Supplementary Material Chapter 8: Urban Systems

In Chapter 8, Figure 8.4 on co-benefits of urban mitigation actions in Section 8.2 and Figure 8.18 on the feasibility assessment based on the enablers and barriers of implementing mitigation options for urban systems in Section 8.5 refers to supplementary materials SM8.1 and SM8.2, respectively. These two materials for the SDG linkages and the feasibility assessment are contained in this contribution.

SM8.1 Supplementary Material to Section 8.2 on SDG Linkages

Co-benefits and trade-offs in the scope of urban mitigation are focused in Section 8.2.1. Based on the urban mitigation options that are synthesized in Section 8.4, SDG linkages are further considered per urban mitigation option, including the integration of urban mitigation options through integrated approaches. The evaluations are based on the linkages with the SDGs considering synergies (+) and trade-offs (-). These linkages are context specific and the possible synergies and/or trade-offs with the SDGs will change according to the specific urban area. Synergies and/or trade-offs may be more significant in certain contexts than others. **Table SM8.1** includes th evaluation of the SDG Linkages of the mitigation options for urban systems and indicates the levels of confidence as high (H), medium (M) and low (L). **Table SM8.2** includes the references / line of sight for these SDG linkages with 64 references that involve the urban context and extends the mappings that are provided in (Thacker et al. 2019) and (Fuso Nerini et al. 2018) in addition to the synthe is that is provided in the main chapter text. The evaluations further support Chapter 17 on "Accelerating the transition in the context of sustainable development." Urban mitigation with a view of the SDGs can support shifting pathways of urbanization towards sustainability (also see Cross-Chapter Box 5 on "Shifting development pathways to increase sustainability and broaden mitigation options" in Chapter 4). Moreover, the multi-dimensional feasibility assessment of mitigation options for urban systems indicates that feasibility is malleable and can increase when more enablers come into play. Strengthened institutional capacity that supports scale and coordination can increase the synergies of the urban mitigation options with the SDGs

Table SM8.1. Evaluation of the SDG Linkages of the Mitigation Options for Urban Systems

Urban Mitigation Options / SDGs	**Urban land use and spatial planning**	**Electrification of the urban energy system**	**District heating and cooling networks**
SDGs	Evaluation of synergies and trade-offs	Evaluation of synergies and trade-offs	Evaluation of synergies and trade-offs
SDG 1 End poverty	(+) Provides employment density and supports productivity (H) (+) Can reduce exposure and vulnerability to climate change given policy integration (H)	(+) Can address energy poverty that is linked to poverty; eradicating poverty is supported by access to modern energy services for all (M)	(+) Can address energy poverty that is linked to poverty; eradicating poverty is supported by access to modern energy services for all (M)
SDG 2 Zero hunger	(+) Better spatial planning will reduce pressures on land use change, including croplands (H) (-) Growth in urban extent can still reduce cropland if not sufficiently managed (H)	(+) Electrification can support welfare; electric stoves can support nutritional food intake (M) (-) Can have trade offs if food systems are coupled with electricity and bioenergy (M)	(-) Can have trade-offs if food systems are coupled with bioenergy and heat (M)
SDG 3 Good health and wellbeing	(+) Improves access to health infrastructure; improves air quality when coupled to shifting energy use, improves wellbeing with green and blue infrastructure (H)	(+) Improves air quality when coupled to shifting energy use as included in the option; Avoids air pollution from energy and transport infrastructure; Supports energy services for quality health services in hospitals (H)	(+) Improves air quality when coupled to shifting energy use as included in the option; Supports energy services for quality health services in hospitals (M)
SDG 4 Quality education	(+) Better spatial planning increases educational opportunities (M)	(+) Electrification and access to electricity supports quality education and educational attainment (H)	
SDG 5 Gender equality	(+) Can increases equal opportunities and effective participation of women, including urban governance (M)	(+) Supports equal opportunities, also through electricity for internet access if previously lacking (M)	
SDG 6 Clean water and sanitation	(+) Can improve water quality water-use efficiency, water harvesting and wastewater treatment; efficient urbanization can also reduce GHG emissions from water infrastructure (H)	(+) Renewable energy powered water treatment facilities can support clean water and sanitation (M)	
SDG 7 Affordable and clean energy	(+) Can reduce energy use and enable access to modern energy infrastructure while urban infrastructure for energy services varies (H)	(+) Supports renewable energy, energy efficiency and access to affordable, reliable and modern energy; renewable-energy generation technologies can enhance infrastructure resilience (H)	(+) Supports renewable energy, energy efficiency and access to affordable, reliable and modern energy (M)

Urban Mitigation Options / SDGs	**Urban land use and spatial planning**	**Electrification of the urban energy system**	**District heating and cooling networks**
SDGs	Evaluation of synergies and trade-offs	Evaluation of synergies and trade-offs	Evaluation of synergies and trade-offs
SDG 8 Decent work and economic growth	(+) Provides employment density and supports productivity (H)	(+) Supports technological upgrading, innovation and decent job creation (H)	(+) Supports technological upgrading, innovation and decent job creation (M)
SDG 9 Industry innovation and infrastructure	(+) Sustainable urbanisation and settlement planning requires development across all infrastructure sectors (H)	(+) Supports sustainable and resilient infrastructure and can support domestic technology development; renewable-energy generation technologies can enhance infrastructure resilience (H)	(+) Is being used to support sustainable and resilient infrastructure, including adaptation and mitigation (M)
SDG 10 Reduced inequalities	(+) Spatial inequalities within cities can be reduced; Urban infrastructure gap between cities can be reduced (H) (-) Unintended gentrification and spatial inequalities are still possible (M)	(+) Supports equal opportunities, e.g. through internet access if previously lacking (H)	
SDG 11 Sustainable cities and communities	(+) Supports capacity for participatory, integrated and sustainable human settlement planning (Target 11.3) and protecting the poor and vulnerable (Target 11.5) (H)	(+) Supports adequate, safe and affordable housing as well as safe, affordable, accessible and sustainable transport (Targets 11.1 and 11.2) (H)	(+) Supports capacity for participatory, integrated and sustainable human settlement planning (Target 11.3) (H)
SDG 12 Responsible consumption and production	(+) Urbanisation with lower material demands will support responsible consumption and production (H) (-) Urban population growth contributes to increased demand for resources with differences in scenarios; increase in urban water demand can increase pressures on water scarcity; over exploitation of groundwater needs to be avoided (M)	(+) Allows leapfrogging to more resource-efficient urban development (H) (-) Material demands of electrification technologies will increase; policies are important (M)	(+) Allows leapfrogging to more resource-efficient urban development (M)
SDG 13 Climate action	(+) Contributes to both climate mitigation and adaptation given integration in urban planning (H)	(+) Energy infrastructure can also strengthen climate resilience and adaptive capacity if addressed together (M)	(+) Energy infrastructure can also strengthen climate resilience and adaptive capacity if addressed together (M)

Urban Mitigation Options / SDGs	**Urban land use and spatial planning**	**Electrification of the urban energy system**	**District heating and cooling networks**
SDGs	Evaluation of synergies and trade-offs	Evaluation of synergies and trade-offs	Evaluation of synergies and trade-offs
SDG 14 Life below water	(+) Can reduce growth in urban expansion that can help protect coastal and marine ecosystems (M) (-) Urban development can still impact coastal and marine ecosystems (M)	(+) Energy systems can be designed to minimize impacts on water ecosystems (M)	
SDG 15 Life on land	(+) Can reduce growth in urban expansion that can help protect biodiversity on land and terrestrial and inland freshwaters (H) (-) Urban development can still impact biodiversity (M)	(+) Clean energy will reduce the impacts of climate change on biodiversity and terrestrial ecosystems (H) (-) Hydropower development and biofuel cultivation may impact ecosystems while there are multiple alternatives e.g. use of degraded lands for solar energy farms (M)	(+) Clean energy will reduce the impacts of climate change on biodiversity and terrestrial ecosystems (H)
SDG 16 Peace, justice and strong institutions	(+) Has synergies with responsive, inclusive and participatory decision-making at all levels and transparent institutions (M)	(+) Improvement in governance through inclusive decision-making improves ability for energy systems to contribute to sustainable development (M)	(+) Improvement in governance through inclusive decision-making improves ability for energy systems to contribute to sustainable development (M)
SDG 17 Partnerships for the goals			

Urban Mitigation Options / SDGs	**Urban green and blue infrastructure**	**Waste prevention, minimization and management**	**Integrating sectors, strategies and innovations**
SDGs	Evaluation of synergies and trade-offs	Evaluation of synergies and trade-offs	Evaluation of synergies and trade-offs
SDG 1 End poverty	(+) Can increase employment and food security, e.g. urban agriculture (H)	(+) Can reduce informality in the waste sector and support poverty alleviation (H)	(+) Increases employment density, reduces poverty and exposure and vulnerability to climate change (H)
SDG 2 Zero hunger	(+) Can increase employment and food security, e.g. urban agriculture (M)	(+) Can support reducing food waste in municipalities and urban centers (M)	(+) Supports livelihoods, reduces pressures on croplands and consumption related land use impacts (H)

Urban Mitigation Options / SDGs	**Urban green and blue infrastructure**	**Waste prevention, minimization and management**	**Integrating sectors, strategies and innovations**
SDGs	Evaluation of synergies and trade-offs	Evaluation of synergies and trade-offs	Evaluation of synergies and trade-offs
SDG 3 Good health and wellbeing	(+) Better ecosystem services improves health and wellbeing, can improve air quality (H)	(+) Better waste management improves air quality (H) (-) Can depend on air pollution control techniques if waste incineration is involved (M)	(+) Improves access to health infrastructure; improves air quality when coupled to shifting energy use, improves wellbeing with green and blue infrastructure (H)
SDG 4 Quality education	(+) Urban green and blue infrastructure can increase opportunities and sites for environmental education (M)		(+) Can increase education opportunities, access to electricity and environmental education (H)
SDG 5 Gender equality			(+) Can increases equal opportunities and effective participation of women, including urban governance (M)
SDG 6 Clean water and sanitation	(+) Also supports water sensitive urban planning and protection of water-related ecosystems (H)	(+) Improved water and wastewater infrastructure will reduc water pollution (H)	(+) Can improve water quality, water-use efficiency, water harvesting and wastewater treatment; efficient urbanization can also reduce GHG emissions from water infrastructure (H)
SDG 7 Affordable and clean energy	(+) Produces a cooling effect, lowering energy use when in relative proximity (M)		(+) Supports renewable energy, energy efficiency and access to affordable, reliable and modern energy (H)
SDG 8 Decent work and economic growth	(+) Can stimulate new green conomies and green jobs (M)	(+) Can stimulate employment for value added products (M) (-) Transforming informality of waste recycling activities into programs are important (M)	(+) Supports technological upgrading, innovation and decent job creation (H)

Urban Mitigation Options / SDGs	**Urban green and blue infrastructure**	**Waste prevention, minimization and management**	**Integrating sectors, strategies and innovations**
SDGs	Evaluation of synergies and trade-offs	Evaluation of synergies and trade-offs	Evaluation of synergies and trade-offs
SDG 9 Industry innovation and infrastructure	(+) Supports sustainable and resilient infrastructure (H)	(+) Supports sustainable and resilient infrastructure (H)	(+) Supports sustainable and resilient infrastructure (H)
SDG 10 Reduced inequalities	(+) Can support equity given policy design (M) (-) Can push out low income residents from main city areas without inclusive policy design (M)		(+) Can reduce the urban infrastructure gap; sustainable urbanization can support reducing inequality within and among cities; Inclusivity of inhabitants in the informal sector is important (H)
SDG 11 Sustainable cities and communities	(+) Supports air quality and universal access to safe, inclusive and accessible green and public spaces (Target 11.7) (H)	(+) Directly related to waste management; supports links between urban, peri-urban and rural areas (Target 11.a) (H)	(+) Supports integrated policies and plans for inclusion, resource efficiency, mitigation and adaptation (Target 11.b) (H)
SDG 12 Responsible consumption and production	(+) Supports sustainable development and lifestyles also "in harmony with nature" as emphasized (Target 12.8) (H)	(+) Reduces waste generation through prevention, reduction, recycling and reuse (Target 12.5) (H) (-) Waste segregation at source and waste processing facilities differs across context (H)	(+) Allows leapfrogging to more resource-efficient urban development (H)
SDG 13 Climate action	(+) Contributes to both climate mitigation and adaptation given integration in urban planning (H)	(+) Reduces emissions through better management of urban waste in different contexts and is important for resilience, including coastal areas (M)	(+) Contributes to both climate mitigation and adaptation given integration in urban planning (H)
SDG 14 Life below water	(+) Blue infrastructure can contribute to protecting coastal and marine ecosystems (H)	(+) Better waste management and wastewater treatment will protect coastal and marine ecosystems, reduce marine debris and nutrient pollution (H)	(+) Can reduce growth in urban expansion that can help protect coastal and marine ecosystems (M)

Urban Mitigation Options / SDGs	**Urban green and blue infrastructure**	**Waste prevention, minimization and management**	**Integrating sectors, strategies and innovations**
SDGs	Evaluation of synergies and trade-offs	Evaluation of synergies and trade-offs	Evaluation of synergies and trade-offs
SDG 15 Life on land	(+) Enhances biodiversity within urban areas and ecosystem services (H)	(+) Better waste management and wastewater treatment will protect terrestrial and inland freshwaters (H)	(+) Can reduce growth in urban expansion that can help protect biodiversity on land and terrestrial and inland freshwaters (H)
SDG 16 Peace, justice and strong institutions	(+) Has synergies with responsive, inclusive and participatory decision-making at all levels and transparent institutions (M)	(+) Has synergies with responsive, inclusive and participatory decision making at all levels and transparent institutions (M)	(+) Has synergies with responsive, inclusive and participatory decision-making at all levels and transparent institutions (M)
SDG 17 Partnerships for the goals			(+) Partnerships support sustainable infrastructure for urban areas; supports policy coherence for sustainable development (Target 17.14) (H)

Table SM8.2. References / Line of Sight for the SDG Linkages of the Mitigation Options for Urban Systems

Urban Mitigation Options / SDGs	**Urban land use and spatial planning**	**Electrification of the urban energy system**	**District heating and cooling networks**
SDGs	References / Line of sight	References / Line of sight	References / Line of sight
SDG1	(Xu et al., 2018; Lall et al., 2021)	(Fuso Nerini et al., 2018; Bonatz et al., 2019; Villalobos et al., 2021)	(Fuso Nerini et al., 2018; Bonatz et al., 2019; Villalobos et al., 2021)
SDG2	(Güneralp et al. 2020)	(Fuso Nerini et al., 2018; IRENA, 2021)	(Fuso Nerini et al. 2018)
SDG3	(Madill et al., 2016; Ramirez-Rubio et al., 2019)	(Fuso Nerini et al., 2018; Thacker et al., 2019; Karlsson et al., 2020)	(Fuso Nerini et al. 2018)
SDG4	(Kleibert et al. 2020)	(Sovacool and Ryan, 2016; Fuso Nerini et al., 2018; Zhang et al., 2019b)	
SDG5	(Horelli, 2017; Raparthi, 2021)	(Fuso Nerini et al., 2018; Stewart et al., 2018)	
SDG6	(Zhang et al. 2019a)	(Stewart et al., 2018; Madurai Elavarasan et al., 2021)	
SDG7	(Stokes and Seto 2016)	(Fuso Nerini et al., 2018; Madurai Elavarasan et al., 2021)	(IEA, 2021; IRENA, 2021)
SDG8	(Lall et al. 2021)	(IEA, 2021; IRENA, 2021)	(IEA, 2021; IRENA, 2021)
SDG9	(Thacker et al. 2019)	(Adenle et al., 2015; Thacker et al., 2019)	(Landauer et al. 2019)
SDG10	(Giles-Corti et al., 2020; Kamiya et al., 2020; Lall et al., 2021)	(Stewart et al. 2018)	
SDG11	(Kii et al., 2017; Thacker et al., 2019)		(UNEP, 2015; Lee and Erickson, 2017)
SDG12	(Swilling et al., 2018; Kookana et al., 2020; Schandl et al., 2020)	(Sovacool et al., 2020; IRENA, 2021)	(UNEP, 2015; Swilling et al., 2018)
SDG13	(Hurlimann et al. 2021)	(Fuso Nerini et al. 2018)	(Fuso Nerini et al. 2018)
SDG14	(de Andrés et al. 2018)	(Thacker et al. 2019)	
SDG15	(Ibáñez-Álamo et al. 2020)	(Fuso Nerini et al., 2018; Thacker et al., 2019)	
SDG16		(Fuso Nerini et al. 2018)	
SDG17			

Urban Mitigation Options / SDGs	**Urban green and blue infrastructure**	**Waste prevention, minimization and management**	**Integrating sectors, strategies and innovations**
SDGs	References / Line of sight	References / Line of sight	References / Line of sight
SDG1	(Raymond et al. 2017)		(Xu et al., 2018; Lall et al., 2021)
SDG2	(de Macedo et al. 2021; Davis et al. 2022)	(Richter and Bokelmann, 2018; Ananno et al., 2021)	
SDG3	(Raymond et al., 2017; IPBES, 2019; de Macedo	(Beylot et al. 2018)	(Beylot et al., 2018; Ramirez-Rubio et al.,

Urban Mitigation Options / SDGs	**Urban green and blue infrastructure**	**Waste prevention, minimization and management**	**Integrating sectors, strategies and innovations**
SDGs	References / Line of sight	References / Line of sight	References / Line of sight
	et al., 2021)		2019)
SDG4	(Wolsink 2016)		
SDG5			(Horel i 2017; Kiranmayi, 2021)
SDG6	(Kuller et al., 2017; IPBES, 2019; Serrao-Neumann et al., 2019; Raymond et al., 2017; de Macedo et al., 2021)	(Thacker et al. 2019)	(Zhang et al. 2019a)
SDG7	(Wong et al. 2021); (Quaranta et al. 2021)		
SDG8	(Raymond et al. 2017)	(de Bercegol and Gowda 2019; Coalition for Urban Transitions, 2020)	(Raymond et al., 2017; IEA, 2021; IRENA, 2021; Lall et al., 2021)
SDG9	(Ürge-Vorsatz et al., 2018; IPBES, 2019; de Macedo et al., 2021)	(Thacker et al. 2019)	(Thacker et al. 2019)
SDG10	(Andersson et al. 2019; Keeler et al. 2019)		(Abubakar and Aina, 2019; Kamiya et al., 2020)
SDG11	(IPBES, 2019; de Macedo et al., 2021)	(AlQ ttan et al., 2018; Baffoe t al., 2021)	(Zinkernagel et al., 2018; Abubakar and Aina, 2019; Thacker et al., 2019)
SDG12		(Kumar et al., 2017; Kaza et al., 2018)	
SDG13	(Ürge-Vorsatz et al., 2018; IPBES, 2019; de Macedo et al., 2021)	(Lenhart et al., 2015; Islam, 2018; Yoshioka et a ., 2021)	(Hurlimann et al. 2021)
SDG14	(IPBES, 2019; de Macedo et al., 2021)		
SDG15	(IPBES, 2019; Ibáñez-Álamo et al., 2020; d Macedo et al., 2021)		
SDG16	(Fuso Nerini et al. 2018)		
SDG17			(Anwar et al., 2017; CDP, 2021; Negreiros et al., 2021)

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SM8.2 – Supplementary Material to Section 8.5 on the Feasibility Assessment

This Supplementary Material to Chapter 8 provides an overview of the extent to which different factors affect the feasibility of mitigation options in urban systems that may differ across context, time and scale of implementation and the line of sight upon which the feasibility assessment in Figure 8.18 in Section 8.5 is based. The multi-dimensional feasibility assessment is based on 18 indicators in the 6 dimensions of geophysical, environmental-ecological, technological, economic, socio-cultural and institutional feasibility. An indicator in this assessment framework can pose positive and/or negative impacts as enablers or barriers of the mitigation option. Indicators that provide positive impacts as enablers (E) are marked in blue while those that can have negative impacts as barriers (B) are marked in orange in **Table SM8.3**. Levels of confidence (LoC) are evaluated as low, medium or high based on the robustness and agreement of the evidence and shaded in light to dark tones. Lines of sight that are used per indicator of the feasibility assessment are contained in **Table SM8.4,** including 414 references across urban mitigation options. Lines of sight utilize the systematic assessment of urban case studies considering 1,373 scientific references during the timeframe of the AR6 cycle based on (Lamb et al. 2019) and additional systematic searches according to the indicators of the feasibility assessment. The lines of sight further build upon the feasibility assessment for land use and urban planning that was initiated by SR15 (IPCC 2018). The feasibility assessment for integrating sectors, strategies and innovations are based on multiple urban mitigation options implemented concurrently, such as co-located densities and electrification of the urban energy system whenever relevant (see Figure 8.20). The feasibility assessment method is explained in detail in Annex II.11 and Annex.II.12.

Levels of Confidence (LoC)	Low	Medium	High
Enablers (E)			
Barriers (B)			

Table SM8.3. Feasibility Assessment of Mitigation Options in Urban Systems

Mitigation options	**Urban land use and spatial planning**		**Electrification of the urban energy system**		**District heating and cooling networks**	
Dimensions/ Indicators	Feasibility barriers or enablers (LoC)	Role of context, time and scale of implementation	Feasibility barriers or enablers (LoC)	Role of context, time and scale of implementation	Feasibility barriers or enablers (LoC)	Role of context, time and scale of implementation
1. Geophysical						
Physical potential	(E) LoC=3	Reduces pressures on land, e.g. a total of 125,000 km^2 of land could be saved between the years 1970 and 2020 if population density remained the same as 1970 levels while cities have had different dynamics of stable, outward and/or upward growth	(E) LoC=3	The realization of the available physical potential depends on the ability to electrify the urban energy system while supporting flexibility and sector coupling options for deep decarbonization	(E/B) LoC=3	Depends on district heating and cooling demands in comparison to the spatial characteristics of urban areas, e.g. heat demand density is a function of both population density and heat demand per capita where physical suitability can be equally present in urban areas with high population density or high heat demand per capita
Geophysical resources	(E/B) LoC=2	Depends on the ability of the mitigation option to limit demands on materials for urban construction needs, thereby avoiding and shifting pressures on geophysical resources, including scarce resources	(E/B) LoC=2	Depends on the demands on geophysical resources in comparison to other energy technologies, recycling of relevant energy technologies and energy storage needs at suitable levels	(E/B) LoC=2	Depends on optimization of the piping layout with metal use and the implementation of eco-design principles for resource efficiency
Land use	(E) LoC=3	Land use efficiency reduces pressures on growth in urban extent while urban land use changes according to the drivers in SSP scenarios. Scenarios that involve sustainability involve lower urban land use, e.g. 1.1 million km^2 in 2100 in SSP1 versus 3.6 million km^2 in SSP5	(E/B) LoC=2	Depends on the energy supply to support electrification and the ability to use urban density to increase the penetration of renewable power and electric public transport, e.g. mixed-use neighbourhoods for grid balancing	(E) LoC=3	Improves based on urban design parameters, including density, block area, and elongation with close impact of urban density on energy density. Walkable and higher density urban form can further enable its implementation
2. Environmental-Ecological						

Mitigation options	**Urban land use and spatial planning**		**Electrification of the urban energy system**		**District heating and cooling networks**	
Dimensions/ Indicators	Feasibility barriers or enablers (LoC)	Role of context, time and scale of implementation	Feasibility barriers or enablers (LoC)	Role of context, time and scale of implementation	Feasibility barriers or enablers (LoC)	Role of context, time and scale of implementation
Air pollution	(E/B) LoC=3	Depends on the energy mix that is involved in the urban infrastructure (energy use in buildings, private vehicles and public transport) while energy use due to vehicle transport is reduced with walkable urban form	(E) LoC=3	Level of improvement depends on the shift to non polluting energy sources e g shifting to 100% renewable energy can save about 408,270 lives per year du to better air quality in 74 metropolitan areas around the world, enabling its implementation	(E) LoC=3	Level of improvement depends on the energy resource that is replaced and air quality regulations when applicable
Toxic waste, ecotoxicity, eutrophication	(E) LoC=2	Better urban land use and spatial planning will limit negative impacts depending on urban land use, urban surface (permeable versus impermeable), ability to limit urban storm water runoff and discharge	(E) LoC=2	Depends on the source of the electrification of urban energy systems while favourable. It is also possibl to displace water and soil pollution from conventional fuels	(E) LoC=2	The energy resource that is replaced can provide additional environmental benefits , e.g. replacing coal use improves air and water pollution
Water quantity and quality	(E) LoC=2	Improves based on the urban water system (supply, purification, distribution, drainage, the magnitude, source and location of water supply), and the level of integration between urban land-use and water planning that requires both policy integration and innovation *(see last option)*	(E) LoC=2	Depends on the source of the electrification of urban energy systems while favourable. It is also possible to displace water and soil pollution from conventional fuels	(E) LoC=2	Resource-efficient and strategic densification for 84 cities indicate life-cycle assessment benefits for water that can also increase when integrated with other options, e.g. urban metabolism
Biodiversity	(E/B) LoC=3	Depends on the context, in luding the ability to limit urban growth, governance capacity, and integrating ecosystem service information into spatial planning. Land use change for urban areas can threaten biodiversity	(E) LoC=2	Deep decarbonization pathways involve electrification, including urban vehicle kilometers and reduction in land use, including for urban areas. These pathways have a positive impact on biodiversity considering reduced land and climate impacts	(E) LoC=2	Increases with the interaction of urban energy planning with urban land use and spatial planning, e.g. limiting the growth in urban extent together with this option can avoid impacts on biodiversity

Mitigation options	**Urban land use and spatial planning**		**Electrification of the urban energy system**		**District heating and cooling networks**	
Dimensions/ Indicators	Feasibility barriers or enablers (LoC)	Role of context, time and scale of implementation	Feasibility barriers or enablers (LoC)	Role of context, time and scale of implementation	Feasibility barriers or enablers (LoC)	Role of context, time and scale of implementation
3. Technological						
Simplicity	(E/B) LoC=3	Urban land use and spatial planning supports other mitigation options as a fundamental necessity for climate mitigation while complex in many ways. The geographical coverage of harmonized algorithms to monitor land use change also remains to be one of the current gaps in knowledge	(E/B) LoC=3	Simplicity varies according to the scale of electrification energy system interactions and system integration to support flexibility in energy systems with high renewable energy penetration	(E/B) LoC=3	Depends on economies of scope in urban areas with access to already existing excess heat, system integration, level of climate ambition for climate neutrality, urban infrastructure and support from GIS for planning district heating and cooling networks that also provide an entry point for decarbonizing thermal needs
Technological scalability	(E/B) LoC=3	Depends on the stage of urban development with more opportunities at earlier stages and or differences in opportunities, e.g. strategic intensification. Scalability also depends on combining urban land use and spatial planning practices with climate mitigation as well as sustainable development objectives	(E) LoC=3	Holds advantages for rapid pace of decarbonization despite carbon lock-in across urban typologies. Also depends on support from flexibility options, e.g. demand response, power-to-heat and electric mobility to increase the penetration of renewable energy in the urban system. The choice of options, e.g. electrified urban rail, can integrate with existing urban design based on walkable neighbourhoods in rapidly growing cities	(E) LoC=3	Is technologically scalable in different regions that increases with the geographic heat/cold demand density of the urban area. There are relatively more opportunities with urban energy planning processes. District heating and/or cooling networks are able to also support flexibility in the energy system and act as low-cost storage options
Maturity and technology readiness	(E) LoC=3	Is favourable while further depending on the level of integration, e.g. energy-driven urban design for optimizing the	(E) LoC=3	Maturity is favourable, including demand response based on power-to-heat in support of electrification and other options	(E/B) LoC=3	Depends on the generation with a role for low temperature, fourth generation district heating and cooling networks in

Mitigation options	Urban land use and spatial planning		Electrification of the urban energy system		District heating and cooling networks	
Dimensions/ Indicators	Feasibility barriers or enablers (LoC)	Role of context, time and scale of implementation	Feasibility barriers or enablers (LoC)	Role of context, time and scale of implementation	Feasibility barriers or enablers (LoC)	Role of context, time and scale of implementation
		impact of urban form on energy infrastructure		that has technical feasibility for providing flexibility in the energy system particularly based on municipal level demonstra ions		emerging and future energy networks with high renewable energy penetration
4. Economic						
Costs in 2030 and long term	(E) LoC=3	Provides cost benefits that increases with characteristics of urban development. Beyond costs, limiting the growth in urban extent has multiple benefits for climate mitigation	(E LoC=3	Costs are favourable. Renewable electricity is also relevant for decarbonizing the heating sector through power-to-he t that can be a cost-effective option, including large-scale heat pumps in district heating and cooling networks	(E) LoC=3	Can already provide total annual cost savings over building level solutions. Future improvements depend on system optimization, the ability to integrate low-temperature renewable energy sources and excess electricity from renewables in upgrading existing or implementing new district heating and cooling networks and modular approach across suitable urban areas
Employment effects and economic growth	(E) LoC=3	The concentration of people and activity in walkable higher density urban areas increases productivity based on proximity and efficiency while providing employment density The ability to decouple urban economic growth from emissions and other parameters, e.g. vehicle kilome ers travelled, can further increase sustainable growth	(E) LoC=3	Is positive and increases with the ability to establish local jobs and use revenues locally. Access to renewable electricity reduces the operational GHG emissions of the local economy, thereby increasing competitiveness, while providing a net status of long-term, full-time jobs	(E) LoC=3	Is positive and increases with the ability to stimulate a green economy, e.g. access to renewable energy based district heating and cooling networks reduces the operational GHG emissions of the local economy, increases competitiveness and supports jobs in design and implementation, equipment manufacturing, operation and maintenance

Mitigation options	**Urban land use and spatial planning**		**Electrification of the urban energy system**		**District heating and cooling networks**	
Dimensions/ Indicators	Feasibility barriers or enablers (LoC)	Role of context, time and scale of implementation	Feasibility barriers or enablers (LoC)	Role of context, time and scale of implementation	Feasibility barriers or enablers (LoC)	Role of context, time and scale of implementation
5. Socio-Cultural						
Public acceptance	(E) LoC=2	Increases with processes that are involved in the planning and implementation of the urban mitigation option, i.e. co-design	(E) LoC=3	Depends on the provision of clean and afford ble energy services through electrification of the urban energy system nd socially-accepted potential for load shifting	(E/B) LoC=3	Depends on role in climate neutrality targets, co-benefits for air quality, addressing energy poverty, citizen and consumer ownership models, technology perception as well as public and consumer awareness
Effects on health & wellbeing	(E) LoC=3	Increases with the quality of spatial planning to increase co-benefits for health and wellbeing, e.g. balancing urban green areas with density	(E) LoC=3	Increases with the energy resource that is displaced through electrification of the urban energy system. Residential electricity access lso provides a positive influence on health, wellbeing as well as life expectancy	(E) LoC=3	Provides improvement in both indoor and outdoor air quality, provision of thermal comfort, alleviation of the urban heat island effect, and improved safety with gas supply outside accommodation as an enabler of the mitigation option
Distributional effects	(E/B) LoC=2	Depends on the policy tools that shape the impacts or benef ts of urban densification on afford ble hou ing while evidence for transit-induced gentrification is partial and inconclusive	(E) LoC=3	Increases with the ability of addressing aspects of energy poverty as well as increasing energy access in informal settlements based on urban planning. Urbanization is also a driver of access to electricity, which if combined with renewable energy, can further support sustainable development. Business models and nature of ownership can increase intra-generational equity while shifting to inter-	(E) LoC=3	Increases based on the business model with local ownership of district heating and cooling networks having the most positive impact on local benefits. Also contributes to addressing energy poverty based on the provision of affordable energy for satisfying thermal comfort in urban areas

Mitigation options	**Urban land use and spatial planning**		**Electrification of the urban energy system**		**District heating and cooling networks**	
Dimensions/ Indicators	Feasibility barriers or enablers (LoC)	Role of context, time and scale of implementation	Feasibility barriers or enablers (LoC)	Role of context, time and scale of implementation	Feasibility barriers or enablers (LoC)	Role of context, time and scale of implementation
				generational equity		
6. Institutional						
Political acceptance	(E/B) LoC=2	Depends on context, increasing with the ability to integrate opportunities for climate mitigation with co-benefits for health and wellbeing	(E) LoC=3	Depends on the coordination ability of local authorities and the local level renewable energy target setting and implementation with close to 1000 cities having adopted climate neutrality targets, including some that further extend into urban climate positive targets	(E/B) LoC=3	Depends on the ability to plan and implement structural policies for climate neutrality as well as the population size of municipalities
Institutional capacity & governance, cross-sectoral coordination	(E/B) LoC=3	Depends on the ability to implement integrated urban planning as well as relations between urban mobility, buildings, energy systems, water systems, ecosystem services, other urban sectors and climate adaptation	(E/B) LoC=3	Depends on policy coherence to avoid policy fragmentation and electrification at scale. High renewable energy targets, high climate ambition as well as high fuel and CO_2 prices support the diffusion of related options	(E/B) LoC=3	Depends on coordination with urban planning, the scope of urban energy planning, forming of partnerships and local ownership
Legal and administrative feasibility	(E/B) LoC=2	Depends on the capacity for implementing land use zoning and regulations consistently with urban land use and spatial planning	(E) LoC=3	Enabled by the policy and financing instruments that are used to support and increase electrification of the urban energy system, including green bonds and green procurement strategies	(E/B) LoC=3	Depends on the ability to implement policy instruments to exploit and integrate local resources for supplying thermal energy cost effectively to urban areas while implementing climate targets. Bottom up and interactive regulatory frameworks based on multilevel policies are suggested for facilitating coordination among energy sectors as an enabler

Mitigation options	**Urban green and blue infrastructure**		**Waste prevention, minimization and management**		**Integrating sectors, strategies and innovations**	
Dimensions/ Indicators	Feasibility barriers or enablers (LoC)	Role of context, time and scale of implementation	Feasibility barriers or enablers (LoC)	Role of context, time and scale of implementation	Feasibility barriers or enablers (LoC)	Role of context, time and scale of implementation
1. Geophysical						
Physical potential	(E) LoC=3	Is favourable, increasing with the physical space that is available for urban green/blue space and infrastructure to an extent that will support climate mitigation strategies	(E) LoC=3	Is favourable, also depending on alleviating resource usage and upstream emissions from urban settlements based on the mitigation option	(E) LoC=3	The ability to reduce pressures on physical land resources for urban areas is a feasibility enabler
Geophysical resources	(E) LoC=2	Urban green and blue infrastructure are based on ecomimicry and sustainability innovations and do not represent pressures on geophysical resource demands	(E) LoC=3	Resource benefits increase with the scale of waste prevention, minimization and material recovery, e.g. reducing demands for new virgin raw resources	(E/B) LoC=2	Depends on lowering the material demands for urban development with opportunities for considering materials with lower GHG impacts and selection of urban development plans with lower material demands
Land use	(E) LoC=3	Depends on the scope of green and blue infrastructure while restoration based nature-based solutions can also restore degraded urban land area	(E) LoC=3	Is favourable, also depending on reducing ecological footprint due to integrated waste management and possibly biochar to improve soil quality. Walkable urban form can also reduce distances for waste collection	(E) LoC=3	Increases with the role of urban land use and spatial planning in the low carbon development (*see first mitigation option*) and the relevance of brownfield urban development for the project
2. Environmental-Ecological						
Air pollution	(E) LoC=3	The indicator is an enabler while the highest benefits depend on the design of urban ecological infrastructure and related parameters that influence better air quality, including leaf area index,	(E) LoC=3	Better waste management enables better air quality, further depending on the adopted waste hierarchy principles and the energy use of facilities for material and/or energy recovery	(E) LoC=3	Integrating across urban land use and spatial planning, electrification of urban energy systems, district heating and cooling networks, urban green and blue infrastructure and

Mitigation options	**Urban green and blue infrastructure**		**Waste prevention, minimization and management**		**Integrating sectors, strategies and innovations**	
Dimensions/ Indicators	Feasibility barriers or enablers (LoC)	Role of context, time and scale of implementation	Feasibility barriers or enablers (LoC)	Role of context, time and scale of implementation	Feasibility barriers or enablers (LoC)	Role of context, time and scale of implementation
		foliage density and the impact on reducing urban energy usage		in the urban vicinity, if any		waste management has positive impacts on improving air quality
Toxic waste, ecotoxicity, eutrophication	(E) LoC=3	Urban green and blue infrastructure can be used for also remediating brownfield sites, e.g. phytoremediation and bioremediation, and limiting urban runoff	(E) LoC=3	Is favourable, also considering the avoided environmental burden of local strategies for waste and wastewater management and avoided resource use	(E) LoC=2	Level of improvement depends on the demands of low carbon development on materials and urban metabolism performance
Water quantity and quality	(E) LoC=3	Is an enabler based on the ability to reduce water runoff, increase permeable surfaces and increase the quality of waterways and wetlands	(E) LoC=3	Increases with the ability of integrated waste management to avoid environmental contamination, including micropollutants, groundwater and marine pollution, and stringency of municipal wastewater treatment systems	(E) LoC=3	Level of improvement depends on the interaction and inclusion of low carbon development options that reduce impacts on water use and increases quality, including water use efficiency, demand management and recycling
Biodiversity	(E) LoC=2	Benefits for biodiversity increase depending on the location, ecosystem and context of intervention as well as connectivity of natural habitats	(E) LoC=2	Level of improvement depends on avoiding waste to landfill and landfill leachate as well as activities for land reclamation for biodiversity preservation	(E) LoC=2	Level of improvement depends on urban metabolism and biophilic urbanism towards urban areas that regenerate natural capital
3. Technological						
Simplicity	(E) LoC=3	Is favourable and increases with the ability to harness local resources and available technologies in multi-actor and cross-scalar processes	(E/B) LoC=3	Depends on the context of implementing the waste hierarchy from prevention onward and the effectiveness of practices for waste separation at source	(E/B) LoC=3	Depends on the ability to initiate and learn from experimentation and the ability to support GHG emission reductions based on both structural, behavioural and lifestyle changes
Technological		Depends on the ability to up-scale		Depends on the waste		Depends on the mitigation

Mitigation options	**Urban green and blue infrastructure**		**Waste prevention, minimization and management**		**Integrating sectors, strategies and innovations**	
Dimensions/ Indicators	Feasibility barriers or enablers (LoC)	Role of context, time and scale of implementation	Feasibility barriers or enablers (LoC)	Role of context, time and scale of implementation	Feasibility barriers or enablers (LoC)	Role of context, time and scale of implementation
scalability	(E/B) LoC=3	interventions, including for urban regeneration and restoration, and the utilization of available urban areas for multifunctional, place and location based ecological solutions	(E/B) LoC=3	management system as well as the stage of urban development, including material use and waste from urban construction	(E/B) LoC=3	options integrated, the stage of urban development and typology of the urban area with certain contexts providing additional opportunities over others
Maturity and technology readiness	(E) LoC=3	Maturity is favourable while further depending on the ability to up-scale interventions and the role of nature-based solutions in urban sustainability, resilience and transformations	(E) LoC=3	Maturity is favourable that further depends on the choices for waste management. There are also opportunities for reducing the embodied energy that is used during material recovery	(E/B) LoC=2	Multiple technologies are available for integration while further depending on context and the level of integration, e.g. energy-driven urban design for optimizing the impact of urban form on energy infrastructure
4. Economic						
Costs in 2030 and long term	(E) LoC=3	The benefit to cost ratio is already favourable based on monetary costs excluding co-benefits while the exact values depend on context and scale	(E) LoC=3	Is favourable with changes according to the choice of technology, strategy and awareness of system users that can represent time-dependent costs and revenue changes	(E) LoC=2	Provides cost benefits that increases with a portfolio approach for cost-effective, cost-neutral and re-investment options with evidence across different urban typologies as well as cost reduction options with urban form
Employment effects and economic growth	(E/B) LoC=2	Depends on the upscaling of interventions to support local employment opportunities and sustainable growth, including employment for urban forestry	(E/B) LoC=2	Depends on labour efficiency, ability to stimulate employment for value added products through circular economy and innovation activities with an estimated 45 million jobs in the waste management sector by 2030	(E) LoC=3	Increases based on the speed that the mitigation option triggers economic decoupling with a positive impact on employment and local competitiveness

Mitigation options	**Urban green and blue infrastructure**		**Waste prevention, minimization and management**		**Integrating sectors, strategies and innovations**	
Dimensions/ Indicators	Feasibility barriers or enablers (LoC)	Role of context, time and scale of implementation	Feasibility barriers or enablers (LoC)	Role of context, time and scale of implementation	Feasibility barriers or enablers (LoC)	Role of context, time and scale of implementation
5. Socio-Cultural						
Public acceptance	(E) LoC=3	Public acceptance is commonly high and represents a positive lock-in with awareness and recreational use also given that potential concerns for green gentrification is addressed	(E) LoC=3	Is favourable and increases with reduced system costs for citizens, greater awareness of primary waste separation and possible positive behavioural spillover across environmental policies	(E/B) LoC=3	Contexts that involve a participatory approach towards urban transformation with a shared understanding of future opportunities and challenges are enablers. Public acceptance increases with citizen engagement and citizen empowerment as well as an awareness of the co-benefits
Effects on health & wellbeing	(E) LoC=3	Urban green/blue infrastructure can provide reductions in the urban heat island effect, provide cleaner airs as well as cardiovascular and mental health benefits that is related to availability and accessibility	(E) LoC=3	Contributes to health and wellbeing through liveable cities, reducing human toxicity, particulate matter, photochemical oxidant and similar with possibilities of increasing the nutrition status of urban diets also considering food systems with less waste, less water, GHG emissions and land impacts	(E) LoC=3	The scope of low carbon urban development measures provides significant potential for co-benefits for public health and wellbeing
Distributional effects	(E/B) LoC=2	Depends on the availability (percentage of total area), accessibility (proportion of the urban population living within an accessible distance) of urban green areas and public versus private ownership. Distributional effects for urban green-blue infrastructure are important and may or may not	(E/B) LoC=2	Depends on the sharing of costs and benefits and the ability to transform informality of waste recycling activities into programs	(E) LoC=3	Level of improvement depends on integrating issues of equity, inclusivity and affordability, safeguarding urban livelihoods, access to basic services, lowering the energy bill, addressing energy poverty, and improving public health

Mitigation options	Urban green and blue infrastructure		Waste prevention, minimization and management		Integrating sectors, strategies and innovations	
Dimensions/ Indicators	Feasibility barriers or enablers (LoC)	Role of context, time and scale of implementation	Feasibility barriers or enablers (LoC)	Role of context, time and scale of implementation	Feasibility barriers or enablers (LoC)	Role of context, time and scale of implementation
		represent inequalities that depends on inclusive policy design and empowerment				
6. Institutional						
Political acceptance	(E) LoC=3	Political acceptance is commonly high with potential additional support from collaborative planning, co-creating solutions and mandate for urban greening in development	(E) LoC=3	Efficient waste manageme t infrastructure is the most widely adopted strategy, including among 210 circular ec nomy strategies in urban areas	(E/B) LoC=2	Depends on the GHG reduction or climate neutrality target that is set as well as support from participatory processes
Institutional capacity & governance, cross-sectoral coordination	(E/B) LoC=3	Depends on transdisciplinary coordination for urban ecological infrastructure that encompasses terrestrial and/or aquatic ecosystems as well as institutional and community capacity for holistic design that is better connected with the ecological constraints of Earth systems	(E/B) LoC=3	Depends on the organizational structure for promoting integrated waste management and capabilities related to program administration	(E/B) LoC=3	Depends on the ability to form partnerships to overcome barriers, including technology development, rule-setting and demonstration, capacity to manage transitions, establishing integrated departments and funding schemes for low carbon urban development, implementing system innovations and aligning system actors, engaging in policy learning among cities and implementing supportive policy mixes
Legal and administrative feasibility	(E) LoC=3	F vourable while further depending on the governance cont nt as well as new targets for r storing degraded ecosystems	(E/B) LoC=3	Depends on local legislation and policies, choices within municipal waste management strategies to reduce investment costs, and compliance with targets for circular economy	(E/B) LoC=3	Depends on the capacity to implement relevant policy instruments in an integrated way and leverage multilevel policies as relevant

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Table SM8.4. Line of Sight for the Feasibility Assessment of Mitigation Options in Urban Systems

Mitigation options	**Urban land use and spatial planning**	**Electrification of the urban energy system**	**District heating and cooling networks**
Dimensions/ Indicators	References / Line of sight	References / Line of sight	References / Line of sight
1. Geophysical			
Physical potential	(Mahtta et al. 2019; Güneralp et al. 2020)	(Hsieh et al. 2017; Wang et al 2018 Aghahosseini et al. 2019; Bogdanov et al. 2019; Child et al. 2019; Hansen et al. 2019; Aghahosseini et al. 2020; Ram et al. 2020)	(Swilling et al. 2018; Möller et al. 2019; Persson et al. 2019; UNEP IRP 2020)
Geophysical resources	(Müller et al. 2013; Bai et al. 2018; Swilling et al. 2018; Magnusson et al. 2019; UNEP IRP 2020)	(Gibon et al. 2017; IEA 2020; Sovacool et al 2020)	(Wang et al. 2016; UNEP IRP 2020)
Land use	(EC JRC 2018; Gao and O'Neill 2020; Güneralp et al. 2020; Daunt et al. 2021)	(Hsieh et al 2017; Tong et al 2017; Fichera et al. 2018)	(Fonseca and Schlueter 2015; Shi et al. 2020)
2. Environmental-Ecological			
Air pollution	(Burgalassi and Luzzati 2015; Zhang et al. 2018a; Zhang et al. 2018b; Pierer and Creutzig 2019)	(Jacobson et al. 2018; Ajanovic and Haas 2019; Bagher et al. 2019; Gai et al. 2020; Jacobson et al. 2020)	(Tuomisto et al. 2015; Dénarié et al. 2018; Zhai et al. 2020; REN21 2021)
Toxic waste, ecotoxicity, eutrophication	(Phillips et al. 2018; Regier et al. 2020; Charters et al. 2021)	(Gibon et al. 20 7; Lohrmann et al. 2021)	(Bartolozzi et al. 2017; Zhai et al. 2020)
Water quantity and quality	(Serrao-Neumann et al. 2017; Rodríguez-Sinobas et al. 2018; Xu et al. 2018; Ahmad et al. 2020; Lei et al. 2021)	(Gibon et al. 2017; Lohrmann et al. 2021)	(Swilling et al. 2018)
Biodiversity	(Huang et al. 2018a; McDonald et al. 2018; Cortinovis and Geneletti 2020; Güneralp et al. 2020; IPBES 2019; McDonald et al. 2020)	(Bataille et al. 2020; Schipper et al. 2020)	(Huang et al. 2018a; McDonald et al. 2018; Cortinovis and Geneletti 2020; Güneralp et al. 2020; IPBES 2019; McDonald et al. 2020)
3. Technological			
Simplicity	(Reba and Seto 2020)	(Kennedy et al. 2017; Kennedy et al. 2018; Drysdale et al. 2019; Thellufsen et al. 2020)	(UNEP 2015; Persson et al. 2019; REN21 2020)
Technological scalability	(Lall et al. 2013; Große et al. 2016; Cheshmehzangi and Butters 2017; Facchini et al. 2017; Lwasa 2017; Stokes and Seto 2019)	(Lund et al. 2015; Calvillo et al. 2016; Salpakari et al. 2016; Seto et al. 2016; Kennedy et al. 2017; Newman 2017; Sangiuliano 2017; Zenginis et al. 2017; Bartłomiejczyk 2018; De Luca et al. 2018;	(Borelli et al. 2015; Webb 2015; Xiong et al. 2015; Felipe Andreu et al. 2016; Zhang et al. 2016; Hui et al. 2017; Loibl et al. 2017; Lund et al. 2017; Pavičević et al. 2017; Bünning et al. 2018; Chaer et al. 2018; Dominković et al.

Mitigation options	Urban land use and spatial planning	Electrification of the urban energy system	District heating and cooling networks
		Kennedy et al. 2018; McPherson et al. 2018; Sharma 2018; Stewart et al. 2018; Yuan et al. 2018; Drysdale et al. 2019; Narayanan et al. 2019; Bellocchi et al. 2020; Calise et al. 2020; Gjorgievski et al. 2020; Meha et al. 2020; Thellufsen et al. 2020; You and Kim 2020; Yuan et al. 2021; Pfeifer et al 2021	2018; Hast et al. 2018; Köfinger et al. 2018; Popovski et al. 2018; Yeo et al. 2018; Bozhikaliev et al. 2019; Dominković and Krajačić 2019; Dorotić et al. 2019a; Möller et al 2019; Persson et al. 2019; Pieper et al. 2019; Sorknæs et al. 2020; Yuan et al. 2021b)
Maturity and technology readiness	(Asarpota and Nadin 2020; Lall et al. 2021)	(Kennedy et al. 2017; Kennedy et al. 2018; Gjorgievski et al. 2020; IEA 2020; Meha et al. 2020; Sethi et al. 2020)	(Baldvinsson and Nakata 2017; Lund et al. 2018a; Lund et al. 2018b; IEA 2020; UNEP IRP 2020; Novosel et al. 2021)
4. Economic			
Costs in 2030 and long term	(Lall et al. 2021)	(Newman 2017; Bloess et al 2018; Jacobson et al. 2018; Bogdanov et al 2021)	(Xiong et al. 2015; Bordin et al. 2016; Petersen 2016; Pavičević et al. 2017; Dorotić et al. 2019b; Möller et al. 2019; Persson et al. 2019; Aunedi et al. 2020; Djørup et al. 2020; (Doračić et al. 2020; Pursiheimo and Rämä 2021)
Employment effects and economic growth	(Lee and Erickson 2017; Salat et al. 2017; Gao and Newman 2018; Han et al. 2018; Li and Liu 2018; Lall et al. 2021)	(Mikkola and Lund 2016; Lee and Erickson 2017; Kennedy et al. 2017; Jacobson et al. 2018; Co lition for Urban Transitions 2020; Jacobson et al. 2020; Ram et al. 2020b; REN21 2020; Ram et al. 2022)	(UNEP 2015; Lee and Erickson 2017)
5. Socio-Cultural			
Public acceptance	(Grandin et al. 2018; Webb et al 2018)	(Newman 2017; Coalition for Urban Transitions 2019; Corsini et al. 2019; Pfeiffer et al. 2021)	(Karlsson et al. 2016; Hvelplund and Djørup 2017; Robinson et al. 2018; Palermo et al. 2020a; Palermo et al. 2020b)
Effects on health & wellbeing	(Li et al. 2016a; Yang et al 2018b; Pierer and Creutzig 2019)	(Gai et al. 2020; Jacobson et al. 2020; Newman 2017; REN21 2020; Steinberger et al. 2020)	(UNEP 2015; Meggers et al. 2016; Zhai et al. 2020)
Distributional effects	(Chava and Newman 2016; Jagarnath and Thambiran 2018; Padeiro et al. 2019; Debrunner and Hartmann 2020)	(Kennedy et al. 2017; Aklin et al. 2018; Brandoni et al. 2018; Hunter et al. 2018a; Teferi and Newman 2018; Lekavičius et al. 2020)	(UNEP 2015; Hvelplund and Djørup 2017; Robinson et al. 2018)
6. Institutional			

Mitigation options	Urban land use and spatial planning	Electrification of the urban energy system	District heating and cooling networks
Political acceptance	(Grandin et al. 2018; Asarpota and Nadin 2020)	(Havas et al. 2015; Li et al. 2016b; Grandin et al. 2018; Coalition for Urban Transitions 2019; Data-Driven EnviroLab & NewClimate Institute 2020; Palermo et al. 2020a; Palermo et al. 2020b; REN21 2020; Takao 2020)	(Grandin et al. 2018; Palermo et al. 2020a; Palermo et al. 2020b)
Institutional capacity & governance, cross-sectoral coordination	(Große et al. 2016; Broto 2017; Endo et al. 2017; Geneletti et al. 2017; Hersperger et al. 2018)	(Fenton and Kanda 2017; Alkhalidi et al. 2018; Bloess et al. 2018; Glazebrook and Newman 2018; Krog 2019; Lammers and Hoppe 2019; Takao 2020)	(Delmastro et al. 2016; Hvelplund and Djørup 2017; Tong et al. 2017; Guo and Hendel 2018; Kim et al. 2018; Chambers et al. 2019)
Legal and administrative feasibility	(Deng et al. 2018; Yılmaz Bakır et al. 2018; Shen et al. 2019; Barzegar et al. 2021)	(Byrne et al. 2017; Kennedy et al. 2017; Suo et al. 2017; Glazebrook and Newman 2018; Xie et al. 2018; Hadfield and Cook 2019; Data-Driven EnviroLab & NewClimate Institute 2020; Lewandowska et al. 2020)	(Hvelplund and Djørup 2017; Möller et al. 2019; Doračić et al. 2020; Moser et al. 2020)

Mitigation options	Urban green and blue infrastructure	Waste prevention, minimization and management	Integrating sectors, strategies and innovations
Dimensions/ Indicators	References / Line of sight	References / Line of sight	References / Line of sight
1. Geophysical			
Physical potential	(Elmqvist et al. 2015; Keeler et al. 2019; Quaranta et al. 2021)	(Swilling et al. 2018; Kaza et al. 2018; Chen et al. 2020; Harris et al. 2020)	(Mahtta et al. 2019; Güneralp et al. 2020)
Geophysical resources	(Collier et al. 2016; Quaranta et al. 2021)	(López-Uceda et al. 2018; Russo 2018; Vaitkus et al. 2018)	(Carpio et al. 2016; Liu et al. 2016; Ramage et al. 2017; Shi et al. 2017a; Stocchero et al. 2017; Bai et al. 2018; Swilling et al. 2018; UNEP IRP 2020; Zhan et al. 2018)
Land use	(Elmqvist et al. 2015; Nastran and Regina 2016; Fan et al. 2017; Raymond et al. 2017; Slach et al. 2019; Quaranta et al. 2021)	(Oliveira et al. 2017; Chiaramonti and Panoutsou 2018; Medick et al. 2018; Peri et al. 2018; Zhang et al. 2018a)	(Gao and O'Neill 2020; Güneralp et al. 2020; Xu et al. 2018)
2. Environmental-Ecological			
Air pollution	(Elmqvist et al. 2015; Jandaghian and Akbari 2018; Kim and Coseo 2018; Santamouris et al.	(Ramaswami et al. 2017; Lima et al. 2018; Zhang et al. 2020; Kanhai et al. 2021)	(Diallo et al. 2016; Nieuwenhuijsen and Khreis 2016; Shakya 2016; Liu et al. 2017;

	2018a; Scholz et al. 2018; Keeler et al. 2019; Song et al. 2019)		Ramaswami et al. 2017; Sun et al. 2018b), Tayarani et al. 2018; Park and Sener 2019)
Toxic waste, ecotoxicity, eutrophication	(Elmqvist et al. 2015; Risch et al. 2018; Keeler et al. 2019; Song et al. 2019)	(Roig et al. 2012; Ibáñez-Forés et al. 2018; Lima et al. 2018; Zhou et al. 2018; Zhang et al. 2020)	(González-García et al. 2021)
Water quantity and quality	(Elmqvist et al. 2015; Raymond et al. 2017; Albert et al. 2019; Keeler et al. 2019)	(Ibáñez-Forés et al. 2018; Kaza et al. 2018; Lima et al. 2018; Pesqueira et al. 2020; Vergara-Araya et al. 2020; Proctor et al. 2021)	(Koop and van Leeuwen 2015; Topi et al. 2016; Drangert and Sharatchandra 2017; Lam et al. 2017; Vanham et al. 2017; Kim and Chen 2018; Lam et al. 2018; James et al. 2018)
Biodiversity	(Elmqvist et al. 2015; Schwarz et al. 2017; McDonald et al. 2018; McPhearson et al. 2018; Nero et al. 2018; Hale et al. 2019; Keeler et al. 2019)	(Weng et al. 2015; Hale et al. 2019; IPBES 2019)	(Thomson and Newman 2018; IPBES 2019)
3. Technological			
Simplicity	(Elmqvist et al. 2015; Sasaki et al. 2018; Keeler et al. 2019)	(Hunter et al. 2018b; Kaza et al. 2018; Sun et al. 2018)	(McLean et al. 2016; Matschoss and Heiskanen 2017; Williams 2017; Zhang and Li 2017; Aziz et al. 2018; Chen et al. 2018a)
Technological scalability	(Chen 2015; Kabisch et al. 2015; Lee et al. 2015; Ruckelshaus et al. 2016; Cleveland et al. 2017; Ferrari et al. 2017; Lwasa 2017; Raymond et al. 2017; Gargiulo et al. 2018; Kanniah and Siong 2018; Albert et al. 2019; De Masi et al. 2019; De la Sota et al. 2019; Dorst et al. 2019; Grafakos et al. 2020)	(Eriksson et al. 2015; Boyer and Ramaswami 2017; Lwasa 2017; Tomić and Schneider 2017; Jiang et al. 2017; Huang et al. 2018b; Islam 2018; Paul et al. 2018; Pérez et al. 2018; Tomić and Schneider 2018; Pérez et al. 2020; Sakcharoen et al. 2021)	(Yamagata and Seya 2013; Dienst et al. 2015; Maier 2016; Beygo and Yüzer 2017; Lwasa 2017; Pacheco-Torres et al. 2017; Roldán-Fontana et al. 2017; Affolderbach and Schulz 2017; Ramaswami et al. 2017; Zhao et al. 2017; Alhamwi et al. 2018; Kang and Cho 2018; Lin et al. 2018; Collaço et al. 2019; Kılkış 2019; Kılkış and Kılkış 2019)
Maturity and technology readiness	(Elmqvist et al. 2015; Collier et al. 2016; Elmqvist et al. 2019; Dorst et al. 2019)	(Kabir et al. 2015; Soares and Martins 2017; Tomić and Schneider 2018; D'Adamo et al. 2021)	(Hu et al. 2015; Shi et al. 2017b; Xue et al. 2017; Dobler et al. 2018; Egusquiza et al. 2018; Pedro et al. 2018; Soilán et al. 2018; Kılkış 2021; Mirzabeigi and Razkenari 2021)
4. Economic			
Costs in 2030 and long term	(Elmqvist et al. 2015)	(Khan et al. 2016; Chifari et al. 2017; Medick et al. 2018; Ranieri et al. 2018; Tomić and Schneider 2020)	(Colenbrander et al. 2015; Gouldson et al. 2015; Colenbrander et al. 2016; Nieuwenhuijsen and Khreis 2016; Saujot and Lefèvre 2016; Sudmant et al. 2016; Yazdanie et al. 2017; Brozynski and Leibowicz 2018; Lall et al. 2021)

Employment effects and economic growth	(Thomson and Newman 2016; Raymond et al. 2017; Kareem et al. 2020)	(Alzate-Arias et al. 2018; Coalition for Urban Transitions 2020; Soukiazis and Proença 2020)	(Kalmykova et al. 2015; Chen et al. 2018b; García-Gusano et al. 2018; Hu et al. 2018; Shen et al. 2018; Lall et al. 2021)
5. Socio-Cultural			
Public acceptance	(Raymond et al. 2017; Ürge-Vorsatz et al. 2018; Song et al. 2019)	(Milutinović et al. 2016; Tomić and Schneider 2017; Díaz-Villavicencio et al. 2017; Ek and Miliute-Plepiene 2018; Romano et al 2019; Tomić and Schneider 2020)	(Blanchet 2015; Bjørkelund et al. 2016; Flacke and De Boer 2017; Gao et al. 2017; Herrmann et al. 2017; Neuvonen and Ache 2017; Sharp and Salter 2017; Gorissen et al. 2018; Fastenrath and Braun 2018; Moglia et al. 2018; Wiktorowicz et al. 2018)
Effects on health & wellbeing	(Huang et al. 2017; van den Bosch and Sang 2017; Privitera and La Rosa 2018; Santamouris et al. 2018b; Andersson et al. 2019; Keeler et al. 2019; Song et al. 2019; Grafakos et al. 2020; Jamei et al. 2020; Quaranta et al. 2021)	(Boyer and Ramaswami 2017; Newman 2017; Coalition for Urban Transitions 2020; Slorach et al. 2020)	(Dodman 2009; Diallo et al. 2016; García-Fuentes and de Torre 2017; Liu et al. 2017; Newman 2017; Laeremans et al. 2018; Li et al. 2018)
Distributional effects	(Lwasa et al. 2015; Huang et al. 2017; Andersson et al. 2019; Khumalo and Sibanda 2019; Keeler et al. 2019)	(Conke 2018; de Berc gol and Gowda 2018; Grové et al. 2018)	(Colenbrander et al. 2016; Friend et al. 2016; Claude et al. 2017; Colenbrander et al. 2017; Ma et al. 2018; Mrówczyńska et al. 2018; Pukšec et al. 2018; Wiktorowicz et al. 2018; Ramaswami 2020)
6. Institutional			
Political acceptance	(Collier et al. 2016; Fan et al. 2017; Linnenluecke et al. 2017; Grandin et al. 2018; Grafakos et al. 2020)	(Yu and Zhang 2016; Affolderbach and Schulz 2017; Dong et al. 2018; Grandin et al. 2018; Hulgaard and Søndergaard 2018; Starostina et al 2018; Matsuda et al. 2018; Petit-Boix and Leipold 2018)	(Larondelle et al. 2016; Fang et al. 2017; Lu et al. 2017; Grandin et al. 2018; Powell et al. 2018; Van Den Dobbelsteen et al. 2018; Salvia et al. 2021)
Institutional capacity & governance, cross-sectoral coordination	(He et al. 2015; Linnenlu cke et al 2017; Raymond et al. 2017; Albert et al. 2019; Childers et al. 2019; Jah nfar et al. 2018; Dorst et al. 2019; Keeler et al. 2019)	(Hjalmarsson 2015; Kalmykova et al. 2016; Conke 2018; Marino et al. 2018; Yang et al. 2018a; Kanhai et al. 2021)	(Dong and Fujita 2015; Kilkiş 2015; Lee and Painter 2015; Niemeier et al. 2015; Olsson et al. 2015; Delmastro et al. 2016; Große et al. 2016; McGuirk et al. 2016; Broto 2017; Engström et al. 2017; Petit-Boix et al. 2017; Valek et al. 2017; Peng and Bai 2018; den Hartog et al. 2018; Engels and Walz 2018; Leck and Simon 2018; Tayarani et al. 2018; Tillie et al. 2018; Westman and Broto 2018; Hölscher et al. 2019; Peng and Bai 2020)

Legal and administrative feasibility	(Elmqvist et al. 2015; CDP 2021)	(Potdar et al. 2016; Agyepong and Nhamo 2017; Tomić et al. 2017; Conke 2018; Tomić and Schneider 2020; Kanhai et al. 2021)	(Agyepong and Nhamo 2017; Roppongi et al. 2017)

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