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Innovation policies for sustainable development: Low-carbon energy and smart-city initiatives

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ABSTRACT

This monograph benchmarks innovation policies for sustainability, focusing on two key areas: low-carbon and environmental technologies, and "smart-city" initiatives in selected OECD countries as well as the European Union. Country coverage of low-carbon technologies includes both natural resource-based energy-rich countries (e.g. Canada and the United States) and energy-challenged countries (e.g. Germany and Japan). Country or regional coverage of smart cities programmes focuses on Australia, Austria, Finland and Sweden, as well as two international programmes operated by the European Commission and the Nordic Council. The monograph assess the policies' sectoral priorities. It reviews their portfolio of instruments, budgets, and monitoring and evaluation strategies, international co-operation strategies and identifies critical success factors.

Acknowledgements: This work is part of a policy benchmark analysis which has been financed and commissioned upon request of the French Surveillance committee of investments for the future (Comité de surveillance des investissements d'avenir), in the context of the evaluation of the first phase of the Programme d'investissements d'avenir (PIA). The benchmark study is presented as a series of six monographs. Each monograph provides examples of research, development, and innovation policies, organised by topic of relevance to the PIA. This document presents the second monograph, focused on the theme of sustainable development. It provides the main messages from the cross-country benchmark analysis of 13 case studies of public policy initiatives.

The detailed case studies can be found at https://community.oecd.org/community/cstp.

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Executive summary

Traditionally, innovation policies have focused on enhancing the rate of innovation – increasing research and development (R&D) intensity as well as the number of high-tech companies – to promote competitiveness and structural change in the economy. However, the transition from a fossil fuel-based energy system to a system based on renewable and low-carbon energy sources requires focusing not only on the rate, but also on the direction, of innovation.

Among the challenges facing policy makers in the low-carbon transition is the need to develop a vision of future energy systems, including which technologies (and combinations of technologies) are likely to play important roles in the future system; which energy infrastructures will be needed; and which business models (e.g. shared urban mobility), regulations and patterns of consumer behaviour will need to change (e.g. to promote energy efficiency). The case studies presented here use both top-down and bottom-up approaches, as well as supply- and demand-side approaches, to create and implement these visions.

A critical dimension emerging from all these case studies is that co-ordination across government ministries and different levels of government is essential. Ensuring stakeholder participation at the bottom means that top-down strategies and international commitments, such as the as the SDGs and the Paris Agreement, must be legitimate and recognisable to those participating in developing solutions.

Another insight is that while relevant technological solutions already exist, institutional rules, political choices, technology lock-in and socio-cultural attitudes can prevent or slowdown the diffusion and adoption of low carbon solutions. Therefore, it is important that research and innovation policies be conceived, designed and implemented in co-ordination with industrial, urban planning, energy policies to overcome the barriers to adoption and diffusion that are deeply rooted in the socio-economic and technological structures governing production and consumption. Because the transitions towards sustainability require time, it important for policy to balance the long-term perspective with short-term actions.

The programmes and initiatives in this monograph will not solve the challenge of transition by themselves. Nevertheless, they do offer insights into how public policies can be better integrated to shift production and consumption modes towards increased sustainability.

The key messages in this monograph can be summarised as follows:

- A systems approach to innovation for low-carbon energy is necessary, especially given the capital intensity and complexity of national energy systems. In other words, efforts to commercialise low-carbon energy technologies must go hand in hand with efforts to change consumer and firm behaviour on the demand side.
- The low-carbon energy challenge requires significant public investments – which, in turn, require both broad-based and high-level political support at the national and subnational levels.
- Tax policies play an important role in reducing greenhouse gas emissions. Together with public procurement, they can play a significant role in incentivising the uptake of early stage technologies that are already on the market. However, support should be time-limited to reduce market distortions as technologies diffuse.
- As regards, R&D grants and demonstration support, strong vetting and selection mechanisms are necessary to ensure grants support breakthrough research and avoid

crowding out firms' investments. Grants to consortia and public-private partnerships appear to be strong mechanisms to reduce such risks.

- Digital technologies are crosscutting technologies that support both energy efficiency and environmental sustainability, especially at the subnational level (i.e. smart cities).
- While the broad mission of innovation policy for sustainable development is to further the transition to low-carbon energy, it is important to promote a broad portfolio of pre-commercial technologies that are too early for investment by the private sector. The participation of small and medium-sized enterprises (SMEs) is critical in many of the programmes surveyed.
- Engaging local agents is critical to implementing smart-city innovations, involving stakeholders and instituting effective multi-level governance arrangements.

1. Introduction

Since the signing of the Paris Agreement and the adoption by the United Nations of the Sustainable Development Goals (SDGs) in 2015, efforts have accelerated to mobilise innovation to address pressing issues. These include producing cleaner energy, reducing environmental pollution, and promoting climate change adaptation and mitigation. Even before the SDGs emerged as a global agenda for sustainable development, many countries were mobilising science, technology and innovation to address social and environmental challenges at the national and subnational levels. They rely on a variety of policy instruments, private-public partnerships, regulatory reforms, and enhanced governance arrangements through greater stakeholder involvement in setting priorities and co-designing innovative solutions.

This document contains a draft synthesis of a benchmarking report on innovation policies for sustainability, focusing on two key areas: low-carbon and environmental technologies, and "smart-city" initiatives. Country coverage of low-carbon technologies includes both natural resource-based energy-rich countries (e.g. Canada and the United States) and energy-challenged countries (e.g. Germany and Japan). Country or regional coverage of smart cities programmes focuses on Australia, Austria, Finland and Sweden, as well as two international programmes operated by the European Commission and the Nordic Council. The detailed case studies are available online (OECD, 2019[1]).

Innovation policies targeting sustainability differ significantly from innovation policies aiming to increase the economic performance of existing systems with unchanged – and even growing – resource demands. Traditionally, innovation policies have focused on enhancing the rate of innovation – increasing research and development (R&D) targets, as well as the number of high-tech companies – to promote competitiveness and structural change in the economy. However, the transition from a fossil fuel-based energy system to a system based on renewable and low-carbon energy sources requires focusing not only on the rate, but also on the direction, of innovation.

Nonetheless, the direction of innovation is not always linear, because sustainability challenges are systemic problems. Energy security, for example, is also tied to environmental regulations on waterways, and waste generation and disposal. Hence, innovation policies for sustainability require considering the synergies or trade-offs in different policy domains. Another dimension of innovation policy for sustainability is the need to consider institutional and technology lock-in that prevents new, more sustainable technologies from entering the market. Therefore, policies that address issues of technology demonstration and commercialisation play a more important role than policies focused solely on R&D. Furthermore, sustainability can only be achieved through the co-design and uptake of innovative solutions at the national, subnational and local levels.

Among the challenges facing policy makers in the low-carbon transition is the need to develop a vision of future energy systems, including which technologies (and combinations of technologies) are likely to play important roles in the future system; which energy infrastructures will be needed; and how business models (e.g. shared urban mobility), regulations and patterns of consumer behaviour will need to change (e.g. to promote energy efficiency). The case studies presented here use both top-down and bottom-up approaches, as well as supply- and demand-side approaches, to create and implement these visions.

Germany's decision to abandon nuclear energy, for example, is one of the top-down policy drivers to increase energy efficiency and the share of renewables in the energy mix through the Energiewende, a comprehensive national strategy that includes actions at the regional (*Länder*)

and local levels. Although Canada and the United States are energy-rich countries, the states and provinces in these countries have increased the share of renewable energy in their energy portfolio, with the support of the central (federal) governments.

A critical dimension emerging from all these case studies is that co-ordination across government ministries and different levels of government is essential. Ensuring stakeholder participation at the bottom means that top-down strategies and international commitments, such as the as the SDGs and the Paris Agreement, must be legitimate and recognisable to those participating in developing solutions.

Another insight is that while relevant technological solutions already exist, institutional rules, political choices and socio-cultural attitudes prevent their implementation. This is one reason, for example, why smart-city initiatives attempt to break down these barriers, through co-funding arrangements and "mission- oriented" approaches that gather wide stakeholder involvement.

Because of the persistent, deeply rooted socio-economic and technological structures governing production and consumption, the programmes and initiatives will not solve the challenge of transition by themselves. They do, however, offer insights into how public policies can be better integrated to shift production and consumption modes towards increased sustainability.

One challenge is that transitions require time, and the idea of a long-term perspective on change conflicts with the inevitably short life of concrete projects. Hence, any project on sustainable innovation has to seek to somehow reconcile planning a short-term project with the (by definition) long-term objective of sustainable development. Ideally, a project should not only result in concrete technologies, business models or organisational changes, but should also help create the conditions under which sustainability as a common goal can be developed and practised on a wider scale, after the project or programme has come to an end.

The key takeaways from the 13 case studies in this monograph are as follows:

- A systems approach to innovation for low-carbon energy is necessary, especially given the capital intensity and complexity of national energy systems. In other words, efforts to commercialise low-carbon energy technologies must go hand in hand with efforts to change consumer and firm behaviour on the demand side.
- The low-carbon energy challenge requires significant public investments – which, in turn, require both broad-based and high-level political support at the national and subnational levels. However, strong vetting and selection mechanisms are necessary to ensure grants support breakthrough research and avoid crowding out firms' investments. Grants to consortia and public-private partnerships appear to be strong mechanisms to reduce such risks.
- Digital technologies are cross-cutting technologies that support both energy efficiency and environmental sustainability, especially at the subnational level (i.e. smart cities).
- While the broad mission of innovation policy for sustainable development is to further the transition to low-carbon energy, it is important to promote a broad portfolio of pre-commercial technologies that at an early stage of development and which makes funding by industry too risky. The participation of small and medium-sized enterprises (SMEs) is critical in many of the programmes surveyed.
- Engaging local agents is critical to implementing smart-city innovations, involving stakeholders and instituting effective multi-level governance arrangements.

2. Synthesis of case studies on low-carbon energy and environmental technologies

Against a background of rising global energy demand, accelerating the energy transition by increasing the production and use of renewable energy, as well as improving energy efficiency, have become policy priorities in many OECD countries.

The Sustainable Development Scenario proposed by the International Energy Agency (IEA, 2018[2])begins with the SDGs most closely related to energy: SDG 7 (achieving universal energy access), SDG 3.9 (reducing the impacts of air pollution) and SDG 13 (tackling climate change). Meanwhile, decentralised renewables mean that a least-cost approach to electricity access does not significantly increase carbon dioxide (CO_2) emissions. Energy efficiency is an essential component of the Sustainable Development Scenario that contributes to all three SDGs, as well as energy security.

This monograph examines five national-level policies supporting research and innovation for sustainable development in the area of energy and environmental technologies, comparing them to similar initiatives in the French *Programme d'investissements d'avenir* (Investments for the Future Programme [PIA]). These are the Energiewende in Germany, the Sustainable Development Technology Fund (SD Tech Fund) in Canada, Energi21 in Norway, the Advanced Research Projects Agency-Energy (ARPA-E) in the United States, and the New Energy and Industrial Technology Development Organisation (NEDO) in Japan (See Table 1).

One element characterising national initiatives to increase R&D investment in low-carbon energy and environmental technologies is the desire to decouple economic growth from environmental degradation and resource (notably energy) depletion. As such, the cases in this monograph generally aim to achieve three goals: reduce environmental pollution and greenhouse gas (GHG) emissions from fossil-based energies, strengthen energy efficiency and advantage in sustainability technologies, and safeguard both energy security and industrial and commercial competitiveness. This section describes the policies' sectoral priorities. It reviews their portfolio of instruments, budgets, and monitoring and evaluation strategies, as well as international co-operation aspects and critical dimensions.

Table 1. Overview of policy examples

Policy initiative	Country	Type	Period	Annual budget	Main objective
Energiewende	Germany	National initiative Demand side	2010-present	EUR 5.8 billion (2016)	Phase out Germany's nuclear power plants by the end of 2022; transform the energy system to become strongly reliant on renewable-energy resources; enhance energy efficiency; and reduce GHG emissions by 80-95% by 2050.
SD Tech Fund	Canada	National grant schemes Demand side	2001-present	EUR 37.1 million (average 2001-17)	Support the development and demonstration of Canadian cleantech projects, to facilitate scaling for commercialisation.
Energi21	Norway	National grant schemes	2008-present	EUR 40 million	Restructure the energy system by developing new technologies to reduce energy consumption and GHG emissions,

		Demand side		(average 2008-17)	and through efficient production of more environmentally friendly energy; increase value creation based on national energy resources and utilisation of energy; and develop internationally competitive expertise and industrial activities in the energy sector.
ARPA-E	United States	National R&D management agency Supply side	2009-present	EUR 226 million (average 2009-17)	Support innovations in energy technology that will enhance US economic and energy security; reduce energy-related emissions; improve energy efficiency across all sectors of the economy; and ensure the United States maintains a technological lead in the development and deployment of advanced energy technologies.
NEDO	Japan	National R&D management agency Demand side	1980-present	EUR 1.3 billion (2018)	Address energy and global environmental problems; raise the level of industrial technology through integrated management of technological development, from the discovery of technology seeds to the promotion of mid- to long-term projects; support practical application.

Source: OECD.

2.1. Sectoral priorities

Most initiatives focus on energy, and as energy is the key player in the climate game, the common policy goal of these cases is to contribute to achieving the targets of national energy and climate policy (mainly for climate mitigation). These targets are especially for environmentally friendly energy system, also included improve industrial and commercial competitiveness (e.g. Energi21 and NEDO); enhance the country's leading position in the field of sustainable energy and environmental technologies (e.g. ARPA-E and the Energiewende), by bringing climate-friendly technologies (i.e. low-carbon, clean air, clean water, carbon capture and storage [CCS]) projects to the demonstration stage (e.g. the SD Tech Fund, Energi21 and NEDO). The Energiewende and Energi21 are both national long-term energy transform strategy with more societal ambitions, such as restructuring energy system, significantly reduce GHG emissions, and energy supply security. Other cases focus more on technological development to advance energy, environmental and climate goals achievement and improve national competitiveness in the energy and environmental sector.

The energy-related case studies focus on renewable energy (e.g. wind, solar, hydrogen) and energy efficiency (e.g. building, neighbourhood and industrial) in the central areas of electricity, heat and transport. They particularly focus on applying digital tools to urban-resource efficiency (e.g. energy systems, transport, water provision, waste), and devising systemic solutions to integrate new digital and energy technologies (e.g. the Smart Energy Showcases – Digital Agenda for the Energy Transition [SINTEG] in the Energiewende, and the digitalised and integrated energy systems in Energi21). It should be noted that the Energiewende does not prioritise one kind of renewable technology over another. Rather, it provides a general direction, without specifying objectives for different renewable-energy technologies.

2.2. Portfolio of policy instruments

Similarly to the funding approach of the PIA, the policies mostly use direct financial support as an instrument, in the form of competitive R&D grants. The Energiewende is a national long-term strategy promoting the development of a low-carbon energy system. In addition to using competitive R&D programmes (e.g. the 6th Energy Research Programme) to support clean-energy objectives, it also employs various laws and acts (e.g. the Renewable Energy Act, the Energiekonzept strategy, the National Action Plan on Energy Efficiency, the Electricity Market Act), as well as low-interest financing (e.g. KfW Bank). In this way, the Energiewende takes a more systems-based approach, supporting not only the technological transition to low carbon, but also the organisational, financial, institutional and consumer changes required for such technologies to reach critical scale, and thus change the energy landscape in Germany.

Most of the initiatives in the case studies focus on pre-commercial technologies and strong vetting mechanisms, favouring riskier projects in low-carbon and environmental technologies. For example, The SD Tech Fund in Canada only supports projects with a technology readiness level (TRL) of ranging between 3 and 7, seeking to demonstrate pre-commercial technology with significant and quantifiable environmental benefits. Similarly, ARPA-E focuses exclusively on high-potential, high-impact energy technologies that are too early for the private sector investment or other applied R&D supported by the United States Department of Energy (DOE).

Some initiatives also target SMEs, such as the Canadian SD Tech Fund, the New Industry Creation and Discovery of Technology Seeds of NEDO, and the OPEN programmes of ARPA-E, emphasise commercialisation support for SMEs and venture businesses, and open innovation.

2.3. Budget of the initiatives

The average annual budget for these initiatives is relatively high, ranging from tens of millions (e.g. EUR 37.1 million for the SD Tech Fund, EUR 40 million for Energi21 and EUR 226 million for ARPA-E) to more than EUR 1 billion (e.g. about EUR 5.8 billion for Energiewende and about EUR 1.3 billion for NEDO). However, the bulk of the Energiewende budget (nearly EUR 4 billion) in 2016 went to phasing out subsidies for hard coal/rehabilitating mines (about EUR 1.5 billion) and energy-efficient retrofitting of buildings (about EUR 2.5 billion).

The amount and duration of funding for R&D projects depend on the different targets and stages, and also vary significantly across projects within the same initiatives. Based on the available data, the average R&D investment per project is roughly EUR 1.35 million (e.g. EUR 0.63 million for Energiewende, EUR 0.6 million for Energi21, EUR 1.74 million for the SD Tech Fund and EUR 2.42 million for ARPA-E), with the exception of NEDO (about EUR 15 million per project). This is slightly lower than the PIA (about EUR 3.35 million per project). According to the *2010-2017 Report: Programme d'investissements d'avenir (PIA)* (French Environment & Energy Management Agency (ADEME), 2018[3]), about EUR 2.5 billion were distributed among a total of 745 projects between 2010 and 2017.

2.4. Monitoring and evaluation strategies

These initiatives usually designate from the onset the departments responsible for monitoring and evaluation, as well as the evaluation period and methods (laws or acts). The responsible departments are independent superior authorities of initiatives or agencies, which adopt external evaluation methods.

For example, the German Federal Ministry for Economic Affairs and Energy (BMWi) is appointed as the lead actor for monitoring the Energiewende. The monitoring report for each year must be approved by the federal cabinet by 15 December, and submitted to the Bundestag and the Bundesrat; an independent commission of four renowned energy experts also provides a scientific opinion on the monitoring report. Every three years, the federal government publishes a progress report on the energy transition. In Japan, the Ministry of Economy, Trade and Industry Commission on Evaluation of Independent Administrative Institutions performs annual evaluations of NEDO, based on NEDO annual self-reporting, in keeping with the Act on General Rules for Incorporated Administrative Agency. Innovation, Science and Economic Development Canada (ISED) oversees the administration of the SD Tech Fund; the Audit and Evaluation Branch (AEB) at ISED is specifically responsible for conducting evaluations. When the United States Congress authorised ARPA-E in the 2007 America Competes Act, it requested an early assessment following six years of operation. In response, the National Academy of Sciences convened an ad hoc study committee to undertake the assessment beginning in 2015. By contrast, the Energi21 board must conduct an internal evaluation of its activities on an annual basis. It has also established a multidisciplinary expert group, comprising resource persons from the energy industry, as well as research and educational institutions. The expert group is primarily charged with providing fact-based scientific assessments and a basis for the board's decision-making on strategic priorities and future national focus areas for research, design and development activities.

Evaluations of initiatives adopt a fact-based approach, based on quantitative and qualitative methods. For example, multiple sources of evidence were used to evaluate the SD Tech Fund, including a literature review; a document review; a financial, administrative and performance data review; a statistical analysis of administrative data; interviews; case studies; and a survey of SD Tech Fund recipients. Similarly, the evaluation of ARPA-E is based on quantitative and qualitative data, including agency data; publicly available data; presentations by personnel from ARPA-E, the DOE and the Defense Advanced Research Projects Agency (DARPA); case studies of completed awards; consultations with current and former ARPA-E personnel; and consultations with individuals from other programmes and offices at the DOE. Four teams were formed to perform different assessment tasks during the evaluation of ARPA-E. The internal operations qualitative data team collected and analysed qualitative data, including information gathered during interviews with current and former ARPA-E personnel and DOE officials, and discussions with stakeholders at agency events, such as programme kick-offs and interim meetings. The case study team conducted three types of case studies (a focused programme, a portfolio of energy storage projects and individual projects). The internal operations quantitative data team accessed internal proprietary ARPA-E data and reported aggregated findings. Finally, the external quantitative data team obtained data from external sources, such as the patent database and publications of the United States Patent and Trademark Office.

To assess project impacts, Japan's NEDO defines those products and processes that use the results of NEDO projects as their core technologies as "NEDO Inside Products." As of fiscal year (FY) 2016, a total of 115 products had been selected. Sales (actual and forecasted), CO_2 emission reductions and primary energy savings for these products are calculated to ascertain their mid- to long-term effectiveness. In the case of Canada's SD Tech Fund, the impact is assessed by estimating the annual costs avoided with regard to air quality, as well as clean water and clean soil benefits, along with annual GHG emission reductions attributable to the supported cleantech projects.

2.5. International co-operation aspects

Climate-friendly technologies are an important aspect of government response to climate change and sustainable development, and therefore play a key role in the transition to a low-carbon economy. The German Energiewende, as the main measure or platform for the government to fulfil its national commitments, directly pursues the delivery of the global energy transition as reflected in the Paris Convention on Climate Change, and SDG 7 on clean energy and SDG 13 on climate action. Ever since its establishment in 1980, the mission of NEDO in Japan has been to achieve sustainable development that is compatible with both the environment and the economy while overcoming environmental, resource and energy constraints. Since the "Kyoto Protocol", NEDO has always prioritised reducing GHG emissions and supported various technological developments to help achieve these goals.

Climate-friendly energy initiatives also directly support or participate in multiple international funding opportunities. In Germany, the Energiewende's international research activities feature among the strategic development lines of the Energy Research Plan of the BMWi, which funds synergies between national and European funding within Horizon 2020 and the European Technology and Innovation Platforms (ETIP), and participates in European Research Area (ERA)-Net Cofunds, such as the Solar-ERA.Net, Geothermal ERA or Accelerating CCS Technologies (ACT). In Norway, Energi21 considers international research collaboration as crucial to the success of technological development targeting future energy systems. The strategy actively encourages Norwegian research institutes and companies to participate fully in EU Horizon 2020. It ranks energy as a priority thematic area focusing on energy efficiency, low-carbon energy, and smart cities and communities, among others. Energi21 also participates in the steering group for the EU Strategic Energy Technology Plan (the SET Plan). In Japan, NEDO aims to introduce advanced domestic technologies to countries with diverse needs and infrastructures. It plans to play a leading role by carrying out international demonstration projects, as well as introducing both standalone technologies and systems integrating various technologies. By April 2018, NEDO had launched 35 projects in 21 countries around the world, as follows: 25 international demonstration projects on Japanese energy-efficiency technologies; 5 projects to facilitate private sector-led promotion of low-carbon technology overseas; 4 international R&D co-funding projects; and 1 project for international promotion and dissemination . In addition, NEDO has established six overseas offices: two in the United States and one each in France, India, Thailand and China.

2.6. Tax incentives to support lower emissions and promote low carbon energy

Germany: Germany was one of the first IEA member countries to successfully implement ecological tax reforms. Reform commenced in April 1999, with the enactment of the Act on the Introduction of the Ecological Tax Reform of 24 March 1999 (Ecological Tax Reform Act), which gradually increased the excise duties applied to fossil fuels and implemented a tax on electricity consumption. The objectives of the tax were twofold: to mitigate carbon dioxide (CO_2) missions and to boost job creation and boost innovation. A defining feature of the tax was the use of a large portion, up to 90%, of the revenue derived from the tax to offset payroll contributions from employers and employees with much of the remainder going towards the funding of renewable energy schemes. An additional feature of the tax was the provision of special exemptions for trade-exposed energy-intensive manufacturers.

Canada: Canada Federal and provincial tax measures and programmes have helped launch the renewable energy industry since early 2002. Provinces have put in place competitive procurement requests for proposals, standard offer contracts, feed-in tariffs, renewable portfolio standards, small equipment rebates, tax credits, etc. The drivers behind the growth of renewables

vary and depend on the province's situation and objectives for GHG emissions reductions, climate change, local economic development, and energy diversification.

Norway: Norway's CO2 tax was first introduced in 1991 in the offshore oil and gas sector, as well as in the transport and heating sectors. Mainland energy - intensive industries were, however, exempt from the tax because of the perceived threat of carbon leakage. The tax rate varies by fuel type and sector. The CO2 tax has encouraged the offshore oil and gas industry to reduce flaring and adopt carbon capture and storage (CCS) at the Sleipner and Snøhvit fields. Further measures include the electrification of some processes and an increased energy efficiency. CO2 taxes on transport and heating fuels have also helped to reduce emissions. In the transport sector, CO2 emissions have been further reduced by introducing CO2 - based vehicle taxation to promote electric and other low-emission vehicles, and biofuels blending obligations.

United States:Federal Renewable Energy Production Tax Credit (PTC): The PTC is an inflation-adjusted, per kilowatt hour, tax credit for electricity produced from qualifying renewable energy sources or technologies. The PTC was initiated with the Energy Policy Act of 1992, and subsequently renewed and amended several times, most recently in the American Recovery and Reinvestment Act (ARRA) of 2009 and the American Taxpayer Relief Act of 2012. Eligible projects can take an inflation-adjusted tax credit for electricity generated over ten years, with some exceptions. The tax credit amount is USD 1.015 kWh in 1993 dollars (indexed for inflation) for some technologies and half of that amount for others. The rules governing the PTC vary by resource and facility type.

Japan

The Tax for Climate Change Mitigation was introduced in October 2012 and gradually increased in April 2014 and April 2016 to reach a rate of JPY 289 per tonne of CO2. The tax is levied on crude oil and oil products, natural gas and coal. The tax revenue, estimated at JPY 260 billion per year at the current rate, is used to support the reduction of emissions from energy use, e.g. renewable energy and energy efficiency projects.

2.7. Critical dimensions

Connecting with the broader civil society to garner widespread public support for addressing sustainability challenges. As the case of the Energiewende shows, the support and participation of German citizens is crucial. The political and popular consensus for phasing out nuclear power at the initial stages turned citizens into initiators. Later, German citizens became co-owners of the distributed energy generation system, thanks to households or energy co-operatives investing in renewable-energy generation. This was largely incentivised by the feed-in tariffs and facilitated by low-cost loans offered by the German development bank(KfW). However, owing to the Renewable Energy Act (EEG) surcharge, average household electricity costs have increased and have been the second-highest in Europe for the last decades, which could in the long term test support from German citizens and industry. The Energiewende initiative also established five dedicated platforms for continuous dialogue with representatives from business and industry, society, science and research over the five energy-transition platforms (energy grids, electricity market, energy efficiency, buildings, and research and innovation). These platforms are the central tools for dialogue and stakeholder consultation.

Close co-operation between academia, industry and capital markets to achieve success and further development. The technology-to-market programme of ARPA-E in the United States has proved key to its success. It helps each funder develop networks with relevant government agencies, technology transfer offices, companies and investors, thereby enhancing collaboration with research, industry, government and the financial sector. Norway's Energi21 puts more

efforts into creating an integrated, harmonised incentive structure along the entire innovation chain, and increasing the business sector's involvement in research and innovation. Co-operation between the business sector, the research and education environments, and the authorities is crucial to achieving Energi21's ambitions and conducting the necessary research activity. The business sector contributes knowledge and technology development by taking greater risks, and investing time and capital in research and innovation activities.

The consortium model of the SD Tech Fund in Canada plays an important role in facilitating collaborative partnerships between funding recipients, their suppliers and their customers. SD Tech Fund recipients form collaborative partnerships along the innovation chain. According to administrative data, approximately three-quarters of all projects that have received SD Tech funding have made progress towards demonstration or have successfully demonstrated. Each project has an average of 4.13 consortium partners; for every dollar of SD Tech Fund support, the total leveraged amount from all partners and collaborators equalled CAD 2.80 (Canadian dollars). The key factors of successful demonstration include the availability of financing and the formation of partnerships.

Co-operation within national government, or between national and state levels of government. The SD Tech Fund works collaboratively with federal and other government departments (e.g. Export Development Canada, Business Development Bank of Canada, Global Affairs Canada, Natural Resources Canada and the Standards Council of Canada) as part of a larger innovation-funding ecosystem (including private interests) that supports demonstration and commercialisation. Norway's Energi21 is led by a board appointed by the Ministry of Petroleum and Energy. To ensure effective implementation, it promotes greater sectoral co-operation at the administrative level of government, including the Ministry of Transport and Communications, the Ministry of Climate and Environment, the Ministry of Local Government and Modernisation, and the Ministry of Agriculture and Food.

Germany's Energiewende is a joint initiative of the Federal Republic of Germany and the 16 German regions (*Länder*). It is co-ordinated by the Ministry for Economic Affairs and Energy, and strongly embedded at the regional level. Every six months, the federal chancellor and the minister of federal economic affairs meet with the presidents of the *Länder* to discuss the status of the energy reforms. The ministers of the federal government and their counterparts in the *Länder* also convene at the biannual Economic Affairs Ministers Conference to discuss their priorities and the next steps in the energy transition. However, multi-level governance (federal government and *Länder*) is not without its challenges and must be managed carefully to avoid inefficiencies in decision-making processes. The federal government also pursues the so-called "Berlin model", which funds bilateral and multilateral research jointly with the *Länder* concerned.

Implement initiatives relying on professional organisations with technical expertise and years of project management experience. Modelled on the success of DARPA, ARPA-E in the United States is in charge of project selection, funding and evaluations, with a core team comprising programme directors and technology-to-market advisors with nearly ten years of project management experience. Thanks to its nearly 30 years of project management, the Japanese NEDO has formed a mature integrated management model for technological development in fields with a promising future, focusing on mid- to long-term initiatives coordinated with standardisation, cross-industrial co-operation, full-scale demonstration and international co-operation activities. In Norway, Energi21 mainly implements projects with professional agencies, e.g. Enova and Transnova for market introduction and investment support, Gassnova for pilot and demonstration projects, Innovation Norway for risk loans and development support, and Research Council of Norway for research projects. This is similar to the approach adopted by Sustainable Development Technology Canada (SDTC), in charge of SD Tech Fund, and

Project Management Jülich in Germany, in charge of the 6th Energy Research Programme of the Federal Government.

Emphasis on investment in pre-commercial high-risk technologies to lead industry and market development. In the United States, ARPA-E focuses exclusively on high-potential, high-impact energy technologies that are too early for the private sector investment or other DOE applied R&D supported, and translate science into breakthrough technologies with a promise of genuine transformation. ARPA-E programme directors have wide authority to select projects that develop new focused technology, which enables ARPA-E to fund relatively risky projects. In Japan, NEDO promotes innovative and high-risk technologies that contribute to market creation and solving social issues. In Canada, the SD Tech Fund aims to fund local SMEs as they develop pre-commercial projects with the potential to demonstrate significant and quantifiable environmental and economic benefits. According to SDTC administrative data, nearly 74% of the 164 completed SD Tech Fund projects eventually demonstrated (i.e. met or exceeded) their TRL goal levels of 7 or higher by the end of the project; about one-third of SD Tech Fund recipients subsequently reached the market (i.e. commercialised) with larger projects. Those receiving other government support had a higher probability of success.

Creating awareness of success to achieve statutory mission and goals. ARPA-E remains closely engaged with awardees from the project's inception to its conclusion, to ensure the project supports ARPA-E's mission and goals. The technology-to-market programme requires innovators to consider their path towards commercialisation in the early stages, as they begin to develop their technology in the lab. Programme directors subsequently engage in "active project management," including reviews of quarterly performance reports, regular site visits, meetings, conference calls, and written feedback on results and reported quarterly progress. These regular contacts can also include general reviews of progress relative to milestones, specific responses to a new challenge, and identification of anticipated problems and potential solutions.

When ARPA-E finds that a project is not meeting its milestones, it acts to redress the situation. The first line of defence is frequent contact between the ARPA-E programme director, the project staff and the performer team, which helps ensure that neither party is surprised to learn of difficulties in meeting milestones. In more challenging cases, telephone calls or meetings may take place weekly The actions taken include complete termination of the project, limited extensions of time to allow projects to meet a given milestone, and revision of milestones and objectives. ARPA-E indicated that as of May 2015, it had terminated 21 projects prior to their co-operative agreement's end date because of failure to achieve stipulated milestones. According to SDTC administrative data for 2017, technical and other issues (e.g. Identifying customers (beyond immediate consortium partners) to take on cleantech solutions, variations in procurement practices and regulations across Canada, and producing cleantech at a price point that meets the needs of the end-users were far more prevalent among terminated projects (54.2%) than completed projects (26.7%), although the investment needed to ramp-up for commercial production remains the key issue.

Provide flexible financial support to fill gaps between technology and market. In Canada, support by the SD Tech Fund has proved very useful in addressing the financial challenges associated with the development and demonstration of pre-commercial cleantech projects, directly addressing the ongoing pre-commercial funding gap. In Germany, the state-owned development bank KfW provides low-interest financing programmes for commercial demonstration projects to accelerate the transition to renewable energy and energy efficiency in the context of the Energiewende. In Japan, NEDO builds a venture ecosystem by providing seamless support for the discovery of technology seeds, acquiring private funding for high-risk/high-return investments and supporting commercialisation. In Norway, Energi21 provides seed capital as an essential way of closing the gap between R&D and instruments for market

introduction with the goal of promoting new companies and market creation. Although such investment may be found in the private market, is often inadequate or inaccessible.

Focus on strategy formulation to optimise and adjust development goals continuously. Loyalty towards long-term goals, combined with effective actions with near-time horizons, is good practice. With initiatives focusing on the long-term goal of national development, strategic adjustments must be made at different stages to guide strategic direction, priorities and management methods. In 2013, the US ARPA-E launched a new "Strategy Vision" setting transportation fuels, energy materials and processes, energy storage, and sensors information and integration as its future investment areas in energy technology. In 2015, the Canadian SDTC launched its "Nurture, Build, Launch and Grow" business strategy to deliver a dynamic and client-centric management model. According to its Fourth Five-Year Plan in 2018, Japan's NEDO will focus on three pillars: achieving results for practical use by managing technology development, promoting technology-based start-ups, and providing a new direction for mid- and long-term technology development. Since 2008, Norway has revised its Energi21 strategy every two to three years. In 2018, Germany's Energi21 launched an updated national strategy for research, development and commercialisation of new, climate-friendly energy technology.

3. Synthesis of the smart-city case studies

3.1. Introduction: Sustainable innovation in regions and cities

In recent years, "smart-city" programmes have gained traction and are increasingly deployed as part of cities' strategies to achieve the SDGs. Smart-city programmes primarily aim to improve the liveability and resource efficiency of urban spaces. More than 50% of the world population lives in cities, a proportion that is projected to rise to 85% over the next century (OECD, 2019[4]). Growing urbanisation will challenge cities' capacity to provide basic services (e.g. housing, health and transportation) without creating an unmanageable environmental footprint. While cities are major creators of wealth, they are also major consumers of natural resources and generate negative environmental externalities that affect urban liveability. Cities are responsible for up to 80% of GHG emissions (World Bank, 2010[5]) and 50% of global waste (UNEP, 2013[6]). The gravity of the challenges posed by rampant urbanisation led to the establishment of SDG 11, "making cities and human settlements inclusive, safe, resilient and sustainable". Achieving SDG 11 will require implementing innovation policies at the local level that address the needs of growing urban populations.

Cities are becoming central players in innovation policy, which is raising the profile of smart-city programmes deployed to improve urban liveability and resource efficiency. In the OECD/Bloomberg Philanthropies (2018[7]) survey on innovation capacity in cities, 77% of surveyed cities indicated they had dedicated funding schemes to support innovation, mostly tailored to improve residents' quality of life. Key areas include improving health, liveability and job outcomes; and improving local service delivery, such as emergency services, housing and mobility. Funding for cities' innovation instruments comes from municipal budgets and other sources, such as external (non-public) funding and national government budgets. Often, local governments do not have their own resources to invest in the required expertise because of public-sector downsizing, exacerbated by the 2008 recession. Hence, collaborating with the private sector to augment seeding capacity, through "innovation delivery teams" and "resilience officers", has become a common trend (Clark, 2018[8]).

Smart-city programmes contribute to making cities more liveable and sustainable by promoting the effective implementation of smart-city innovations, e.g. building retrofitting, smart grids, smart recycling facilities, electric vehicles and local solar panels (Wijkman and Skånberg, 2016[9]). Because local governments make key decisions on public services, transport, solid waste, water and energy, they can contribute to smart approaches promoting synergies across sectors (e.g. better integration of water, waste and energy management). A common emphasis of smart-city programmes is to encourage the use of new digital technologies to increase urban resource efficiency. For example, the Viable Cities in Sweden programme provides R&D grants for projects that use digital tools to integrate urban infrastructure, such as energy generation, power grids, district heating and cooling, water, transport and waste systems.

Smart-city innovations are not only technological. The successful development and implementation of new smart-city solutions relies on their effective use by local agents, as well as their scale and replication in different contexts. Social and institutional innovations, such as new business models, public-private partnerships and information sharing, are essential to smart-city innovation. Local governments can act as intermediary actors and facilitators, by connecting multiple stakeholders that operate along the value chain but are not necessarily used to collaborating with one another. Intermediation activities include directing and facilitating contacts, informing about existing projects, and providing soft and hard infrastructure for new sustainable businesses (OECD, 2019[4]).

Engaging local agents is critical to implementing smart-city innovations, but is more challenging when smart-city programmes are designed and managed at a national level. To be effective, national urban programmes require multi-level governance and stakeholder engagement. National smart-city programmes often rely on subnational governments for implementation and management; the Australian "Smart cities and suburbs plan", for example, issues R&D calls targeting local authorities. Subnational governments not only have knowledge of local conditions and close proximity to citizens, but also have the capacity to adapt policies to the context. They need to be engaged at every stage of national urban programme processes, rather than being considered as implementation agents only (OECD/UN-HABITAT, 2018[10]).

Eight smart-city programmes were selected for analysis on the basis of their relevance to the PIA (Table 2). PIA funds for sustainable innovation are mostly managed by the French Environment and Energy Management Agency (ADEME), which specialises in five priority areas. Excluding PIA funds, ADEME provided EUR 87 million over 2014-16 (EUR 30 million per year) for a total of 450 projects, including 112 projects (25%) in the smart-city priority area of "Sustainable cities, towns and territories".

Table 2. Overview of smart-city initiatives

Policy initiative	Country	Type	Period	Annual budget	Main objective
Australia's Smart Cities and Suburbs Programme	Australia	National initiative Supply side	2017-20	AUD 50 million over three financial years	Encourage local government agencies and bodies to deliver collaborative smart-city projects that improve the liveability, productivity and sustainability of Australian cities, suburbs and towns.
City of Tomorrow (part of the Austrian ERI)	Austria	National grant Supply side	2013 - present	Between EUR 6 million and EUR 9 million	Develop and scale intelligent-energy solutions for urban buildings on a building as well as a district level.
Mobility of the Future	Austria	National grant Mission-oriented	2012-20	EUR 15 million	Achieve low-emission mobility to reach the government's goal of reaching fossil-free mobility by 2050 and position Austria as a leader in electro mobility.
Smart Cities and Communities lighthouse projects	European Commission (Horizon 2020)	Intern'l co-operation Supply side	2012-20	EUR 70 million	Demonstrate smart technology solutions at city and district level, based on open specifications.
Witty City	Finland	National grants Supply-side and diffusion-oriented	2014-17	EUR 14 million	Support innovation in urban energy systems, urban transport and mobility.
City of the Future	Germany	Supply and demand side	2016-23	EUR 30 million	Support application-oriented, cross-departmental and transdisciplinary research and innovation projects that contribute to the sustainable development of cities, with a focus on energy transition but also climate change adaptation and resilience.

Sustainable Urban Development and Smart Cities	Nordic Countries	Intern'l co-operation Supply side	2019	EUR 5.4 million	Interdisciplinary research projects with applications to sustainable urban development and smart cities.
Viable Cities	Sweden	National grants Supply-side and diffusion-oriented	2017-29	EUR 7.8 million	Apply information and communication technology (ICT) to enable cities to transition to sustainable urban energy systems, while minimising the impact of climate change.

Source: OECD.

Between 2010 and 2017, ADEME managed EUR 2.5 billion of PIA funds, investing 9% in "circular economy and waste management", 11% in "buildings, industry, agriculture, green chemicals", and 36% each in "renewable energy, energy storage and smart grids" and "transport and vehicles of the future". The selected smart-city case studies provide examples of programmes targeting innovative solutions in different domains of relevance for ADEME, such integrated urban systems (e.g. for energy, water or waste management), energy-efficient buildings and eco-mobility.

3.2. Sectoral priorities

The goal of smart-city programmes is to improve urban liveability and resource efficiency (e.g. energy systems, transport, water provision and waste). Common sectoral priorities include buildings' resource efficiency, micro-generation of renewable energy at a local level, green mobility and the application of digital tools to enable intelligent integration of urban infrastructure. Digital technologies to manage urban resources more efficiently can include tools for generating, collecting, storing and processing data. Data can be used to better manage, for example, local energy generation, power grids, district heating and cooling, and water, transport or waste systems. Big data and mobile platforms can also be used to inform and minimise the climate impact of citizens' choices.

3.3. Portfolio of policy instruments

Competitive R&D grants are the main component of smart-city programmes. Most programmes open annual calls for funding in specific smart-city themes, targeting applications from local consortia. Consortia are typically led by businesses offering smart-city solutions; they include members from universities or other research organisations and other entities, such as public authorities or civic organisations. An alternative mode is to target applications from subnational governments, which implement and oversee new smart-city solutions.

3.4. Budgets

The annual budgets of smart-city programmes are typically small compared with other areas of sustainable innovation, such as programmes promoting new renewable-energy technologies. Most programmes have total annual budgets of approximately EUR 10 million, with the exception of the German and Australian programmes (total annual budgets of approximately EUR 30 million), and the European Commission programme (annual budget of EUR 70 million). The size of each grant depends on the type of project being funded. Often, programmes provide funding for projects of a different nature, from preliminary studies to demonstration projects. Support for applied demonstration projects range between EUR 1 million and EUR 2 million, covering only a portion of the projects' total estimated eligible costs. For example, grants from Australia's Smart Cities and Suburbs Programme may

cover up to 50% of demonstration projects' estimated costs, while Austria's Mobility of the Future programme may cover between 35% and 80% of their costs.

3.5. Critical dimensions

Stakeholder engagement and replicability are essential elements of successful smart-city programmes. Smart-city programmes promote local solutions at a city level that address global challenges, such as air pollution, resource waste or poor mobility options. Beyond the purely technological considerations, successfully implementing new solutions requires pursuing other elements enabling systemic transformations, e.g. developing new business models, creating a community of users that engage with developers, and focusing on scaling and replicating solutions in different contexts from where they were initially tested.

Stakeholder engagement

Networking events, workshops and fairs are examples of initiatives with high potential to promote stakeholder engagement at a relatively low cost. In Austria, an evaluation exercise showed that accompanying measures to the calls for the "City of tomorrow" programme – e.g. organising events for networking and showcase presentations, and participating in international fairs – were critical to its success and recommended expanding them. While such initiatives only garnered minor funding, they had a large impact in building up a community in Austria and making it internationally visible.

Designing programmes with specific missions is an additional way of promoting stakeholder engagement towards a common goal and co-operation across different ministries. While the concept of mission-oriented innovation is not new, it has undergone a revival in recent years in response to frontier academic thinking and high-level international policy agendas, such as the SDGs, the clean-energy Mission Innovation programme, and the European Commission's new mission-oriented approach to funding research and innovation. Mission-oriented programmes aim to bring together different actors to solve global challenges at the national or international level. These challenges include many of the problems addressed at the local level by smart-city programmes.

Examples of initiatives promoting mission-based stakeholder engagement include Germany's "City of the Future" and Austria's "Mobility of the Future" programmes. The City of the Future initiative in Germany leverages the impact of newly developed solutions through the creation of a shared vision emphasising a strong alignment with the SDGs (both at the level of call design and at the project selection stage). Following the 2017 recommendations from the German interministerial working group "Sustainable Urban Development in a National and International Perspective" (IMA City), the initiative opined that SDGs needed to be pursued at the municipal level as a way of providing a shared vision that helps co-ordinate different actors. Projects are asked to specify which SDGs they are addressing and to measure their success in contributing to such goals. The programme also promotes cross-industry collaborations, by organising networking events and supporting joint projects. It created the platform SynVer*Z to promote stakeholder engagement by promoting participatory governance events for sustainable urban development. The Mobility of the Future programme in Austria is an additional example of mission-oriented innovation policy. It is included in Mission 2030, a national co-ordinated policy action of four different ministries aiming to reduce GHG emissions in Austria by 30%. It fits into Mission 2030 by contributing to decarbonising the transport sector, the country's second-largest CO_2-emitting sector in 2016.

The operational requirements and design of competitive calls can help promote stakeholder engagement, for instance through application rules governing the composition of consortia and

co-funding requirements. These features encourage potential applicants to engage with other relevant stakeholders and bring them onto their projects. Consortia are often required to include private firms that commercialise and implement new solutions, as well as universities and other research organisations that co-generate new solutions, and public authorities (which are particularly relevant in order to address potential regulatory hurdles). For example, the Swedish Viable Cities programme requires applications to contain at least three members from different sectors. Consortia can be built around collaboration between a private for-profit company, a municipal authority and a non-profit organisation. In Australia, the co-funding requirement of the Smart Cities and Suburbs Programme serves to leverage the impact of the programme's public resources and promote stakeholder engagement. The programme funds 50% of smart-city projects' costs, requiring projects to provide evidence of how the remaining 50% share of the eligible project costs are funded, e.g. through a letter from the city's mayor, chief executive officer, chief financial officer or equivalent, or from "other stakeholders". In the selection process, any additional contributions over the 50% minimum requirement are highly regarded. The co-funding requirement encourages applicants to engage with further stakeholders. In the programme's first call for projects, other stakeholders contributed USD 36 million (EUR 41.2 million), compared to the direct programme disbursement of USD 27.7 million (EUR 32 million). Thus, other stakeholders contributed more than 50% of the projects' costs.

Replicability

Replicability is a key challenge in smart-city programmes: new solutions are developed locally, but their impact is limited if not replicated in different contexts. An example of a feature promoting replicability is requiring applications to be made by consortia comprising multiple partners from different locations. One of the key elements of the European Commission's Smart Cities and Communities lighthouse projects is its emphasis on scaling and replicating new solutions. Public funding is used to support new solutions that can benefit multiple cities and regions, instead of focusing on a specific city. The mechanism to promote scale and replication consists in requiring consortia to include partner cities in different countries at two levels: each funded project should include at least three different cities from different EU Member States or associated countries that are developing a new solution; at least three more cities from additional different EU Member States or associated countries need to participate to replicate the solution under development.

Sound communication and internationalisation strategies also promote replicability. Smart-city projects are typically required to provide a final report describing the newly developed solutions and their impact, contributing to scaling up new solutions in different locations. Promoting the internationalisation of solutions developed nationally is also a pathway to replicability, as they need to be adapted in order to be replicated in different countries. In Finland, Witty Cities is an example of a programme with a strong emphasis on communication and internationalisation. According to the feedback collected during the programme and in its final reporting phase, the key element of success was the interplay between communication, finance and networking. The programme strengthened firms' capacity to scale sustainable smart-city solutions through multiple internationalisation measures, such as participating in international fairs, international networking events and training sessions. Witty Cities also communicated effectively with international audiences, raising the visibility of Finnish solutions at home and abroad. In Austria, the City of the Future programme's online communication strategy was identified as an important element requiring further improved through continuous website maintenance and updating, and user-friendly content (e.g. improving the search function for guidelines, funding options and processes). The creation of a project repository was therefore recommended, including information on current and past projects to enable learning across agents in different regions and cities.

3.6. Monitoring and evaluation strategies

Science and technology ministries are typically in charge of defining the strategy and design of smart-city programmes. National innovation agencies are responsible for their implementation, including monitoring and evaluation. Monitoring of selected projects generally consists in defining key technological, operational or financial milestones, and disbursing grants in tranches, conditional on successful achievement of agreed objectives. A programme manager from the national innovation agency is assigned to each funded project, and is responsible for project supervision and defining the key milestones with the grant recipients. The disbursement of the final grant tranche is conditional on the submission of a financial report and a final report describing the project's achievements. Final project reports are generally published online for the general public. The projects' final evaluation reports consist of a technical summary of newly developed solutions and a description of their impact. Metrics used to determine impact may include environmental, financial and social indicators, such as a reduction of CO_2 emissions and energy savings, financial revenues and volume of exports, and the number of new jobs.

The overall evaluation of smart-city programmes generally takes place at the end of each programme. Final evaluations are usually conducted by external independent organisations, taking into account the final reports submitted by each funded project. Some programmes conduct ex-post surveys among participants and final users of newly developed solutions to identify the main areas where the programme performed successfully and areas for improvement.

3.7. International co-operation aspects

A common international feature of smart-city programmes is the inclusion of foreign partners in project consortia, which is typically encouraged and increases the chances of funding. However, foreign organisations cannot generally receive direct funding from smart-city programmes, nor can they act as consortium project leaders. In some cases, programmes are based on international co-operation by design, e.g. the Smart Cities and Communities lighthouse projects run by the European Commission, and the Sustainable Urban Development and Smart Cities programme run by the Nordic Council of Ministers (an inter-governmental co-operation of Denmark, Finland, Iceland, Norway, Sweden, Faroe Islands, Greenland and the Åland Islands). These programmes require consortia to include institutions from different countries. By requiring international partnerships, smart-city collaborations are well placed to develop new solutions that address local problems but also have the potential to scale up in different regions with a different context.

The pursuit of synergies in international funding is an additional element of international co-operation in smart-city programmes. National programmes and their specific calls for projects are often designed with available funding synergies in mind. This is especially true in Europe, where national programmes often attempt to align with supranational funding opportunities designed by the European Commission. The national innovation agencies managing smart-city programmes often provide information about international funding opportunities, as well as expert advice and guidelines for applications. Applicants to national smart-city programmes are typically allowed to receive complementary funding from different international financing opportunities.

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