebola), makes it starkly clear that in many regions of the world, these objectives are not well-balanced. Rapid urbanization, continuing habitat loss, climate change, and declining biodiversity are all driving greater human-wildlife interaction and resulting impacts (Jones et al. 2013). This is due in part to a lack of clear processes for systematic planning at larger scales that integrate essential information: socioeconomic aspects like employment, health, and income; land ownership and use; natural capital and biodiversity; climate change impacts and future risks; and processes for equitable access to services and participation and disaggregated data. These sectors are often managed in isolation by different departments in national and local governments. An IADB study of 40 years' worth of infrastructure investments found that lack of upfront planning to anticipate and address social and environmental impacts, usually around local communities' access to natural resources, was a major driver of infrastructure-related conflict, resulting in substantial delays and costs (Watkins et al. 2017).

Integrated land use and mobility planning rely on an established discipline of dynamic digital models that use global information system grids and agent-based modeling to determine optimal investments to meet service delivery needs. It is now important for these tools to also measure human, ecological, and environmental health and the way these are impacted by infrastructure; basic resource flows and efficiencies; and the business case for infrastructure investment over its lifetime (Rydin et al. 2015). One study (Koppelaar, Kunz, and Ravalde 2013) found 17 models in operation for land use and infrastructure planning, of which only five were available as open-source models. None of them included human and ecological health and ecosystems qualities such as biomass, soils, and hydrology. At the same time, modeling of natural capital and the ecosystem services it provides has become increasingly common around the globe since the Millennium Ecosystem Assessment, including influencing land use and development planning (Bartlett 2019; Howe et al. 2014). These efforts, however, continue to be limited in scope and influence, due in part by insufficient tailoring to specific policy questions or management needs, including proposed infrastructure investments (Bartlett 2019). Subsequent work by the authors has demonstrated that more advanced models are possible and practical (Wang et al. 2018; Bartlett 2019), and this is being studied by the GIZ Sustainable Infrastructure Solutions Lab during the first half of 2020 (Global Leadership Academy n.d.).

Such models can help mobilize more affordable integrated systems solutions, such as technologies for decentralized generation, storage, and use of renewable energy; water supply; waste management in circular systems; and electric mobility and nature-based solutions for cooling and managing flooding in urban areas. These tools can also help identify essential services provided by "natural infrastructure"—that is, functioning ecosystems—and their relative costs and benefits compared to, or complementary to, engineered systems. If sustainable infrastructure is to be delivered affordably on a large enough scale to help meet the SDGs, Paris Agreement, CBD, and Sendai Framework, a variety of policy changes, new data systems, and funding vehicles will be necessary to facilitate integrated systems planning and de-risked investments in critical infrastructure across all sectors.

Having successfully planned the sustainable infrastructure, it is vitally important that the procurement processes for construction and management ensure that the resilience and sustainability performance goals identified in these planning processes are met, which involves collaboration between multiple agencies over the infrastructure lifetime, as part of the planned infrastructure system.

The following section outlines recommendations for how the G20 can make progress in all these areas.

---

## Proposal

There are many benefits of deploying integrated systems planning apart from cost savings. For example, improving urban-rural linkages in which waste from the city is recycled into nutrients for use in farms, and land used for growing crops is also used to harvest solar energy for city life. City streets can be made porous and swales introduced to give water to street trees to reduce flood risk and cool the streets. Food can be grown in the city, energy gathered on roofs and walls, and play areas turned into wildlife havens. Buildings can gather, store, and use their own energy, removing the need for so many centralized power stations and extensive power grids (Gebre and Gebremedhin 2019). These examples show that a smart, systematic approach can provide the affordable, new, retrofit, and natural infrastructure needed to meet service needs and exemplify achieving up to 40% cost savings as noted above.

With a present-day shortage of public investment capital (G20 2019; Nofal et al. 2019), infrastructure investors are looking to move away from a focus on spending more to a focus on spending better—on the right objectives supported with relevant data and metrics (Rozenberg and Fay 2019; UNEP 2019). The ambitious investment agenda, of \$2 trillion per year just in low- and middle-income countries, can be realized by creating a careful and systematic approach to estimating the capital as well as operations and maintenance costs needed to close the service and benefit gap. There is a need to move away from relying solely on simple estimates of new capital investment needs (Rozenberg and Fay 2019). The tools and methods need to accurately and comprehensively assess operating costs and benefits. They must assess

comprehensive multi-hazard risks so that resilient development pathways that reduce disaster risks can be found.

Integrated planning also needs to cover sufficiently broad geographic scales and future time horizons. The geographic scale will depend on the degree to which national strategic planning and more detailed regional urban/rural planning is integrated. The method also needs to balance short-term needs with long-term desired outcomes of a competitive economy, including high quality of life, and a healthy, functioning environment that continues to provide critical ecosystem services and mitigates pandemic risks in a rapidly warming world. National governments will benefit from developing coordinated urban and rural policies that recognize the contributions of subnational and local governments, civil society, and other relevant stakeholders, like local affected communities, in a transparent and accountable manner. This can best be done by using open data (INSPIRE Thematic Working Group Land Use 2013) and having a national plan showing how appropriate resources are being made available, which is updated at least every five years, requiring regional/subnational delivery plans to be updated in a synchronous cycle. This entails multi-disciplinary collaboration among all levels of government and a decentralized development planning system (Dallhammer et al. 2018), embracing new ways to measure mutual benefits.

Increasing the efficiency of public infrastructure spending in this way, combined with risk assessment methods to improve resilience, can also lead to an increase in the contribution of the private sector as the investment environment becomes more attractive (Woetzel et al. 2017). Economic returns associated with climate-resilient development are positive in the overwhelming majority of publications reviewed, with benefit/cost ratios often of 3:1 and in some cases as high as 50:1 (Price 2018). This means there are huge benefits in risk-informed integrated systems planning in terms of reduced risks, lower investment costs, and improved returns, which provides strong incentives for the public and private sectors to implement it.

Integrated, systems-level infrastructure planning is necessarily complex due to the multiple interdependencies of infrastructure systems in different sectors and the necessity of accounting for the needs of different demographics; ecological protection/ regeneration and the ecosystem services provided as a result; natural resources oversight and efficiencies; soils; land, sea, and food systems; and urban resilience. Most of all, planning needs to include flexibility and robustness to adjust to changing social, economic, and climate conditions over time (UN Habitat 2017). Indeed, there is a large gap currently in data specifications, tools, and capacity to undertake this type of infrastructure planning and engagement with communities. This brief points to emerging solutions and recommendations to address these challenges.

**1. Develop funding programs explicitly designed to support more holistic, crosssectoral landscape- or regional-scale planning in G20 countries and emerging markets**

Infrastructure planning and funding at the regional and local levels is usually done on a sector-by-sector, or project-by-project basis. These practices create entrenched boundaries that deter the coordination required to address the cross-sectoral nature of development objectives and challenges. Urban and rural planning are often done separately, with urban planning, for example, focused on economic and social development, land use, and infrastructure, while rural planning is usually focused on agriculture. Additionally, large-scale investments like highways, toll roads, or railways are either planned in isolation or drive separate planning processes that often fail to consider comprehensive landscape-scale impacts, spatially or temporally, like unanticipated deforestation along road corridors.

Existing international funding mechanisms—for example the Green Climate Fund and Global Environment Facility (GEF)—do have project preparation funds that could support improved integrated systems landscape- and regional-scale spatial planning. These can be used to target improvements in natural resource management and solutions that meet climate change mitigation and adaptation goals. These and other sources targeting conservation and sustainable development—including bilateral aid—should be used to support design and capacity-building to improve the skills and quality of technical teams toward such data-driven, upstream planning approaches. They can then go on to carry out the critical technical assessments and mobilize procurement that supports outcomes and goals. It will be important to build capacity within national and subnational planning agencies, and these funding sources will be appropriate for certain targeted low- and middle-income economies. Bilateral aid agencies and development banks should expand investments to cover “readiness, project preparation, and capacity enhancement for individual projects” (The Ecological Sequestration Trust 2015). They must also support improved, integrated upstream planning for infrastructure systems.

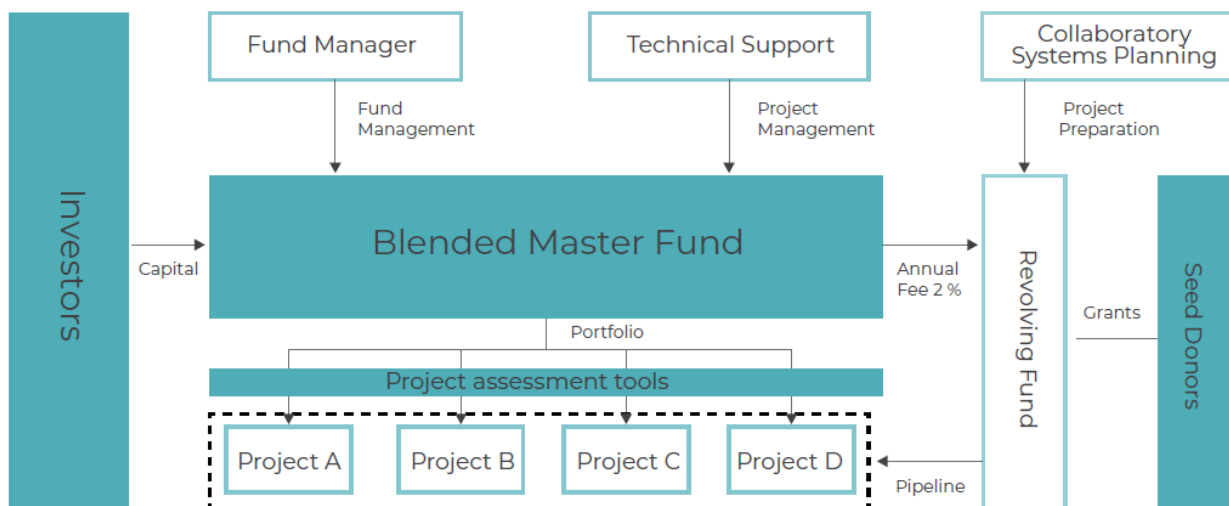


Figure 1. Regional Systems Planning and Project Funding Approach

An example of a new approach that can enable this is shown in Figure 1. Risk-based integrated systems planning at the regional scale, supported by a collaborative laboratory, or "Collaboratory," and open data can enable a regional master fund. This can support public-private-partnership investments in a portfolio of infrastructure projects to deliver global goals. This fund could contain a blend of green, social, and municipal bonds. A revolving fund mechanism can then be set up in which the value brought by integrated systems planning can be recycled into further capacity enhancement and scaled up by applying a small levy (around 2%) on the resulting project investments to pay for the planning service. These funds can also be used to pay for cadastral rollout where land ownership is not yet established (The Ecological Sequestration Trust 2015).

#### **Recommendation 1:**

G20 countries should create and add to the existing sustainable infrastructure policies developed over the last 10 years (G20 2019; Nofal et al. 2019), create new policies and associated resources that require regional- and local-scale risk-based integrated planning, and support capacity-building within the public sector to carry it out. Such planning should: 1) address urban-rural linkages and the health and resilience of people and the ecosystems that support them (including reducing exposure to and responding to disasters and pandemic risks); and 2) enable smart choices to be made for sustainable infrastructure planning and delivery, including the contributions of nature-based solutions. These policies would include the setting up of inclusive collaborators and the use of revolving funds to build capacity and capability at all levels of government and in the private sector. These funds can also be used to establish critical land ownership registers, where they are not in place, that are essential for successful planning outcomes.

### **2. Develop integrated regional and local planning tools and standards**

At the national level, planning instruments tend to be visionary, setting the general goals or the agenda of principles for spatial planning over globally adopted time horizons such as 2030/50/65. Common instruments are national spatial plans or territorial development strategies featuring development corridors and zones. There are also related national building and infrastructure standards that need to be constantly updated in line with increasing climate risks and new solutions.

At the subnational or regional levels, strategic or framework-setting instruments are needed, linking subnational plans to broader planning frameworks and defining how to meet national sustainable development policy goals through regional implementation. For example, the post-2020 CBD Framework, SDG metrics, Paris Agreement Nationally Determined Contributions, National Adaptation Plans, and other references for decision-making. New integrated systems tools are critical in supporting these policies, which provide a frame of reference for coordinated action (Dallhammer et al. 2018). At the local/municipal level, planning instruments are usually regulative in nature, involving local planning authority land use plans, especially zoning, building schemes, and ecological protection. They, too, need to be integrated into the process (Botchie 2000).

#### **Recommendation 2:**

G20 countries should adopt new integrated planning tools for cross-sector collaboration at regional and local scales. Thus, landscape, urban, rural, and infrastructure planners can apply integrated approaches that explicitly consider nature-based solutions, evaluate and measure climate risks, and demonstrate delivery of project-level sustainability and resilience requirements. G20 countries should also update national building and infrastructure standards in line with increasing climate risks as part of these larger efforts to require use of new integrated systems planning tools and standards.

### **3. Expand and develop platforms for using open data and adopt data standards to improve transparency and accessibility**

Data and digital infrastructure such as artificial intelligence (AI), 5G, cloud and edge computing, supercomputers, and the Internet of things can accelerate and maximize the impact of policies for resilient, sustainable development (Zhou et al. 2019). Accessible and interoperable data will be at the heart of data-driven innovation (European Commission 2019). Transfers of knowledge and best practices and human, ecological, and resource flow data are needed for planning at different scales—from local communities and regions to city, national, and in some cases global scales. National statistical and reporting systems may need strengthening, for example, to disaggregate social data by age, gender, and disability.

To accomplish this, data specification development plans are needed that include data needs, collection strategies, specifications, handling (cleaning, formatting, validating, and testing), and brokerage. They must demonstrate functionality for the full lifecycle of investments (Global Partnership for Sustainable Development Data n.d.). Data specifications should be standardized across wider regions, as has been done in the European Union (EU) with the INSPIRE system and is being considered by the African Union (Van Belle 2018). Interoperability will be needed between earth observation and national, regional, and local open datasets, proprietary datasets, ground-based sensors, and crowd-sourced data. The International Centre for Earth Simulation was established in 2010 to develop the next-generation of holistic modeling, simulations, and visualizations that accurately depict the medium- and long-term future direction of planet Earth (ICES Foundation n.d.). A defined cataloging and data processing service would enable the systems models to access these datasets.

#### **Recommendation 3:**

G20 countries should support global efforts so that every country creates a data specification development plan that includes data needs, disaggregated data collection strategies, data specifications, data handling, and data brokerage for the full lifecycle of sustainable infrastructure investments and that has interoperability between different data sources. Data needs should be matched to those required for screening by multinational bank funders. They should support capacity-building across different stakeholders around new data policies and data processing. Mechanisms should be put in place within this effort that can ensure individual autonomy, data protection, and the privacy of personal health data, both in the short- and long-term.

### **4. Create new performance-based procurement approaches for large-scale sustainable infrastructure funding in collaboration with major funders.**

The sustainable infrastructure solutions that emerge from the integrated planning process will each have resilience and sustainability performance requirements over the

The sustainable infrastructure solutions that emerge from the integrated planning process will each have resilience and sustainability performance requirements over the construction and service lifetime. Procurement for implementation may include design, construction, and management. Updating procurement standards to ensure that contracts include responsibility for delivering these performance outcomes over all timescales is essential so that the benefits of integrated planning are not lost or dependent on the goodwill of contractors. Often these outcomes depend on multiple partners, and so the responsibility for delivery may need to be shared. Progress has been made globally in creating and using these innovative contract forms, including new forms of procurement contracts suitable for delivering single or integrated sets of construction and infrastructure projects (The Ecological Sequestration Trust n.d.).

For example, the new contract forms of Framework Alliance and Term Alliance cover governance of a long-term relationship with a multi-party integrated team, including collaborative governance, improved performance systems, and measures of success. The Framework Alliance can be used with any standard form of contract, while the Term Alliance is a new version of the "TPC Term Partnering Contract." The Project Alliance is a streamlined version of the "PPC2000 Project Partnering Contract." All three set out clear processes for early appointment of contractors/subcontractors with shared information including performance outcomes that explicitly account for ecosystem services and climate risks alongside social and economic needs (The PPC Suite 2015). There are also tools for ensuring that the sustainable infrastructure proposed in the procurement process meets the objectives of investors. For example, SAVi is an assessment methodology that helps governments and investors steer capital toward sustainable infrastructure, and it can be combined with suitable forms of procurement contracts (International Institute for Sustainable Development n.d.).

#### **Recommendation 4:**

Through collaboration with leading funder institutions like multilateral development banks, national development banks, and major infrastructure contractors, G20 countries should develop and implement updated performance-based procurement standards for sustainable infrastructure. These will commit public- and private-sector contracting parties to deliver short- and long-term performance outcomes that match the sustainability and resilience goals and objectives outlined in national sustainable development strategies, subnational integrated development plans, and municipal and community priorities.

### **5. Increase investment in linked global-to-local-scale climate risk and ecosystem service modeling science**

Some efforts are already underway to create greater access to spatial modeling data and tools that support improved, integrated planning approaches:

- the UN's MapX tool and UN Biodiversity Lab and the work of Convention on International Trade in Endangered Species. However, these continue to be limited in their usability for subnational spatial planning, as they lack the necessary comprehensive data;
- the ICES Foundation is working to utilize advanced computing, modeling, simulation, and visualization to create a "near real-time" high-resolution digital model of Earth, with inputs from sensor networks and the Internet. It is also deploying AI techniques where necessary (ICES Foundation n.d.; UNDRR);
- the European Commission (2019) is similarly trying to meet some of this need, bringing together European scientific and industrial excellence to develop a very high-precision digital model of the Earth in the period 2021-26;
- the China Earth System Model version 3 (NESM v3) has been developed, aiming to provide a numerical modeling platform for cross-disciplinary Earth system studies, projecting future Earth climate and environment changes and arriving at subseasonal-to-seasonal predictions (Cao et al. 2018).

While rapidly improving technology and increasing access to spatial data through efforts like these are making complex social-ecological system-scale modeling increasingly cost-effective and ubiquitous, there are still important limitations preventing greater uptake and, thus, more effective planning. It is estimated by ICES that a total of €1 billion is needed to create a fully functioning Earth Systems model for global use, and a significant contribution could be made as a "moonshot" in the EU Horizon 2021-26 program with improved geospatial tools, allowing greater flexibility, ease of use, and standardization, in collaboration with developers and academia. The goal, through building "a global digital ecosystem for the planet," is to improve the accounting of climate change and pandemic risk dynamics and assessing the risks explicitly tailored to regional development planning and infrastructure pre-planning contexts (Campbell and Jensen 2019).

#### **Recommendation 5:**

G20 countries should fund science collaboration through existing independent global facilitators, like ICES and Future Earth, to create a series of ongoing meetings and other regular collaboration among leading earth systems modelers and academics and their models, with AI support. They must develop a high-resolution digital model of the Earth and associated public global access web platform—a global digital ecosystem for the planet. It should provide freely available essential data to support national and subnational land use planning, with layers including natural capital, ecosystem services, climate change scenarios, current and proposed major infrastructure investments, urbanization trends, and the like. These data can then be used directly to complement integrated systems modeling for people and ecology at national and regional scales so that the risk assessment for future scenarios for sustainable infrastructure designs and their impacts can be improved over time.

---

#### **Disclaimer**

This policy brief was developed and written by the authors and has undergone a peer review process. The views and opinions expressed in this policy brief are those of the authors and do not necessarily reflect the official policy or position of the authors' organizations or the T20 Secretariat.

#### **References**

- Bartlett, Ryan. 2019. Visioning Futures: Improving Infrastructure Planning to Harness Nature's Benefits in a Warming World. Washington, DC: WWF. Accessed August 18, 2020. [https://c402277.ssl.cf1.rackcdn.com/publications/1289/files/original/WWF\\_Visioning\\_Futures\\_2020\\_lo-res.pdf?1580259525](https://c402277.ssl.cf1.rackcdn.com/publications/1289/files/original/WWF_Visioning_Futures_2020_lo-res.pdf?1580259525).
- Botchie, George. 2000. Rural District Planning in Ghana: A Case Study. Environmental Planning Issues No. 21. London: International Institute for Environment and

Development. Accessed August 18, 2020. <https://pubs.iied.org/pdfs/7825IIED.pdf>.

Campbell, Jillian, and David E. Jensen. 2019. "Building a Digital Ecosystem for the Planet." UNEP. Accessed August 18, 2020. [https://medium.com/@davidedjensen\\_99356/building-a-digital-ecosystem-for-the-planet-557c41225dc2](https://medium.com/@davidedjensen_99356/building-a-digital-ecosystem-for-the-planet-557c41225dc2).

Cao, Jian, Bin Wang, Young-Min Yang, Libin Ma, Juan Li, Bo Sun, Yan Bao, Jie He, Xiao Zhou, and Liguang Wu. 2018. "The NUIST Earth System Model (NESM) version 3: description and preliminary evaluation." *Geoscientific Model Development* 11: 2975–2993. <https://doi.org/10.5194/gmd-11-2975-2018>.

Dallhammer, Erich, Roland Gaugitsch, Wolfgang Neugebauer, and Kai Böhme. 2018. *Spatial Planning and Governance within EU Policies and Legislation and Their Relevance to the New Urban Agenda*. European Committee of the Regions. Accessed August 18, 2020. <https://cor.europa.eu/en/engage/studies/Documents/Spatial-planning-new-urban-agenda.pdf>.

European Commission. 2019. *Communication from The Commission to The European Parliament, The European Council, The Council, The European Economic and Social Committee and The Committee of The Regions. The European Green Deal*. Accessed August 18, 2020. [https://ec.europa.eu/info/sites/info/files/european-green-dealcommunication\\_en.pdf](https://ec.europa.eu/info/sites/info/files/european-green-dealcommunication_en.pdf).

G20. 2019. *G20 Principles for Quality Infrastructure Investment*. Accessed August 18, 2020. [https://www.mof.go.jp/english/international\\_policy/convention/g20/annex6\\_1.pdf](https://www.mof.go.jp/english/international_policy/convention/g20/annex6_1.pdf).

Gebre, Tewelde, and Berhanu Gebremedhin. 2019. "The Mutual Benefits of Promoting Rural-Urban Interdependence Through Linked Ecosystem Services." *Global Ecology and Conservation* 20: e00707. <https://doi.org/10.1016/j.gecco.2019.e00707>.

Global Infrastructure Hub. (n.d.). "Forecasting Infrastructure Investment Needs and Gaps." Accessed August 18, 2020. [https://outlook.gihub.org/?utm\\_source=GIHub+Homepage&utm\\_medium=Project+tile&utm\\_campaign=Outlook+GIHub+Tile](https://outlook.gihub.org/?utm_source=GIHub+Homepage&utm_medium=Project+tile&utm_campaign=Outlook+GIHub+Tile).

Global Leadership Academy. n.d. "The Solutions Lab for Sustainable Infrastructure." Accessed August 18, 2020. <https://www.we-do-change.org/the-action/the-solutionslab-scaling-for-sustainable-infrastructure>.

Global Partnership for Sustainable Development Data. n.d. *Everybody Counts*. Accessed August 18, 2020. [http://www.data4sdqs.org/sites/default/files/2018-08/IDC\\_onepager\\_Final.pdf](http://www.data4sdqs.org/sites/default/files/2018-08/IDC_onepager_Final.pdf).

Hallegatte, Stéphane, Jun Rentschler, and Julie Rozenberg. 2019. *Lifelines: The Resilient Infrastructure Opportunity*. Washington, DC: The World Bank. Accessed August 18, 2020. <http://documents1.worldbank.org/curated/en/1111181560974989791/pdf/Lifelines-The-Resilient-Infrastructure-Opportunity.pdf>.

Howe, Caroline, Helen Suich, Bhaskar Vira, and Georgina M. Mace. 2014. "Creating Win-Wins from Trade-Offs? Ecosystem Services for Human Well-Being: A Meta-Analysis of Ecosystem Service Trade-Offs and Synergies in the Real World." *Global Environmental Change* 28: 263–275. <https://doi.org/10.1016/j.gloenvcha.2014.07.005>.

ICES Foundation. n.d. "Mission." Accessed August 18, 2020. [http://www.euro4m.eu/Presentations\\_ACRE/Bishop\\_ICES\\_Mission-2.pdf](http://www.euro4m.eu/Presentations_ACRE/Bishop_ICES_Mission-2.pdf).

INSPIRE Thematic Working Group Land Use. 2013. *D2.8.III.4 Data Specification on Land Use – Technical Guidelines*. European Commission Joint Research Centre. Accessed August 18, 2020. [https://inspire.ec.europa.eu/documents/Data\\_Specifications/INSPIRE\\_DataSpecification\\_LU\\_v3.0.pdf](https://inspire.ec.europa.eu/documents/Data_Specifications/INSPIRE_DataSpecification_LU_v3.0.pdf).

Inter-American Development Bank. 2018. *What is Sustainable Infrastructure? A Framework to Guide Sustainability Across the Project Cycle*. IDB. Accessed August 18, 2020. [https://publications.iadb.org/publications/english/document/What\\_is\\_Sustainable\\_Infrastructure\\_\\_A\\_Framework\\_to\\_Guide\\_Sustainability\\_Across\\_the\\_Project\\_Cycle.pdf](https://publications.iadb.org/publications/english/document/What_is_Sustainable_Infrastructure__A_Framework_to_Guide_Sustainability_Across_the_Project_Cycle.pdf).

International Institute for Sustainable Development. n.d. "The Sustainable Asset Valuation (SAVi)." Accessed August 18, 2020. <https://www.iisd.org/project/SAVisustainable-asset-valuation>.

Jones, Bryony A., Delia Grace, Richard Kock, Silvia Alonso, Jonathan Rushton, Mohammed Y. Said, Declan McKeever, et al. 2013. "Zoonosis Emergence Linked to Agricultural Intensification and Environmental Change." *PNAS* 110, no. 21: 8399–8404. <https://doi.org/10.1073/pnas.1208059110>.

Koppelaar, Rembrandt, Hannes Kunz, and Thomas Ravalde. 2013. *Review of Current Advanced Integrated Models for City-Regions*. The Ecological Sequestration Trust. Accessed August 18, 2020. <https://ecosequestertrust.org/wp-content/uploads/2015/02/TSB-Report-Final-2013-04-16.pdf>.

Mikovits, Christian, Wolfgang Rauch, and Manfred Kleidorfer. 2018. "Importance of Scenario Analysis in Urban Development for Urban Water Infrastructure Planning and Management." *Computers, Environment and Urban Systems* 68: 9–16. <https://doi.org/10.1016/j.compenvurbsys.2017.09.006>.

Nofal, Beatriz, Amar Bhattacharya, Kevin Gallagher, Minji Jeong, and Linda Krueger. 2019. *G20 Insights -Policy and Institutional Framework for Delivering on Sustainable Infrastructure 2019*. Accessed August 18, 2020. [https://www.g20-insights.org/policy\\_briefs/policy-and-institutional-framework-for-delivering-on-sustainableinfrastructure](https://www.g20-insights.org/policy_briefs/policy-and-institutional-framework-for-delivering-on-sustainableinfrastructure).

- OECD. 2018. Developing Robust Project Pipelines for Low-Carbon Infrastructure. Paris: OECD Publishing. <https://doi.org/10.1787/9789264307827-en>.
- Price, Roz. 2018. Cost-Effectiveness of Disaster Risk Reduction and Adaptation to Climate Change. K4D Helpdesk Report. Brighton: Institute of Development Studies. Accessed August 18, 2020. [https://assets.publishing.service.gov.uk/media/5ab0debce5274a5e20ffe268/274\\_DRR\\_CAA\\_cost\\_effectiveness.pdf](https://assets.publishing.service.gov.uk/media/5ab0debce5274a5e20ffe268/274_DRR_CAA_cost_effectiveness.pdf).
- Rozenberg, Julie, and Marianne Fay. 2019. Beyond the Gap: How Countries Can Afford the Infrastructure They Need while Protecting the Planet. Washington, DC: World Bank Group. <https://openknowledge.worldbank.org/handle/10986/31291>.
- Rydin, Yvonne, Yasminah Beebeejaun, Marco Bianconi, Juliana Borowczyk Martins, Ben Clifford, Claire Colomb, et al. 2015. Five Radical Ideas for a Better Planning System. UCL Bartlett School of Planning. Accessed August 18, 2020. <https://www.ucl.ac.uk/bartlett/planning/sites/bartlett/files/five-radical-ideas.pdf>.
- Thacker, Scott, Daniel Adshead, Marianne Fay, Stéphane Hallegatte, Mark Harvey, Hendrik Meller, Nicholas O'Regan, Julie Rozenberg, Graham Watkins, and Jim W. Hall. 2019. "Infrastructure for Sustainable Development." *Nature Sustainability* 2, no.4: 324–331. <https://doi.org/10.1038/s41893-019-0256-8>.
- The Ecological Sequestration Trust. n.d. "Roadmap 2030-Financing and Implementing the Global Goals in Human Settlements and City Regions." Accessed August 18, 2020. <https://ecosequestrust.org/roadmap2030>.
- The Ecological Sequestration Trust. 2015. Smart Ways to Mobilise More Efficient and Effective Long Term Investment in City Regions. Accessed August 18, 2020. <https://ecosequestrust.org/financeforSDGs.pdf>.
- The PPC Suite. 2015. PPC Alliance Contracts. Summary of Forms and Consultation Group Feedback. Accessed August 18th 2020 <http://acarchitects.co.uk/wp-content/uploads/2015/10/Alliance-Contracts-and-Consultations.pdf>.
- UNDRR Video-Taking a systems approach to disaster and cascading risk reduction GAR Explainer Peter Head. Accessed August 18, 2020 <https://www.youtube.com/watch?v=mUJnwI6SpkE>.
- UNEP. 2019. Integrated Approaches to Sustainable Infrastructure. Accessed August 18, 2020. [https://www.greengrowthknowledge.org/sites/default/files/downloads/resource/Integrated\\_Approaches\\_To\\_Sustainable\\_Infrastructure\\_UNEP.pdf](https://www.greengrowthknowledge.org/sites/default/files/downloads/resource/Integrated_Approaches_To_Sustainable_Infrastructure_UNEP.pdf).
- UN Habitat. 2017. New Urban Agenda. United Nations. Accessed August 18, 2020. <http://habitat3.org/wp-content/uploads/NUA-English.pdf>.
- United Nations Office for Disaster Risk Reduction. 2019. Global Assessment Report on Disaster Risk Reduction. Geneva: UNDR. Accessed August 18, 2020. <https://qar.undrr.org/sites/default/files/gar19distilled.pdf>.
- United Nations Statistics Division. 2016. "Leaving No One Behind." Accessed August 18, 2020. <https://unstats.un.org/sdgs/report/2016/leaving-no-one-behind>.
- Van Belle, Jean-Paul. 2018. Africa Data Revolution Report 2018-Status and Emerging Impact of Open Data in Africa. United Nations Economic Commission for Africa. Accessed August 18, 2020. <https://webfoundation.org/docs/2019/03/Africa-datarevolution-report.pdf>.
- Waddell, Paul. 2011. "Integrated Land Use and Transportation Planning and Modelling: Addressing Challenges in Research and Practice." *Transport Reviews* 31, no. 2: 209–229. <https://doi.org/10.1080/01441647.2010.525671>.
- Wang, Xiaonan, Miao Guo, Rembrandt H.E.M. Koppelaar, Koen H. van Dam, Charalampos P. Triantafyllidis, and Nilay Shah. 2018. "A Nexus Approach for Sustainable Urban Energy-Water-Waste Systems Planning and Operation." *Environmental Science & Technology* 52, no. 5: 3257–3266. <https://doi.org/10.1021/acs.est.7b04659>.
- Watkins, Graham, Sven-Uwe Mueller, Hendrik Meller, María Cecilia Ramirez, Tomás Serebrisky, and Andreas Georgoulas. 2017. Lessons from Four Decades of Infrastructure Project Related Conflicts in Latin America and the Caribbean. Washington DC: Inter-American Development Bank. Accessed August 18, 2020. <https://publications.iadb.org/publications/english/document/Lessons-from-Four-Decades-of-Infrastructure-Project-Related-Conflicts-in-Latin-America-and-the-Caribbean.pdf>.
- Woetzel, Jonathan, Nicklas Garemo, Jan Mischke, Priyanka Kamra, and Robert Palter. 2017. Bridging Global Infrastructure Gaps: Has the World Made Progress? McKinsey Global Institute. Accessed August 18, 2020. <https://www.mckinsey.com/industries/capital-projects-and-infrastructure/our-insights/bridging-infrastructure-gaps-has-the-world-made-progress>.
- Zhou, Zhi, Xu Chen, En Li, Liekang Zeng, Ke Luo, and Junshan Zhang. 2019. "Edge Intelligence: Paving the Last Mile of Artificial Intelligence with Edge Computing." *Proceedings of the IEEE* 107, no. 8: 1738–1762. <https://doi.org/10.1109/JPROC.2019.2918951>.
-

## Existing Initiatives & Analysis