**Online appendix A.3: Overcoming barriers to Procurement of LEDs**

Innovative end-use energy technologies such as light-emitting diodes (LEDs) represent a cornerstone of a $CO_2$ emission reduction strategy (IEA, 2018a; Sorrell, 2015). Installing LEDs and other energy-efficient lighting systems in German streets could yield emission reductions of up to 2.7 million tons of $CO_2$ – an 85 per cent reduction from 2014 levels – and savings on energy costs of up to 400 million EUR per year (Polzin et al., 2016a).

However, LED street lighting requires significant upfront investments for planning and construction ranging between EUR800–1000 per lamp post in 2017 (Dena, 2017). The choice of contractor or in-house procurement depends mainly on (technical and administrative) competencies, existing contractual arrangements and the property and budgetary situation (Polzin et al., 2018). A performance contracting solution (with a specialised contractor, for example) would permit the retrofitting of existing municipal infrastructure without incurring upfront investment and with guaranteed savings. However, many municipalities face barriers, such as existing contracts and partnerships and missing personnel capacity when engaging with energy service companies (Polzin et al., 2016b). Facilitators (such as energy agencies) play a role in diffusing technological and procurement capacities. Standardised procurement frameworks (such as the RE:FIT programme) and contracts can reduce transaction costs as the main obstacle and enable private contractors to engage with municipalities more effectively (Nolden et al., 2016).

EU directive 2014/24/EU requires EU member states to include award criteria such as lifecycle costs that translate into $CO_2$ emissions in their procurement decision; however, many government officials, especially at the local level, still select tenders based on lowest cost. Therefore, national policy makers are well-advised to enact an internal price on carbon for government procurement or to use lifecycle greenhouse gas accounting in pricing options alongside generating and diffusing knowledge and experience (in the form of standardised energy performance criteria and guarantees) to accelerate the process of modernisation (Polzin et al., 2018).

**Online appendix A.4: State Investement Bank (SIB) functions for leveraging private capital**

As described in Geddes et al. (2018) there are five different functions through which SIBs were able to leverage private capital. First, through *Capital provision function,* they address investment gaps of projects with very large upfront capital requirements (such as offshore wind farms). Capital provision by SIBs was also important during the financial crisis, due to liquidity constraints and a general reluctance to invest in private capital markets. Second, SIBs can have a *de-risking function*, using risk-transfer instruments such as loan guarantees (CPI, 2018). Providing these de-risking instruments attracted private investors that had previously abstained from financing new low-carbon technologies. Third, SIBs can have an *educational function*, informing investors and project developers based on the SIBs' in-house specialist expertise regarding risk assessment and de-risking mechanisms. SIBs also develop new tools and practices, such as new contractual deal structures or risk assessment tools, that help investors better assess project risks, enabling them to participate at a lower entry cost. Fourth, SIBs can have an important *signalling function* if they have developed a reputation for expertise and trust among investors. An SIB's signal to participate in a project often results in strong private sector finance participation (even to the extent that the SIB

financing is no longer needed). Fifth, SIBs can take over an *early-mover function*. Private Investors are often unwilling to invest in projects that are the first of their kind or feature technologies that do not have a track-record, such as a new biomass boiler design. When SIBs finance these projects, they demonstrate that the technology is mature enough for deployment, and thus enable private sector finance for follow-up projects. The signalling role results in direct crowd-in of private capital to the project that has been 'signalled', but the early-mover role refers to a subsequent crowding-in of private capital for later projects, once a track record has been created and SIBs are no longer participating.