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The multiple roles of state investment banks in low-carbon energy finance: An analysis of Australia, the UK and Germany

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ABSTRACT

Low-carbon energy technologies (renewable energy and energy efficiency) are considered essential to achieve climate change mitigation goals, so a rapid deployment is needed. However there is a significant financing gap and many policymakers are concerned that investment for the large-scale deployment of low-carbon technologies will not materialise quickly enough. State investment banks (SIBs) can play a key role in closing this finance gap and leverage additional private finance. Based on 52 interviews, this paper presents empirical evidence on the role of three SIBs in addressing the barriers to financing low-carbon energy projects; the Clean Energy Finance Corporation (CEFC) in Australia, the Kreditanstalt fuer Wiederaufbau (KfW) in Germany and the Green Investment Bank (GIB) in the UK. We investigate the activities and financial instruments offered by SIBs and compare these to the need for such from low-carbon developers when sourcing finance. Findings show that aside from capital provision and de-risking, SIBs take a much broader role in catalysing private investments into low-carbon investments, including enabling financial sector learning, creating trust for projects and taking a first or early mover role to help projects gain a track record.

1. Introduction

Mitigating climate change will require a rapid and significant transition of our energy system in order to reduce CO_2 emissions (IPCC, 2014). The development and deployment of new technology, especially of renewable energy and energy efficiency technology is considered key to this transition and so there is a need for policy to speed-up and redirect this technological change (Pizer and Popp, 2008; Schmidt et al., 2012). But there is a significant 'financing gap' for the low-carbon energy projects required to reduce global CO_2 emissions to target levels and many are concerned that investments for the large-scale diffusion of renewables will not materialise fast enough (IEA, 2014, 2016; IFC, 2010; SE4ALL, 2014). The International Energy Agency estimates annual global investments in low-carbon technologies will need to total USD 730 billion by 2035, more than doubling the 2015 figure of USD 290 billion, and will then need to reach over USD 1.6 trillion a year from 2030 to 2050 to meet global climate targets (IEA, 2014, 2016; Shlyakhtenko and La Rocca, 2012). However, public support and utilities' balance sheets are currently constrained and, given the necessary scale of investment, new private finance is required (FS-UNEP and BNEF, 2016, 2017; GIBC, 2010; Mathews et al., 2010).

Although finance plays an important role along the entire innovation chain, it is especially downstream finance for commercialisation that is important for the rapid deployment of low-carbon technologies (Bürer and Wüstenhagen, 2009; Grubb, 2004; Karltorp, 2015; Mazzucato and Semieniuk, 2017). While, due to innovation, the cost of low-carbon technologies has significantly fallen in recent years (Huenteler et al., 2015; Schmidt and Sewerin, 2017; Trancik et al., 2015), many projects are still perceived as risky by investors and are not financed (CPI, 2013; Hall et al., 2015; Jacobsson and Jacobsson, 2012; Jacobsson and Karltorp, 2013; Karltorp, 2015; Lang et al., 2015; Ondraczek et al., 2015; Sadorsky, 2012). The period post 2008 also saw a drop in low-carbon project investment activity in many countries due to the financial crisis and new reserve requirements for banks (IEA, 2009). Barriers to sourcing finance faced by developers differ by technology type, project size and context conditions (CPI, 2013; Hall et al., 2015; Kann, 2009; Polzin, 2017; Richards et al., 2012). Furthermore Waissbein et al. (2013) and Schmidt (2014) have shown that when the perceived investment risk is high the resulting increase in financing costs deteriorates the competitiveness of low-carbon vis-à-vis fossil fuel based projects. With many developers still facing barriers to sourcing finance the limited public finance that is available is being called on to leverage in private sector finance (Jacobsson and Jacobsson, 2012; Karltorp, 2015; Mathews et al., 2010; Schmidt, 2014; Steffen, 2017).

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In recognition of this issue, some governments have appointed state investment banks (SIBs) to close the financing gap and help green their economies. The UK's Green Investment Bank (GIB) and Australia's Clean Energy Finance Corporation (CEFC) were both founded in 2012 with government funding and a similar remit: to assist their country's transition towards a more sustainable economy by mobilising private sector capital into low-carbon energy projects (CEFC, 2016a; GIB, 2016b). Germany's Kreditanstalt fuer Wiederaufbau[1] (KfW), while originally established as the country's development bank, has also been very active in low-carbon energy financing (KfW, 2015a).

Recent work by the OECD reported that SIBs leverage private investment into green infrastructure (OECD, 2015, 2016, 2017). Other reports analysed models for the creation of green investment banks in light of receding government support (Berlin et al., 2012) and investigated the potential role of such banks in scaling up climate finance in emerging markets (NRDC, 2016). Mazzucato and Penna (2016) determined that SIBs 'shape and create' markets, rather than solely fix their failures and that KfW and BNDES[2] play a 'mission-oriented' role, making key investments in new sectors to address 'grand societal challenges', such as climate change (Mazzucato and Penna, 2015). More recently Mazzucato and Semieniuk (2017) found that public owned entities invested heavily in some high-risk renewable energy projects. However literature also discusses the concern that public financial intervention might crowd out private investment, which could lead to capital allocation inefficiencies[3] (Cumming and MacIntosh, 2006; Hall et al., 2015; Stiglitz, 1993).[4] More generally, Campiglio (2016) discusses the potential role of banking and monetary policy in expanding credit creation to finance the energy transition and Hall et al. (2016) examine how the industry structure of the banking sector can shape ownership structures and technology choices of energy transitions.

The literature to date falls under one of two categories; general public sector finance in energy transitions, or the general role of banking and finance in energy transitions. There is little empirical work on the role of SIBs specifically in overcoming barriers to mobilising finance. There is also an absence of detail on which instruments, channels and activities employed by SIBs have been effective and why, and little understanding of the mechanisms which allow SIBs to help mobilise private finance into the low-carbon energy sector. Our work in this paper aims to address this research gap by asking the research question: *What is the role of SIBs in addressing the barriers faced by low-carbon project developers in sourcing finance?*

To answer this question we investigate the instruments and activities supplied by SIBs and compare these to the actual demand for such from low-carbon energy developers in the context of the barriers they encounter in sourcing finance. We examine both how and how well SIBs address these barriers and in doing so we identify the roles taken by SIBs that successfully address developers' needs. We also investigate evidence for crowding-out and supply of inappropriate provisions. We present empirical evidence sourced from 52 interviews with 56 interviewees in Australia, Germany and the UK. With this work we aim to improve the understanding of the role of public finance in overcoming barriers to the energy transition.

The remainder of the paper is structured as follows: Section 2 introduces our cases, extending on the literature advanced in the introduction by presenting background to the three SIBs and their country contexts, and describes our method and data. In Section 3 we present and discuss our results, and we conclude with policy recommendations in Section 4.

2. Cases, methods and data

2.1. Case selection

Our study focuses on three cases from different industrialised countries with SIBs that are either primarily or heavily involved in financing low-carbon energy projects: Australia and the CEFC, Germany and the KfW Group and the UK and the GIB. The OECD (2015) reports on 13 'green' investment banks (GIBs) or GIB-like entities (such as funds) operating globally as of 2015. We selected the CEFC and GIB because they operate on a national level, perform more operations and activities than a fund and have a longer operating record (5 years). We excluded institutions from our study that operate solely as a fund, whose operating record is too short or that operate on a sub-national or regional level only. We include KfW in our study because, although not exclusively a 'green' state investment bank, it is mandated to support Germany's energy transition and was the biggest development bank investor in clean energy projects globally from 2007 to 2012 (Louw, 2013). Hence this case offers a large amount of empirical evidence to observe how SIBs address barriers to low-carbon finance.

In the following section we describe the policy context and financial sector background for each country and introduce background information to each bank. Table 1 provides renewable capacity and % total generation statistics for each country to indicate the relative level of development of each country's low-carbon sector. Table 2 summarizes each SIB's background information.

2.2. Australia and the Clean Energy Finance Corporation

2.2.1. Policy context

In contrast to the UK and Germany, Australia's low-carbon sector (beyond rooftop solar) remains in its infancy[5] (Table 1), with most technologies still considered to be new to the country and its actors, especially its financial system. Various context conditions have posed a challenge to sourcing finance for the deployment of low-carbon projects (Cheung and Davies, 2017; Kann, 2009; Nelson et al., 2013). Firstly electricity is generated in Australia under a fully commercial market-based system where historically developers have sourced power purchase agreements (PPAs) from commercial retailers (Kann, 2009). Secondly, apart from the Renewable Energy Target (RET) scheme,[6] there has been limited federal policy support for low-carbon technologies (Cheung and Davies, 2017; Talberg, 2013). Finally, long-term renewable energy and climate change policy uncertainty has been created through a lack of bipartisan support, on-going federal debate and policy change[7] (Cheung and Davies, 2017; Kann, 2009; Nelson et al., 2013, 2012). While policy uncertainty existed around Australia's RET, retailers were no longer prepared to enter into long-term PPAs. Financiers were then unwilling to fund such projects and investment in large-scale projects dropped 88 per cent in 2014 compared to the

[1] Translates to Reconstruction Credit Institute.

[2] The Brazilian Development Bank.

[3] Note there are various debates around public intervention in markets to support new technologies, including whether there is justification for any policy intervention at all, and around the level of specificity of such interventions in markets (Hall et al., 2015; Schmidt et al., 2016). Literature has extensively reported on a wide range of market failures (including structural barriers, information asymmetry, project finance markets differing to high frequency traded markets etc.) for low-carbon technology implementation and associated project finance markets, as well as co-ordination/ system failures, justifying policy intervention (Gillingham and Sweeney, 2010, 2012; Hall et al., 2015).

[4] In the context of SIBs 'crowding out' refers to public institutions investing in the place of private financiers, displacing and/or reducing private investment participation, and thus inhibiting the development of an effective and robust private sector market for financing (Cumming and MacIntosh, 2006).

[5] As of end 2014 there were only 5 operating large-scale (> 1 MW) solar PV plants, with a total installed capacity of 44 MW, well behind similar international markets (CEC, 2014, 2015).

[6] The Renewable Energy Target (RET) is a certificate-based scheme for large-scale renewables implemented in 2001.

[7] The country's carbon pricing scheme was repealed within 2 years of its launch by an incoming government (Taylor, 2014) and in 2012 and 2014 the same government reviewed and revised the RET scheme.

Table 1
Low-carbon energy statistics 2016[a].

	Australia		United Kingdom		Germany	
	Capacity GW	% total generation	Capacity GW	% total generation	Capacity GW	% total generation
Solar PV	5.6	3.2%	11.3	3.0%	41.0	6.0%
Offshore wind	0.0	0.0%	5.2	4.7%	4.1	1.9%
Onshore wind	4.3	5.3%	10.0	6.3%	45.6	10.0%
Waste-to-energy, bioenergy	0.8	1.5%	5.0	8.8%	9.3	7.0%
Total	10.7	10.0%	31.5	22.8%	100.0	24.9%

[a] Numbers based on AGEB (2017), BEIS (2017), CEC (2017) and IRENA (2017).

Table 2
SIB Background[a].

SIB	**CEFC**	**GIB**	**KfW**
Founding Year	2012	2012	1948
Source of Capitalisation	AUD 10 billion (USD 7.9 bn) provided by Australian Government, the sole shareholder	GBP 3 billion (USD 3.9 bn) provided by UK Government, the sole shareholder (with a view to eventually giving the bank full access to capital markets in order to borrow freely)	EUR 3.75 billion equity (USD 4.4 bn) provided by German Federal (80%) & State (80%) shareholders EUR 72.8 billion (USD 85.9 bn) borrowed in 2016 from capital markets via government guaranteed bonds
Number of Staff as of end 2016	61	130	KfW Group: 4763 KfW IPEX: 657
Focus Sectors			
Solar PV	X		X
Onshore wind	X	X (from 2016)	X
Offshore wind		X	X
Waste-to-energy, bioenergy	X	X	X (until ca. 2014)
Energy efficiency	X	X	X
Small scale renewables	X	X	X
Financial instruments	• Debt (market rate, long-term) • Debt (concessional, limited to AUD 300 million (USD 237 mn) in NPV terms per year) • Equity (introduced after interviews) • Securitisation/ aggregation products • Guarantees (restricted to 5% uncommitted balance)	• Debt (market rate, long-term) • Debt (subordinated, mezzanine) • Equity (incl. bridging equity loans) • Securitisation/ aggregation products	• Debt (concessional, long-term) • Debt (market rate, long-term, for offshore wind, energy transition related R&D, SME & large corporate projects) • Equity (limited amount) • Grants • Guarantees/ insurance
Major finance channels	• Direct lending via co-investment/ syndication • On-lending via local intermediaries • 3rd party & own managed investment funds • Climate bond investment	• Direct lending/ investing via co-investment/ syndication • 3rd party & own managed equity and debt investment funds • Joint Venture	• On-lending via local intermediaries • Limited direct lending to municipalities and some large corporations • KfW IPEX: Direct lending/ investing via co-investment/ syndication
Example programs and funds	• Commercial on-bill financing program • Clean Energy Innovation Fund • Australian Bioenergy Fund (cornerstone investor)	• UK GIB Operating Offshore Wind Fund • Foresight UKWREI (UK Waste Resources and Energy Investments) Fund • Societe Generale Equipment Finance (SGEF) Partnership for energy efficiency	• Renewable Energy Program - Standard (Renewable electricity and small scale heat) • Energy Efficiency for the Housing Sector - Energy Efficient Construction and Rehabilitation program (EECR) • KfW Offshore Wind Energy Program • Energy Advice program for SMEs

[a] Data based on CEFC (2016a, 2016b), GIB (2016a, 2016b) and KfW (2015a, 2016b, 2017a, 2017b).

previous year (CEC, 2016; Talberg, 2013). Most low-carbon energy developers, OEMs and investors exited the Australian market entirely, only to start returning in late 2015.

2.2.2. Financial sector background

Australia's market-based financial system is mostly privately owned and is dominated by 4 main banks[8] with significant market power (RBA, 2006, 2017). Moreover, Australia's banking system is primarily funded by short-term deposits and short-term funding (Atkin and Cheung, 2017). Local lenders tend to offer short to mid-term loans of around 5 years that are unsuited to low-carbon projects with longer lifetimes. Developers have more successfully sourced finance from Europe and Asia where financiers display more comfort with low-carbon projects and are willing to offer longer-term finance.

2.2.3. CEFC background

CEFC was established in 2012 under a mandate to “mobilise and leverage the flow of funds for commercialisation and deployment of renewable energy, low-emissions and energy efficiency technologies necessary for Australia's transition to a lower carbon economy” (CEFC,

[8] Australia and New Zealand Banking Group, Commonwealth Bank, National Australia Bank and Westpac.

2016b). An independently operated government institution, it has a mandate to invest its AUD 10 billion[9] (USD 8.6 billion) on commercial terms similar to commercial banks and must compare its financial performance to a portfolio benchmark return based on the five-year Australian Government bond rate plus 4–5% (CEFC, 2016b). The CEFC provides capital to low-carbon projects and funds where it deems sufficient capital is not available and simultaneously aims to crowd-in private finance, targeting institutional investors, commercial banks and individuals for co-investment (Act104, 2012; CEFC, 2016a, 2016b). Since its launch an incoming government has twice tried to abolish the CEFC, both attempts of which were halted in the parliament (Taylor, 2014).

The CEFC focuses on large-scale solar PV, onshore wind, waste-to-energy, bioenergy, energy efficiency, small-scale renewables and low emissions vehicles[10] (see Table 2 for further SIB features). Fig. 1a shows a breakdown of the CEFC's investments by sector and technology type. As the CEFC is committed to investing on commercial terms, its main financing instrument is the provision of long-term fixed market rate debt. The CEFC supplies its financing through four main channels: direct investment in mostly large-scale projects, co-financing programs with credit intermediaries, own and third-party investment funds and green bond investment. As of end 2016 the CEFC has been involved in over 60 direct investments and is currently involved in 9 co-finance and aggregation programs (GBN, 2017). The CEFC has made AUD 3 billion (USD 2.6 billion) of cumulative investment commitments in a total of AUD 7 billion total (USD 6 billion) project value and, as of end 2016, every AUD 1 from the existing portfolio had helped catalyse AUD 2 from the private sector (GBN, 2017).

2.3. The UK and the Green Investment Bank

2.3.1. Policy context

Although more mature than the Australian low-carbon sector, the UK was considered more of a mid- to late-comer, until more recently catching up to Germany (see Table 1). In 2008 the UK became the first country to set a legally binding carbon reduction target into law agreeing to an ambitious 80% reduction in emissions by 2050, with an interim cut of 34% by 2020, from 1990 levels (CCA, 2008). The country has seen an increase in renewable energy support over the years, from certificate based schemes to feed-in tariffs and the more recent contracts for difference (CfD) auction scheme (DECC, 2011; Lilliestam et al., 2014). Changes in government and support policy[11] have seen many boom-bust cycles for renewables in the last 10–15 years as developers rush to connect plants before subsidy scheme deadlines are imposed (Bolton et al., 2016).

2.3.2. Financial sector background

The UK financial system is market-based, like Australia's, however it's banking sector is less concentrated and consists of a more diverse range of participants (Hall et al., 2016; Wójcik and MacDonald-Korth, 2015). Capital markets in the UK struggled to provide liquidity during and just after the global financial crisis of 2008, which, along with new reserve requirements on banks, contributed to the financing gap for projects. Markets didn't see capital availability improve again until 2011–2012[12] and by 2015 investors showed substantially more interest

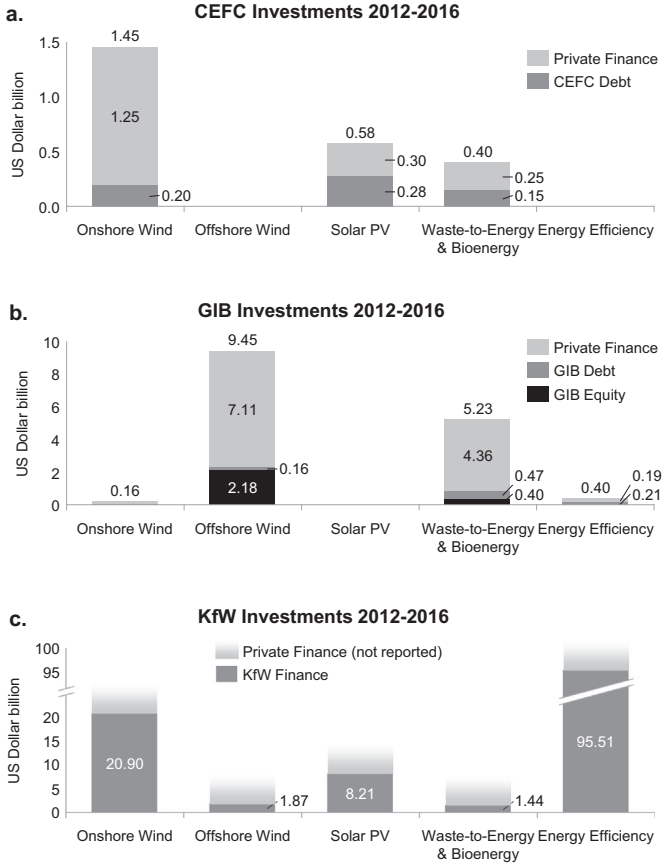

Fig. 1. *SIB Investments.* CEFC figure excludes low emission vehicles, community housing, green bonds and commitments not yet resulting in disbursement of funds, including energy efficiency funds. KfW figure excludes KfW IPEX offshore wind commitments and private finance leveraged not reported. Data based on CEFC (2013, 2014, 2015a, 2016a), summary of transactions in GIB (2016b) and KfW promotions reports KfW (2013, 2014, 2016a).

in low-carbon projects. Developers' and investors' biggest concern is that policy uncertainty is stalling investment.

2.3.3. GIB background

The UK's GIB was founded in 2012 to help the UK meet its emissions targets cost effectively by mobilising private finance into low-carbon projects (CCA, 2008; EAC, 2011; Holmes, 2013). The GIB is an independent, government owned[13] entity capitalised with GBP 3 billion (USD 4.6 billion). The GIB only invests on terms equivalent to those of commercial banks and must meet a minimum 3.5% annual return on investments before tax (EAC, 2011; OECD, 2015). In-line with EU state aid rules, EU commission approval of the GIB's establishment was made subject to it providing capital only to those projects and sectors where there is not considered sufficient private or commercial funding (EAC, 2011). Where possible the GIB aims to simultaneously crowd-in private finance to projects (EAC, 2011; GIB, 2016b).

The GIB's target sectors are offshore wind, waste-to-energy, bioenergy, energy efficiency and more recently onshore wind (see Fig. 1b). The bank provides a wider range of financial instruments than the

[9] Government supplied equity with AUD 2bn (USD 1.7bn) disbursed annually for 5 years.

[10] Out of scope for this study.

[11] Regular policy changes are often cited as a significant source of uncertainty for investors, contributing to the lack of required investment in renewables (Foxon et al., 2005).

[12] The two traditional lenders to UK project finance for medium to large-scale renewable projects (Lloyds and RBS) backed away from lending in response to the recession and then in 2014 many other European banks stopped providing 15-year commitments to renewable projects in response to the new reserve obligations via the Basel III requirements (Blyth et al., 2015). Developers and deal arrangers have observed Japanese banks, such as BTMU and SMBC, and French banks, such as Société Générale, become more actively re-engaged in the market and institutional investors are starting to invest in large scale solar PV and wind.

[13] The UK Government announced its intention to privatise the GIB in 2015 and in April 2017 its sale to a Macquarie Bank-led consortium was given approval under the condition the Government maintains a minority 'special share' in order to monitor the banks' green performance (Pickard, 2017).

CEFC, including long-term fixed market rate debt, mezzanine and subordinated debt, equity and bridging equity loans.[14] It disburses its finance through three main supply channels, including direct financing, co-financing partnership programs and own and third-party managed funds, financing 69 projects between 2012 and 2016 (GIB, 2016b). The GIB has committed GBP 2.1 billion (USD 3.2 billion) cumulative investment towards a total of GBP 8.5 billion (USD 13 billion) worth of project value, leveraging GBP 3 from the private sector for every GBP 1 invested by the GIB (GIB, 2016b).

2.4. Germany and the KfW group

2.4.1. Policy context

The German energy industry has been heavily shaped in recent decades by the Federal Government's Energiewende (energy transition), an initiative that aims to reduce the use of high-carbon and nuclear energy, and transition to a renewable and sustainable energy system (Lauber and Jacobsson, 2016; Morris and Pehnt, 2016). As of end 2016 Germany has a mature and established low-carbon energy sector (Table 1). Like the UK, Germany also has ambitious carbon reduction targets, aiming to reduce emissions by 40% by 2020 and by 80% by 2050 compared with 1990 levels. In order to reach these targets Germany's government has provided a very supportive environment for renewables and energy efficiency via technology specific feed-in-tariffs, priority feed-in and other complimentary support schemes (EEG, 2000; Lauber and Jacobsson, 2016; Lauber and Mez, 2006).

2.4.2. Financial sector background

Compared to the market-based financial sectors in the UK and Australia, Germany has a more bank-based sector characterised by an extensive network of over 1600 local banking institutions (compared to the UK's 162) (Hall et al., 2016; Wójcik and MacDonald-Korth, 2015). German developers experienced an investment gap when the capital sector struggled to provide liquidity for low-carbon projects during and just after the global financial recession of 2008 and with banks' subsequent new reserve requirements (Blyth et al., 2015). Developers described improvements around 2011–2012 and could access plenty of finance in the marketplace from early 2014. They also report that investors have become very knowledgeable and comfortable with low-carbon technology and its financing and that German banks in particular have become very competitive within all low-carbon sectors.

2.4.3. KfW background

KfW[15] was founded in 1948 as Germany's reconstruction and development bank and has supported the country's development in various ways since. Originally established with Marshall Funds, it is a AAA-rated institution and currently raises over 90% of its funds in capital markets through government-guaranteed bonds (KfW, 2015b, 2016b; Kraft, 2003; Mazzucato and Penna, 2015). Its shareholders, the Federal Government (80% share) and German States (20% share) together hold EUR 3.75 billion (USD 4.6 billion) of equity capital and it raised EUR 72.8 billion (USD 89 billion) from capital markets in 2016 (KfW, 2015b). KfW has most recently supported Germany's energy transition directly through its 'KfW Energy Turnaround Action Plan', implemented in 2012. However the bank has been active in environmental protection for many decades and invested heavily from 2005 to 2011 in renewables and energy efficiency (KfW, 2015a; Kraft, 2003; Louw, 2013).

KfW's low-carbon focus areas are energy efficiency, renewable energy (solar PV, wind, waste-to-energy & bioenergy) and energy-related innovation projects (see Fig. 1c and Table 2). Unlike the CEFC and GIB, KfW mostly provides standardised, fixed-rate concessional debt[16] through its domestic programs, which it channels through Germany's extensive network of local banks via on-lending (Carrington, 2012; Kraft, 2003).[17] It also offers guarantees, grants, up-front repayment-free periods, and a limited amount of equity and long-term market rate debt for large corporate projects. Domestically KfW IPEX[18] focuses on large-scale offshore and onshore wind and specialises in project finance offering a dedicated fixed market rate, long-term debt product. In the years 2012–2016, KfW launched EUR 103 billion (USD 126 billion) under the Energy Turnaround Action Plan (Poethig, 2017).

2.5. Methods and data

We undertook a qualitative case study design following the procedure of Eisenhardt (1989), iteratively collecting and analysing data on the three SIBs. Primary qualitative data has been collected through in-depth semi-structured interviews with low-carbon energy project developers, equity and debt providers, bankers (SIBs and commercial banks), and industry experts. To prevent bias we interviewed both developers who had and had not successfully engaged with SIBs. In total we performed 52 semi-structured interviews with a total of 56 interviewees from late 2015 to mid 2016, listed in Table 3. Interviewees[19] were found through searches of SIB websites, renewable energy associations, Internet searches and snowball sampling. All interviews were conducted under the "Chatham House Rule"[20] and hence no references to interviewees or their affiliations are made. Secondary qualitative data was sourced from publicly available literature on each bank and the projects they have undertaken.

Key themes within the data set were identified via a qualitative content analysis. To enable the analysis, interviews were recorded and transcribed. The primary and secondary data was then coded using the qualitative data analysis software MAXQDA12 and categorized into conceptual groups using a bottom-up iterative procedure. These categories were then abstracted to generate key themes. We then iteratively tested these themes with each successive interview, sourcing additional data when contradictions were encountered. We continued holding interviews until no additional thematic insights were observed (Eisenhardt, 1989). We then 'mapped' developers' demand for risk mitigation instruments or barrier removal against the supply of instruments and activities from SIBs. In this way we were able to determine how well SIBs addressed the needs of developers.

3. Results and discussion

The results of our evaluation on how and how well each SIB addresses the barriers faced by low-carbon developers are summarised in Fig. 2, Section 3.2. This figure shows the entirety of our results whereas we only describe below in detail the technology sectors that best illustrate the types of results seen in each country: Large-scale solar PV in Australia, wind and waste-to-energy and bioenergy in the UK and wind, solar PV, energy efficiency & small-scale renewables in Germany

[14] Short-term financing to allow completion of deals before longer-term financing is secured.

[15] For this work we investigated those business units and subsidiaries of the KfW Group that are active in the low-carbon energy sector domestically: KfW Mittelstandsbank, KfW Kommunal-und Privatkundenbank/ Kreditinstitute and KfW IPEX.

[16] KfW offers low lending rates (1–2% in 2012) due to KfW's top credit rating plus further government subsidy of the interest rate.

[17] Rather than investing directly, KfW mostly channels its standardised financial products through Germany's extensive network of local banks via on-lending. KfW IPEX however does lend directly to its large-scale projects, usually acting as the lead investor in a syndicate. KfW has a wide range of programs that are part of KfW's Energy Turnaround Action Plan, under which it provides finance to the low-carbon sector (see examples in Table 2).

[18] We refer to KfW IPEX when specifically discussing the subsidiary's activities. KfW IPEX occasionally disburses equity on behalf of KfW.

[19] All interviewees were initially contacted via e-mail. Approximately 85% of interviews were conducted via Skype or telephone and 15% conducted in-person. Interviews lasted from between 30 min and 90 min with the average interview taking 60 min.

[20] When a meeting, or part thereof, is held under the Chatham House Rule, participants are free to use the information received, but neither the identity nor the affiliation of the speaker(s), nor that of any other participant, may be revealed.

Table 3
Interview Sample.

Category		Organisation[a]	Technology Focus[b]	Country[c]	Interviewee's Role
Developer	**1**	Project Developer	Wind, Solar PV	AU	Head of Business Development
	2	Project Developer	WtE	AU	Chief Executive Officer
	3	Project Developer	WtE	AU	Managing Director
	4	Project Developer	WtE	AU	Managing Director
	5	Project Developer	Bioenergy, WtE	GB	Independent developer
	6	Project Developer	Wind, Bioenergy	GB	Managing Director
	7	Project Developer	WtE	GB	Managing Director
	8	EPC, OEM	Wind, Solar PV	AU	Business Development Manager
	9	IPP	Wind	AU	Executive General Manager
	10	IPP	Wind, Hydro	AU	Executive Manager, Development
	11	IPP	Renewables	AU, GB, DE	Chief Financial Officer
	12	IPP	Solar PV	DE	Project Developer
	13	IPP	Bioenergy	GB, DE	Independent developer
	14	IPP	Wind, Solar PV	GB, DE	Manager, ESG
	15	IPP	Wind, Solar PV	GB, DE	Executive General Manager
	16	IPP	WtE, Bioenergy	GB, DE	Head of Origination
	17	OEM	Wind, Solar PV	AU	Head Structured Finance
	18	OEM	Small-scale wind	AU, GB, DE	General Manager
	19	OEM	Renewables	AU, GB, DE	Sales Manager, Renewables
	20	OEM	Renewables	AU, GB, DE	Senior VP Project Development
	21	OEM	Wind	GB, DE	Senior Investment Manager
	22	Utility	Renewables, FFs	DE	Managing Director
	23	Utility	Renewables, FFs	DE	Head Business Development
	24	Utility	Wind, Solar PV	GB, DE	Business Development Manager
	25	Utility	Wind, Solar PV	GB, DE	Managing Director
Investor	**26**	Commercial Bank	Renewables, FFs	AU	Executive General Manager
	27	Commercial Bank	Renewables, FFs	AU	Senior Consultant
	28	Commercial Bank	Renewables, FFs	AU, GB, DE	Director Corporate Clients
	29	Commercial Bank	Renewables, FFs	AU, GB, DE	Consultant, Green Banking Expert
	30	Commercial Bank	Renewables, FFs	GB, DE	Consultant, Innovative Finance
	31	Gov't funding entity	Renewables	AU	Transactions and Development
	32	Green Bank	Renewables	GB, DE	Relationship Manager, Arranger
	33	Invest. Advisors	Renewables	AU	Principal Financial Advisor
	34	OEM investors	Renewables, FFs	AU, GB, DE	Managing Director
	35	Invest. platform	Renewables	GB	Managing Director
	36	SIB	Renewables, EE	AU	Division Director
	37	SIB	Renewables, EE	AU	Researcher
	38	SIB	Renewables, EE	AU	Department Director
	39	SIB	Renewables, EE	AU	Associate Director
	40	SIB	Renewables, FFs	DE	Department Director
	41	SIB	Renewables, EE	GB	Department Head
	42	SIB	Renewables, FFs	GB, DE	Investment Officer
	43	SIB	Renewables, FFs	GB, DE	Project Assessor
	44	SIB	Wind, Renewables	GB, DE	Team Head, Wind Power
	45	Sustainable Bank	Renewables	GB, DE	Chief Financial Officer
	46	VC Investor	Renewables, FFs	AU, GB, DE	Director
Expert[d]	**47**	Consultancy	Renewables	AU, GB, DE	Arranger, Due Diligence
	48	Consultancy	Renewables, FFs	GB, DE	Associate Principal, Energy
	49	Consultancy	Wind	GB, DE	Senior Consultant, Power Market
	50	Consultancy	Wind	GB, DE	Partner, Energy and Resources
	51	Energy Think-tank	Renewables	GB	Director, Finance, Energy Policy
	52	Envir. Consultancy	Renewables, FFs	GB, DE	Principal Consultant
	53	Envir. NGO	Renewables, FFs	AU, GB, DE	Director of Strategy and Finance
	54	Legal Consultancy	Renewables	AU	Partner, Project Finance, Energy
	55	Legal Consultancy	Renewables	AU	Senior Associate, Project Finance
	56	Legal Consultancy	Renewables	AU, GB, DE	Partner, Arranger

[a] IPP: Independent Power Producer, OEM: Original Equipment Manufacturer, EPC: Engineering, Procurement and Construction.
[b] WtE: Waste-to-energy, EE: Energy Efficiency, FFs: Fossil Fuel based power generation.
[c] AU: Australia, GB: The United Kingdom, DE: Germany.
[d] Experts include deal arrangers, due diligence experts and expert consultants. These are interviewees who work closely with SIBs or are heavily involved in the development process.

(remaining technologies can be found in the Appendix). A summary of the results is followed by a discussion of SIBs' key roles.

3.1. How do SIBs address barriers to finance?

3.1.1. Australian large-scale solar PV developers and the CEFC

Australian large-scale solar PV project developers identified four main barriers to sourcing finance. Firstly, in recent years, revenue uncertainty due to a lack of long-term power purchase agreements (PPAs) has been an issue. This is a result of policy uncertainty that occurred during the reset of the RET such that projects now face full or part merchant exposure: that is, they must sell their generated electricity onto a merchant power market at uncertain prices rather than deliver via pre-agreed prices under PPAs. As one developer reported *'in Australia it is very, very tough to get a PPA, and without a long-term PPA the commercial banks won't fund your project'*. The CEFC has provided long-term market rate debt to projects that have part or full merchant exposure to both address the debt gap and to create a track record for the

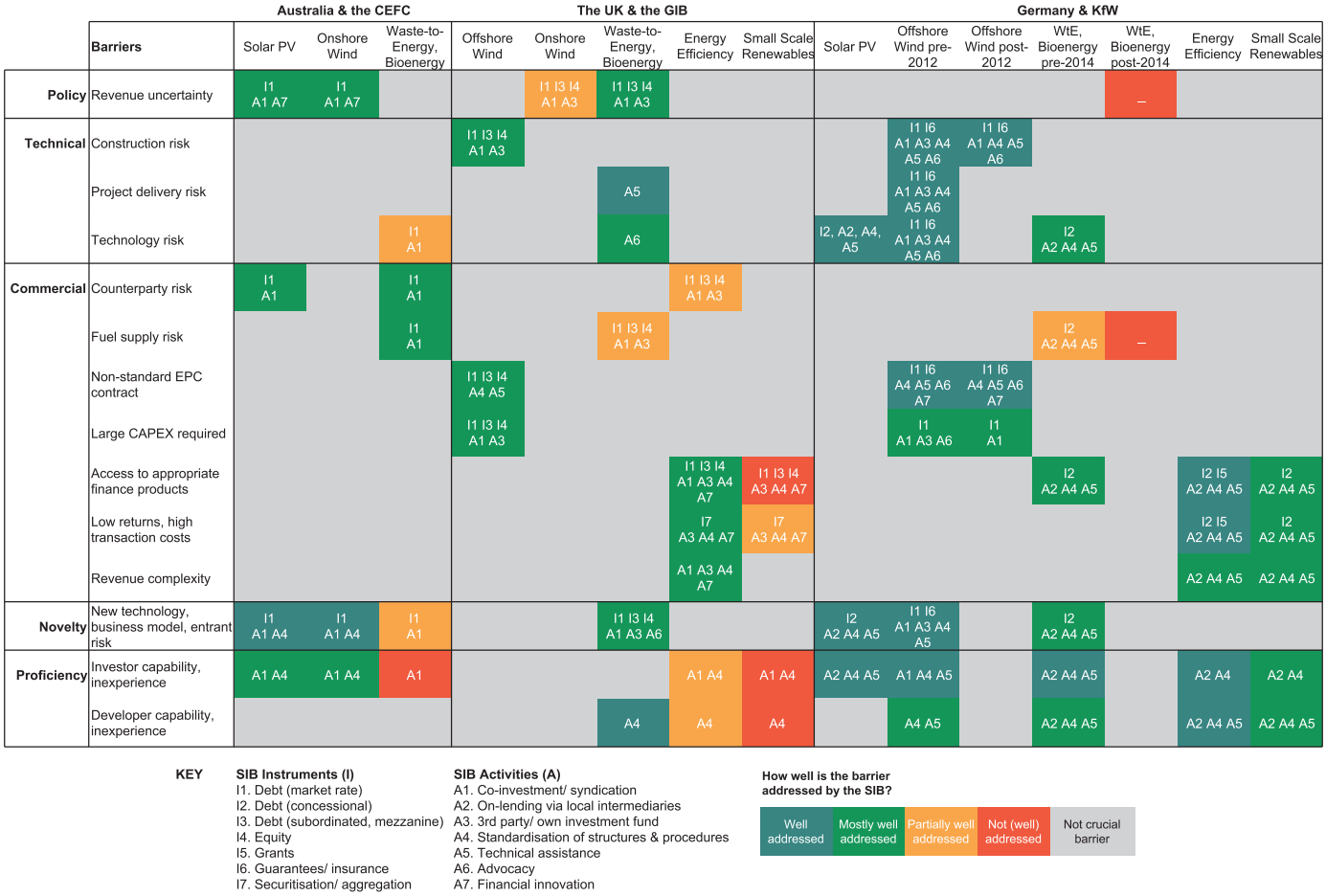

Fig. 2. *Summary of Results.* The crucial barriers to sourcing finance for developers are listed on the left-hand side of the figure, grouped into categories. The letters and numbers denote the instruments and activities supplied by the SIBs and the colour scheme represents how well the barrier is addressed by the SIB.

industry, showing banks and investors that projects displaying this risk can be successfully developed. The CEFC has also been working with developers and investors on an innovative loan product that would reduce the merchant exposure to a project, taking advantage of high power prices by charging higher interest rates into a reserve account and then lower rates if prices dropped. This is a direct result of the CEFC having developed specialist internal capabilities, having a good understanding of the risks involved in developing projects, and then leveraging these strengths to create innovative financial products.

Secondly there are other issues unique to Australian projects that increase the off-take counterparty risk, even for projects with long term PPAs. For instance, one solar PV-diesel hybrid plant developer was unable to arrange debt funding even while holding a long-term PPA, because the counterparty, a long-life mine, was located in a very remote location. The developer reported that *'if our counterparty fails, we can't evacuate our electricity to someone else. We would literally have to pick up our panels and move them thousands of kilometres to find another customer. The banks were not interested'*. This project, the first of its kind in Australia, was successfully developed with CEFC debt funding and now other remote businesses are initiating projects with similar settings.

Thirdly projects displaying new technologies, new business or income models and new entrants, such as first-time developers or equipment suppliers, have been unable to source finance in Australia due to the lack of a track record, something investors require. The CEFC has repeatedly taken the first or early mover role for new project settings. The CEFC agreed to debt fund one of the very first large-scale PV plants, which was also unable to source a long-term PPA, hence acting as an early mover both in terms of technology type and scale as well as in terms of project business model.[21] The CEFC also generates trust and increases legitimacy for new project settings. The bank announced its intention to provide debt to a world-first project featuring new technology combinations[22] in a remote desert location and developed by a family-owned company with little full-scale development experience. Having unsuccessfully tried to source bank debt for over a year, the CEFC announcement enabled the developer to attract equity and in turn an oversubscription of debt on even better terms than those offered by the CEFC. The CEFC funding was no longer required and the project was successfully developed without government funding. The mere announcement of the presence of the CEFC in a project 'signals' trust in a project and previously disinterested investors crowd-in.

Finally, due to the immaturity of the sector, Australia's investors are less experienced. By financing these projects and ensuring they are successfully developed, the CEFC is educating investors and helping them to become familiar with risks so they are more likely to fund projects in the future.

3.1.2. UK offshore wind developers and the GIB

UK offshore wind developers identified three main barriers to sourcing finance. The first concerns difficulty in sourcing enough funding, given the sheer scale of investment required. Secondly,

[21] New business model in this case refers to a business model that displays partial merchant market exposure. Previously business models featured no merchant market exposure due to having PPAs for the entire life of the project.

[22] Concentrated solar panels to desalinate water with cooling and heating systems for hydroponic agricultural greenhouses.

sourcing early stage finance from investors willing to accept higher construction risks is also a challenge. These construction risks arise from the technological and logistical challenges faced during construction in a hostile deep-water marine environment. A third barrier is the non-standard engineering, procurement and construction (EPC) contracting structures, compared to other infrastructure projects. The GIB has directly financed the construction of wind farms via equity and debt, simultaneously helping to fill the funding gap while showing a willingness to accept higher construction stage risks and non-standard EPC structures. Secondly, by providing equity,[23] the GIB has been able to attract cheaper private debt into the earlier construction stage of a wind farm project. This was the first of its kind in terms of the project financing structure and two other wind farms have since been financed in a similar fashion.

Developers also reported that the activities of the GIB Offshore Wind Fund were valuable in indirectly addressing the above issues. The Fund is the first of its kind to provide refinancing for operating offshore wind projects. Long-term institutional investors have a larger appetite to lend to operational projects, rather than to the higher-risk construction phase. The GIB Offshore Wind Fund crowds-in these investors to refinance operational wind farms, in turn freeing up capital from project developers and other early-stage investors with greater risk appetites so they can re-invest in the higher risk development and construction stage of projects. As one expert said, *'that fund really helps the (high risk) investors to recycle their capital…and there are lots of big pension funds… that really want to take a piece of that (operating wind projects)'*. Developers would like to see the GIB address construction risks more directly by supplying guarantees to help address the constant technological and logistical innovation that still occurs during the construction phase.

3.1.3. UK waste-to-energy and bioenergy developers and the GIB

Waste-to-energy (WtE) and bioenergy developers reported six major barriers to sourcing finance. Firstly, revenue uncertainty is a great issue with the sector experiencing changes to support level and scheme design.[24] Two additional issues exacerbate this policy-induced revenue uncertainty. Interviewees agree that many developers in this sector do not have the capabilities and experience required, also re-enforcing a third barrier, an increased risk in delivering projects successfully, especially under the tight deadlines imposed due to scheme changes. There can be a mismatch between what a smaller, inexperienced developer thinks is *'construction-ready'* versus what an investor thinks, and many developers do not achieve the due diligence level needed before a financier will commit funds. This is where the GIB played a key role, with the bank bringing its expertise to help developers meet their due diligence requirements in order to reach financial close, addressing the three barriers simultaneously. Interviewees reported that the GIB hired people with extensive experience from within the industry who are very familiar with project risks, engaged specialist funds, and put more man-hours into each deal than private institutions. As one developer put it *'the Green Investment Bank helps to come in and close these projects. I cannot emphasize how important it was for a lot of biomass and waste projects, because of the support deadlines…they were so strong'*.

Fourthly, many technologies, and developers, need to gain a better track record in the sector before they can attract finance. The GIB has taken a role as a first mover, investing in a successful biomass gasification project developed by a new, inexperienced developer who also utilised a new type of fuel. Once the first project was implemented, the developer was able to attract capital with ease for subsequent projects. As with the CEFC, biomass gasification developers found that when the GIB announced (signalled) they would finance a project, banks were soon competing to provide debt. As one investor reported, *'banking is about perception and perceived comfort with risks and if the Green Investment Bank has said that it's good then it's good. It is a huge deal'*.

Fifthly, investors still perceive certain technology risks as being too high. Some original equipment manufacturers (OEMs) in the waste-to-energy gasification sector were not providing guarantees on their specialised feed processing equipment; something that investors had indicated was necessary in order to more readily provide finance. The GIB actively lobbied these OEMs, who now provide such guarantees, essentially de-risking projects and making them more attractive to investors. Interviewees reported that the bank was instrumental in ensuring the guarantees were provided as a standard. Finally, developers report that investors still show concern around fuel supply risks and would like to see the GIB provide insurance or guarantees for fuel supplies. Developers cannot get feedstock contracts from forestry or farms for more than a few years and need longer contracts to source finance.

Finally although developers appreciated the general flexibility of the GIB in being able to offer both equity and debt type products, some biomass developers and sponsors reported that the GIB was willing to offer only equity in certain projects where they preferred debt. The developers and sponsors wanted to maintain ownership of such projects and saw this as crowding-out, given that they already had the capacity to maintain equity in such projects.

3.1.4. German wind developers and KfW

In the early days of Germany's offshore wind industry (prior to 2012), projects displayed a wide range of high risks and barriers to financing.[25] Projects exhibited high technology risks, and a lack of technical expertise and experience intensified construction and project delivery risks. High upfront capital costs and non-standard EPC contracts also proved to be barriers to sourcing finance. It was difficult to identify, assess and mitigate risks and developers found it very challenging to source finance. KfW IPEX recognised the expertise gap in the industry early and addressed this in several ways. It provided technical and risk advisory services in the industry as far back as 2004, having engaged its own internal engineers specialising in offshore wind projects to become familiar with the associated risks. KfW IPEX[26] invested in Germany's very first offshore wind farm commissioned in 2010 and has invested in every project since, working closely with developers and insurers to develop better contingency structures around the unique project delivery conditions. The bank requested early stage due diligence processes that helped developers, and investors, to better understand risks. OEMs report that KfW staff actively visit sites and investigate innovative technology to develop their expertise. As one developer said *'KfW know renewable energy inside out…they have a real technical grounding in understanding how renewable energy works'*.

It was not just developers who benefited from KfW IPEX's technical expertise. Banks especially had a lack of knowledge and KfW IPEX regularly took the lead role in syndicates, helping to educate participating banks on the risks involved. Interviewees described KfW IPEX as 'a real opinion leader' where they are known to be *'the technical bank'* in any consortium. IPEX's due diligence processes, risk assessments and registers are considered throughout the industry to be *'technically*

[23] Many investors and developers state that providing equity or other higher risk capital (mezzanine, sub-ordinated debt) sends a stronger de-risking signal to the market and helps crowd-in additional finance.

[24] For example in moving from ROCs to CfDs.

[25] Early projects saw vast delays and budget overruns due to the myriad construction and project delivery risks not being adequately addressed, such as wave heights causing delays, insolvencies during construction and inexperience with the non-standard EPC contracting setups.

[26] Before banks had become comfortable with the risks around offshore wind and developers were struggling to source the necessarily large volumes of finance, KfW IPEX recognised the huge funding gap at that time (2004–2012) and submitted a proposal to the KfW Group, requesting assistance to provide the additional funds. KfW responded by creating the KfW Offshore Wind Energy Programme, which supplied market rate debt for filling the financing gap in offshore wind projects. This in turn helped to bring in new private investors who saw this as a further de-risking signal for offshore wind projects.

excellent and accurate'. They then bring these processes and knowledge to other investors, helping them to become familiar with the risks.

Today Germany's offshore wind developers face similar issues as UK developers[27] however they report that they no longer struggle to source finance as they once did. Many developers said that KfW was no longer essential[28] in their industry with one saying *'are they even needed anyway to finance these projects now? Haven't they done their job already by sending those early signals?'*.

3.1.5. German large-scale solar PV developers and KfW

Germany's large-scale solar PV industry was still seen as an innovative prior to 2005, displaying higher technology risk and much higher costs than those seen today and investors, especially banks, were not familiar with the risks nor willing to invest. To address these barriers, KfW offered developers concessional fixed-rate, long-term debt via on-lending programs through local banks. The local bank is awarded a fee for 'originating' the deal and can choose to take a portion of the loan onto its own books, essentially risk-sharing the project with KfW. In addition, KfW provides standardised project risk assessment profiles and due diligence processes for the local banks to follow when considering whether to lend to a project. This simultaneously allows KfW to access local banks clients more easily, developers to receive cheaper debt while local banks familiarise themselves with the risks of projects. Developers reported that the concessional debt combined with the fixed-rate gave more favourable terms than the variable rates offered by banks and helped keep down capital costs. They report that from 2013 to 2016 there has been no lack of either debt or equity in the market and the costs for both have dropped. They also report that German banks are now so experienced at investing in solar PV that the market place has become very competitive. However they concede that concessional rates are no longer essential for the industry and may in fact start to crowd-out private finance.

3.1.6. German energy efficiency and small-scale renewables developers and KfW

Developers of both energy efficiency and small-scale renewables face similar barriers to sourcing finance.[29] Projects display low returns and high transaction costs compared to larger scale projects. Both investors and developers can lack experience and capability in terms of understanding project benefits and there can be some complexity in accurately pricing projects and their revenue streams. In addition there is usually a lack of appropriate fit-for-purpose finance products in the market. KfW addressed these barriers by harnessing the local banking network to channel its concessional debt products, and by providing grants for homeowners that were easily accessible on-line. These provisions allowed a very wide range of smaller to mid-sized beneficiaries, including individuals, co-operatives, SMEs and public authorities, to easily access a local supply of affordable and appropriately sized and structured finance. Utilising these local banks and an on-line portal to undertake transactions reduces transaction costs for KfW and standardised risk assessments and due diligence processes reduce transaction costs for the local bank, whilst they simultaneously become familiar with the risks involved. Inexperienced energy efficiency developers were also aided by KfW's advisory and technical support programs including the Energy Advice program that supports SMEs to work with external independently accredited experts for advice.

3.2. How well do SIBs address barriers to finance?

A summary of our results showing how and how well the three SIBs address the barriers faced by low-carbon energy developers in sourcing finance is shown in Fig. 2.

For large-scale solar PV and onshore wind the CEFC has addressed barriers to financing projects well by providing long-term debt financing to projects displaying revenue uncertainty, counterparty risk (solar PV) and risks involved with introducing novelty to projects.[30] But developers agree that provision of equity or higher risk debt by the CEFC would better assist in addressing revenue uncertainty, something the CEFC does not (yet) supply. Waste-to-energy and biomass developers' needs are not as well met, with smaller developers calling for better access to a wider range of capital products including equity and subordinated debt. Although the CEFC has provided long-term debt finance to projects displaying various risks that commercial banks have declined to finance (counterparty and fuel supply risks), the CEFC isn't addressing technology risk well. Some developers also felt that the CEFC wasn't as experienced or as capable of assessing risks around waste-to-energy & biomass projects as the UK's GIB who is considered to be excellent in this field[31] and that greater education of the investment sector is needed.[32]

The GIB's provision of market-rate and subordinated debt and equity for wind farm construction in conjunction with the finance recycling activities[33] of the GIB Offshore Wind Fund have addressed the range of risks and barriers to financing (construction and new technology risks, non-standard EPC and large capital expenditure barriers) for UK offshore wind farm development mostly well. Developers would like to see the GIB address construction risks more directly by supplying guarantees. Biomass and waste-to-energy project barriers and risks have been addressed well by the GIB, via technical support, the provision of a wide range of financial instruments and successful lobbying for technology guarantees. Provision of an insurance or guarantee type product would help address the remaining fuel supply risks. For energy efficiency, the GIB has managed to address a range of barriers and risks mostly well by using its highly skilled personnel and specialist funds to help set up, package and standardise structurally complex deals and aggregation and securitisation products. However developers are calling for a counterparty risk guarantee product and greater technical assistance to address the lack of capabilities. While the GIB has partially met some of the needs of small-scale waste-to-energy and bioenergy projects it has not had a significant impact on addressing barriers to finance among other small-scale projects.

As Fig. 2 shows KfW has supported a wider range of technology sectors than the CEFC and GIB and has addressed many of the barriers well or mostly well. The bank addressed a wide range of high risks and barriers faced by offshore wind developers in the early days of the industry well, leveraging on its technical expertise. Solar PV and early stage waste-to-energy and bioenergy project risks and barriers were also well addressed by KfW, thanks to its provision of concessional, fixed rate, long-term debt via on-lending programs through local banks. However today's waste-to-energy and biomass developers face revenue uncertainty (due to reducing policy support) and fuel supply risks and,

[27] They require large scales of finance especially for the riskier construction phase displaying non-standard EPC contracts.

[28] Developers report that private investors offer them better and more flexible terms and that dealing with a syndicate involving a state investment bank like KfW often *'takes too long'*.

[29] We have grouped these sectors together here because they face some similar barriers in sourcing finance although we recognise that from both a technology and financing point of view they are different.

[30] Novelty risk can refer to new technology, new business model and new entrant risks.

[31] While we were completing interviews for this work the CEFC announced the formation of the Australian Bioenergy Fund with the specialist fund manager, Foresight, who has had previous success in this sector in the UK with the GIB (CEFC, 2015b).

[32] At the time we performed this investigation the CEFC had not been very active in the energy efficiency and small-scale renewables sectors. It has since launched a range of funds and programs that involve co-lending with local credit institutions in order to make the funding more accessible to a wider range of beneficiaries as well as providing aggregation and securitisation products to help overcome investors' aversion to the low income, high transaction costs of these projects.

[33] The Fund crowds-in investors to refinance operational wind farms, in turn freeing up capital from project developers and other early-stage investors with greater risk appetites, so they can re-invest in the higher risk development and construction stage of projects.

because the German Government sees these sectors as less sustainable methods for energy production, developers receive much reduced KfW support. Finally, providing concessional finance via on-lending through local banks, offering grants via an on-line portal, and advisory and technical support allowed KfW to address barriers around sourcing finance for energy efficiency and small-scale renewable projects well.

3.3. Synthesis: the roles SIBs take to successfully address barriers to finance

By iteratively analysing and classifying key emergent 'themes' from our interviews, and systematically comparing these across each case and interview, we abstracted five pre-dominant roles taken by SIBs who successfully address barriers faced by developers sourcing finance.[34] We define a role as the function (based on observations of its activities in the market) an SIB assumes in order to catalyse finance for low-carbon projects.

3.3.1. Capital provision role

By taking a capital provision role, SIBs have successfully addressed investment gaps for projects with very large upfront capital costs as well as gaps that arose owing to reduced global and local investment activity due to the financial crisis (see 3.1.2 and 3.1.4). This finding substantiates work by Mazzucato and Penna (2016) that SIBs can successfully take a countercyclical role during times of economic downturn and supports the concept that public finance can help address structural barriers such as those around very high capital cost projects (Hall et al., 2015).

3.3.2. De-risking role

SIBs use their limited capital to also perform a de-risking role to mobilise private capital into low-carbon projects. Risk has a significant impact on financing costs and also plays an important role in determining whether a project is financed. There are distinct differences in the de-risking instruments these three SIBs have at their disposal. Whereas Germany's KfW maintains that a combination of concessional finance (e.g. 1–2% interest rates for energy efficiency improvements to households) and guarantees are the pillar of de-risking projects and mobilising private finance (Enting, 2013), the CEFC and GIB take a different route, where it is argued that providing de-risking instruments and capital at commercial terms sends a greater de-risking signal to investors that the projects they invest in are 'commercial' ready and bankable (see 3.1.1, 3.1.5 and 3.1.6. In addition, the wider range of instruments provided by GIB and the flexibility it shows in offering them is well suited to different developer types and their changing needs. Although the instruments on offer differ, all three SIBs have had major impacts through de-risking while taking on higher risk projects, indicating that the observations of Schmidt (2014) in developing countries also apply to OECD countries for new technologies.

3.3.3. Educational role

A third key role of SIBs relates to education, both internal to the SIB itself and external, of developers and financiers (see 3.1.3 and 3.1.4). SIBs foster specialist internal expertise, in order to better assess risks, create and standardise innovative de-risking instruments and then diffuse this new knowledge throughout the industry. Developers and investors repeatedly reported that SIBs actively employ highly qualified people so that they are specialists both financially (bankers and financiers) and technically (technology specialists and in-house engineers). SIBs also actively develop their internal capabilities[35] in areas where they may lack experience and knowledge. SIBs then harness their specialist internal capabilities to achieve several outcomes. Firstly they can focus on more accurately assessing the risks of (especially new and unproven) low-carbon energy projects and are known to spend more man-hours on transactions than commercial banks in order to do so. They apply their expertise to structuring investment deals in order to ensure the division of risk is spread in such a way that those involved are comfortable and ensuring risk is priced correctly, reducing the cost of capital. Secondly the SIBs and their specialist teams also innovate and standardise, creating new de-risking products, contractual structures and procedures in order to help projects become bankable. Then, in conjunction with technical assistance, SIBs can educate and support investors and developers by diffusing knowledge throughout the sector; helping investors better assess risk and become familiar with new projects while supporting developers with due diligence in order to reach financial close. The various activities captured under this education role heavily overlap and are interdependent.[36] Although the value of technical assistance provided by SIBs has been mentioned in the literature (Cochran et al., 2014) our findings highlight that an SIB's educational role takes many forms and that its importance and impacts have been previously underestimated.

3.3.4. Signalling role

SIBs have mandates to co-finance the majority of their larger-scale projects, ensuring they are not the sole debt or equity provider; they must directly 'crowd-in' additional finance. Where an SIB has successfully developed a reputation for expertise, there is an understanding within the investment community that the SIB's decisions to invest are worthy of trust. Hence when SIBs 'signal' they will participate in a project, soon after previously disinterested investors commit funding, sometimes even leading to an oversubscription of finance to that project that can lead to the exclusion of the SIB itself (see 3.1.1). An SIB's signalling role to directly crowd-in investors (based on its expertise and ability to create trust) has not been recognised in the previous literature. This trust generating and signalling role is especially powerful when an SIB also acts as a first or early mover in a project and is then able to bring private finance to projects containing novelty or innovation.

3.3.5. First or early mover role

Finally, SIBs are seen taking the risky role of 'first or early mover', investing in projects that in some way are among the first of their kind or contain some sort of novelty or innovation that is new to a country or its actors, such as a new technology, business model or a new entrant, such as a first-time developer or equipment supplier (see Sections 3.1.1 and 3.1.3 for examples). Debt providers in particular are risk averse and rarely adopt the role of first mover, preferring to see ample evidence of a track record before they will invest with one developer saying *'investment doesn't usually lead, it follows'*. When SIBs are a first or early mover in these projects, they do so to demonstrate a track record that shows the project can be developed successfully. As opposed to the signalling role, which crowds-in *directly* to a project, the first or early mover role only crowds-in private investment to *subsequent future projects*, having already established a track record. A demonstration role taken by some SIBs has been mentioned by Cochran et al. (2014) but in general the tendency of SIBs to take a first or early mover role, the subsequent crowding-in effect and the positive impact upon innovation diffusion has not been well acknowledged in previous work.

[34] This analysis and abstraction process compares to the Shaping Hypotheses step of Eisenhardt (1989).

[35] SIBs visit project sites to inspect new technologies, regularly interact with key stakeholders, join informal collaborations, such as the Green Bank Network and take part in SIB staff exchanges to share knowledge.

[36] SIBs work to diffuse both explicit and tacit knowledge to investors and developers. Standardisation allows the diffusion of explicit or codified knowledge (knowledge that can be precisely articulated and is easily communicated via written or verbal format) whereas technical assistance and other more demonstrative assistance allows the diffusion of tacit knowledge (knowledge that is more intuitive and experience based and is difficult to communicate via written or even verbal methods; it is more based on action and involvement) (Smith, 2001).

4. Conclusions and policy implications

As the study clearly shows SIBs are important actors in addressing the low-carbon financing gap in Australia, the UK and Germany. They *provide capital* and perform *de-risking*, but also go far beyond these activities. They take an *educational role*, building and developing their own capabilities in order to better identify, assess and mitigate risk. In doing this they create and standardise new knowledge with the dual aims to enable financial sector learning and support developers. Drawing on their reputation for expertise, SIBs also perform a *trust creation and signalling role* where their decision to support a project has a labelling effect and their presence directly crowds-in additional finance. Finally, leveraging on their capabilities and de-risking instruments to assess, take and manage risks, SIBs perform a *first or early mover role* by supporting risky innovative projects to create a track record which indirectly crowds-in private finance to future projects. In particular this work brings a spotlight onto the previously unrecognised *trust generation and signalling role* and emphasises the importance and impact of the *educational* and *first or early mover* roles, which are too often overlooked in previous work on SIBs.

Those policymakers considering following Australia, the UK and Germany in appointing a 'green' SIB to catalyse finance into low-carbon energy projects would need to consider a range of factors that can impact upon the roles an SIB performs. An SIB's mandate (e.g. technology focus areas, performance criteria, allowed de-risking instruments, conservatism of investment mandate etc.) has an impact, directing where an SIB provides its capital and how well it is able to perform de-risking. The set-up of a country's financial and banking system and how an SIB interacts with it affects both the type and size of project that can be financed, and how an SIB can diffuse new knowledge and educate its finance sector. Finally the source and amount by which an SIB is capitalised may limit the impact it can have in terms of mobilising capital, the width of its investment scope, and may impact upon its approach to risk.

Policy makers also need to consider the balance between public and private investment. Our work generally showed that KfW's provisions have played a part in making domestic wind and solar PV mature, to the point where private investors provide capital at low cost. Hence there is a question as to whether KfW is still necessary given the more mature stage of these markets and that it may be crowding-out[37] private finance. Offering inappropriate provisions, such as in the case of GIB offering equity to certain biomass developers and sponsors, who wanted to maintain equity ownership control of projects but needed debt, can also be seen as a type of crowding out (if the offerings are accepted). Our empirical evidence suggests that at earlier phases of a low-carbon technology's deployment, SIB provisions have not led to major crowding-out. However, to prevent this, if an SIB is deemed successful, such as KfW in Germany's solar PV and wind sectors, then its interventions need to be well designed in order to trigger an appropriate phase-out strategy (compare Rodrik (2014); Stiglitz (1993)).

Policymakers can think of SIBs as a key policy component within a country's overall energy policy mix. The German case indicates that KfW's widespread financing, in conjunction with policy support, was influential for the country's advanced stage of low-carbon sector development. Support schemes for renewables do not necessarily address all the barriers to financing projects. In the early phase of a technology's development in a country, feed-in tariffs for example provide revenue certainty but do not necessarily address novelty risk and the need for a track record. A first or early mover is required to produce a track record and this is one way SIBs prove useful as part of the policy mix. When a country later transitions between policy support schemes, such as moving from a feed-in-tariff to an auction scheme (onshore wind in the UK) or when renewable energy targets are being revised (the Australian case) SIBs can help address policy uncertainty. Ultimately, if designed carefully, SIBs can be a powerful tool to foster and diffuse innovation. To have mandates focusing on capital provision and de-risking is too narrow and innovation guidelines are needed in order to more broadly support the deployment and diffusion of innovation. Finally a policy mix that affects both the financial sector (e.g. Basel or national reforms, policies to mainstream green investment etc.) and the low-carbon energy technology system is needed to properly support energy system transformation; an SIB can be seen as a systemic instrument that effectively contributes to this policy mix (Wieczorek and Hekkert, 2012).

[37] KfW may be crowding out private finance in more mature markets, particularly with its concessional rates. Note that KfW also offers cheaper concessional finance to other countries including the UK, and that the GIB intends to eventually invest outside the UK. Although not investigated as part of this work, policy makers should consider the impact of cross-border SIB interventions in terms of crowding-out.

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Appendix A. Supplementary material

Supplementary data associated with this article can be found in the online version at http://dx.doi.org/10.1016/j.enpol.2018.01.009.

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