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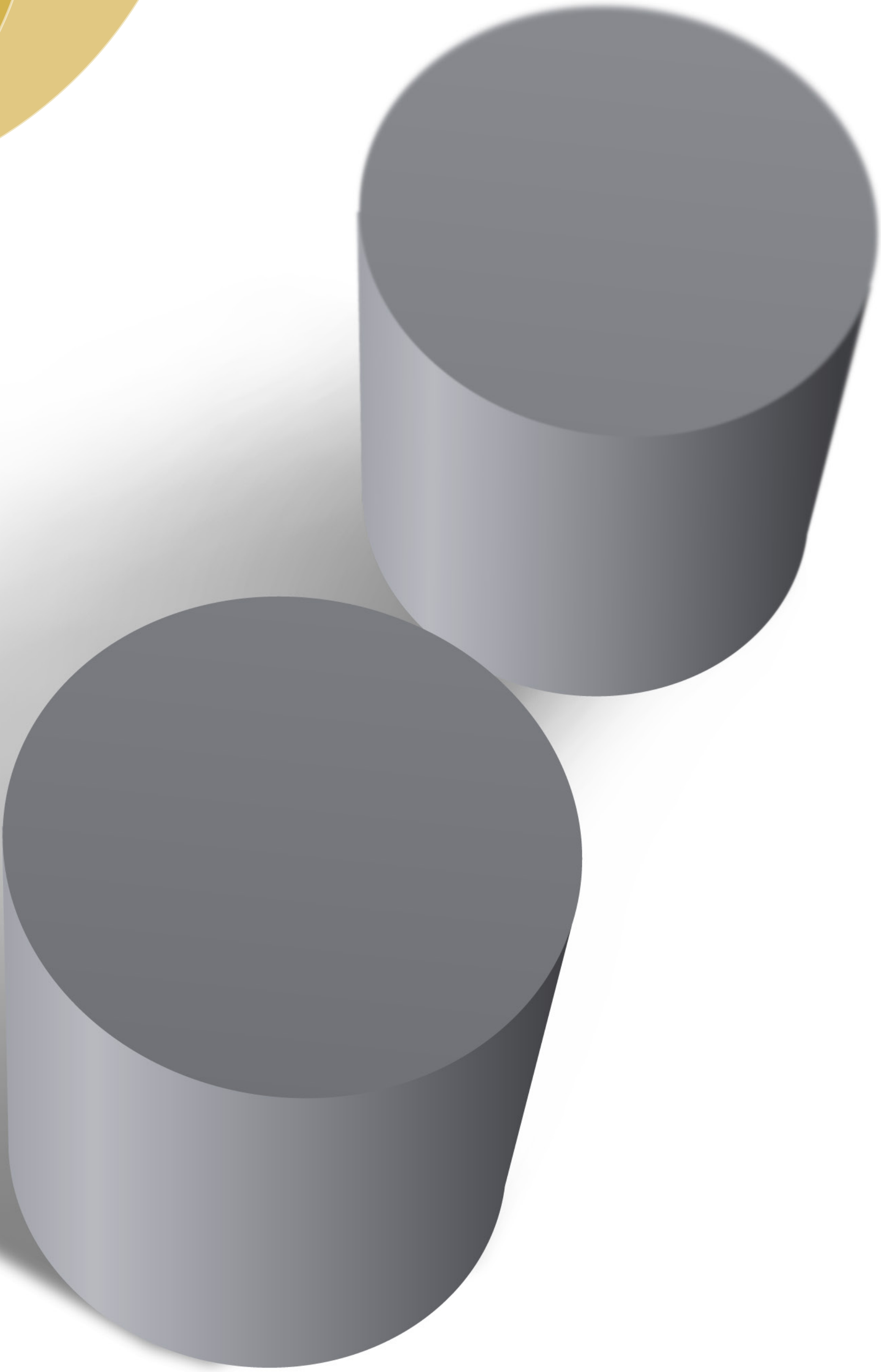

Drivers and Barriers for a Transition to a **Sustainable Energy System**

- An analysis of the electricity market

This report is a result of the broader cooperation between Growth Analysis and the Swedish Energy Agency on the future of the Swedish energy system. The purpose is to outline challenges and opportunities for low-carbon innovation throughout the electricity industry and presents a possible transition pathway to an efficient, low-carbon system.

growth analysis

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Foreword

A transition to a low-carbon energy system requires structural transformation of the electricity sector in addition to high penetration of renewable energy. Driving innovation in the system itself – in regulation, market structures, business organization, as well as in development and cost reduction of system critical components such as flexible dispatch, system capacity, and storage – is a significant challenge that carbon policies will not alone address. Design and implementation of targeted policy instruments will have to be a part of the mix, and there are many lessons to be learned from past experiences, in Sweden and elsewhere around the world.

This report is a result of the broader cooperation between Growth Analysis and the Swedish Energy Agency on the future of the Swedish energy system. The purpose is to outline challenges and opportunities for low-carbon innovation throughout the electricity industry and presents a possible transition pathway to an efficient, low-carbon system.

The analysis arrives at four main questions to address for the Swedish government and the Energy Agency in shaping the energy policy of the future:

- How can Sweden update its renewable policies and market structures to reduce the cost of capital-intensive renewable generation?
- Can the regulatory environment be modified to enable the theoretically attractive match between Swedish pension funds and renewable generation projects?
- How can Sweden capitalise on its balancing assets – in particular, its hydropower and growing electric vehicle fleet?
- How can Sweden accelerate technology innovation in electrical energy storage and transportation electrification?

Based on the analysis and modelling of market data from Europe and the US, the report also offers some recommendations for Swedish policy makers and agencies.

The report has been written by Climate Policy Initiative on commission from Growth Analysis. Project manager at Growth Analysis has been Martin Flack, Senior Analyst at the Innovation and Global Meeting Places division. CPI authors were Dario Abramskiehn, Donovan Escalante, Karen Laughlin, David Nelson, Uday Varadarajan, and Julia Zuckerman, all at the CPI office in San Francisco.

Stockholm, June 2014

Enrico Deiaco
Director, Innovation and Global Meeting Places
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Förord

Övergången till ett kolsnålt energisystem kräver utöver en hög andel förnybar energi också en genomgripande strukturomvandling av elsektorn. Innovation på systemnivå – i regleringar, marknadsstrukturer, företagsorganisation såväl som i utveckling och kostnadsminimering av kritiska komponenter som flexibelt kapacitetsutbud och lagring – är en betydande utmaning som inte kan hanteras enbart med generella styrmedel för att minska utsläppen av koldioxid. Utformning och implementering av riktade insatser kommer sannolikt också att behöva ingå i policymixen framöver. Rapporten diskuterar lärdomar som går att dra från tidigare erfarenheter, i Sverige och runt om i världen.

Rapporten ingår som ett underlag i samarbetet mellan Tillväxtanalys och Energimyndigheten om framtiden för det svenska energisystemet. Syftet är att beskriva utmaningar och möjligheter med innovation för kolsnål energiförsörjning, med fokus på elsektorn, och att skissa på en möjlig färdplan mot framtidens hållbara energisystem.

Analysen har resulterat i fyra centrala frågor för den svenska regeringen och Energimyndigheten att beakta i arbetet med att utforma framtiden energipolitik:

- Hur kan Sverige uppdatera politiken för förnybar energi och dagens marknadsstruktur för att minska kostnaderna för kapitalintensiv förnybar energi?
- Kan regelverken förändras för att möjliggöra den teoretiskt attraktiva matchningen av mellan de svenska pensionsfonderna och investeringar i projekt inom förnybar energi?
- Hur kan Sverige dra nytta av balanstillgångar i energisystemet – i synnerhet vattenkraften?
- Hur kan Sverige accelerera innovationstakten för lösningar inom energilagring och elektrifiering av transportsystemet?

Baserat på analyser och modellberäkningar av marknadsdata från USA och Europa presenterar också rapporten några rekommendationer för politiska beslutsfattare och myndigheter i Sverige.

Rapporten har skrivits av Climate Policy Initiative på uppdrag av Tillväxtanalys. Projektledare på Tillväxtanalys har varit Martin Flack, senior analytiker vid avdelningen Innovation och globala mötesplatser. Författare på CPI har varit Dario Abramskiehn, Donovan Escalante, Karen Laughlin, David Nelson, Uday Varadarajan och Julia Zuckerman, samtliga vid CPIs kontor i San Francisco.

Stockholm, juni 2014

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Summary

Today, electricity generation, transmission, distribution, and consumption represent trillions of dollars in investment around the world. However, the system is on the brink of a transition. Increasingly cost-competitive renewable energy technology, pressing environmental concerns, and changing customer needs are transforming how we make and use electricity. In Sweden, this transition is being accelerated by the uncertain future of nuclear energy and ambitious policy driving deployment of renewable generation.

The low-carbon transition has made significant progress already – not only in Sweden but in other parts of the world as well. Technological innovation has brought down the cost of renewable energy generation technologies, and carbon pricing regimes are changing incentives in some regions. But there is much more work to be done. A major overhaul of electricity industry design, along with hundreds of billions of dollars in new investment, is needed to make the electricity industry structure fit for the clean and efficient economy of the 21st century. The need to restructure and decarbonise the power industry is arguably the biggest climate change-related challenge facing developed countries.

Public efforts have focused on technological innovation and cost reduction in renewable energy generation, and innovation has brought down the cost of renewable generation technologies. However, innovation is needed across the rest of the system as well to drive accelerating deployment at an acceptable cost to governments and electricity consumers. Current market, regulatory, and business structures are designed to support the fossil fuel-based model of generation; they are not structured to achieve delivery of low-carbon energy at wide scale and low overall system cost. Moving to a low-carbon future requires coordinated innovation in markets, business models, and finance across the electricity sector.

This report outlines challenges and opportunities for low-carbon innovation throughout the electricity industry and presents a possible transition pathway to an efficient, low-carbon system.

Challenges and opportunities in the low-carbon transition

To make a successful transition, each of the five major business segments of the traditional integrated utility model – generation, transmission, market balancing, distribution, and customer management – face major challenges and requirements for new investment and restructuring. Transition to a low-carbon energy system will be impossible, or impossibly expensive, without addressing these challenges. This report focuses in particular on three of these challenges:

Challenge 1: Financing low-carbon generation efficiently

Technological innovation has successfully brought down the cost of power from some renewable energy technologies, but further financial and institutional innovation would allow the electricity system to reap greater benefit from these lower costs. In particular, wind and solar energy projects can provide clean electricity over long periods of time with low operational or technology risks. Well-designed policies take advantage of these low operational and technology risks to provide long-term revenue certainty, which in turn lowers the financial risk associated with wind and solar projects. Nevertheless, these projects pay higher financing costs than are justifiable given their low risk profiles. Our analysis shows that new financing models reflecting the underlying financial characteristics of low-carbon energy projects, as well as the requirements of investors such as pension funds and insurance companies for steady long-term returns, can reduce the cost of renewable energy by up to 20 per cent. These new business models have already begun to emerge in many countries, and policymakers have an important role to play in allowing them to thrive. They include:

- **YieldCos**: A YieldCo is a listed corporation that owns renewable energy projects whose generation has been bought up-front through a long-term power purchase agreement (PPA). YieldCos provide investors with a steady yield in exchange for an upfront payment. Risk is minimised because projects held by YieldCos have secured long-term revenues through PPAs and have a performance guarantee from the project developer or technology manufacturer.
- **Municipal or industrial-owned generation**: Industrial or municipal customers can purchase long-term power supplies through part-ownership of generation facilities. German municipalities have been key actors in financing and deploying renewable energy to meet their electricity demand.
- **Crowdsourced lending**: New platforms permit public investors to invest directly in (portions of) renewable energy projects, making new sources of capital available and lowering financing costs.

Challenge 2: Updating markets and business models to promote efficient investment in flexibility for a low-carbon grid

Meeting flexibility needs in a low-carbon electricity system requires changes in markets and business models for both conventional and low-carbon technologies that can adjust energy supply or demand to maintain a reliable power supply. Regulators will need to modify markets and create new ones to ensure that these resources are deployed cost-effectively to meet system needs, and to create incentives for development and deployment of new low-carbon flexibility resources. Promising pathways in market design and regulation include:

- Expanding energy markets and balancing systems to include additional power generation and balancing resources in the system
- Restructure electricity markets so that marginal-cost-based dispatching is only applied to generators with fuel costs
- Expanding the use of forward capacity markets for trading long-term resources
- Allowing price signals to reflect the true cost of generation will create incentives to invest in flexibility

Challenge 3: Changing the role of electricity customers

Most utility customers are passive users of electricity with little ability or incentive to adjust their usage in response to the needs of the electricity system. But innovative technologies such as smart meters and appliances, distributed generation, and electric vehicles are challenging the traditional passive model. Further innovation in market design and regulation would allow customer generation, storage, and flexible demand to substitute for fossil fuel generation as a grid flexibility resource, and could also help lower barriers to financing long-lasting energy efficiency measures. Customer-side innovations include:

- Public guarantees and risk-sharing facilities to reduce the risk borne by private investors and drive more private investment in energy efficiency
- Allowing demand response, energy efficiency and other demand-side resources to participate in wholesale markets for energy, capacity, and balancing services
- New models for competitive retail electricity providers to package services such as distributed generation, electric vehicles, and efficiency

New business models could bring down costs throughout the system

Based on the three challenges outlined above, we can sketch an outline of a generic future electricity system for the EU or U.S., presented in Figure 0.1. The various elements presented here can work together to mobilise renewable energy investment and incentivise investment in flexibility needed to integrate renewable energy into the grid.

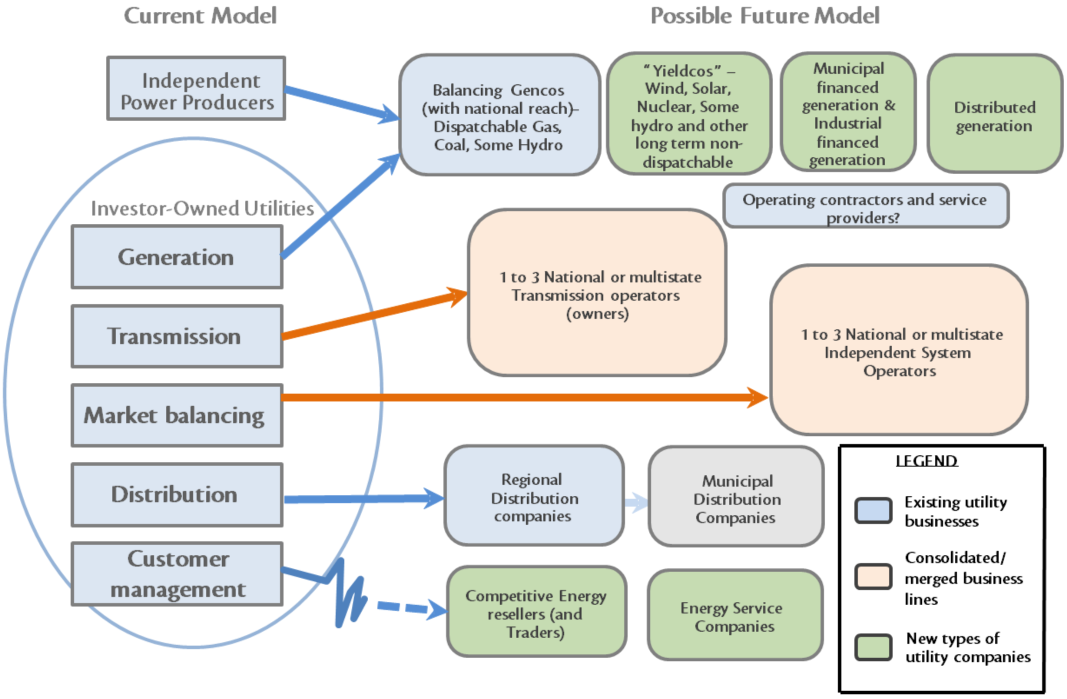


Figure 0.1 Moving to an efficient low-carbon system involves changes to institutions throughout the electricity system

This picture of a low-carbon electricity system includes changes to business models and market structures, building on trends that are already underway. In this report, CPI modelled a scenario that includes restructured electricity markets combined with new business models, in order to illuminate the potential impact of these new models on electricity prices and the economics of renewable and conventional electricity generation. We modelled an electricity market based on power plant and demand data from the state of New York, and separately modelled the impact of moving to new utility business models using data from a large European utility. The results of these modelling exercises are discussed in the following sections.

Changes in electricity markets

Renewable generators have effectively zero marginal costs, so the power they produce is used first, displacing higher marginal cost resources from the supply stack. The resulting decline in electricity prices has made other generators uneconomic, even if they are needed to provide reliability to the grid. The challenge is to create the right incentives to maintain investments in reserve capacity and flexible resources. Removing renewables from the wholesale energy market has been discussed as an option to address this challenge.

We find that **a separate market for renewables increases electricity prices but could make both renewables and flexible generation viable.** Separating renewables from wholesale energy markets eliminates renewables' price suppression effect, helping promote investment in flexible generation. In addition, the cost of renewable energy declines, since it is no longer exposed to the volatility of wholesale electricity prices and can therefore obtain financing at lower cost. This changes the risk profile of renewable energy projects and, therefore, investors' return requirements, helping to lower financing costs. This new structure thus creates a healthy market that can support both reliable supply and low-cost renewable generation.

Changes in business models for generation

Large, utility-scale generation will continue to play a role during a transition to a low-carbon electricity system. However, less of it will be fossil-fuel-based and less of it will provide dispatchable, flexible output. In a future electricity system, a larger share of electricity will come from renewable generators with long-term contracts. The remaining flexible, mainly fossil fuel generators will increasingly be valued more for their flexibility than for their total energy output. New business models will need to reflect these changes.

We find that **all the independent entities under the new model are financially viable, with the exception of nuclear due to its historical liabilities**. If the assets of a typical European utility were partitioned into potential new businesses, each new business appears to be financially viable, but may benefit from horizontal consolidation by merging with similar entities across Europe. Network and renewable assets are likely to see increased valuation in such a scenario, while fossil fuel assets may be an attractive acquisition target for private equity funds. Nuclear assets, however, are unlikely to be financially viable without government intervention, due to ongoing costs that include provisions for decommissioning and waste disposal.

Policy implications for Sweden

Sweden has already undergone a remarkable transformation from an oil-dependent economy to one that is largely fuelled by low-carbon energy. However, with the uncertain future of nuclear energy in Sweden and ambitious policy measures in place to increase the deployment of renewable energy, the Swedish electricity sector will soon be facing the challenges outlined above. Here, we outline some key questions for future work to assess opportunities to tackle these challenges in the Swedish context.

- *How can Sweden update its renewable policies and market structures to reduce the cost of capital-intensive renewable generation?* Changes to the Swedish electricity and renewable certificate markets are currently being discussed. It is important that any changes to the system reflect the challenges presented above, especially the issues regarding financing costs and increased incentives for low-carbon grid flexibility.

- *Can these changes be optimised to unlock Swedish pension fund financing for renewable generation?* With over SEK 1 trillion under management, Swedish pension funds could play a significant role in financing these shifts, if appropriate policy, regulatory, and market structures are in place.
- *How can Sweden capitalise on its balancing assets – in particular, its hydropower?* Higher penetration of intermittent renewable energy in Sweden and across the EU creates increasing value in flexible grid resources such as large-scale hydroelectric power and energy storage.
- *How can Sweden accelerate technology innovation in electrical energy storage and transportation electrification?* Sweden has a great deal of knowledge and competence in transport solutions that could be mobilized to innovate also in electric mobility. There are efforts in place, but the results so far have not been on par with the potential. Lessons from successful innovation in this space in the U.S., Japan and South Korea might be helpful in guiding Swedish efforts.

Sammanfattning

Investeringar i infrastruktur för produktion, överföring och konsumtion av elektricitet motsvarar runt om i världen idag tusentals miljarder kronor. Elsystemet är dock på väg in i en period av betydande omvandling. Allt mer konkurrenskraftiga förnybara energilösningar, växande miljöproblem och förändrade konsumentbehov driver förändringar i hur vi producerar och konsumerar el. I Sverige understryks denna förändring dels av kärnkraftens osäkra framtid och dels av en ambitiös politik för att främja utvecklingen av förnybar elproduktion.

Omvandlingen har redan kommit en bra bit på vägen, inte bara i Sverige utan i många länder runt om i världen. Teknisk innovation har pressat ner kostnaderna för förnybar energi och prissättning på utsläpp av koldioxid i vissa delar av världen förändrar relativpriser och incitament. Men mycket återstår att göra. Omfattande reformer, inklusive hundratals miljarder kronor i nyinvesteringar, kommer att krävas för att göra kraftindustrin anpassad för framtidens hållbara och resurseffektiva ekonomi. Behovet att bryta fossilberoendet i kraftindustrin är en av de viktigaste klimatrelaterade utmaningarna för utvecklade industrinationer.

Offentliga insatser har till stor del fokuserat på teknisk innovation för att sänka priset på den förnybara elen. Ett bredare perspektiv på innovation kommer dock att bli nödvändigt framöver. Dagens marknadsstruktur, affärsmodeller och regelverk byggdes för ett system baserat på stabil, fossil, energiproduktion, inte för framtidens system med växande andel förnybar, intermittent(variabel), produktion. Därför kommer även andra delar av energisystemet att behöva omvandlas för att kostnaderna för den nya energi som tillförs systemet ska bli acceptabla för såväl staten som för elkonsumenterna.

Denna rapport identifierar utmaningar och möjligheter för kolsnål innovation genom hela elsektorn och presenterar en möjlig färdplan mot ett framtida effektivt och hållbart elsystem.

Utmaningar och möjligheter med den kolsnåla omvandlingen

För att lyckas med denna omvandling krävs innovation och nyinvesteringar i samtliga fem segment av elindustrin: produktion, transmission, balansering, distribution och efterfrågan. Om inte dessa investeringar genomförs kommer omvandlingen att antingen vara omöjlig eller bli så kostsam att den inte blir genomförbar även om det är tekniskt möjligt. Rapporten fokuserar på tre centrala utmaningar i detta sammanhang:

Utmaning 1: effektiv finansiering av kolsnål elproduktion

Teknologisk innovation har framgångsrikt pressat ner priset på kraft från flera förnybara produktionsalternativ. Finansiell och institutionell innovation skulle öka de positiva effekterna av detta för elsystemet som helhet. Främst handlar det om sol- och vindprojekt som kan producera ren elektricitet över långa tidsperioder och till låg teknisk risk. Med stödsystem på plats som förmår dra nytta av denna låga risk (och kostnad) och som därmed möjliggör långsiktiga intäktsströmmar för investerare innebär detta också en låg finansiell risk som uppmuntrar till långsiktiga investeringar. I dag betalar dessa projekt en betydligt högre kapitalkostnad än vad som är motiverat utifrån den potentiellt låga riskprofilen.

Analyserna i denna rapport visar att nya finansieringsmodeller som reflekterar ovanstående resonemang, liksom behoven hos pensionsfonder och försäkringsbolag av långsiktiga, stabil avkastning, skulle kunna sänka kapitalkostnaden för förnybara elprojekt med så mycket som 20 procent. Dessa nya modeller har redan börjat utvecklas, och politiska beslutsfattare har en viktig roll att spela i att tillåta dem att växa ytterligare. Några exempel är:

- **YieldCos**: Ett YieldCo är ett företag som äger projekt inom förnybar energi vilkas produktionskapacitet har köpts i förskott genom så kallade power purchase agreements (PPA). YieldCo-företaget erbjuder investerare en stabil avkastning och minimerar risk genom att säkerställa den långsiktiga avkastning via produktionsgarantier från projektägarna eller teknikleverantörer.
- **Kommun- eller industriägd kraftproduktion**: Industrier eller företagskunder kan köpa långsiktig elförsörjning genom delägarskap i produktionsenheter. Tyska kommuner har exempelvis redan varit en nyckelaktör i energiomställningen genom att investera i förnybar energi för egna behov.
- **Crowdsourced lending**: Nya finansieringsplattformar möjliggör för offentliga investerare att investera direkt i projekt inom förnybar energi. Detta skapar tillgång till nya kapitalströmmar och kan sänka kapitalkostnaderna.

Utmaning 2: Uppdatera marknader och affärsmodeller för att underlätta och effektivisera investeringar i flexibilitet och elnät för kolsnål elproduktion

Ökad flexibilitet i elnäten kommer att vara en nödvändighet för omställningen av systemet mot ökad andel förnybar produktion. Detta i sin tur ställer krav på förändringar i marknader och affärsmodeller, som kan matcha utbud mot efterfrågan och tillförsäkra en stabil elförsörjning. Några exempel på vägar framåt är följande:

- Utvidga energimarknader och balanseringssystem till att inkludera ytterligare produktions- och balanseringsresurser i systemet.
- Strukturera om elmarknaderna så att marginalprissättning endast tillämpas där produktionskostnaden styrs av bränslepriset.
- Bygga ut användandet av terminsmarknader för handel av långsiktig produktionskapacitet.
- Att tillåta kostnadssvängningar på produktionssidan att reflekteras i konsumentpriser i högre utsträckning skapar incitament att investera i flexibilitet.

Utmaning 3: Konsumenternas förändrade roll på elmarknaden

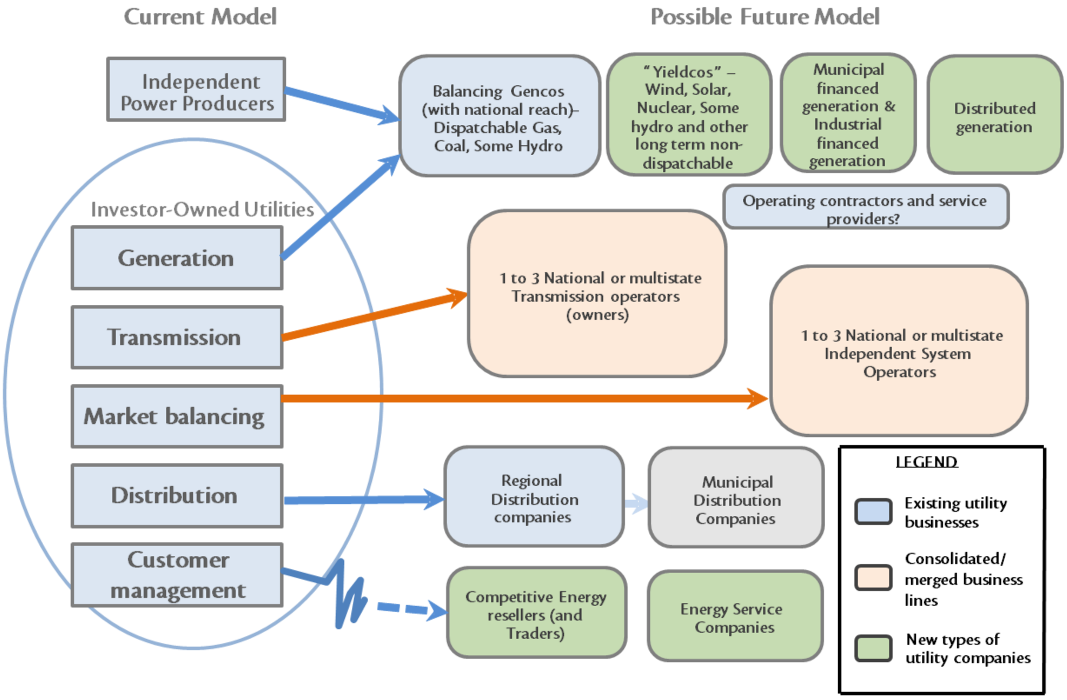
De flesta kunder är passiva användare av elektricitet med begränsade möjligheter eller incitament att förändra sin elanvändning beroende på situationen i elsystemet i stort. Med ny, innovativ teknik såsom smarta mätare och hushållselektronik, distribuerad produktion och elfordon utmanas denna traditionella, passiva modell.

Ytterligare innovation i marknadsdesign och reglering skulle kunna öka möjligheterna för konsumenter att bli producenter (prosumenter), öka möjligheterna till distribuerad lagring och öka möjligheterna att genom flexibel efterfrågan ersätta fossil energi med förnybar som flexibel resurs i elsystemet. Detta skulle också bidra till att sänka barriärerna för investeringar i långsiktiga åtgärder för energieffektivisering. Några exempel på sådana innovationer är:

- Offentliga garantier och riskdelning för att minska den privata risken och därigenom stimulera privata investeringar i energieffektivitet.
- Tillåta demand response (efterfrågejustering), energieffektivitet och andra åtgärder på efterfrågesidan att inkluderas på grossistmarknaden för energi, kapacitet och balanseringstjänster.
- Nya modeller för återförsäljare att erbjuda pakettjänster inom exempelvis distribuerad produktion, elfordon och energieffektivitet.

Nya affärsmodeller kan sänka systemkostnaderna

Baserat på utmaningarna ovan kan vi formulera en förenklad bild av ett möjligt framtida kolsnålt elsystem, vilket presenteras i figuren nedan. De olika delarna som ingår i systemet kan tillsammans bidra till att mobilisera investeringar i förnybar energi och skapa incitament till den ökade flexibilitet som krävs för att den förnybara energin ska kunna integreras i elnätet.



Figur 0.1 Vägen till ett effektivt, kolsnålt elsystem kräver reformer inom alla systemets delar

Figur 0.1 ovan bygger på modellberäkningar som inkluderar förändrade affärsmodeller och marknadsstrukturer, vilka till viss del redan har påbörjats. Syftet med illustrationen är att understryka betydelsen av dessa förändringar för elpriser och den ekonomiska bärkraften för förnybar respektive konventionell elproduktion. Beräkningsresultaten diskuteras mer ingående i följande avsnitt.

Förändringar på elmarknaderna

Producenter av förnybar elektricitet har i praktiken noll marginalkostnad, vilket betyder att den kraft de genererar alltid konsumeras först. När produktionen av förnybar el är hög innebär detta att den dyrare elen från andra delar av systemet blir överflödig och de kraftverk som genererar den måste stängas av. Det innebär också att genomsnittspriset för elen sjunker, och därmed även lön samheten för de etablerade elbolagen och. En sjunkande lönsamhet för riskerar att underminera systemstabiliteten, om inte lämpliga incitament kan skapas för dem att bibehålla en tillräcklig kapacitet av flexibel baskraft. Ett alternativ som diskuterats är att helt separera den intermittenta förnybara elen från basnätet.

Av våra analyser framkommer att en **separat marknad för förnybar el skulle öka elpriserna men också att detta skulle kunna göra både förnybar och konventionell elproduktion ekonomiskt hållbar**. Att separera förnybar el från grossistmarknaden innebär att den prisdämpande effekten för konventionell el uteblir, vilket undanröjer viktiga hinder för investeringar i förnybar teknik. Dessutom minskar kapitalkostnaderna för den förnybara energin eftersom den inte längre påverkas av prissvängningarna på den ordinarie elmarknaden. Därmed förbättras riskprofilen och projekt för utbyggnad av förnybar energi kan få tillgång till kapital till lägre ränta.

Denna nya struktur möjliggör således en hälsosam marknad som kan stödja både ett stabilt utbud och förnybar elproduktion till låg kostnad.

Förändringar affärsmodeller för elproduktion

Storskalig, centraliserad, elproduktion kommer att fortsätta spela en viktig roll under övergången till framtidens kolsnåla energisystem. I utvecklingen ligger dock en minskad andel fossil energi samt, i takt med att den förnybara elproduktionen växer, minskade möjligheter att kontrollera utbud för att möta efterfrågan. I framtiden kommer således en allt större del av utbudet att levereras av producenter av förnybar el genom långa kontrakt. De kvarvarande, i huvudsak fossila, produktionsenheterna kommer att värderas i första hand för flexibilitet än för den volym de levererar. Nya affärsmodeller kommer att behöva reflektera dessa förändringar.

Våra analyser visar att **alla de aktörer som ingår i den nya modell som skisserats ovan är finansiellt hållbara, undantaget kärnkraften som påverkas negativt av historiska belastningar.** För ett representativt Europeiskt elbolag som delas upp i de nya potentiella affärsområdena tycks alltså samtliga områden vara lönsamma. Samtidigt uppstår horisontella konsolideringsfördelar mellan liknande aktörer inom samma affärsområde i Europa.

De områden som tjänar mest, i termer av vinstmöjligheter och finansiellvärdering, på en omstrukturering av marknaden är nättillgångar och den förnybara elproduktionen, medan tillgångar inom fossil elproduktion framstår som attraktiva uppköp för privata aktiefonder. Som nämnt ovan är kärnkraftstillgångar den stora förloraren på en segmentering av elmarknaden – dessa kommer troligen inte att ses som attraktiva investeringar utan statligt stöd.

Policyimplikationer för Sverige

Sverige har redan genomgått en omfattande reformering, från stort oljeberoende före 1970-talet till huvudsakligen fossilfri energi idag. I den framtida utvecklingen växer dock ett antal utmaningar fram, i synnerhet i samband med den osäkerhet som råder vad gäller kärnkraftens framtid samt kring effekter och kostnader av de ambitiösa satsningar som genomförs för att främja utbyggnaden av förnybar energi.

Här presenteras fyra centrala frågeställningar, mot bakgrund av dessa utmaningar, att beakta i arbetet med att utforma framtidens svenska energipolitik.

- *Hur kan Sverige uppdatera politiken för förnybar energi och dagens marknadsstruktur för att minska kostnaderna för kapitalintensiv förnybar energi?* Förändringar av det svenska elcertifikatsystemet diskuteras för närvarande och kommer sannolikt att bli nödvändiga framöver. Det är viktigt i detta sammanhang att de utmaningar som presenteras här ovan beaktas, i synnerhet när det gäller metoder för att minska kapitalkostnaderna och att skapa incitament för ökad flexibilitet i elförsörjningen.
- *Kan dessutom dessa förändringar, och andra instrument, anpassas för att tillgängliggöra medel från pensionsfonderna för investeringar i förnybar energi och energisystemutveckling?* Med över 1000 miljarder kronor i förvaltade medel kan pensionsfonderna spela en avgörande roll för energisystemets omställning, förutsatt att rätt politik, regelverk och marknadsstrukturer kommer på plats.
- *Hur kan Sverige dra nytta av balanstillgångar i energisystemet – i synnerhet vattenkraften?* Högre andel intermittent förnybar energi i Sverige och i övriga Europa medför ett ökat värde för energislag som kan användas för att flexibelt balansera energiutbudet, såsom storskalig vattenkraft och energilagring.

Hur kan Sverige accelerera innovationstakten för lösningar inom energilagring och elektrifiering av transportsystemet? Sverige har en stark kompetens och konkurrenskraft inom transportområdet som skulle kunna mobiliseras för att utveckla fler nya lösningar inom elektrifiering. Vissa insatser finns redan på plats men resultaten har ännu så länge inte levt upp till potentialen. Lärdomar från framgångsexempel i USA, Japan och Sydkorea skulle kunna vara vägledande för utformningen av nya policyinitiativ på området.

1 The low-carbon transition requires innovation in technology, finance, and policy

Today, electricity generation, transmission, distribution, and consumption represent trillions of dollars in investment around the world. However, the system is on the brink of a transition. Increasingly cost-competitive renewable energy technology, pressing environmental concerns, and changing customer needs are transforming how we make and use electricity.

Transitioning to a low-carbon electricity system at a politically viable cost will require innovations across the system – including new technologies, new regulatory and market structures, and new business models. The low-carbon transition has made significant progress already – technological innovation has brought down the cost of renewable energy generation technologies, and carbon pricing regimes are changing incentives in some regions. But there is much more work to be done.

Based on publicly available data, current investment in low-carbon innovation totals approximately $340 billion, mostly focused on commercialization and deployment. CPI analysis suggests that private investment in low-carbon innovation could potentially reach as much as $2 trillion for large-scale renewable energy alone if barriers to investment were removed (Climate Policy Initiative 2013a).

In conjunction with increased investment in low-carbon technologies, a major overhaul of electricity industry design, along with hundreds of billions of dollars in new investment, is needed to make the electricity industry structure fit for the clean and efficient economy of the 21st century. The need to restructure and decarbonise the power industry is arguably the biggest climate change-related challenge facing developed countries.

This report outlines challenges and opportunities for low-carbon innovation throughout the electricity industry and presents a possible transition pathway to an efficient, low-carbon system.

Table 1.1 The low-carbon transition requires innovation across each business segment of the electricity system

Business segment	Examples of technological innovation	Examples of financial and institutional innovation
Generation	Renewable energy Carbon capture and sequestration Nuclear?	YieldCos Municipal finance Utility restructuring
Transmission	High-voltage DC Supergrids	Continental grids Financial transmission rights Locational pricing
Market balancing	Electricity storage Demand forecasting Improved control	New pricing models Ancillary service auctions Independent System Operators
Distribution	Distributed generation Integrated control at local level Microgrids	New distribution company models
Customer management	Electrification of services Sophisticated metering, pricing, and information services	New Energy Service Company models Integration with other markets

The electricity industry comprises five business segments (see Table 1.1) – each of which will see both technological innovation and financial and institutional innovation as part of the low-carbon transition. Table 1.1 gives examples of each type of innovation across each business segment.

Moving to a low-carbon system requires two distinct but interdependent forms of innovation. Through technological innovation, more low-carbon technologies enter the system and reach commercialization and broad deployment as their prices fall. Through financial and institutional innovation, business models, markets, and policy and regulatory structures evolve to meet the needs of a low-carbon system and lower the cost of transition. The following sections discuss each type of innovation in the context of the low-carbon transition.

The remainder of Section 1 describes current and potential investment in technological low-carbon innovation in the EU, U.S., Brazil, China, and India and outlines current challenges to financial and institutional innovation in the electricity systems of the EU and U.S. Relevant insights from the innovation literature are also highlighted in boxes throughout this section. Section 2 lays out the progress of technological, financial, and institutional innovation across the system and the opportunities to further enable innovation for an efficient, low-carbon system. The discussion centres on three main challenges: (1) Financing low-carbon generation efficiently; (2) Updating markets and business models to promote efficient investment in flexibility for a low-carbon grid; and (3) Changing the role of electricity customers.

1.1 Technological innovation: Investment has focused on late-stage deployment

The technological innovation cycle can be divided into three segments: research and development (R&D), early commercialization, and commercialization and deployment (C&D). At each stage, low-carbon technological innovation must meet the objectives of both policymakers and investors. Policymakers need policy to (1) meet energy and environmental goals, (2) reduce technology costs to provide value to the economy, and (3) minimize the impact on public budgets by involving private capital. Investors need to (1) achieve an adequate return given the risks of their investment at each stage of development, and (2) create a sustainable advantage for themselves in a new and profitable business line. Driving continued innovation in low-carbon technology requires public support in many forms – including not only direct investment by governments, but also changes in policy and regulation to encourage private investment and lower barriers that stand in its way.

Understanding how and why different private-sector entities invest in certain stages and technological areas of innovation is critical to formulating policy that can unlock the greater pools of potential capital for innovation for a low-carbon transition. This section introduces the different types of investors involved in financing low-carbon innovation and describes current investment trends and potential capital that could be mobilized for each stage of low-carbon technological innovation.

1.1.1 The universe of investors in technological innovation

Figure 1.1 shows the universe of investors typically involved in innovation. Research and development are primarily financed by government and corporate investment. High uncertainty about outcomes or benefits and a long time frame until commercial payback creates risks at this stage that weaken private sector incentives and raise the need for government investment. R&D investment is based on long-term commercial benefits but can also be based on social benefit (Climate Policy Initiative 2013b).

Commercialization and deployment (C&D) are largely financed by institutional investors, banks, corporate balance sheets, and government instruments. Venture capital (VC) funds and angel investors (a subset of high net-worth individuals, or “HNW”) play a unique role in financing early commercialization. During C&D of low-carbon energy, payback periods begin to shorten and commercial incentives strengthen private response. Earlier stages may continue to depend on confidence in public support; later stages can build their own momentum, although public support still may be required to reduce risks or improve economics (Climate Policy Initiative 2013b).

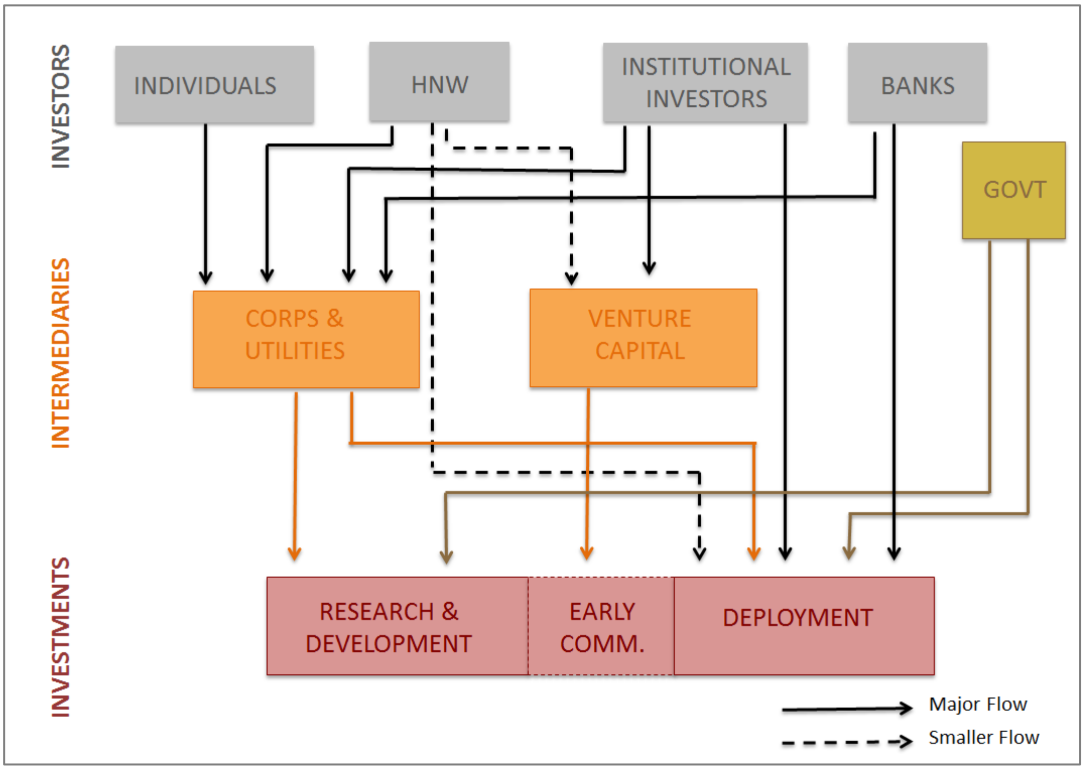


Figure 1.1 Different investors fund each stage of innovation

1.1.2 Investment trends along the stages of technological innovation

Research and development (R&D)

Net global government and corporate R&D investment in low-carbon generation has continued to increase since 2004, almost doubling by 2012 at $9.6 billion (Frankfurt School-UNEP Centre/BNEF 2013). While estimating the required amount of R&D investment specifically is beyond the scope of this work, $9.6 billion per year is still a very small share of the $5 trillion in investment through the end of this decade IEA estimates is required to limit temperature increase to 2 degrees C. Numerous observers have concluded that worldwide R&D expenditures in low-carbon energy are well below levels seen in closely related industries and therefore likely far from adequate to drive transformative change (Nemet and Kammen 2007). Table 1.2 summarises current trends in major economies around the world.

Table 1.2 Current low-carbon technology R&D trends in major economies

Region	R&D Trends
EU	European investment in R&D remains the highest in the world with corporate investment outstripping government investment in R&D by $7 billion (Frankfurt School-UNEP Centre/BNEF 2013)
U.S.	For the third year in a row, U.S. government and corporate R&D investment in clean energy remained roughly even, increasing by 2% and 3%, respectively (U.S. Department of Energy 2011; Frankfurt School-UNEP Centre/BNEF 2013)
Brazil	Biofuels continues to receive a large portion of Brazil's R&D investment Transmission and distribution R&D investment has seen an upward trend since Brazil's Act 9,991 of 2000 which establishes the mandatory application of 1% of annual net operating revenue of concessionaires, permitees, and licensees in Brazil's power sector
China	In 2012, China led the world in government R&D investment at $1.4 billion and leads the world in total solar R&D investment at $1.3 billion between corporate and government investment ($360 million and $927 million, respectively) (Frankfurt School-UNEP Centre/BNEF 2012)
India	India's government R&D investment in nuclear energy far outstrips all other R&D programs In 2008/2009, transmission and distribution, solar, and bioenergy received between $10–40 million in R&D investment

Insights from innovation research: Successful commercialization of an innovative technology can slow further innovation

Solar and wind generation technologies have both seen diminished investment in further research and development (R&D) during periods of rapid growth in deployment and decline in unit costs (Nemet 2009). Growing deployment also tends to lock in current technologies and market structures, as novel technologies that cannot currently compete in the market have difficulty attracting further investment (Zheng and Kammen 2014).

In part, this dynamic may reflect that superior technologies out-compete others – for example, as 3-blade upright wind turbines came to dominate the wind power market, innovation in wind power shifted from exploring alternate turbine designs to refining the 3-blade design (Nemet 2009). However, the cost to the system going forward could be significant, if the decline in R&D detracts from the development of the next wave of innovative technology.

Corporate R&D budgets and capital expenditure data for major listed corporations indicate that globally roughly $0.5–9 billion is available today for all balance sheet-financed R&D from utilities, and $4–31 billion from the oil and gas industry (estimates in 2013 USD) (CPI analysis based on: Rystad Energy 2014; European Commission Joint Research Centre 2013; Hirschey, Skiba, and Wintoki 2012; Bloomberg data).[1] While this provides a broad

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[1] Listed utilities make up approximately one-third of utilities, so the $0.5-9 billion figure is highly conservative. Globally, major listed corporations in the utility sector and the oil and gas sector average from 0.02% to 4% and 0.5% to 3.5%, respectively, of their corporate budgets on R&D (European Commission Joint Research Centre 2013; Hirschey, Skiba, and Wintoki 2012). High estimates of R&D budget shares are more reflective of high R&D investors in the utility and oil and gas sectors — they are derived from data in the EC Joint Research Centre's 2013 EU Industrial R&D Investment Scoreboard, which tracks the world's top 2000

starting place for understanding the potential capital available on corporate balance sheets for low-carbon energy R&D, further analysis is required to determine how much capital is available for allocation to low-carbon R&D investment.

Comprehensive, regularly reported data on R&D investment in low-carbon generation technologies are available for OECD members but not consistently for emerging economies. Even for OECD countries, studies vary in their estimates of total R&D. Without more regular, system-level analyses of low-carbon energy system R&D across major economies, R&D investment guidance based on robust analysis will continue to be a challenge.

Early commercialization

The last decade saw a boom and subsequent bust in venture capital and angel funding for early commercialization of low-carbon technology around the world – a funding role that is rapidly evolving due to the lessons learned. Venture capital funds and angel investors are the typical investors at this stage of innovation. Both look for short-term, small-scale investment in technologies with high potential rewards.

In the 2000s, clean tech venture funds and angels invested heavily in low-carbon technologies to generate electricity and fuel. The long lead times, high capital requirements, and long-term returns of these projects made them ill-suited to venture capital investment profiles. Surviving clean tech venture funds and angels have shifted their low-carbon investment strategies accordingly: They are shifting away from capital intensive investments and increasingly focusing on shorter-term, small-scale investments in consumer-facing products and services, as evidenced by the domination of the energy efficiency and transportation spheres in the top deals over the last two years (see Figure 1.2) (Cleantech Group 2013). The United States continues to dominate clean tech venture capital investment.

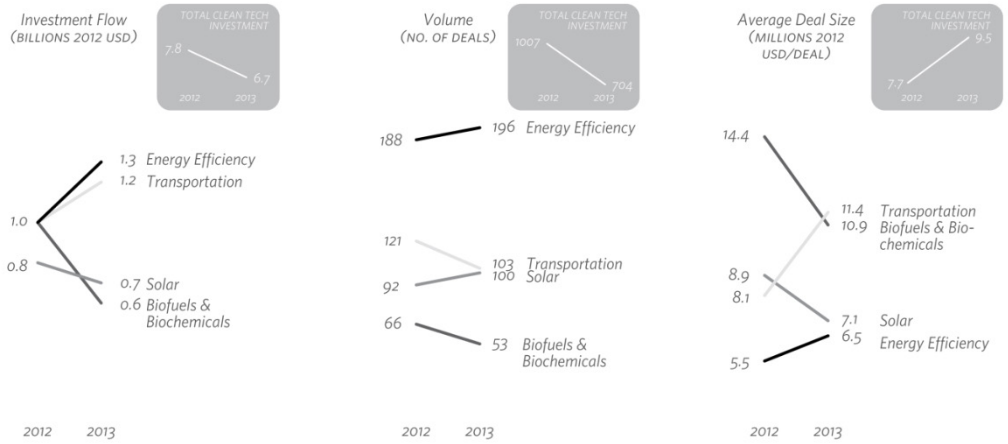

Figure 1.2 Venture capital investment flow, deal volume, and deal size (2012–2013)

Note: Figures include investment in clean tech technologies that address environmental challenges outside of the energy sector, such as water and agriculture.

(Data sources: Cleantech Group 2014; Cleantech Group 2013.)

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companies ranked for their R&D investment. Major utility or gas and oil corporations that rank low in R&D expenditures are not taken into account in this data set (European Commission Joint Research Centre 2013).

The shift toward services and information technology (and away from capital-intensive industry) means that venture capital and angel investors have the potential to spur needed innovation in information technology and customer services for an energy system transformation. These parts of the electricity system may receive less attention than generation technologies in the low-carbon energy finance and policy discussion today, but they will play a critical role in facilitating a smooth low-carbon system transformation.

Insights from innovation research: Policies supporting innovation must balance public and private interests

Allowing firms the exclusive right to profit from innovation can increase potential returns, but it can also encourage duplicative private efforts, increase costs by delaying others' access to innovation, and slow further innovation (Levin et al. 1987). This is a particular problem for the low-carbon energy transition, because new knowledge must be developed and disseminated quickly across the world. Public investment in research and development will surely continue to play a role, although it cannot be the only answer. Historically, greater public R&D has been accompanied by higher levels of private R&D; this implies that public investment can serve to encourage private investors to invest in an industry, rather than "crowding out" private investment (Nemet and Kammen 2007).

For private-sector innovation, firms' methods for securing the returns to their R&D investments vary for different types of innovation (Levin et al. 1987). Given the diversity of needed innovations across the electricity system, it is likely that the optimal approaches for securing private investment in low-carbon innovation will vary as well.

Commercialization and deployment (C&D)

Globally, 2012 marked the second-highest year ever for investment in commercialization and deployment (C&D) of low-carbon generation – but current levels are not enough. Current C&D investment in low-carbon generation is between 50 per cent and 60 per cent of the $288 billion (2010 USD) annual investment IEA estimates is needed for renewable energy (Climate Policy Initiative 2013a). Broader investment in low-carbon energy commercialization and deployment across all parts of the energy system lags behind the $1.4 trillion needed annually for the broader energy supply infrastructure (Climate Policy Initiative 2013a). C&D investment is increasing in emerging economies but has recently declined in developed countries.

The lion's share of low-carbon energy investment goes to the commercialization and deployment (C&D) stages of innovation. Examination of 2012 C&D investment reveals two interweaving stories: one of faltering renewable energy policies and declining investments in developed countries, and another of markedly increased investment in emerging economies, driven largely by China's massive increase in solar investment.

While governments provide support for both early-stage and late-stage technological innovation, most funding goes to the later stages of commercialization and deployment. Developed and emerging economies are experiencing different investment trends in C&D, and they are dealing with different barriers to investment and to low-cost low-carbon energy. Public sector financing plays a different role in C&D financing across different regions – a pattern that does not break down neatly by developed-emerging lines (see Figure 1.3

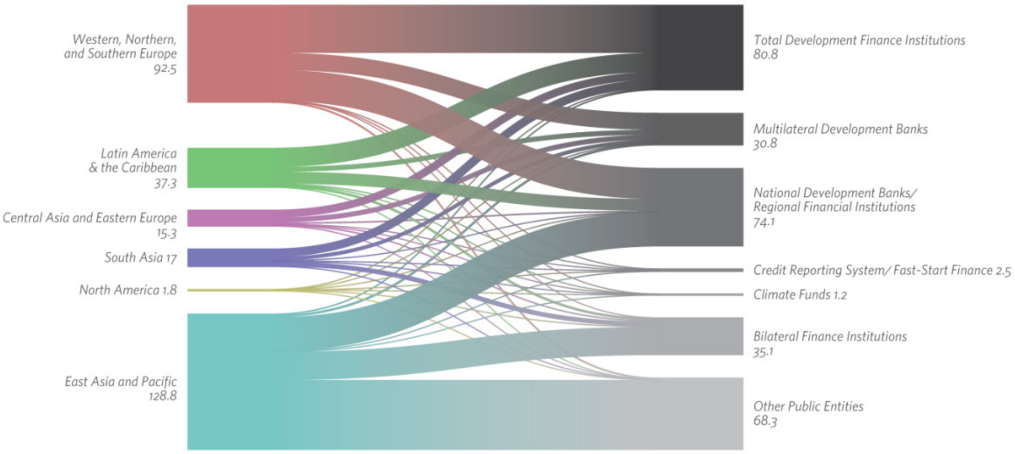

Figure 1.3 Current public investment in C&D by region and type of financial institution (billion 2012 USD)

(Data source: Climate Policy Initiative 2013c)

1.1.3 Scale of current and potential investment

Currently available data from a range of governmental and non-governmental sources indicate that the world is not meeting the $1.4 trillion annual investment IEA estimates is needed to limit a global increase in temperature to 2°C. Among investors with publicly available data, current investment in low-carbon innovation totals approximately $340 billion, with most of that total focused on commercialization and deployment. CPI analysis suggests that private investment in low-carbon innovation could potentially reach as much as $2 trillion, also primarily for late-stage deployment, if barriers to investment were removed. Table 1.3 summarises current and potential investment in low-carbon energy, and highlights remaining questions.

Insights from innovation research: Learning curves reward concentrated investment

Successful investment in innovative technologies leads to cost reductions that enable a new technology to take off in the market. From an investor's perspective, this means there would be a greater potential payoff from concentrating investment in a single innovative energy technology, rather than spreading investment thinly among many technologies (Farmer and Trancik 2007). This presents a challenge to the portfolio theory that traditionally guides investment, which indicates that a diversified portfolio of investments can best balance risk and return.

Estimating the untapped private sector capital that could potentially be mobilized for investment in low-carbon energy innovation is, in essence, a filtering process that requires an understanding of project financing needs for different types of low-carbon energy innovation and investor constraints. To estimate the scale of potential capital available, the following steps are required:

1. Assess the required scale of capital and required cost of capital for classes of low-carbon energy innovation. Different classes of energy innovation will require different financing and should appeal to different investors with different constraints. For instance, long-term infrastructure-like assets such as wind or solar generation attract different investors than shorter-term, small-scale investments in differentiated products or services such as energy efficiency applications or electric vehicles.
2. Identify the investor types with investment requirements that align with risk-return profile of the low-carbon energy innovation class.
3. Estimate the capital pool for each investor type by filtering for potential investments that meet diversification, sector-focus, human resource capacity, and illiquidity requirements.

Investment of the remaining capital in the targeted low-carbon energy innovation should be attractive to the investor and thereby provide the lowest-cost financing for low-carbon energy.

Data availability and reliability are substantial challenges in assessing investment levels. A large volume of private investment in low-carbon energy at the research, development, commercialization, and deployment stages goes unreported to publicly available sources, making only rough estimates of investment levels possible. The share of capital that investors could potentially allocate to low-carbon energy remains largely unassessed across most major investor types, with the exception of CPI’s recent analysis of institutional investors, which undertook a detailed filtering process as described above (Climate Policy Initiative 2013a).

Estimates of potential capital for corporate R&D and for early commercialization shown in Table 1.3 represent the broadest potential pool of capital, based on an initial broad filtering assessment that used data sources and current state of knowledge for each stage of innovation. In-depth analysis is required to provide a more certain – and likely smaller – estimate of the potential capital for these stages of innovation.

Table 1.3 Current investment in low-carbon energy, potential private capital for investment, and outstanding questions across innovation stages (figures in billion 2012 USD)

Current Investment		Potential Private Capital		Remaining Questions
Research & Development				
Total Low-Carbon Energy	**n/e**	**Total Low-Carbon Energy**	**< 40**[ii]	What portion of utility and gas/oil corporate R&D budgets could potentially be mobilised for low-carbon energy innovation?
Low-Carbon Generation	9.6[i]	*Utilities* *Oil and Gas*	*< 9* *< 31*	What additional corporate sector R&D budgets may also be mobilised for low-carbon energy innovation?
Government	*4.8*			How is the potential R&D capital distributed across countries?
Corporate	*4.8*			
Other Low-Carbon	n/e			
Early Commercialization				
Total Low-Carbon Energy	<6.8[iii]	**Total Low-Carbon Energy**	**n/e**	What is the current investment in low-carbon energy technologies within the $6.8 bn clean tech investment pool? How much more VC and angel investor investment could be mobilised for low-carbon energy innovation, given investor requirements? Can the venture capital and angel investor space play a specialised role in fuelling a transition to a low-carbon energy system?
Commercialization & Deployment				
Total Low-Carbon Energy	**n/e**	**Total Low-Carbon Energy**	**n/e**	How do we expect potential institutional investor capital to be distributed across countries?
Low-Carbon Generation + Public EE *(does not include private financing of energy efficiency)*	337[iv]	Low-Carbon Generation	n/e	What is the potential pool of institutional investor capital that could be available for investment in other types of low-carbon energy innovation projects?
		Institutional Investors	*1,300-1,900*[v]	What is the potential additional capital that banks and corporates could invest in low-carbon technology?
		Banks	*n/e*	
		Corp. & Utilities	*n/e*	
Other Low-Carbon	n/e			
Global Low-Carbon Investment Required				
Total energy supply infrastructure 2011–2035		**35.6 trillion (1.4 trillion annually)**[vi]		
Low-carbon generation 2011–2035		.2 trillion (288 billion annually)		

Notes: n/e: Not estimated.

Data sources: (i) Frankfurt School-UNEP Centre/BNEF (2013); (ii) CPI internal analysis based on data from Hirschey et al. (2012), European Commission Joint Research Centre (2013), Rystad Energy (2014), and Bloomberg; (iii) Cleantech Group (2014); (iv) Climate Policy Initiative (2013c); (v) Climate Policy Initiative (2013a); (vi) International Energy Agency (2011; 2013a), Climate Policy Initiative (2013a).

1.2 Financial and institutional innovation could address challenges throughout the electricity system

Public efforts have focused on technological innovation and cost reduction in renewable energy generation, and innovation has brought down the cost of renewable generation technologies. However, innovation is needed across the rest of the system as well. Current market, regulatory, and business structures are designed to support the fossil fuel-based model of generation; they are not structured to achieve delivery of low-carbon energy at wide scale and low cost. Moving to a low-carbon future requires coordinated innovation in markets, business models, and finance across the electricity sector.

While replacing an aging, fossil-fuel generation fleet may seem the most obvious challenge to achieving a new low-carbon electricity supply industry, it will not be enough. Integrating renewable energy at scale into the existing industry structure, which has been built around the operational and financial characteristics of a fossil-fuel-driven system, will be very expensive and may not work at all. Market operations, grid system design, and utility incentives in the long term could easily exceed original investment costs.

In both the EU and U.S., the current electricity sector has been shaped by its traditional reliance on fossil fuels. These traditional industry structures present challenges to low-carbon transformation that persist despite the influence of a carbon price and other climate policies:

- Regulation: The electricity sector is heavily regulated in order to address market power, access, and reliability, as well as carbon emissions and other environmental issues. While regulators have used market mechanisms to increase the efficiency of regulation, the markets and other regulatory mechanisms currently in place were designed in the context of a system dominated by centralised, fossil-fuel generation – not renewables.
- Incumbency: The business and financial models employed in the electricity sector were similarly designed around optimizing the use of electricity supply from centralised, large fossil-fuel generation in the context of the regulatory or market structures already in place. They were not designed to optimise electricity use from low-carbon generation.
- Stranded assets: Governments, businesses, and financiers now face the legacy of a century of public and private investment in current system in Europe and the U.S., representing trillions in assets that make it both politically and financially challenging to transition the system as quickly as necessary to address climate change.
- Underinvestment in system innovation: As discussed in the previous section, there has been little support or incentive for system-level innovation for the electricity sector to guide a coordinated transition and bring down costs.

To make a successful transition, each of the five major business segments of the integrated utility model face major challenges and requirements for new investment and restructuring (see Table 1.4). Transition to a low-carbon energy system will be impossible, or impossibly expensive, without addressing these challenges.

Table 1.4 : Key challenges requiring institutional and financial innovation

Business segment	Challenge
Generation	Financing low-carbon generation efficiently
Transmission	Reorganizing to better integrate renewable energy
Market balancing	Updating markets and business models to promote efficient investment in flexibility for a low-carbon grid
Distribution	Developing new models for financing and operating distribution systems
Customer management	Changing the role of electricity customers

The innovation required for a low-carbon transition is unique in its urgency: Low-carbon energy innovation must meet a societal deadline at a global scale to avert the worst impacts of climate change. Given the urgency of the task at hand, it is critical that policymakers look across the system at a whole to find ways to advance the low-carbon electricity transition in a smooth, coordinated, and cost-effective manner.

Current investment in low-carbon technological innovation must grow in order to meet national and global climate goals – and public policy has an important role to play in accelerating investment. But given the progress that has already been made in bringing down the cost of low-carbon electricity, and the powerful influence of traditional business structures in the electricity system, financial and institutional innovation will be just as important.

With so much history and investment at stake, restructuring to support the transition to a low-carbon energy system will be difficult. However, policymakers can minimise the cost of the low-carbon transition with a clear vision for the future industry model and a transition path that addresses financing requirements, leverages the existing industrial structure to meet increased flexibility needs, and facilitates integration of customer-generated electricity.

Section 2 of this report delves into more detail on three of the key challenges highlighted in Table 1.4: financing low-carbon generation efficiently, updating markets and business models to promote investment in flexibility, and changing the role of electricity customers. In Section 3, we lay out a model that fits all of these pieces together in an integrated picture of an efficient, low-carbon electricity system, and explore how this model would work in practice for existing U.S. and European utilities. Section 4 explores how this new model might apply in the specific context of Sweden's electricity sector.

Insights from innovation research: Institutional structure affects investment in innovation

Institutional structure within an industry has an impact on the innovation strategy pursued by firms in that industry. The degree of monopoly power exercised by firms is important, but so are more complex dynamics within and among firms (Nelson and Winter 1977). For example, large firms that hold market power within their industries may serve as centres for innovation, or may lack the incentive to innovate, depending on other factors within their industry and within the decision-making processes of the firms themselves. In the United States, restructuring of the electricity sector in the 1990s was followed by a marked decline in research and development activities by utilities and a similar decline in utility funding for the industry's joint research consortium (Nemet and Kammen 2007).

The electricity system encompasses many different institutional structures with different objectives and time horizons – businesses and regulators, monopolies and competitors, large firms and individual households, incumbents and upstarts. Looking forward, the challenge of financing low-carbon innovation will vary across the different institutional structures within the system.

2 Key challenges in the low-carbon transition

The low-carbon transition brings new challenges and opportunities across all business segments within the electricity system. This section focuses on three key challenges: financing low-carbon generation efficiently, updating markets and business models to promote investment in flexibility, and changing the role of electricity customers. In the next section, we present findings on the progress that has been made to date on each of these challenges, and the opportunities for moving to a low-cost, low-carbon electricity system.

2.1 Challenge 1: Financing low-carbon generation efficiently

The cost and structure of renewable energy finance demonstrates the inadequacies of the existing industry structure and the benefits that could be achieved by moving towards a structure more aligned with the characteristics of low-carbon generation. Addressing renewable energy finance and creating business and regulatory structures to reduce financing costs will provide a catalyst to enable the industry to transform more smoothly and cost-effectively.

2.1.1 Technological innovation: Technology costs have declined dramatically for low-carbon generation

Substantial investment has focused on technological innovation and cost reduction in renewable generation. Public investment in research and development for low-carbon generation technologies grew rapidly over the last decade in the EU and U.S. (see Figure 2.1).

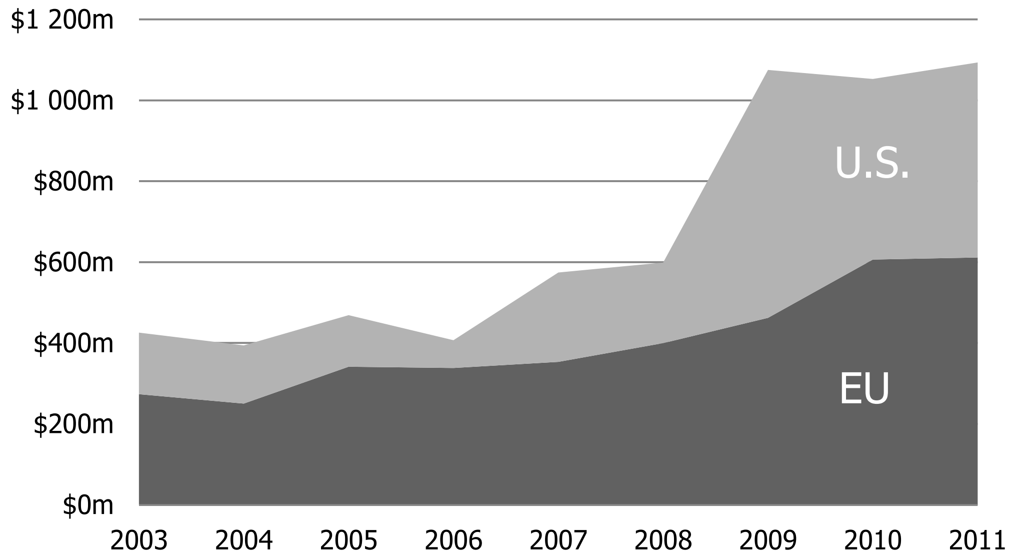

Figure 2.1 Public RD&D investment in solar PV and wind, 2003–2011 (million 2012 USD)

(Data source: International Energy Agency 2013b)

Investment in late-stage deployment has been much greater. Current C&D investment in low-carbon generation is between 50 per cent and 60 per cent of the $288 billion (2010

USD) annual investment IEA estimates is needed for renewable energy (Climate Policy Initiative 2013a). While this amount is still insufficient to meet the global demand, it puts low-carbon generation ahead of other low-carbon technologies in making progress toward deployment and cost reduction goals (International Energy Agency 2012a)

With broad support for deployment, the cost of low-carbon electricity has declined dramatically. Figure 2.2 illustrates the sharp decline in the cost of electricity from solar PV, along with annual public spending on deployment in the U.S. Explosive growth in deployment means that the total cost of public support has grown rapidly in recent years, even as the cost of each PV system has declined.

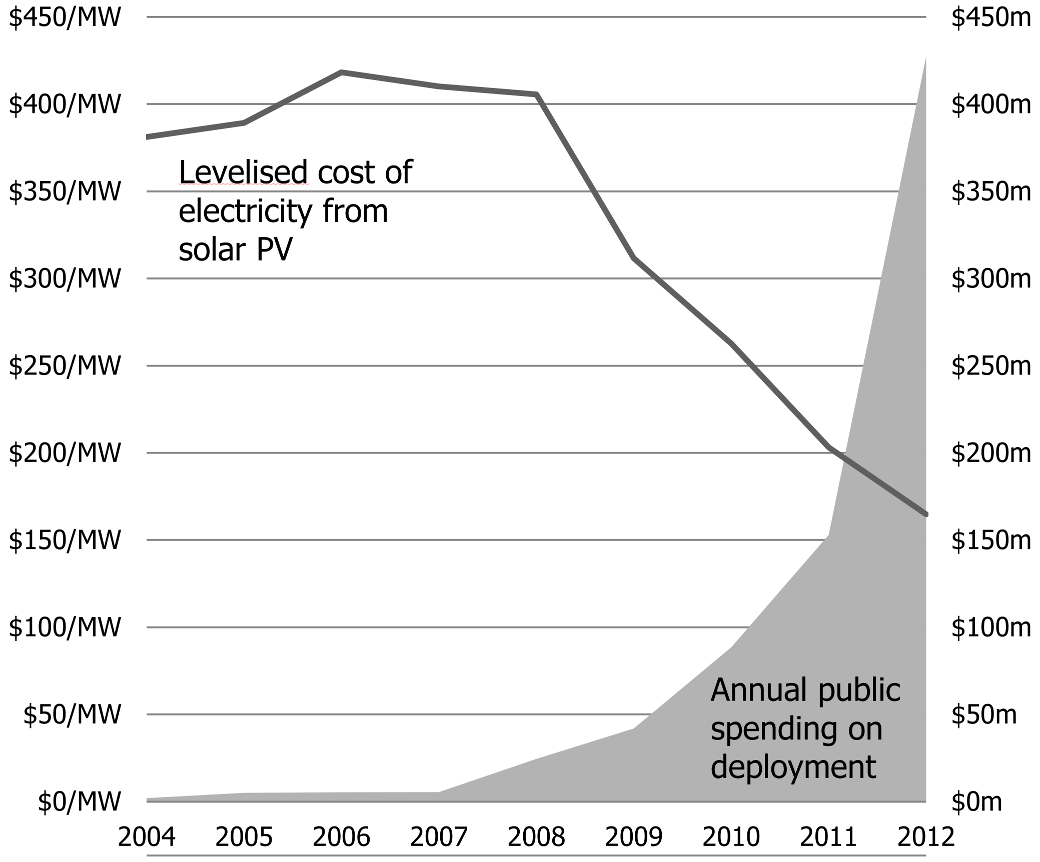

Figure 2.2 Levelised electricity cost and U.S. public support for deployment of solar PV, 2004–2012 (2012 USD)

(Data sources: Nemet 2006; Bloomberg; U.S. Energy Information Administration. Public spending on deployment is defined as the difference between the levelised cost of electricity from solar PV and the prevailing market price for electricity, multiplied by PV deployment.)

As technology costs have declined, other factors such as financing costs and institutional barriers become more important in determining the public cost of deployment – and therefore the level of deployment that is achievable at a politically acceptable cost. Financing costs must be the next target for cost reduction.

2.1.2 Financial and institutional innovation: New financing models could lower costs by attracting low-cost institutional investment

Renewable energy projects pay higher financing costs than justifiable given their risk profile. Wind and solar have no exposure to fuel price volatility and a large part of their revenues are guaranteed through power purchase agreements and production guarantees. These arrangements – often made possible by policies offering long-term support – can significantly lower the cost of financing renewable energy.

However, utility companies demand the same return on investment from their renewable energy projects as conventional generation. New financing models can reduce the cost of renewable energy by up to 20 per cent if policymakers create the necessary conditions to overcome key constraints that have kept institutional investors on the sidelines.

Policy affects the cost of financing renewables

The cost of financing is a key driver of renewable energy costs. Tweaking key policies can substantially lower financing costs without increasing overall policy costs. Figure 2.3 illustrates the impact of policy factors on the cost of financing renewable energy projects – and therefore on the cost of the electricity delivered by those projects. The figure illustrates the impact of each policy impact pathway on total project costs, based on financial data from a selected group of renewable energy projects in the U.S. and Europe. The projects, and the ways in which policy influenced their costs, are described in detail in Climate Policy Initiative (2011). Across the projects studied, the following trends hold true:

- The duration of revenue support has the largest impact on financing costs. Reducing the duration of revenue support by 10 years results in a 10–15 per cent increase in project cost.
- Revenue certainty is the second most important factor in determining financing costs. Moving from a fixed tariff (public support is fixed) to a fixed premium (public support varies depending on future electricity prices) increases project costs by 4–11 per cent.
- Investors' perceptions of risk also impact project financing costs. Perceptions of risk can be closely connected to policy – investors are likely to demand a premium if projects depend on public supports that they do not believe to be politically sustainable.

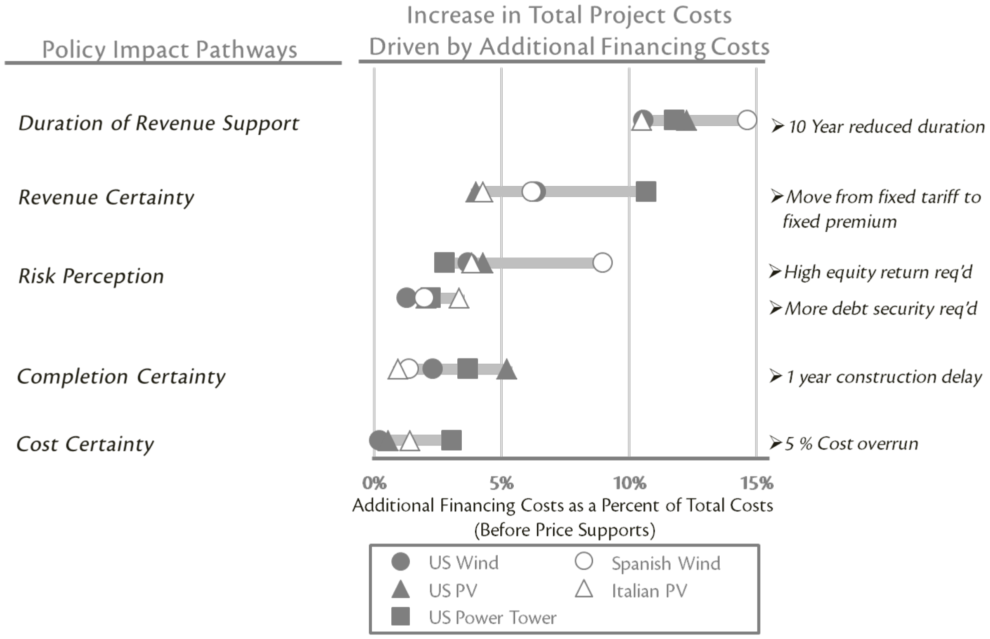

Figure 2.3 Impact of policy on renewable energy project costs

(Source: Climate Policy Initiative 2011)

Utilities drive investment in electricity system infrastructure today but are not well positioned to do so for low-carbon infrastructure

Utilities' current business and financial models are adapted to fossil fuel generation and markets – not low-carbon generation. Low-carbon energy investments (e.g., investments in large-scale renewables or energy efficiency) are far more like infrastructure investments than typical utility fossil-fuel plant investments. Fossil-fuel generation is based around optimizing fuel costs and plant dispatch. Investors expect moderate returns on investment and growth for the risk involved in optimizing for variable fuel costs. By contrast, low-carbon energy investments, like infrastructure, should provide investors low risk and steady returns after a high upfront capital cost (see Table 3.1).

Despite these differences, the same financial structures are often used to finance both fossil and non-fossil generation. The current structures can often make renewable energy more expensive and less desirable to finance, putting it at a considerable cost disadvantage. Fixing these structures can provide value to investors and consumers alike.

Meanwhile, current industry trends are putting substantial stress on utility business and financial models:

- **Slowing demand growth** driven by energy efficiency, rising commodity prices, technology improvements, and slower-growing economies, which reduces growth opportunities
- **Increasing distributed generation,** such as rooftop solar or captive cogeneration for industrial and commercial electricity consumers, which may further erode the share of generation of the large incumbent players and change the economics of the energy distribution system

- **Regulation of carbon and coal-fired power plants**, which is changing the generation mix and the relative economics of generation fleets, potentially to the detriment of many incumbent utilities
- **In the U.S., the emergence of cheap natural gas** is adding further pressure to coal, but also to other sources of generation such as nuclear
- **The increase in renewable energy** can further crowd out some existing generation, but with its intermittent output, can put a higher premium on standby and flexible generation and alter needs and operation of the transmission system.

As a result, utilities are losing the confidence of investors just as they need to start ramping up investments in low-carbon infrastructure to meet climate and clean energy targets. Over the last five years, utilities have underperformed relative to the stock market, particularly in Europe (see Figure 2.4). As utility company revenues and profits fall, many companies no longer have enough revenues to support their debt. With share prices low, raising new equity is expensive. Therefore, utilities are slowing investment and growth just when the opposite is needed to meet environmental goals and maintain system reliability.

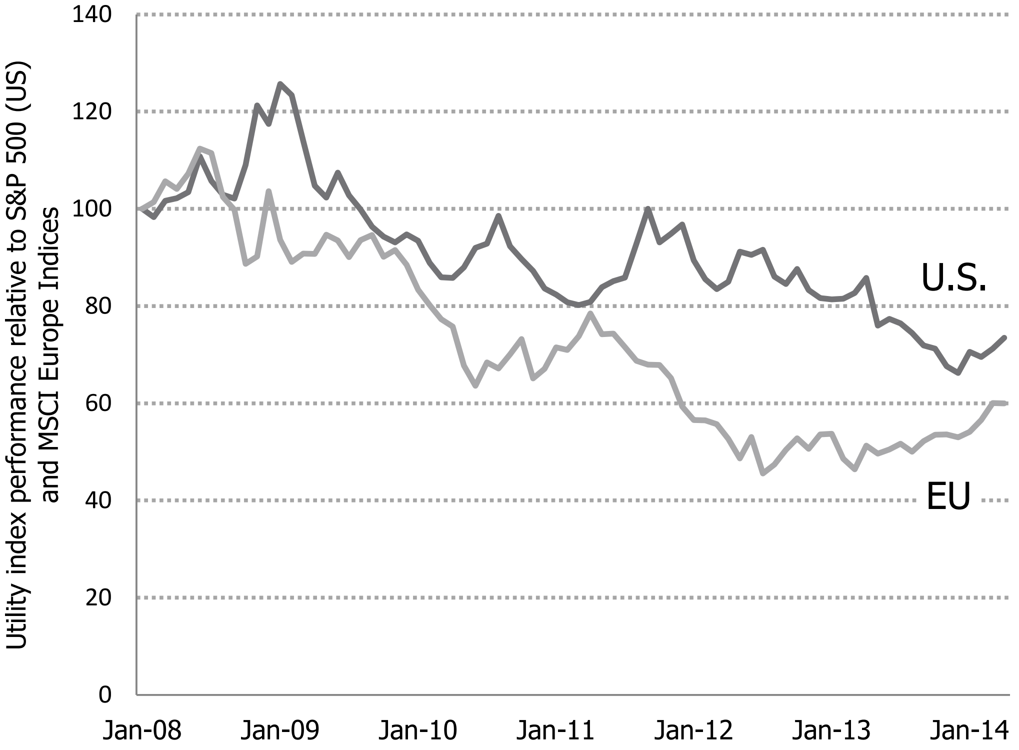

Figure 2.4 Share price performance of EU and U.S. utilities relative to general market (2008–2014)

Institutional investors could be a good match for renewables, but a number of policy and financial barriers limit the potential

There are groups of investors that are perfectly matched to the risk/return characteristics of renewable energy projects but are not participating due to the lack of appropriate investment products. Institutional investors such as pension funds and insurance companies have investment requirements that are in theory well-matched to renewable energy projects

– in fact, based on traditional investment requirements, institutional investors are a better fit than utilities to finance renewables (see Table 2.1).

Table 2.1 Financial characteristics of renewable energy projects match the investment requirements of institutional investors better than those of utilities

	Typical renewable energy project characteristics	**Typical institutional investor requirements**	**Typical utility business characteristics**
Cash flows	**Similar to bonds**: High upfront capital costs followed by small ongoing costs	**Bond-like for most investment**: Looking for predictable long-term cash flows	**Low-risk equity** with moderate capital costs; income variable depending on fuel prices and dispatch
Opportunities for outperformance	**Relatively limited** by cost-reducing fixed-price contracts	**Less important**: Seek predictability more than outperformance	**Several**, including fuel contracting, energy trading, operation, availability and efficiency improvement
Risk	**Limited** by contracts and may have little market exposure	**Limited**: Often look for low-risk opportunities to reduce market exposure	**Moderate**, including fuel price, dispatch, market demand, regulation
Return	**Low** due to lower risks	**Low**: Willing to take lower expected returns in order to limit volatility	**Moderate**, equity-type returns to manage risks and provide incentives for outperformance
Growth	**Limited** for project-only investments	**Limited**: Seek inflation protection, but not growth	**Moderate**, through natural fuel price inflation and performance and availability enhancement

Institutional investors could contribute up to $1.9 trillion for renewable energy debt and equity if some barriers were lifted. Key constraints limiting institutional investment in renewable energy include: (Climate Policy Initiative 2013a)

- **Investment practices:** Many pension funds will not invest directly in illiquid assets, while others have not built the investment expertise required to invest directly in renewable energy.
- **Policy uncertainty:** Inconsistent policies like retroactive tariff cuts in Spain and start-stop incentives in the U.S. create uncertainty that keeps institutional investors on the sidelines.
- **Policies that discourage institutional investors:** For example, the U.S. relies on tax credits as an incentive mechanism, but these do not appeal to investors like pension funds that are tax-exempt.

Potential solutions: new financing models and policy supports

New financing models that reflect the underlying financial characteristics of low-carbon energy projects, as well as the investment objectives of investors such as pension funds and insurance companies, can reduce the cost of renewable energy by up to 20 per cent. These new financing models have the potential to meet institutional investor needs and open up significant new pools of low-cost funds for renewable energy projects.

These new business models have already begun to emerge, and policymakers have an important role to play in allowing them to thrive. Some models, like municipal finance, involve direct action by policymakers to support renewables. In other cases, regulators' approval is likely necessary to allow the new model to proceed, depending on the jurisdiction (e.g., crowdsourcing of renewable energy projects). These models are discussed in detail in Section 3 of this report.

2.2 Challenge 2: Updating markets and business models to promote efficient investment in flexibility for a low-carbon grid

Managing the variability of renewable energy production requires additional system flexibility. Meeting flexibility needs in a low-carbon electricity system requires changes in markets and business models for both conventional and low-carbon flexibility resources. Regulators will need to modify markets and create new ones to ensure that flexibility resources can be deployed cost-effectively to meet system needs, and to create incentives for development and deployment of new low-carbon flexibility resources.

2.2.1 Technological innovation: More R&D could be devoted to providing system flexibility

Investment in technological innovation for grid flexibility has lagged behind other segments of the electricity system

In an electricity system dominated by flexible fossil fuel plants, there has been little investment in technological innovation to improve the electricity grid, relative to other components of the system. With a new focus on the potential of "smart grid" infrastructure to improve system reliability, this picture is beginning to change, but investment levels still lag behind other low-carbon energy technologies in both the U.S. and Europe. Figure 2.5 depicts grid investment in the U.S.

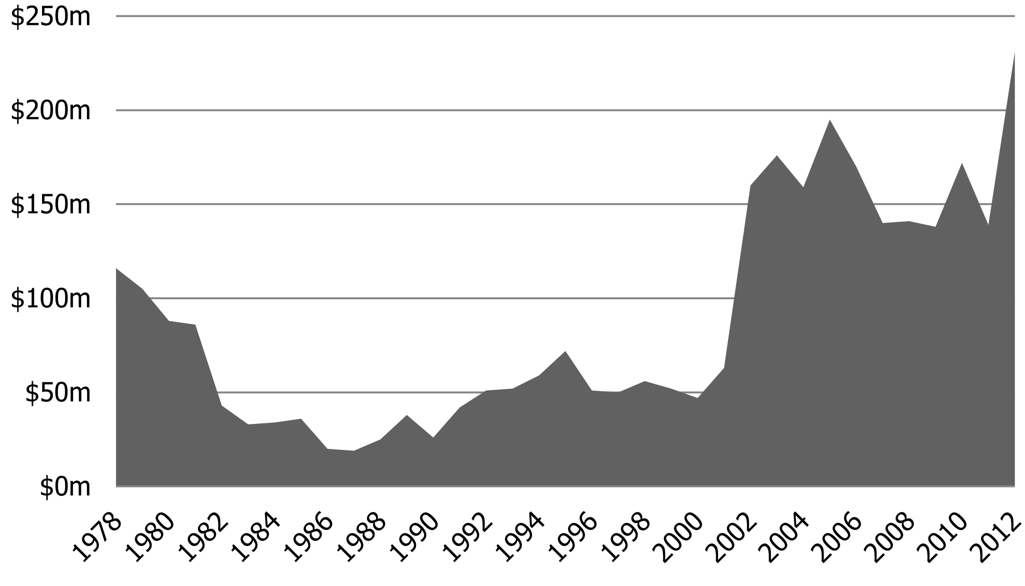

Figure 2.5 U.S. RD&D investment in electricity grid, 1978–2012

(Data source: U.S. Department of Energy)

Greater penetration of renewables requires more system flexibility

Investment in grid balancing is becoming more important than ever as renewable generation grows. Balancing services are needed to respond to changes in electricity generation in timeframes ranging from minutes to hours. These services include: **peaking** to accommodate daily peaks in demand; **ramping services** to deal with fluctuation in renewable energy generation (such as increased wind production from a low pressure weather pattern or decreased solar generation during a cloudy day); **negative supply and storage** to absorb excess production of renewable energy; and **spinning reserve** to follow loads in real time and deal with forecasting errors.

An electricity system dominated by wind and solar will have greater need for balancing services, depending on the generation mix. Grid resources must adjust to match electricity demand net of the output of variable wind and solar. For example, on days with high solar production, Germany's grid requires little non-renewable energy in the middle of the day but faces a steep ramp-up in demand as the sun sets (see Figure 2.6).

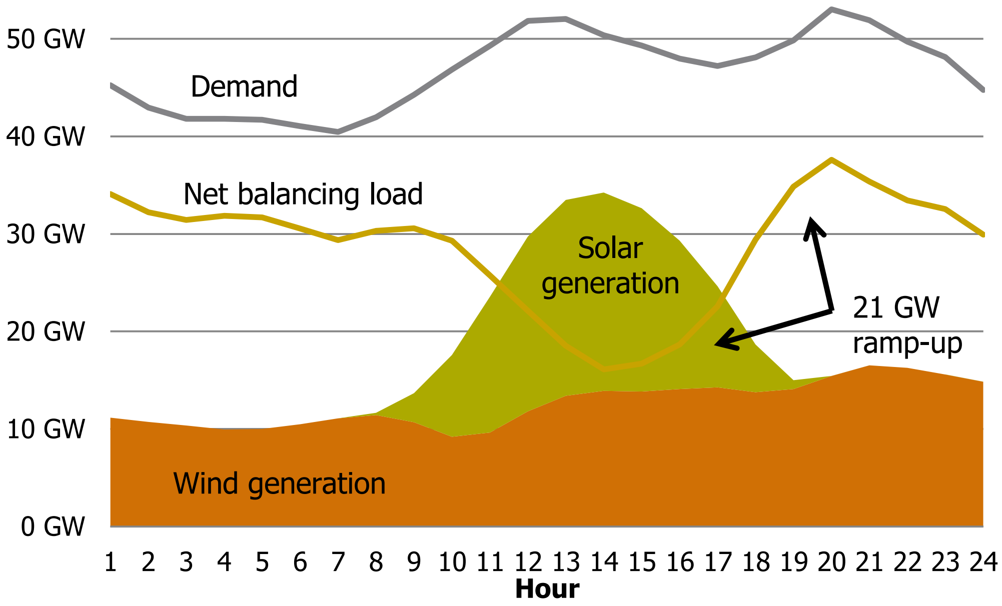

Figure 2.6 German electricity load and balancing with high solar generation (3 October 2013)

(Data source: EEX 2014)

Electricity storage is an important grid flexibility resource with a great deal of room for cost reduction and growth in deployment. Currently, the main forms of grid-level flexibility in place are pumped hydro storage and gas turbines (see Figure 2.7). Growth in other forms of storage – particularly batteries and other forms of flexible storage – would provide the grid with an additional valuable balancing resource.

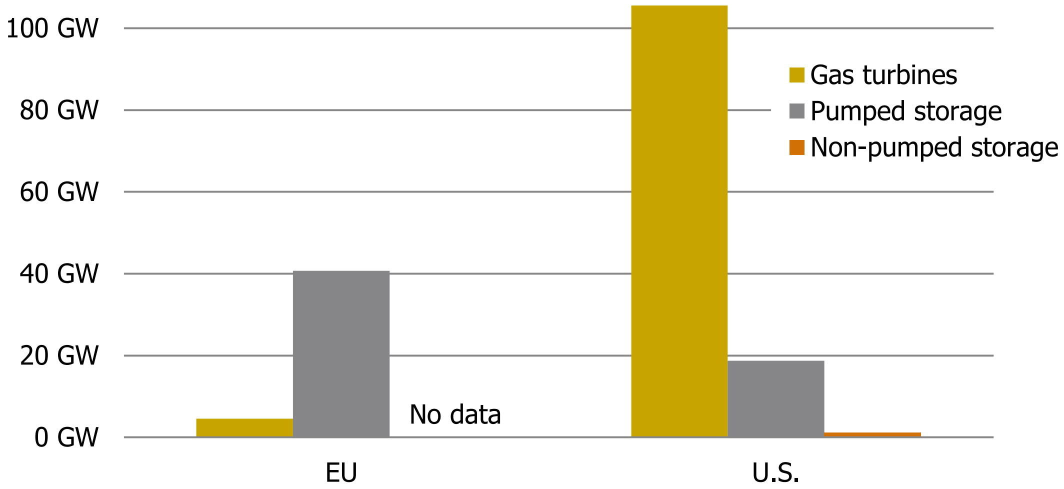

Figure 2.7 Flexibility technologies deployed in the EU and U.S. (2013)

(Data source: Platts World Electric Power Plants Database)

2.2.2 Financial and institutional innovation: Market structures and priorities will need to change in a low-carbon system

Energy policymakers and regulators often use markets to help achieve their goals, which traditionally have included:

- Ensuring a reliable power supply by attracting investments in requisite generation and transmission capacity to meet system needs
- Discouraging market power abuses by generators, so that prices remain fair and reasonable for consumers
- Allowing broad access to electricity at a reasonable price, including those who may not otherwise affordably access grid electricity
- Minimizing health, safety, and environmental impacts – critical issues that are driving policymakers' and regulators' interest in transforming the electricity sector

Current market structures were designed to achieve regulators' goals in the context of a fossil-fuelled electricity sector. The balance of costs in today's system is dominated by the cost of energy provision (see Figure 2.8 as an illustration), but could change markedly in a system dominated by low-carbon generation. Regulators will need to adapt the design of markets to accommodate the new mix of system costs.

Figure 2.8 shows the relative contribution of each component to the wholesale cost of electricity in 2012, in a liberalised electricity market in the eastern United States. Energy costs made up by far the largest share (74%).

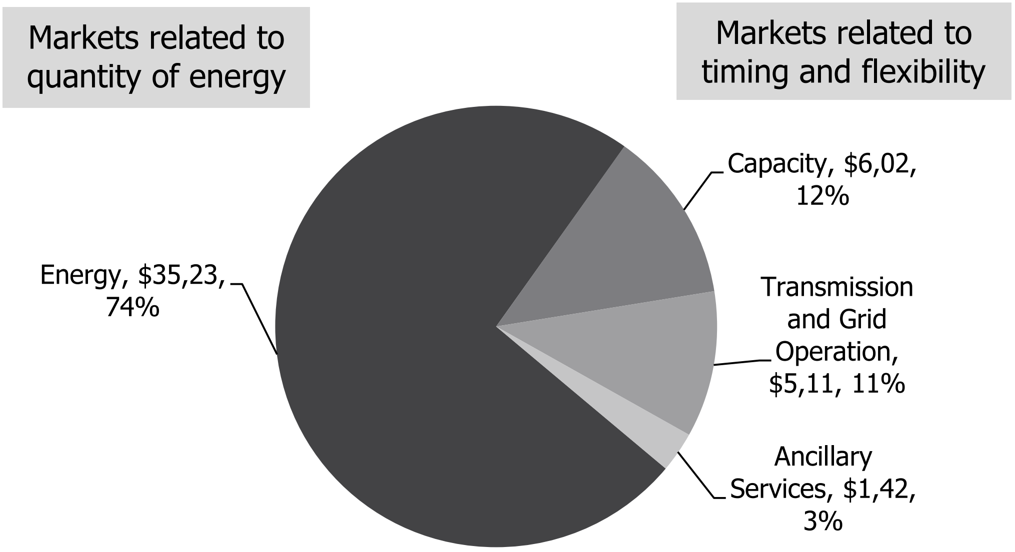

Figure 2.8 Wholesale cost by function in PJM, a liberalised regional electricity market in the eastern United States (2012)

(Data source: Ott 2013. Costs are yearly averages, given in USD per MWh. Total cost was 47.77 USD/MWh.)

Most revenues from today's energy markets are associated with efficient delivery of the required **quantity** of energy**.** Energy markets provide signals to fossil fuel power plant operators about whether or not to run their plants. Energy prices are largely determined by the price and availability of the marginal fuel (usually gas) and are very volatile.

In contrast, wind and solar have no fuel costs. And while supply of wind and solar power is predictable on an annual timescale, it is more variable at daily and sub-daily timescales. Wind and solar plants cannot choose when to produce power; they can only choose to provide or not provide power to the grid. The only action they can take in response to a price signal is to *not* provide power when prices are too low or even negative. As a result, the current **quantity-based** market doesn't sufficiently value the potential for clean electricity nor the capacity to store energy, which is important for a low-carbon energy system. Markets are also not set up to respond at daily and sub-daily timescales that reflect the characteristics of renewable energy generation.

Other markets focused on energy **timing** (for example, capacity markets) deliver a smaller share of revenue today but could become much more important in a low-carbon system. Today's capacity markets are largely short-term markets, providing additional payments to existing generators as an incentive to remain available. While these markets serve an important function in the current system, they are not sufficient to incentivise new flexibility resources that will be needed to balance intermittent renewables in the low-carbon grid.

To meet grid balancing needs in a low-carbon electricity system, conventional generation assets must have viable business models not based primarily on energy provision, but on the efficient provision of **balancing** services. In addition, the system must be able to efficiently incentivise deployment of new low-carbon **flexibility** resources.

Current electricity market structures, developed in the context of fossil-fuel generation, implicitly assume that most generators are flexible and do not adequately value flexibility as a resource distinct from generation. Balancing services have been traditionally supplied by dispatchable fossil fuel generators that cycle on and off to follow loads or spinning reserve to maintain system frequency at very short time frames. The current structure may not be enough, because:

- When renewable energy generators (with zero fuel cost) participate in the same electricity markets as fossil fuel plants, they lower the capacity factors and market prices for fossil electricity, making fossil fuel plants uneconomic to operate.
- The value of flexibility is often not priced in wholesale energy markets. Markets need to provide the right market signals for research and deployment of balancing assets and storage to enable a large deployment of intermittent renewable energy.
- Additional options such as demand response can help provide flexibility, but flexible demand is poorly represented in wholesale electricity markets (discussed further in Section 2.3).

As a result, current market structures are not adequately incentivizing investment in new or existing assets that would provide the balancing services needed for a low-carbon grid. Section 3 discusses opportunities for addressing this issue in a systematised way.

2.3 Challenge 3: Changing the role of electricity customers

Most utility customers are passive users of electricity – they consume electricity and receive monthly bills from the single utility serving their area. The traditional industry structure does not provide a clear business case for customers to change their electricity demand based on varying supply costs, either through energy efficiency and demand response or customer-hosted energy storage.

Innovative technologies such as smart meters and appliances; distributed generation; and electric vehicles are challenging the traditional passive model. These technologies allow utility customers to play a more active role in managing their own energy usage in response to real-time prices and system needs. They also allow customers to produce and sell energy services, including peak load reduction and energy storage. This active engagement can reduce system costs by better matching supply and demand – but it will only happen with the help of innovation in markets, regulation, and business structures. These activities will only become more important with a higher penetration of renewables.

2.3.1 Technological innovation: Technology is opening up new options for customers to engage with electricity markets

Public support has focused on deployment of energy-efficient technologies

Both the EU and U.S. have extensive public support for deployment of energy-efficient technologies– largely in the form of ratepayer-funded, utility-run programs in the U.S. (see Figure 2.10), and through a combination of government-run and utility-run programs in the EU. Public funding for R&D in energy efficiency has also grown over the last decade (see Figure 2.9).

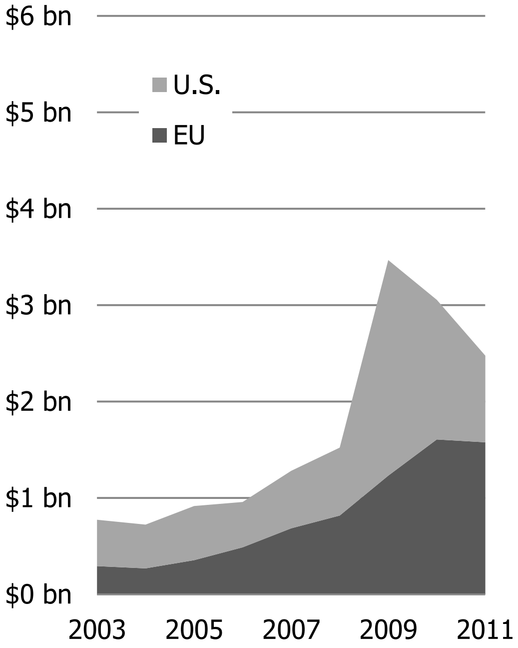

Figure 2.9 Public RD&D investment in energy efficiency, 2003–2011

(Data source: International Energy Agency 2013b)

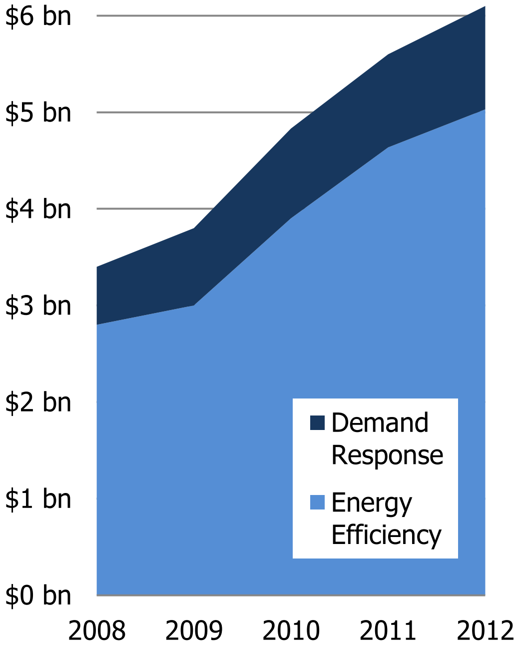

Figure 2.10 Demand-side management spending by U.S. electricity providers, 2008–2011

(Data source: Consortium for Energy Efficiency 2014)

New technologies enable customers to provide services to the grid

Technological innovation has created more potential for customer-side resources to add value within the electricity system, and companies are finding opportunities to capitalise on customer-side resources within current market and regulatory structures. These opportunities will grow in the future, especially as markets and regulations evolve to recognise the full value of customer-side resources.

Technological innovations unlocking value on the customer side of the meter include smart meters; building automation technologies, including smart thermostats and appliances; electric vehicles; the declining cost of batteries; the declining cost of distributed solar PV systems; and data analytics to better understand and disaggregate demand. These technologies are at varying stages of deployment. Smart meters, a key enabling technology, have achieved market penetration of approximately 23 per cent in the United States and 15 per cent in Europe and are growing rapidly in both regions (Federal Energy Regulatory Commission 2012; Lacey 2013; Telefónica 2014; Council of European Energy Regulators 2014).

Figure 2.11 and Figure 2.12 illustrate the growth in two key customer-side technologies that can provide services to the grid – distributed solar generation and electric vehicles.

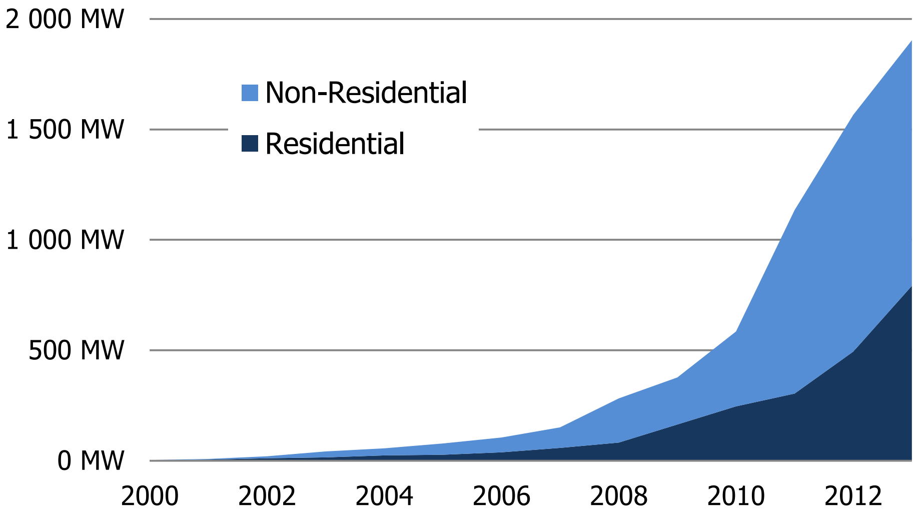

Figure 2.11 Non-utility solar PV installations, 2000–2013 (U.S.)

(Data source: Solar Energy Industries Association and Greentech Media 2014)

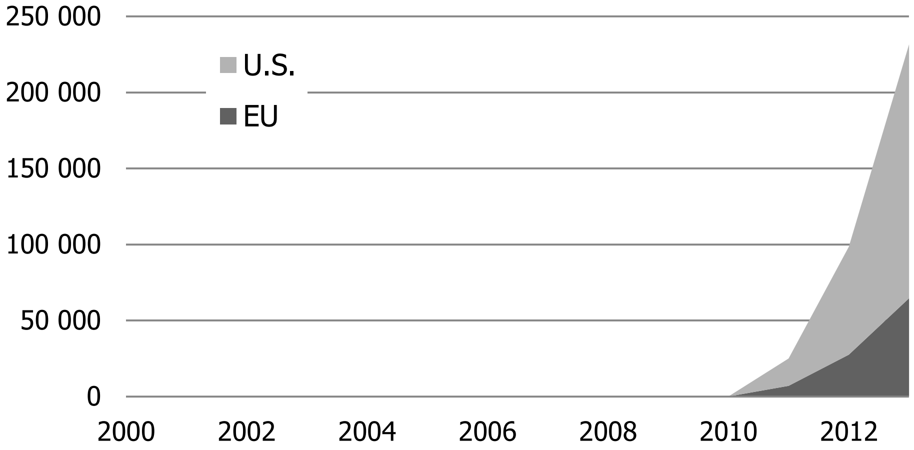

Figure 2.12 Sales of electric vehicles, 2000-2013

(Data source: International Energy Agency 2013c)

2.3.2 Institutional and financial innovation: Business and policy solutions for selling and deploying comprehensive solutions are still needed

In an electricity system with a higher penetration of renewables, customer-side assets will gain value – in particular, customers' energy consumption and production flexibility and long-term reductions in demand through efficiency. But these services are not fully incorporated into today's electricity market structures. In order for these resources to contribute value in the low-carbon electricity system, they must have a market to participate in – and a feasible way to participate, given that customer-side resources are spread out across many consumers.

Innovation in market design and regulation would allow customer generation, storage, and flexible demand to substitute for fossil fuel generation as a grid flexibility resource. A dedicated market for balancing services that allowed equal access for customer-side and supply-side resources, along with broader deployment of automation technology, would allow the grid to take advantage of the value that exists on the customer side of the meter.

Current examples of innovation in markets and regulation include:

- Grid operators in Germany are working to incorporate demand response into electricity markets, including both upward and downward flexibility (Tweed 2014)
- The U.S. Federal Energy Regulatory Commission has issued a series of orders to enable demand-side resources to participate more easily in wholesale energy markets, including demand response (Order 745) and ancillary services such as frequency regulation (responding to very short-term fluctuations to keep voltage stable) (Order 755).
- Two operators of regional electricity grids in the United States – ISO New England and PJM Interconnection – allow energy efficiency and other demand-side resources to participate in forward capacity markets (Fetter et al. 2012). Efficiency makes up approximately 10 per cent of total resources in the New England forward capacity market (Hogan 2013).
- To address the uncertainty of returns to investments in efficiency, governments are using public guarantees and risk-sharing facilities to reduce the risk borne by private investors and draw more private investment in energy efficiency (International Energy Agency 2012b, 43–45). For example, New York State recently issued bonds to finance a portfolio of energy efficiency loans. The bonds, backed by a state agency guarantee, were rated AAA and raised 24.3 million USD in their first issuance (New York State Energy Research and Development Authority 2014)

Innovations in markets and regulatory structures could also help lower barriers to financing long-lived energy efficiency measures. A long-term capacity market would be one way for grid operators to consider the value of energy efficiency alongside supply-side resources. Governments can also use their lower cost of borrowing to provide financing or guarantees to support energy efficiency investments. Transaction costs and low customer interest have limited the potential reach of public programs promoting energy efficiency (Borgeson, Zimring, and Goldman 2012), but if changes in regulation allow better monetization of all the services provided, new business models may emerge that can better drive demand.

New competitive models for electricity retail may be helpful as well, if they can remove perverse incentives by replacing a system that largely relies on utilities to reduce demand for their own product. But a note of caution is warranted: This transition will not be automatic. In the 1990s, the state of California deregulated energy efficiency services on the theory that private companies would step in to finance efficiency improvements; instead, investment and energy savings declined (Martinez, Wang, and Chou 2010). Careful policy design and continued public support and guidance will be needed as the current model of utility provision of efficiency and demand response gives way to a more competitive, decentralised model.

2.4 Policy should target financial and institutional innovation

In summary, while technological innovation is still important to further bring down costs in renewable generation technologies, financial and institutional innovation may now be at least as important to enable widespread deployment. In markets and balancing systems, both technological innovation and new business and market structures are needed to make the grid more flexible. In customer management, new technologies are already making headway, but innovations in finance and markets would create much more opportunity for these new technologies to add value in a low-carbon system.

3 Innovation in business models could bring down costs throughout the system

The previous chapter assessed the main challenges of deploying greater levels of renewable electricity. This chapter will present ideas for solutions to these challenges with a focus on how these can work in synergy to catalyse a system transformation.

Specifically, we will address the following:

- **New financing models for generation that appropriately value different energy sources**: We assess financing/utility business models and conduct financial modelling to understand potential impacts on the cost and availability of capital for renewable and conventional energy projects.
- **Electricity markets and balancing systems that can handle a changing energy make-up**: We explore how the structure of electricity markets can be improved to incentivise investment in renewable energy and in flexibility services that can balance the intermittency of renewable generation.
- **Business/corporate structure of the utility of the future**: Finally, we assess how balance sheets, earnings, and valuations of a sample utility company might be affected by greater penetration of renewable energy.

Based on the preceding discussion, we can sketch an outline of a future electricity system, presented in Figure 3.1. The various elements presented here can work together to mobilise renewable energy investment and incentivise investment in flexibility needed to integrate intermittent renewable energy into the grid.

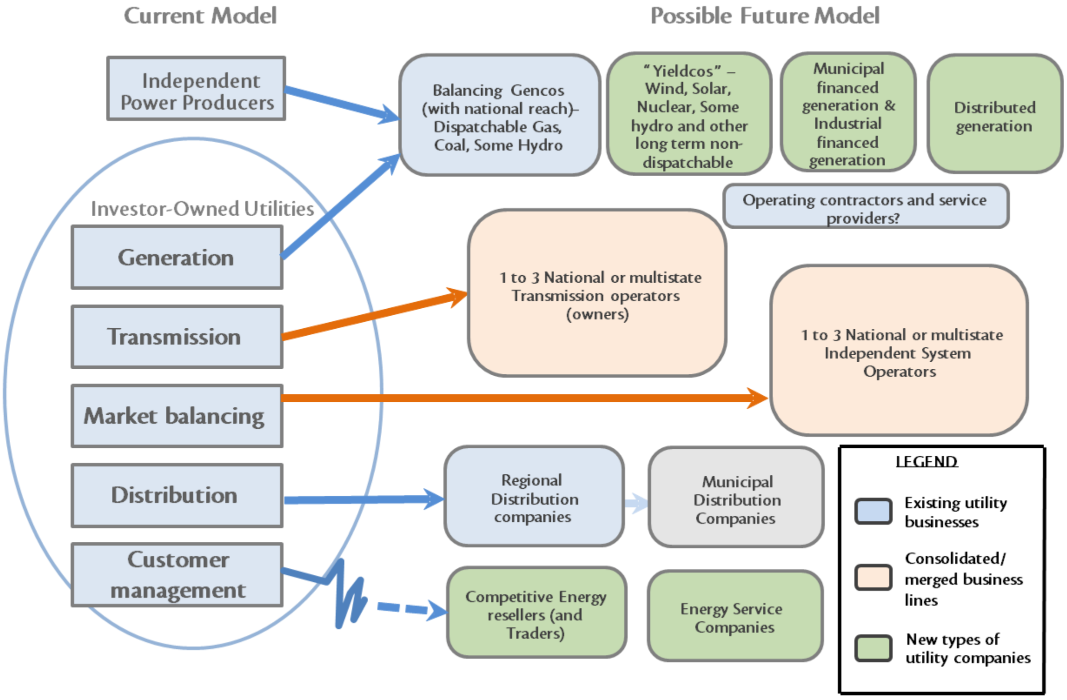

Figure 3.1 Moving to an efficient low-carbon system involves changes to institutions throughout the electricity system

3.1 New financing models for generation

Financing and business models for electricity generation will be greatly transformed in a future energy system. Large, utility-scale generation will continue to play a role during a transition to a low carbon electricity system. However, as discussed in Section 2, less of it will be fossil-fuel based and less of it will provide dispatchable, flexible output. The remaining flexible, mainly fossil-fuel generators will be increasingly valued more for their flexibility than for their actual energy output.

New business models will need to reflect these changes. Incentives and business structures can be revamped to reflect incentives that make sense for the new types of generation, driving them to reduce capital and financing costs. The new models would reflect changing risk and performance expectations for both old and new generation sources and could lead to significant reductions in financing costs thus reducing the cost of the new electricity model. This section explains possible future business models, describing how they fit along the value chain and how their development could drive improvements in either the cost of financing or integrating both renewable energy and fossil fuels. We begin with renewable energy.

3.1.1 Renewable energy

The characteristics of renewable energy projects create new opportunities to innovate in business models and thus bring down costs – notably through the cost of financing, which makes up a significant portion of non-system costs. For example, wind and solar generation projects require large capital investments, but once they have sold their energy production up-front through long-term power purchase agreement (which they often do), they offer steady returns with little revenue risk. This is a perfect scenario for institutional investors, who seek to match reasonably well-defined cash flow needs over a long period of time to service liabilities such as pensions and life insurance policies.

The key to optimizing financing costs for any investment is to match the investment and the related regulatory and corporate structure with the investment pool that is most closely aligned with the financial characteristics of the investment in question. New businesses models have emerged that address the challenges of financing renewable energy; some of these are listed in Table 3.1.

Table 3.1 Potential business model solutions for financing renewables

Business/ financing model	**Description**	**Example**
YieldCo	Listed corporation that owns renewable energy projects with long-term power purchase agreements. The structure allows investors to own portfolios of projects with substantially lower transaction costs.	NRG Yield is a publicly traded spinoff of American utility NRG. It owns 1.3 GW of mostly renewable generation facilities with an average contract life of 16 years.
Municipal and industrial owned and financed generation	Industrial or municipal customers purchase long-term power supplies through part-ownership of generation facilities.	German municipalities have been key actors in financing and deploying renewable energy to meet their electricity demand. In Mexico, Walmart has contracted to buy 17% of its electricity through power purchase agreements with wind projects.
Distributed generation	Technologies such as rooftop solar PV are rapidly expanding thanks to new leasing options and the fact that projects are competing against retail and not wholesale electricity tariffs.	SolarCity in the U.S. is targeting a 70% compounded annual growth rate by 2018. Estimates suggest that a 30% decrease in the installed cost of PV can grow the market 500%, to reach 20 million U.S. homes.
Crowdsourced financing	New platforms permit public investors to invest directly in (portions of) renewable energy projects.	Mosaic and SolarCity in the U.S. have announced plans to raise as much as $5 billion in crowdsourced debt.
Master Limited Partnerships (MLPs)	Unique to the U.S., these tax structures allow renewable energy projects to receive favourable tax treatment.	Currently used for tax efficiently financing midstream oil and gas infrastructure (pipelines). Current law allows MLPs to devote up to 10% of their portfolios to renewables.

Using YieldCos to drive down financing costs and engage institutional investors

We analysed the YieldCo model further as its characteristics are well suited to the needs of institutional investors, who could potentially deploy up to $1.9 trillion in new investments for renewable energy (Climate Policy Initiative 2013a). The scale of this investment could significantly bring down the cost of financing and reduce renewable energy costs. Figure 3.2 shows the characteristics of investments sought by institutional investors, which include liquidity, low fees, predictability, and a critical mass to facilitate asset allocation.

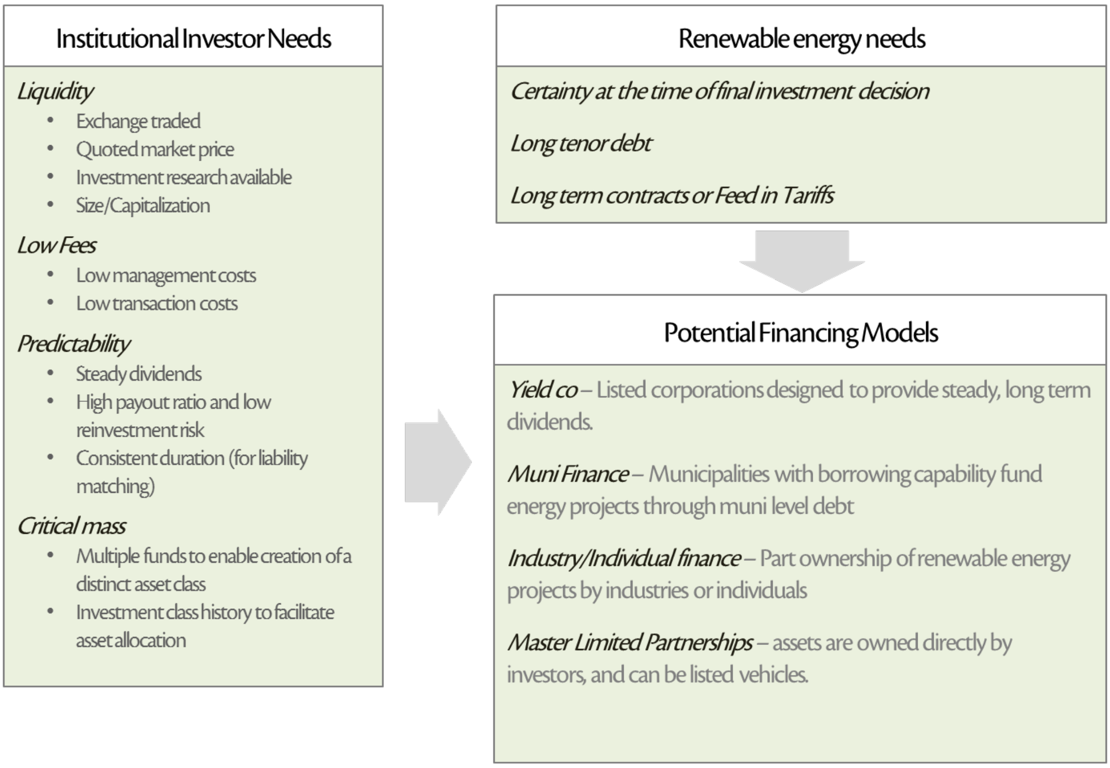

Figure 3.2 New financing and business models can help realise the benefits of lower-cost financing from institutions

Using a YieldCo structure can reduce the cost of financing because it allows investors to own a portfolio of renewable energy projects. This provides liquidity, diversification and reduces transaction costs. These features allow new types of investors, such as institutional investors to participate, increasing the pool of available capital and lowering financing costs. Because a YieldCo is considered a "pure-play" investment on renewable energy projects, its cost of capital should reflect the fact that wind and solar projects have high up-front costs but operational risks are minimal, justifying lower returns. Finally, a YieldCo may provide certain tax advantages. In the U.S., the corporate level of taxation is avoided through this structure.

To understand the impact of YieldCos on financing costs, we conducted a modelling exercise using CPI's project finance model.[2] This model relies on a variety of inputs, including technical characteristics, costs and expenses, taxes and depreciation, and financing assumptions to calculate renewable energy project cash flows and levelised cost of energy (LCOE).

We estimated the impact of a YieldCo structure on the cost of wind energy in the U.S. and EU. The inputs for an illustrative large wind project were based on data from Bloomberg New Energy Finance (BNEF) and the U.S. Energy Information Administration (EIA). These project-level assumptions are detailed in CPI's 2012 report, *Supporting Renewables while Saving Taxpayers Money*. We modelled four financing scenarios, listed in Table 3.2:

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[2] This model has been used for previous CPI analyses, including *The Impacts of Policy on the Financing of Renewable Projects* (2011) and *Supporting Renewables while Saving Taxpayers Money* (2012). Our modelling approach is described in more detail in appendices of those reports.

- Project Finance: A mix of 15-year senior debt and equity provided by the project developer. Debt amount is determined by debt service coverage requirements.
- Project Finance with 7-Year Debt: Same as above, but debt is constrained to a maximum tenor of 7 years.
- Utility Balance Sheet: A utility purchases the project from a developer, financing the acquisition on balance sheet with an equal mix of equity (with a 10% after-tax hurdle rate) and corporate debt (20-year senior debt at a 5% interest rate).
- YieldCo: A YieldCo purchases the project from a developer with a mix of YieldCo debt (20-year senior debt at a 5% interest rate) and equity (with an 8% hurdle rate). The debt amount is determined by debt service coverage requirements. Based on conversations with long-term investors and rating agencies, we believe that such low-risk structures could attract equity investment at costs 200 bp lower than traditional utilities and that they could support more debt on their balance sheets.

Table 3.2 Financing scenarios in project finance model

Scenario	**Amount of debt (EU case)[3]**	**Cost of debt**	**Long-term investor cost**	**Developer equity cost**	**Developer premium (% of project costs)**
Project Finance	74%	7%	-	12%	-
Project Finance with 7-Year Debt	52%	7%	-	12%	-
Utility Balance Sheet	50%	5%	10%	12%	7%
YieldCo	77%	5%	8%	12%	7%

Results of this modelling exercise are given in Figure 3.3. With today's financing model – project financing – the wind project costs around $80/MWh. However, even this may be an underestimate, as the financial crisis has resulted in banks reducing the term of debt they offer, which could increase costs by 15–24 per cent. If utilities had the capacity to finance wind on their balance sheets, they could reduce the cost of wind by around 5 per cent relative to project financing. But, as discussed earlier, utilities are facing increasing pressure on their balance sheets that make this approach more and more difficult.

YieldCos could bring down renewable energy costs by close to 20 per cent, if developers could make investment decisions with relatively high certainty that they could sell their projects to a YieldCo after completion.

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[3] In the U.S., the amount of debt depends on how tax benefits are monetised.

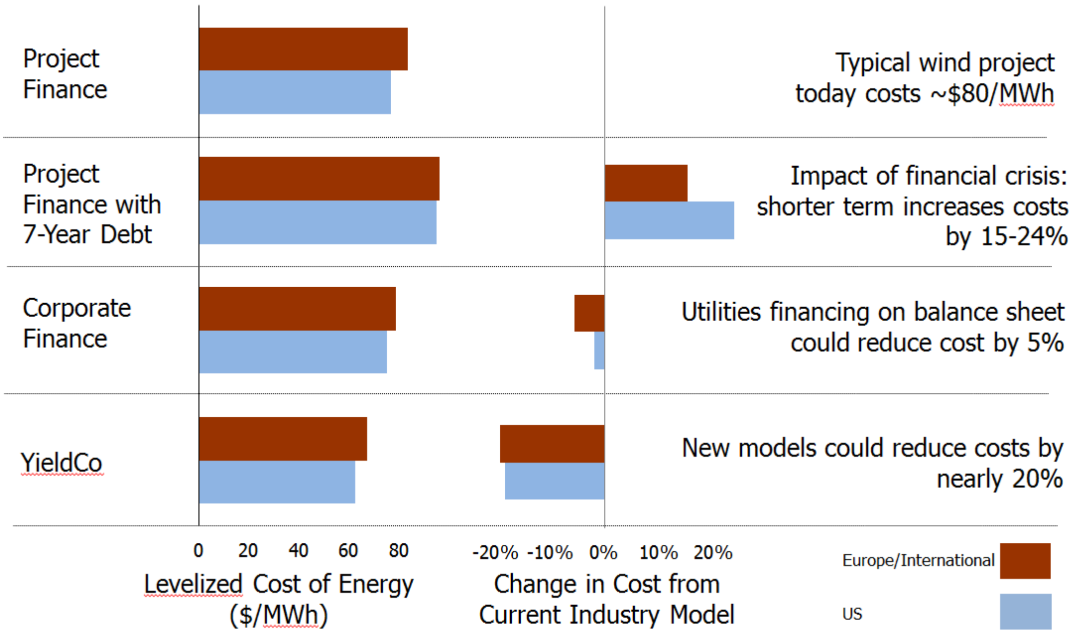

Figure 3.3 New finance models could reduce renewable energy costs by close to 20%

3.1.2 Fossil fuel generation

In a future scenario, the dominance of fossil generation will fade, but it will continue to play a crucial role in the operations of the electricity system. Fossil plants will derive an increasingly larger share of their value from the fact that they are “dispatchable” – that is, available on demand as opposed to being dependent on climatic conditions. Future business models could place great emphasis on when and how electricity is delivered rather than just the quantity of it.

An innovation in business models for fossil fuel generation is the Balancing GenCo. This is a company that owns dispatchable plants including fossil fuel and hydroelectric generators with storage as well as other types of electricity storage systems. Rather than derive value from units of energy sold, a Balancing GenCo derives the greater share of its earnings from the balancing, ramping, peaking, and reserve services it provides to the electricity grid.

The corporate structure and cost of capital of a Balancing GenCo should reflect the fact that it takes on significantly more risk than a traditional generator. Some of its assets may only operate 5 per cent of the time, but these can be extraordinarily profitable. As such, the inherent risk and unpredictability of playing in a small and volatile part of the electricity market will increase its cost of capital. Balancing GenCos will not be best positioned as owners of renewable energy projects that have very different characteristics and niches within the electricity market.

In the next two sections, we will continue the discussions of Balancing GenCos in the context of restructured electricity markets and corporate structures.

3.2 Innovations in electricity markets

Energy markets have been at the core of efficiency improvements and competitive generation over the last 30 years. While some have been very successful under various designs – improving dispatch, reducing costs and enhancing competition – the designs have been largely based around competition between fossil fuel generators. As greater levels of renewable energy enter the system, flexibility services will be needed to balance the variability of renewable energy.

Renewable energy does not fit the mould cast in electricity markets over the last 30 years. Power plants in competitive markets are dispatched based on least-marginal cost. Renewable generators have marginal costs that are effectively zero so they displace higher marginal cost resources from the supply stack. Electricity markets that have seen a large influx of renewable energy have observed a significant suppression in electricity prices (Felder 2011), (Woo et al. 2011). This effect is artificial and purely based on a market design that assumes electricity plants have fuel costs.

Price suppression will make large chunks of generating capacity uneconomic and unsustainable. Parts of this capacity may still be extraordinarily important to provide reliability to the grid on days when the wind doesn't blow and the sun doesn't shine. The challenge then is to create the right incentives to maintain investments in reserve capacity and flexible resources.

One innovation in market design is to restructure electricity markets so that marginal-cost-based dispatching is only applied to generators with fuel costs. Renewable energy would be removed from the wholesale electricity market and procured as part of long-term planning. The advantage is two-fold. Renewable energy would no longer be exposed to volatility in electricity prices and second, conventional generators would not have to compete in markets distorted by renewable energy with zero marginal costs.

Table 3.3 lists some options for electricity market regulators to modify existing markets, or create new ones, in order to ensure that flexibility resources are valued appropriately in a low-carbon system.

Table 3.3 Market design options to value flexibility in a low-carbon system

Option	Description	Example
Integrate energy markets and balancing systems	Efficiency and flexibility can be gained by integrating electricity markets to include additional resources in the system. If there are no linkages, low cost flexible resources may not be utilised while more expensive resources are utilised in a neighbouring region.	In February 2014, fifteen EU nations linked their power markets. A single market now encompasses 75% of Europe's energy supply. It will bring savings to consumers of as much as four billion euro a year.
New ramping/ flexibility products	Flexibility/ramping products can be incorporated within electricity markets to encourage additional flexibility investment.	The California Independent System Operator introduced an upward and downward flexible ramping product in 2014 that trades as an ancillary service for resources that can increase or decrease production in five-minute increments. This can include demand response and energy storage.
Develop demand-side flexibility	End users of electricity (e.g. industrial plant) can be given the information and ability to change their electricity usage in response to a market or network signal.	The PJM interconnection, a regional transmission organization in the U.S., has been a leader in incorporating demand-side flexibility in energy markets. Electricity consumers can participate in markets for wholesale energy, capacity, and short-term frequency regulation.
Forward capacity mechanisms	Electricity markets do not always provide long-term price signals to stimulate investment in capacity and ensure reliability. Instruments to compensate capacity can be set up to incentivise investors in maintaining existing capacity and investing in additional capacity.	The hydro-dominated system in Brazil makes electricity prices very volatile and increases risks to investors. Brazil set up forward capacity payments after facing shortages and rationing in 2001–2002. Since 2004, energy auctions have been held with forward durations of 15–30 years.

3.2.1 Putting all the pieces together: a restructured market scenario

We modelled a scenario that includes restructured electricity market combined with a YieldCo business model to understand how these innovations may affect electricity prices and the economics of electricity generation from renewables and conventional plants.

We find that this restructured market yields several benefits for the electricity system. Renewable energy costs decline, because renewable projects can be financed at lower cost. Among fossil fuel plants, flexible generators become more profitable than baseload generators, creating an incentive for generators to provide additional flexibility. The result is a healthy market that can provide a reliable supply of electricity at a high penetration of renewables, with viable business models for both low-carbon generation and flexible fossil fuel generation.

In this scenario, the wholesale electricity market is split between dispatchable and non-dispatchable resources. Non-dispatchable renewable electricity is traded through bilateral contracts i.e. power purchase agreements (PPAs) with no direct influence on marginal prices in wholesale electricity markets.

Renewable generators are owned by YieldCos that act purely as an entity to hold portfolios of assets. They have little revenue risk as electricity sales are assured through PPAs and they have first priority in feeding electricity into the grid.

Dispatchable generation is left in the wholesale energy market, which in essence becomes a balancing market (see Table 3.4 for more details). Balancing GenCos participate in wholesale electricity markets and deliver electricity to meet a net balancing load (electricity load minus renewable generation).

Table 3.4 New business models and market participation in CPI model

Utility business models	Market structure
YieldCo: Entity that holds renewable energy assets. It earns a return purely from electricity sales that are assured through long-term contracts.	YieldCo sells electricity through long term Power Purchase Agreements (PPAs). It does not participate in wholesale electricity markets.
Balancing GenCo: Entity that holds dispatchable generators and earns a return from both electricity sales and the delivery of additional services like flexibility and assured capacity.	Balancing GenCo participates in a balancing market to dispatch electricity to meet load net of renewables. Generators that are able to meet new requirements such as faster ramping rates are able to benefit. Generators are also compensated separately for the generation capacity to maintain grid stability through a capacity market.

Modelling methods

The simulated market works as a single-clearing-price auction which is a common design for deregulated markets worldwide. In it, the cheapest power plants are successively dispatched until all electricity demand is met. The marginal cost of the last-dispatched unit becomes the market-clearing price and all plants that are dispatched are paid this price.

Plant dispatching is constrained by ramping rates which limit the rate at which generators can increase or decrease generation to meet variable loads. Quick ramp-ups may require flexible, but more expensive, power sources like gas turbines to be dispatched instead of cheaper, but less flexible plants. Another constraint is the start-up cost of power plants. Cycling power plants requires personnel and equipment to perform. There are inefficiencies such as wasted fuel to heat boilers and other costs like increased wear-and-tear of machinery. The model captures this through a start-up cost that is incorporated in power plant bids. The interplay between the variability of renewable energy generation and the physical and economic constraints that determine the flexibility of other resources in the system ultimately dictate the cost of renewable energy integration.

Assumptions

As a representative case, we modelled the Central Zone of the State of New York's Independent System Operator. Electricity demand, power plant characteristics, share of fuels and solar and wind data are based on actual data from the State. Types of power plants represented include steam coal, nuclear, combined-cycle gas turbines and conventional oil and gas turbines. A subset of 17 plants was modelled along with their unique physical and economic characteristics that affect flexibility, as shown in Table 3.5 and Table 3.6.

Table 3.5 Power plant assumptions in model

Plant type	**Total Capacity in System (MW)**	**Average Efficiency**	**Hourly ramping factor**	**Startup cost ($/MW)**	**Minimum generation (% of total capacity)**
Coal–ST	515	30%	60%	$65	40%
CCGT	1264	40%	53%	$55	40%
Gas–GT	403	32%	100%	$24	70%
Oil–GT	410	25%	100%	$24	70%
Nuclear	642	33%	5%	$200	90%

Table 3.6 Market assumptions

Annual electricity demand	16.4 TWh
Minimum and maximum load	Min = 680 MW Max = 3080 MW
Dispatch interval	Hourly

Scenarios

We evaluated four scenarios: a low renewables (10% of load served) and a high renewables (50% of load served) scenario with two market design options for each. In one, all generators including renewable energy participated in a single-clearing-price auction to dispatch power. In the second scenario, renewables were entirely removed from the market. They fed all power produced into the grid but they did not participate in the auction. We observed how electricity prices were affected in each of these scenarios.

Results

Figure 3.4 shows how prices developed in the model in the single-market scenario with low and high renewables. The price suppression effect is clear. On average, electricity prices go from $51/MWh in the low RE scenario to $32/MWh in a high RE scenario. While this seemingly suggests a benefit to consumers, it is not the case. Most of the conventional generators are unprofitable which may squeeze capacity margins and system reliability over the long term as unprofitable plants are decommissioned. To maintain capacity, regulators may need to add additional mechanisms such as capacity markets, further distorting economic signals and increasing costs.

Renewable generators are also affected. The average price for solar and wind power goes from $55/MWh and $48/MWh respectively in the low renewables scenario to $24/MWh and $21/MWh in the high renewables scenario. This is unsustainable for investors and if renewable electricity prices are guaranteed – for example, through feed–in-tariffs – taxpayers may be left with an increasingly large bill to support renewables.

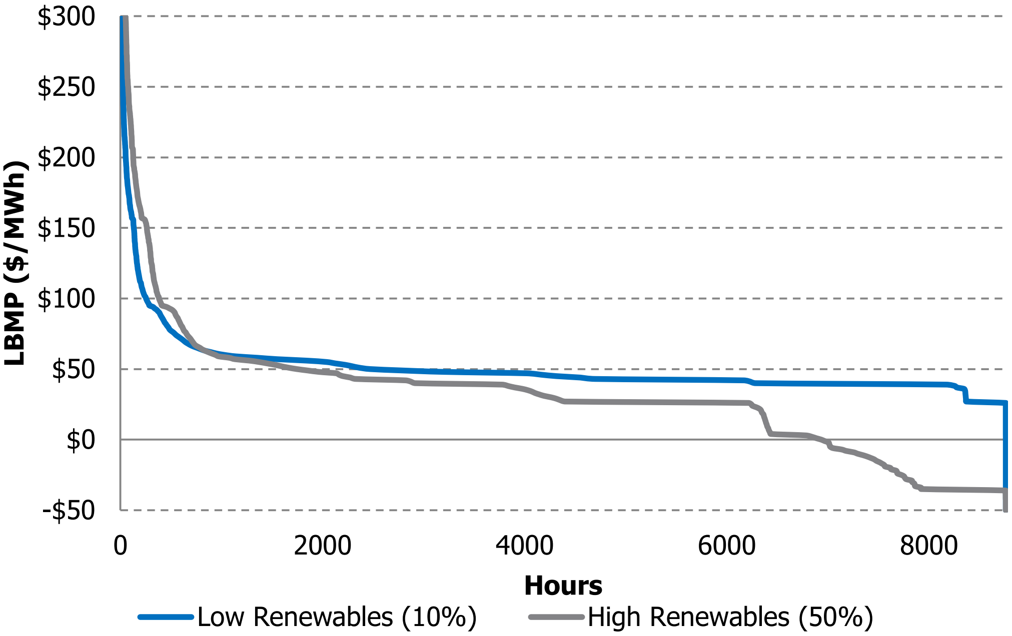

Figure 3.4 Price duration curve with renewables in single energy market

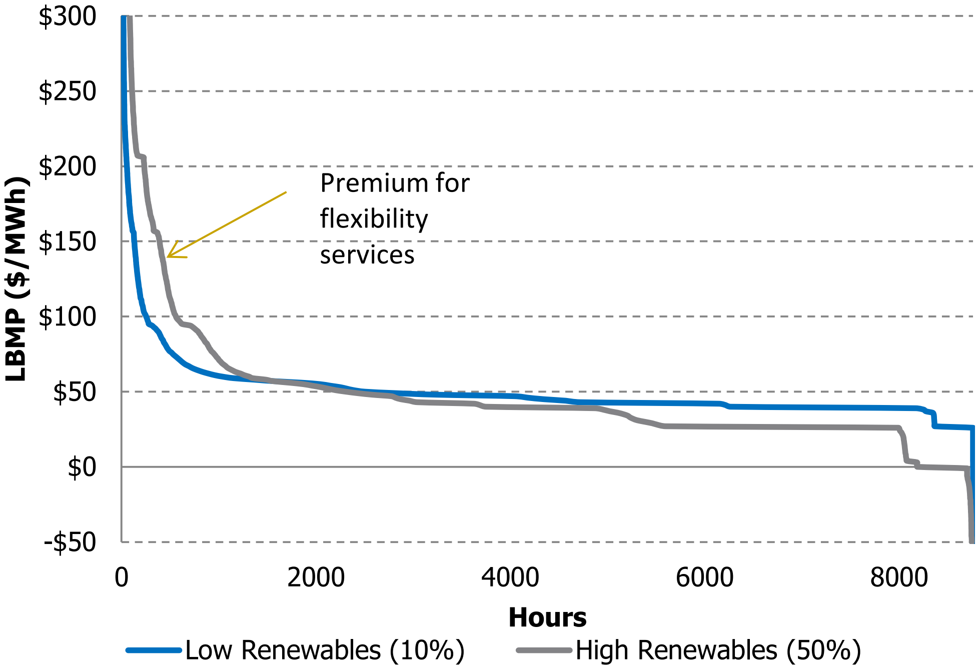

Figure 3.5 Price duration curve with separate renewables market

On the other hand, Figure 3.5 shows the impact of removing renewable energy from the wholesale electricity market. The average price remains relatively constant at $52/MWh and $54/MWh respectively in the low and high renewable energy scenario. This market is much healthier. Renewable energy displaces baseload generation, lowering overall demand and putting pricing pressure on intermediate and baseload generators. However, as can be seen by the shift on the left side of the curve. The market generates a premium for infrequently used generators, precisely those able to provide ramping, balancing and other flexibility services needed in a high renewables scenario.

Figure 3.6 and Figure 3.7 further demonstrate how greater levels of renewable energy in the system change the value of different types of plants. Flexible plants used to provide balancing and ramping services could significantly benefit from a restructured market. In this example, a flexible gas turbine sees its capacity factor jump from around 2 per cent to 6 per cent and there is a corresponding increase in profits. An inflexible steam coal power plant sees its value drop considerably. Capacity factor moves from close to 100 per cent – baseload generation – to below 60 per cent, depending on the market scenario. The graphs also show how current and restructured market scenarios affect individual plant financials and capacity factors.

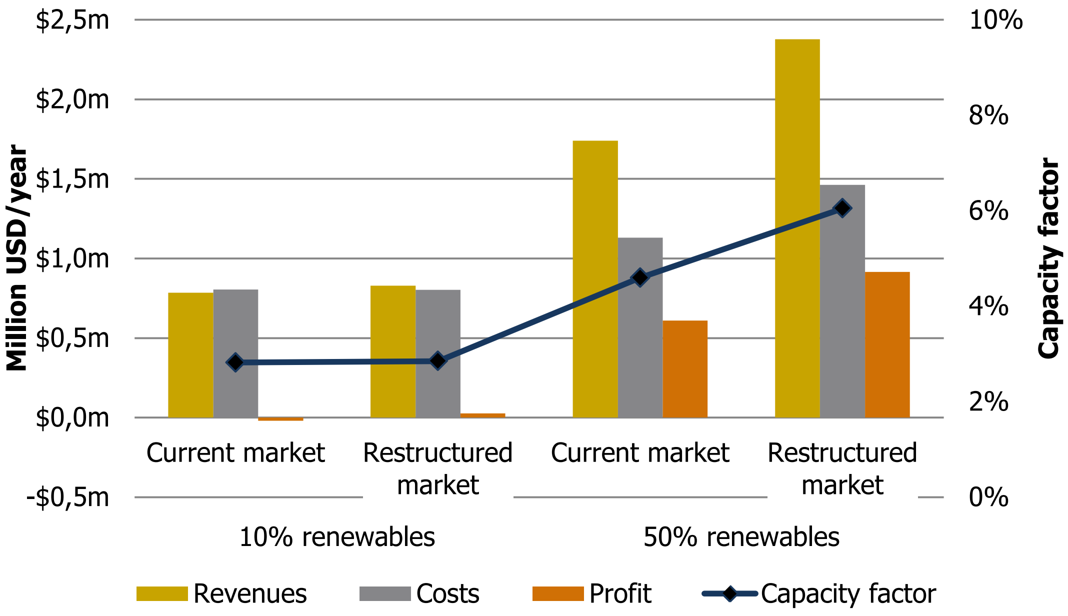

Figure 3.6 Revenues and profitability for flexible plant under a restructured market scenario

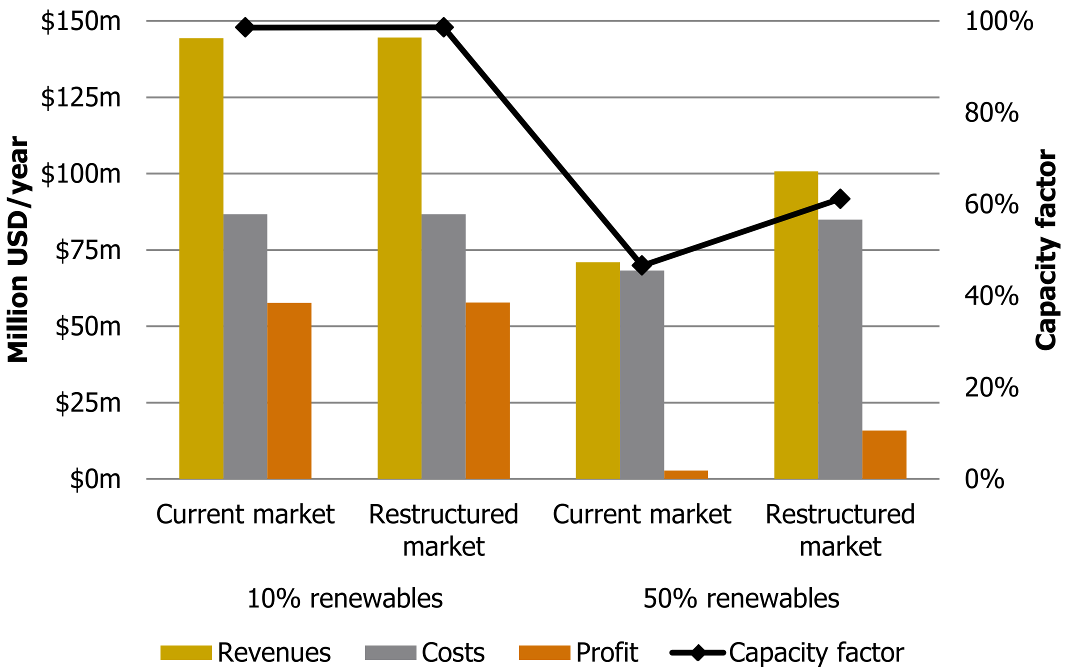

Figure 3.7 Revenues and profitability for inflexible plant under a restructured market scenario

Our modeling results show that the current electricity market structure is not optimal for both renewable and conventional generators. Conventional generators are affected by suppressed electricity prices, while renewable generators are exposed to electricity price volatility that increases risk and financing costs – clearly a lose–lose situation. When renewables do not participate in wholesale electricity markets and are instead procured through long-term PPA contracts, the cost of renewable energy decreases. This also creates a healthier market environment for conventional generators, increasing incentives to invest and maintain flexible resources needed for integrating greater shares of renewable energy.

Overall costs to the electricity system are likely lower in the restructured market scenario. Although price suppression does lower wholesale electricity prices in the current market scenario, this is not necessarily a good thing for consumers. Regulators may be forced to compensate conventional generators in other manners, such as capacity markets, while the bill to support renewables would continue to grow.

In the next section, we will discuss one last piece of the puzzle. How can corporate structures be aligned around new business models and market structures to enable a transition from the existing system?

3.3 Innovations in business/corporate structure

As the global energy system transitions to one dominated by renewable energy, existing electric utilities will have to evolve and respond to the vast changes that will occur. This section explores what restructuring means in practice to understand how a transition can be facilitated by policymakers in a manner that aligns with policy priorities and maximises investment and innovation potential in the sector.

The changing business landscape

The business landscape for electric utilities has been rapidly shifting. Historically, utilities generated stable revenues and dividend payments enabled by long-term capital investments and growing demand projections. Their business environment has deteriorated substantially in the last five years and European and North American utilities are undertaking major strategic shifts. In Europe, the ten biggest utilities mothballed over 20 GW of gas-powered capacity which is approximately 12 per cent of Europe's generation fleet as higher gas prices, lower coal prices and increased competition from renewables greatly affected margins. 8.8 GW of these were plants built in the last 10 years (Mcdaniels 2014). At the same time, coal generators have benefitted from lower coal prices. In 2013, electricity generated from coal in Germany reached its highest level in 20 years (Der Spiegel 2014).

Stock prices have fallen substantially, increasing the pressure on management struggling to satisfy both current and future debt-holders (credit ratings) and shareholders (maintain dividend payout ratios). To address these challenges, management is already taking major strategic shifts. These include:

- Cost cutting and de-leveraging: Starting in 2007, all the major European electric utilities have announced multi-year cost-cutting plans of up to EUR 3.5 bn.
- Cuts in investment plans: Multi-annual utilities investment plans have been revised downwards by a third over the last couple of years.
- Divestment from non-core business, geographies, divisions of close to EUR 67 bn over 2010–2015
- Definitive and temporary closure of non-profitable power plants
- Diversification outside of Europe to reduce exposure to EU regulation and market conditions. The main geographies are Russia, Turkey and South America.

Table 3.7 provides some examples of major strategies being undertaken by major European utilities.

Table 3.7: Major strategies employed by electric utilities to address current industry challenges

Company	**Strategy**	**Description**
E.ON	Invest in distributed generation	EON launched "Connecting Energies" to provide customers with comprehensive distributed energy solutions. These include on-site power generation, energy management services, heating and cooling, energy efficiency and integration of customer's onsite energy systems into the wholesale energy market.
RWE	Investing in flexibility	RWE is investing in increasing the flexibility of its power stations to help meet the challenges of fluctuating renewables. One of its newest lignite plants can ramp capacity up or down by 500 MW in 15 minutes
Vattenfall	Geographic and sectoral diversification	Vattenfall is diversifying its generation portfolio to deal with fuel price risks – renewables are an important part of that.
Several EU	Decommissioning	European utilities shut down 21.3 GW of gas-powered generation in 2013, approximately 12% of the generation fleet in Europe.
Several EU	Changing ownership structures	To deal with new financial realities, many utilities are bringing new public and private investors for projects

Why utilities' efforts to date are not enough

Our analysis shows that the scale of changes in the sector will bring about unprecedented challenges to electric utilities. The disruptive trends observed so far will worsen as greater levels of renewables enter the system so a more radical approach is likely necessary. Management responses centred on adjusting rather than changing the business model may not be adequate.

The fate of utilities is central to society not only because of the essential services they provide but also because the billions of euro in pensions tied to the sector both from employees and investors. Regulators must also ensure that an electricity sector transition will decarbonise the system while maintaining capacity margins and maintaining affordability. The challenge here is to take advantage of the conventional assets in place in the most cost-effective way to enable the lowest-cost decarbonisation.

Could a restructuring of utilities better match future needs in a low-carbon electricity system? In order to test this proposition, we examined a representative European utility's balance sheet to understand how breaking up its assets into new business units might impact its finances. We focused on analysing whether spinning off such new businesses could enable it to maintain its commitments as well as its capacity to continue investing in the decarbonisation of the electricity system. As shown in Table 3.8, the resulting renewable "GreenCo" as well as the "NetCo" consisting of its distribution assets are viable and would experience significant benefits in terms of reduced capital costs and correspondingly increased valuation.

However, the company remains burdened by legacy nuclear liabilities. If the remainder of the company is further split into a "Nuclear GenCo" and a "Balancing GenCo," then we see that the Balancing GenCo could still be viable, but that the Nuclear GenCo requires government assistance to continue as a going concern, primarily as a result of nuclear provisions. Note that the Balancing GenCo would see an increase in cost of capital, and that its viability in a high renewable penetration system is dependent on market reform that focuses on valuing balancing services, along the line discussed in section 3.2.

Table 3.8: Modelling results: All ongoing businesses are viable in the new model, but nuclear is burdened by historical liabilities (EUR bn)

	"EWR" **A typical German utility**	"Balancing GenCo" **Power generation from fossil fuels**	"Nuclear GenCo" **Power generation from nuclear**	"NetCo" **Supply, distribution, and trading**	"GreenCo" **Power generation from renewables**
Discounted value from future operations	43	9	2	28	4
Net financial position[4]	(8)	(2)	(1)	(5)	(1)
Provisions for pensions[5]	(8)	(2)	(1)	(5)	(1)
Provisions for mining	(3)	(3)			
Provisions for nuclear	(10)		(10)		
Resulting value for investors	**14**	**3**	**(9)**	**18**	**2**
Cost of capital: internal calculation	9%	10%		8%	9%
Cost of capital: external estimate	-	12%	-	6%	5%

We can also see that this suggests very different potential investors for each new business model. The NetCo and GreenCo are viable businesses on their own and likely have yields appropriate for direct institutional investment or direct municipal ownership. The Balancing GenCo could be an attractive candidate for acquisition by private equity investors, who are comfortable with higher levels of risk. These results show that there may be benefits of a restructuring to create more nimble, better capitalized utilities to invest in an energy system transition. However, current nuclear liabilities that include provisions for decommissioning and waste disposal are a significant barrier that may need policy intervention to address.

3.4 Policymakers can facilitate a transition

Our modelling results yield the following key conclusions:

- Renewable energy costs can be reduced by up to 20 per cent if structures used to finance projects are optimized around the characteristics of renewable energy. Policymakers can work with institutional investors and financial regulators to enable the development of new financing vehicles such as YieldCos.
- Electricity markets as currently designed are not always optimal for low-cost renewable energy and for incentivizing conventional generators to provide flexibility to the grid. New structures can significantly improve this without adding any cost to society. By changing current market structures – for example, splitting the market between dispatchable, less capital-intensive resources and non-dispatchable, capital-intensive resources – policymakers and regulators can allow markets to better value flexibility while minimizing financing costs for renewables.

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[4] Net financial position = net debt – net equity investment by the company, weighted by expected value from operations

[5] Weighted by expected value from operations

- Creating better-capitalized and more nimble electricity companies through restructuring will be necessary to scale up investments. At present, incumbent electric utilities are significantly burdened by legacy liabilities that include the cost of decommissioning their nuclear capacity. This makes it difficult for them to significantly increase investments in renewables. If governments could facilitate the resolution of these nuclear liabilities, it would leave more opportunities for viable businesses in the remaining business lines. Policymakers and regulators can also leverage their influence over incumbent utilities to facilitate both the resolution of nuclear liabilities and the broader restructuring of the utilities.

4 Implications of the electricity sector transition for Sweden

Sweden has already seen a remarkable transformation in its energy use over the last four decades, moving from a predominantly oil-dependent economy (75% of energy consumption) to one that is now powered primarily by renewables (36%, mostly hydropower) and nuclear energy (33%). Figure 4.1 illustrates this transformation.

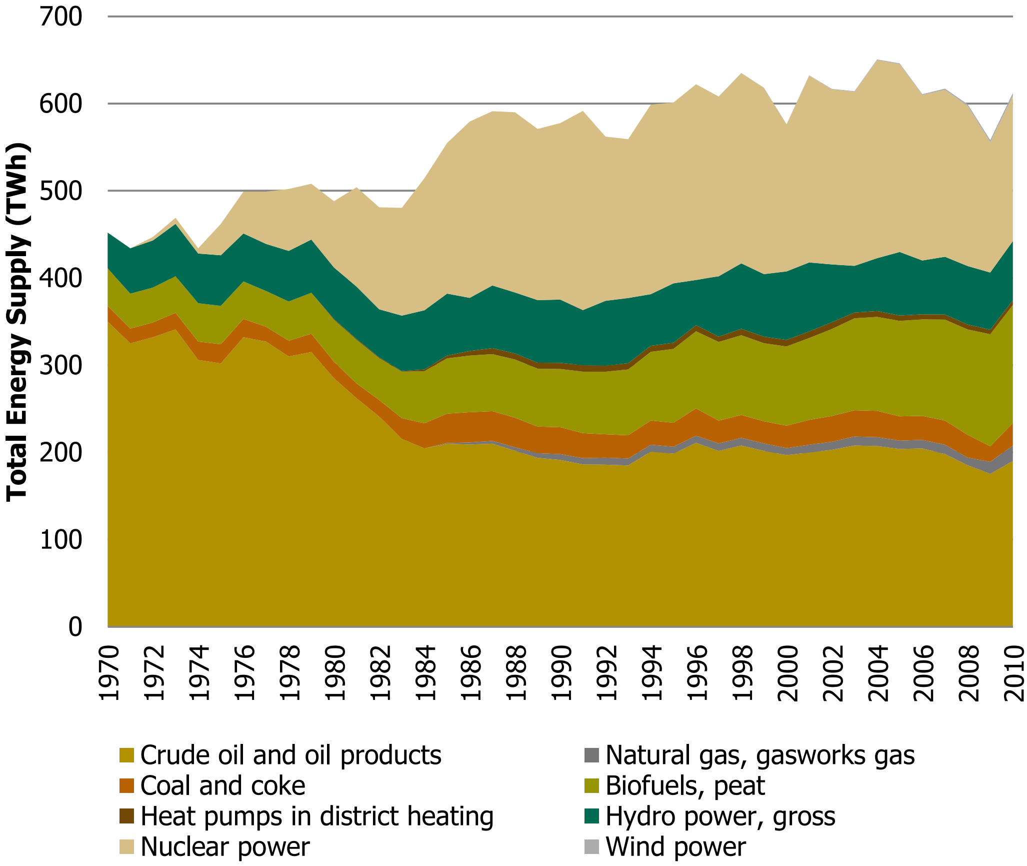

Figure 4.1 Evolution of Sweden's energy supply, 1970–2010

(Data source: Swedish Energy Agency 2013)

Nevertheless, the transformation of the electricity sector is likely to pose new challenges and opportunities for Sweden over the coming decades. The immediate challenges in Sweden are uncertainty about the future of nuclear energy (currently providing 40% of electricity supply in Sweden) and aggressive renewable policy (Swedish Institute 2012; International Energy Agency 2013d). Until very recently, national policy aimed to phase out nuclear energy, and even today, new power plants may only be built to replace existing plants. In response, Sweden has put in place an aggressive policy regime to drive the deployment of renewable energy. With the introduction of a renewable energy certificate system in 2003 (now, joint with Norway as of 2012), Sweden has seen significant deployment of wind and biomass electricity generation in the last few years, with new wind turbines installed in 2012 alone expected to provide 2.1 TWh of generation annually.

As a result, Sweden is on track to substitute intermittent renewable generation for its substantial baseload nuclear energy.

As discussed in this report, innovation in technology and institutions can be critical to reducing the cost of deploying and integrating renewable resources into the electricity grid. While a detailed analysis of the specific technology investments and institutional changes that could most benefit Sweden is beyond the scope of this paper, we believe that the following potential barriers and opportunities may merit such further study:

- How can Sweden update its renewable policies and market structures to reduce the cost of capital-intensive renewable generation? Our analysis suggests that financing capital-intensive renewable technologies such as solar and wind is much more expensive when the projects are subject to electricity market price risk. These risks and financing costs are compounded by having to bear renewable certificate market price risks.6 The combination of these risks makes it unsuitable for low-cost financing by long-term investors such as pension funds.7 Changes to the Swedish electricity and renewable certificate markets are currently being discussed, and a number of policy, market, and regulatory options could be employed to address this issue. For example, Sweden could modify the quota obligation on electricity suppliers (distribution companies) to require that renewable generation used to meet the obligation produced without fuel costs be purchased through competitively bid, long-term bundled renewable certificate or electricity contracts, and modify the renewable certificate market to allow trading of such contracts. Another approach may be to offer a long-term bundled contract–for–differences to capital-intensive renewable generators. Further work is needed to assess the potential benefits and costs of each of these options.
- Can these changes be optimised to unlock Swedish pension fund financing for renewable generation? With over SEK 1 trillion under management and investment objectives to achieve returns (roughly 5–6%) consistent with those achievable through investments in renewable generation, the First through Fourth National Pension Funds (AP1 through AP4) could provide an important source of low-cost capital for renewables (see for example Severinson and Stewart (2012)). However, as discussed in section 2.1, institutional investors are generally unable to effectively manage market price risk. Further, while each of the funds individually are just marginally large enough to build teams to invest in individual projects, they would likely benefit from the option to invest in new renewable generation businesses such as YieldCos. A more detailed financial and market analysis followed by a stakeholder engagement process that brings together managers of the pension funds and government and utility stakeholders could help Sweden develop a coordinated strategy to develop the appropriate policy, market, and financial structures needed to catalyse this investment.
- How can Sweden capitalise on its balancing assets – in particular, its hydropower? Higher penetration of intermittent renewable energy in Sweden and across the EU creates increasing value in flexible grid resources such as large scale hydroelectric power and energy storage. Sweden already boasts substantial hydro capacity, and is just starting to see significant deployment of plug-in hybrid and pure electric vehicles

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[6] Note, however, that a market determined price for renewable certificates plays an important role in reducing the resource price risk borne by investors for fuel-intensive renewable technologies such as biomass.

[7] As discussed in CPI (2012) “The Challenge of Institutional Investment in Renewable Energy,” long-term institutional investors generally do not have the capacity to manage commodity or market risks, and will only invest directly if they are shielded from bearing such risks.

that can serve as grid energy storage resources while they are plugged in for charging.[8] With a goal in place to eliminate fossil fuel use in the vehicle fleet by 2030, electric vehicle deployment will likely accelerate. Together, these resources could be aggregated to provide valuable balancing services to Sweden as well as the rest of the EU, particularly as the penetration of intermittent renewable generation increases. However, reforms to market structures are likely needed to coordinate the introduction and valuation of these services. As discussed in section 3, the choice of both wholesale and retail market structure can significantly impact the financial viability of flexibility resources. A specific assessment of how to maximise the value of Sweden's unique resources could provide guidance on undertaking such a reform process.

- How can Sweden accelerate technology innovation in electrical energy storage and transportation electrification? Sweden has a great deal of knowledge and competence in transport solutions that could be mobilised to innovate in electric mobility. There are efforts in place, but the results so far have not been on par with the potential. Lessons from successful innovation in this space in the U.S., Japan and South Korea might be helpful in guiding Swedish efforts. One option might be to explore ways to involve the Sixth National Pension Fund (AP6). AP6 has a mandate to invest in venture capital, and could work with the Swedish Energy Agency to explore opportunities to provide financing for the commercialization of advanced energy storage or fuel cell technologies.

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[8] Sales of plug-in hybrid electric and all-electric vehicles in Sweden in early 2014 now make up over 1% of vehicle registrations (http://www.bilsweden.se/statistik/nyregistreringar_per_manad_1/nyregistreringar-2014/hogtryck-pa-fordonsmarknaden).

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