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A diverse and resilient financial system for investments in the energy transition

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Diversity makes the financial system more resilient. In addition, there is a diverse investment demand to make the transition to a more sustainable energy system. We need, among others, investment in energy transition, circular resource use, better water management and reducing air pollution. The two are linked. Making the financial system more diverse implies more equity, less debt, more non-bank intermediation and more specialized niche banks giving more relation-based credit. This will arguably also increase the flow of funds and resources to innovative, small-scale, or experimental firms that will drive the sustainability transition. Higher diversity and resilience in financial markets is thus complementary and perhaps even instrumental to engineer the transition to clean energy in the real economy.

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Introduction

A 'grand challenge' facing humanity in the 21st century, perhaps the biggest challenge humanity has ever faced, is to manage the energy transition to a more decentralized and renewable system [1,2••,3]. Technologically and energetically this transition is feasible and even economical [4,5•,6,7•]. Our modern economies have become completely dependent on a reliable and low-cost supply of heat, power and mobility, and fossil fuels still supply 80% of that demand [8]. This has to drop to 0% by 2050 to stay below the 2°C increase in global temperature compared to pre-industrial levels [4]. Transforming our energy systems into more decentralized and renewable energy sources will require a vast deployment of innovations and, accordingly, huge investment [5•,9]. Estimates for the total investment begin at about USD 700 billion [10] which amounts to a mere 1% of global GDP [6]. However, this amount simply pales in comparison to the daily trade in global financial markets[a] or total estimated financial losses in the 2008 crisis.[b]

There is no doubt that the financial sector could, in principle, finance the transition [11••]. But all too often, this is taken for granted in the literature [2••,12,13] neglecting underlying issues.[c] The financial system gives direction to the development in the real economy. Its traditional role is to mobilize and transform savings into productive investments [14] and the latter crucially includes investments in new capacities of existing firms, new ventures, new technologies and complementary assets such as infrastructure across a range of institutional and geographical contexts [15] that the transition to sustainability will entail [16,17,18•]. The real economy

[a] Reuters reports foreign exchange trade on a daily basis is about 3–5 USDtn: http://www.reuters.com/article/global-forex-volumes-idUSL5N1GK1F5. Adding global bond and stock markets and total bank credit would multiply that number manifold.

[b] Global financial losses in the crisis have been estimated at staggering numbers of 10–15 USDtn: https://blogs.wsj.com/economics/2012/10/01/total-global-losses-from-financial-crisis-15-trillion/.

[c] Theoretically there are *three* underlying problem categories. *First* consider the CO_2 abatement options that are in fact Net Present Value (NPV) positive under current circumstances [94]. With efficient financial markets, such opportunities should not exist, but they do, in fact [94–96]. Incentives and corporate governance structures of large, publicly traded companies focus typically on capital expenditure (CAPEX). Gains from clean energy investments typically come in the form of lower operational costs (OPEX) [48,97]. Any financial intermediary would be willing and able to finance these investments with debt. The collateral is high quality and OPEX reductions cover interest payments and installments. The short time horizon and high discount rates of most shareholders, however, make minimizing CAPEX more attractive than minimizing OPEX. In a *second* situation NPV is close to zero or context-specific. Such specificity can arise from asset complementarity in systemic interdependencies, e.g. (hybrid) electric vehicles and charging infrastructure [13]. Thus, (private) investors may shy away from otherwise perfectly functioning technologies. The *third* category includes deep uncertainty that characterizes (radical) innovation. In such cases an NPV simply cannot be computed [98,99]. While financial intermediaries are specialists in managing risk through diversification and trading, non-calculable uncertainty cannot be managed using advanced risk management tools [100]. If it does not fit the risk model, the dominant players in modern financial markets are unwilling, but also simply unable to engage.

has come to heavily depend on the smooth functioning of financial markets. Especially after the financial crises, a focus on risk reduction and stability is justified. But, paradoxically, minimizing financial risks at the micro level may expose the real economy to large climate risks.

Our contribution in this paper is that we synthesize the literature on clean-energy innovation and finance with a particular focus on innovation policy and financial market regulation, in order to understand why investment in the energy transition is lagging. We argue that innovation policy efforts alone would not be sufficient to jointly achieve financial system resilience and an innovation-led transition toward a sustainable economy. The two are rarely discussed in coherence, so here we identify a gap in the literature, and make the case for diversity as an important element that can both stabilize financial systems and foster funding of investment required for the energy transition.

In the remainder of this paper we first discuss the most relevant trends in the financial system. Then we propose policies promoting more diversity in the financial sector that would address both the valid concern for financial stability and mobilize more resources to promote the energy transition.

The financial system and the energy transition

Deregulation, globalization and consolidation waves in the financial sector since the mid-1980s have, perhaps paradoxically, exacerbated a trend toward a homogenous financial system which culminated in the financial crisis of 2007 [19]. Haldane and May [20] and others [21•,22] argue that part of the problem is the decline in diversity. It is not a problem per se that some intermediaries made mistakes and missed risks in their portfolio management strategies. A healthy ecosystem will simply flush out such faulty strategies through competition. The problem arises when all intermediaries start using the same strategies. Then risks, fully diversified at the micro level, become highly correlated across the system [23,24•]. In addition, a more diverse and therefore more competitive financial environment could actually reduce the capital costs of clean energy, given that capital markets function more efficiently when markets are contested [25].

The crisis caused a regulatory backlash prioritizing size and secure assets (e.g. highly rated government or blue-chip obligations) over diversity and more equity-like risk-bearing assets (e.g. Venture Capital (VC) in innovative startups). Regulatory and supervisory entities reacted to the crisis by banning or severely restricting complex financial products. They formulated stricter resolution mechanisms to reduce implicit public guarantees, requiring high reserves for assets deemed more risky and curbing perverse incentives such as excessive bonuses [26–28]. Some of these tighter rules and regulations are particularly likely to adversely reduce the flow of funds and intermediation to new ventures [29,30•,31•]. It is clear that investment through equity and equity-like interest-bearing assets is most urgently needed and best suited for innovative firms (see Figure 1). Such assets are typically deemed risky, also by regulators that require high reserves be held by both banks and institutional investors. In addition, such investors need to price their assets 'to market' and as these assets are only rarely priced in deep, liquid markets, it is even often outright impossible to invest in such asset classes. Thus, a system dominated by regulated banks and institutional investors is likely to underfund the innovations a transition requires.

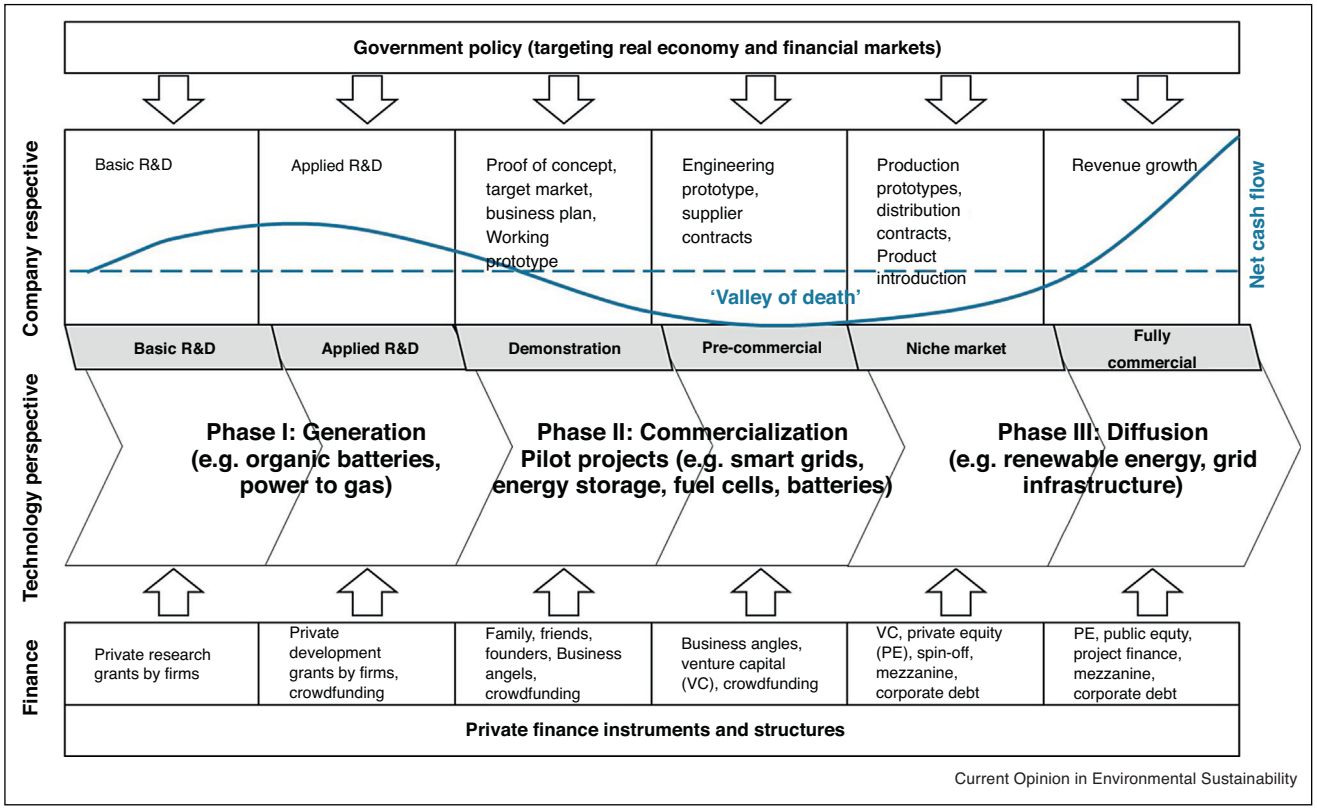
Financing early-stage clean energy innovation

In the early stages of the (clean energy) innovation cycle the challenges outlined above are partly overcome through R&D grants and early-stage investors (Figure 1). However, their size is small in comparison, given their importance in driving a transformation to clean energy [32,33••,34,35]. When it comes to early-stage finance, debt instruments are simply not available due to lack of collateral and track record [36]. Innovative firms often add market and technical uncertainty to the regulatory uncertainty. When investing in such ventures (also new business units by incumbent energy companies), intermediaries cannot rely on standard, modern risk-management techniques [37]. Instead they must establish trust in the investee through soft information and relationships or, alternatively, take a stake in the venture that also gives some control rights. This is what venture capitalists and business angels (and also friends and family) do [38•,39].

The problem with this model is that it cannot be easily scaled and involves large amounts of tacit knowledge in any single transaction. Moreover, the only countries in the world that can boast a significant VC and private equity (PE) market are the US, UK and Israel, where many complementary institutions support these sectors [40,41,42•]. In particular Europe, with its highly concentrated and regulated, bank-dominated financial system, channels only a very small and declining fraction of its savings through these PE intermediation channels (to clean energy) [36]. While PE firms are entrusted with funds by institutional investors such as pension funds or, more precisely, their asset managers and banks, the vast bulk of Europe's substantial savings surplus is invested directly by institutional investors and banks themselves. These intermediaries are reluctant and, given their regulatory and fiduciary constraints and accounting practices, even outright prohibited to engage with deep uncertainty such as VC/PE investments.

Fintech solutions, such as crowdfunding and peer-to-peer lending, are growing, yet channel relatively small fractions of savings into early-stage investments [33••,43•].

Figure 1



Financial instruments to finance clean energy innovation.
Adapted from [58,75].

Such investments for example amount to only 358 USDm [35] compared to 1658 USDbn in corporate debt to non-financial firms in Europe [44]. These funding platforms bring back the judgment call aspect of relationship banking and VC, but 'scale' the investment process through organizing the flow of information in a different, non-proprietary way [45]. By making their decision known to the rest of the investor community, crowdfunders seem to be a promising source of finance for the energy transition by enabling community finance of smaller RE projects [46•,47•].

Financing later-stage clean energy diffusion and infrastructure

The energy transition will inevitably feature significant investments in off-the-shelf technologies such as solar PV and wind that need to come from mature firms. In the later stage of the clean energy innovation cycle, additional sources of finance are available (see Figure 1) despite the fact that technology-specific problems such as long pay-back periods and policy uncertainty still prevail [11••]. The remaining regulatory uncertainty implies the default risk on any project is substantial and, importantly, not calculable. This implies credit ratings are low or absent and only (private) equity or junk bonds can channel savings into these types of investments. This also affects established companies engaging in the energy transition.

In developed economies, later-stage corporate finance mostly comes from insurers, banks or pension funds [34]. They finance larger, mature clean energy companies as well as projects and infrastructure with debt or equity. Debt investors do not receive dividends and do not benefit from higher profitability and cost reductions directly. So they care about the downside much more than they do about the potential upsides. Hence incentives for debtors are to reduce capital expenditure (CAPEX) and leverage to have a better credit rating and thus lower cost of capital, increasing the value of the stock in the short run [48]. Asset managers of institutional investors also do not have strong incentives to push for operational expense (OPEX) reductions if such investments do not translate into (quick) capital gains, as they are typically evaluated and rewarded comparing performance to market benchmarks with high frequency. However, more patient capital, for example, from state investments banks, finances large-scale infrastructure projects (e.g. for e-mobility or hydrogen) that are needed

to complement the decentralized energy transition [49]. In developing countries and emerging markets, on the other hand, financing of renewable energies takes on a very different stance. Given the lack of electrification in rural areas of regions such as India, Brazil or Sub-Saharan Africa, the decentralization of energy sources comes center-stage through off-grid energy supply. More importantly, this off-grid access to energy implies a very different, unscaleable business model that cannot rely on any conventional business-oriented financing source. Small-scale solar or wind projects are often funded through some co-operation between local project developers and public (development) banks, rather than multinational asset managers [15,50,51] or crowdfunding [52•].

The focus of the ecosystem for financing toward debt and later stages creates a bias toward calculable risks in incremental innovation and, importantly, the maintenance and expansion of the existing capital stock in existing firms. These incumbents have high-quality marketable collateral and established track records, but lack the incentive to introduce and diffuse true innovations, as they cannibalize existing profit flows [53]. For example, oil companies like Shell and Exxon only hesitantly engage in clean energy.

Policies to stimulate investments into clean energy

Central governments arguably have the means to break the 'lock-in' problems which favor fossil-fuel-based energy technologies [11••,54,55]. Mistakes, however, are terribly costly and can create new lock-ins for which politicians do not want to be held accountable. Sticking to the existing system may be more attractive, even at the country level, than running the chance of locking in to a losing technology. But there are some areas of policy where we do see some action.

Innovation policy

The obvious angle from which policy makers could approach the challenges for the energy transition is innovation policy [11••,12,55]. Market-based incentives such as GHG emissions-trading systems represent the theoretical optimum as argued by climate and energy economics since the early 1990s [56,57••]. However, due to the lack of global mechanisms, second-best instruments are required. To accelerate the diffusion of clean energy and associated investments, policy makers first could deploy technology-push mechanisms such as direct R&D investments, subsidies and tax-credits that target the early stages of the innovation cycle or early stage VC/PE which favors SMEs [32,36,58]. Direct investments and co-funding also mobilize private early-stage finance [59,60]. Olmos and colleagues [32] suggest public loans, or guarantees provided by public bodies backing private loans, along with public investments in the equity of innovating companies to accelerate the commercialization. By getting more involved in financing investments directly, the government would increase financial diversity, as the criteria and conditions under which such public funds become available will differ from those offered by banks and institutional investors today [55,61•].

Second, research conducted on clean energy diffusion and investment highlighted demand-pull policies mostly targeting the later stages of the innovation cycle [58,62,63]. Fiscal and financial incentives such as grants and subsidies [32,36,64] prove less effective than feed-in tariffs [65–68,69••] that also target smaller distributed capacity and early stage investments that again benefits smaller players [47•,70••]. To address network externalities and reduce private risks regarding complementary assets (e.g. infrastructure), public investments have been suggested [71,72]. The (quality) regulation of the (clean energy) portfolio and emission standards advances deployment of more mature technologies [73,74]. Systemic policies such as standard-setting, long-term planning and policy support accelerate both early and later investments [36,61•,75,76]. In particular, consistency, stringency and predictability to reduce deep uncertainty and policy risk are deemed crucial [77,78]. Overall, a policy mix is suggested to make the transition [79•]. Most of these policies, however, actually favor mature, established technologies geared toward the existing monoculture of debt-based financial markets.

Framework conditions and financial market regulation

Unprecedented monetary policies in the Eurozone (Quantitative Easing) have driven the cost of debt finance to zero or below and flooded financial markets with cheap debt finance. Still only very little of that monetary expansion finds its way into the real economy, let alone into clean energy [34,80••]. Instead, we argue that these policies tend to entrench the existing linear, carbon-based economy, as debt favors the low-risk status quo. More equity and, more specifically, PE investments are needed to finance uncertain but much-needed innovation (both for incumbent firms and new ventures). Hence, the less obvious but equally important angle from which policy makers affect private investment for clean energy consists of framework conditions and financial market regulation.

Framework conditions for either debt or equity-based instruments influence their contribution to a clean energy transition, as a developed capital market is needed to channel resources [42•,81]. Most importantly, a fiscal preferential treatment of debt finance, which is widespread today, should be avoided. Typically, interest is deductable as costs, while dividend payments only occur after tax. Policy makers should try to level the playing field across sources of finance. Hence a favorable tax policy could allow for tax deductibility of early-stage company investments [82,83]. A less stringent bankruptcy and labor market legislation would also promote entrepreneurship and

experimentation in sectors characterized by high uncertainty, such as cleantech [84]. Securities legislation should allow VC funds to sell parts of their investments [84].

Capital market regulation shapes investment mandates and risk models and thus ultimately determines the feasibility and viability of investments into clean energy [80••,85]. Regulation (e.g. Basel III, Solvency II), especially since the crisis, is almost exclusively geared toward stability and security [26,28,83]. Consequently, they encourage or force deposits into 'safe' asset classes and calculable risks, such as rated (energy) firms, government debt and real estate. Institutional investors and their intermediaries are forced to stay away from risky asset classes such as VC/PE [29,80••,86]. A solution would be to 'loosen' equity requirements for green investments specifically [80••]. But this would put the deposits and pension premium at risk. More fundamentally, one should therefore look for ways to clearly separate intermediation and investment from transactions and savings, as not all deposits are held for investment purposes [87]. A no-regret is to require financial intermediaries to lower their overall leverage ratio and operate with more equity [88]. With more skin in the game, banks and institutional investors can responsibly handle more risk and uncertainty on their balance sheets. The current practice of discriminating among asset classes (e.g. Basel III) on measurable risk seems to make perfect sense, until one realizes this inevitably works against innovative entrepreneurs, who face deep uncertainty and have no track record and collateral to secure their loans.

Alternative intermediaries such as VC/PE have also become regulated, for example through the Alternative Investment Fund Managers (AIFM) Directive, increasing reporting burdens and forcing funds to accumulate more capital to cover higher costs, hence reducing diversity in the system. Prospects for more VC/PE — or even more traditional friends, family and fools financing — is limited in the more egalitarian European welfare states as there are fewer wealthy private investors than in the US and UK who can freely invest their wealth [83]. Fiscal reforms in the tax treatment of private wealth, gifts and bequests and arms-length investments could go a long way to direct more (equity) investments to ventures and projects that would otherwise stay unfunded [89].

New alternative finance such as equity and debt-based crowdfunding could also benefit greatly from such reforms [90•], but instead are also becoming more regulated in many countries [91]. Regulators should abstain from clamping down on shadow banking and new forms of intermediation, for example through a regulatory sandbox [92]. This will prove harder than one might think, as the 'experts' in traditional banking and even PE and VC will warn for 'irresponsible risks' being taken there [93]. Moreover, ordinary people will lose money, inevitably creating political pressure for such regulatory tightening. It is more promising to be clear about the fact that such investments are not regulated and that investors willingly accept uncertainty and risk. As we have argued above, however, the volumes to be expected from these emerging intermediation channels are limited.

While many clean energy investments projects are economical, the question is why even these are not funded under record-low interest rates. This problem stems from unintended consequences of stability-oriented regulation that constrain existing intermediaries to channel funds to risky ventures and even long-term RE projects. In addition, this lack of transmission to the real economy stifles the effectiveness of monetary easing [80••]. To alleviate this problem of diffusion, together with issues of innovation financing, a more co-ordinated approach of policy measures is warranted. Such policies will result in a more diverse and therefore more stable financial system that at the same time channels more resources into the risky, but urgent, transition to a more sustainable real economy.

Conclusion

In this paper we show that in the discussion about mobilizing private finance for clean energy innovation, the literature has neglected the structure and regulation of financial markets as potential determinants. In order to mobilize resources to break out of the fossil fuel technology complex and to finance radical and transformative innovations, we need intermediation to take different channels (see Figure 1). More risk at the micro level in a more diverse financial system implies we stand a chance of avoiding macro catastrophe. While low-risk institutionalized debt finance is at best suitable to finance *diffusion* (but more likely channels our resources into the riskless reproduction of the status quo), a shift to more expensive and uncertain equity is needed to finance *innovation*. Financial market regulations are currently 'boxing in' intermediaries in a way that biases finance toward the status quo and it is not responding to the financial requirements of an innovation-led energy transition (e.g. early-stage risk capital, equity, risk-bearing debt, etc.).

Financial regulatory reforms could free up the resources in banks and institutional investors for more uncertain and equity-like intermediation. This may imply a shortening of bank and pension fund balance sheets and more risk landing with individual small-scale investors. But this risk will be rewarded in higher returns. The ensuing diversity in intermediation will increase financial resilience and shift the bias in intermediation (back to) the innovative experimentation we desperately need. Regulators, however, can also allow banks and intermediaries to take higher risks with their assets, *if* they compensate such higher risk with higher equity ratios. In the end, implicit and explicit guarantees for deposits and other debt liabilities on the banks' balance sheets must be

eliminated altogether. This sets the necessary preconditions for a more diverse financial sector in which all varieties of intermediation compete on a level playing field, and implicit public support for banks no longer tilts the system toward cheap debt finance of status quo assets. A more diverse financial system allows for an (easier) transition toward clean energy.

Conflict of interest

None declared.

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