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Scaling up Renewable Energy
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Scaling up Low-Carbon Investments Focus on Renewable Energy in Latin America

working paper

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Scaling up Low-Carbon Investments

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Summary

This paper describes the current background and state of energy sector investments and examines the needs in the future to transition to a low carbon, globally accessible energy system. The discussion is global but the Latin America region is particularly highlighted.

Global greenhouse gas emissions need to peak within a decade or two and decline vigorously thereafter if we are to limit the climate change to 2 oC by the end of the century, thus highlighting the need for immediate investments into low carbon energy. It is necessary to effectively integrate these investments with development goals including access to energy, reduction of in-door air pollution, improvements of labour productivity and reduction of land degradation. Thus, low carbon development is a new paradigm for limiting climate change while at the same time enhancing development outcomes. The recent economic crisis, while impacting global investments has also lead to stimulus packages in many countries that are directed towards 'green' development. It will be important to continue this trend to prioritize low carbon energy in development strategies and identify the main recipients of energy investments in the next two decades.

A global energy system that can effectively limits climate change to 2 oC and provides access to energy is seen to require annual investments of 2-3 trillion US \$ by 2030, less than 3% of the estimated global GDP in that year. Low carbon energy supply and energy efficiency improvements are identified as principal areas for investments in the next two decades. Renewable energy in particular is seen to be a major component of a low carbon energy strategy. However there will need to be an enormous scale up of current investment levels in these sectors in the next two decades and will entail massive restructuring of existing infrastructure. For Latin America and the Caribbean, this would involve annual investments of around 180 billion US\$ in 2030 and lead to more than a 30 percent reduction of CO2 emissions from the energy sector compared to current levels. Renewable energy will need a major share of these investments (more than 50 percent of total investments), mainly in decentralized electricity and biofuels production, both of which would need to be enormously scaled up compared to current levels

The scale-up of investments in the energy system will require continued public funding through innovative financing mechanisms and but private-public partnerships will be important. Establishing carbon markets will be essential to provide the necessary impetus for investments. Technology will need to be at the forefront of the climate debate and framework for a massive scaling up particularly of investments in energy research and development. Also, technological transfer and deployment would need to be clearly defined.

Background

A fundamental paradigm change is needed for a shift towards more sustainable development paths. The last fifty years have seen unprecedented growth with improved human conditions but at the same time have resulted in continued inequities between the rich and poor and in adverse environmental impacts on all scales, from indoor air pollution to climate change.

Avoiding dangerous climate change is an increasingly urgent challenge. According to the Intergovernmental Panel on Climate Change (IPCC) (2007), the global mean temperature has increased by some 0.8°C since the onset of the industrial revolution. Most of this increase is attributed to the anthropogenic emissions of the greenhouse gases. Provision of energy services is the major source of these emissions. The consensus is that global mean temperature increase greater than two degrees Celsius above preindustrial levels sharply increase the risks of climate change.¹

Energy use is growing but remains inequitable. Energy use is almost equally divided among industrialized and developing countries. However per capita energy use continues to be high in developed countries (6-11 kW per person) as compared to very low levels in developing countries (0-1.6 kW per person). While energy use is growing rapidly in developing countries, about two billion people in the world are still without access to modern energy and a large segment of the world's population lives in conditions of acute 'energy poverty', which has wide spread impacts on health and development.

The time is ripe for a fundamental shift in energy systems. Many power plants in industrialized countries, such as the USA, Japan and the European Union are nearing retirement; more than half of all operating power plants are over 20 years old. At the same time developing countries, are looking to satisfy the growing energy demand created by their expanding economies.

Change is underway but risks remain. Investments in sustainable energy are growing. Green energy has now overtaken fossil fuels in attracting new investment. There has been a shift in national policies in many countries that reflects increasing global concerns on climate change. As a response to the recent economic crisis, many countries like China, South Korea, United Kingdom, and the USA have announced national stimulus packages that promote 'green' development. Governments in many countries have announced policies that support renewable energy, energy efficiency and climate-change mitigation. However, the recent economic crisis has resulted in an absolute decline in renewable energy investments by up to 40% since the last year² and the trend is expected to continue.

On a global scale, opportunities are many. The Global Green New Deal³ put forward by the UN Environment Program (UNEP) proposes that about 750 billion dollars be invested to build an environmentally sustainable global economy. There is hope that a global deal in Copenhagen at the Fifteenth Conference of Parties in December this year can pave the way for accessible, clean and low carbon energy systems.

Current State of Energy Investments

Where do we stand?

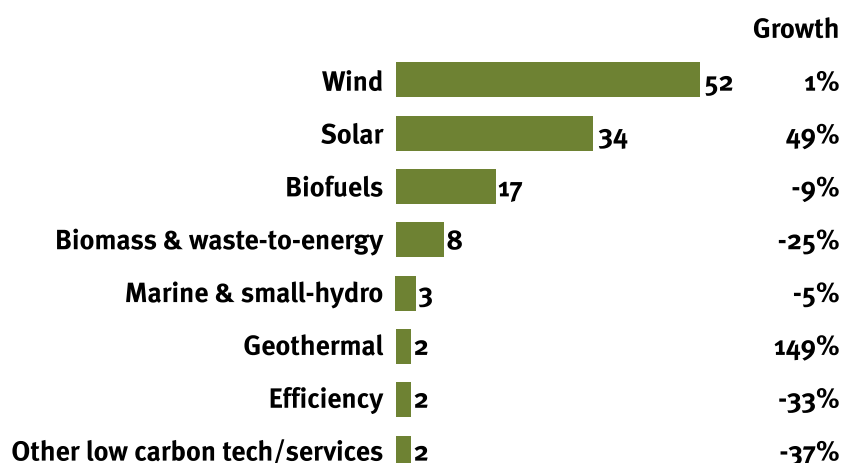
Globally, current investments in the energy sector are around 650 billion US\$.⁴ Fossil fuel sectors-exploration, mining and power generation constitute more than half of total investments. Current investments in the renewable energy sector were around 125 billion US\$ in 2008. Roughly half of current energy-related investments occur in industrialized countries, with developing regions accounting for the rest. Energy related investments are currently at around a global average of 1.5 % of total Gross Domestic Product (GDP) and have remained at these levels for the past decade. However, the composition of energy-related investments has been especially dynamic in the past few years. Renewable energy investments in particular have been growing at an unprecedented rate of 59 percent annually since 2004, but have seen around a 30 percent drop due to the recent economic crisis.

Domestic savings are the main source of financing for new energy projects followed by international banks, equity markets, and specialized energy funds. Private capital is especially emerging as an important source of investment in the energy sector in developing countries both as a result of larger flows of Foreign Direct Investment (FDI), as well as mobilization of capital within emerging markets. Within the energy sector, petroleum and natural gas industry remain major recipients of FDI which still tends to be concentrated in a few big developing countries.

Current estimates of global public Research and Development (R&D) in energy technologies are around 13-20 billion US\$ of which OECD countries like the USA, EU and Japan account for 90-95 percent. The International Energy Agency (IEA) indicates that private R&D spending in member countries is approximately 40-60 billion per year, which is four to six times higher than current government energy expenditure. Since the mid-1990s, both public and private sector R&D spending has been stagnant for renewable energy and energy efficiency, and has declined for fossil fuel and nuclear technology. R&D in renewable energy is currently at around 16 billion in 2006 from both public and private spending.⁵

Approximately 40 gigawatts of new renewable energy capacity were installed globally in 2008, corresponding to around 80 billion US\$.⁶ Wind power has been the largest sector of new investment, followed by solar power and biofuels. Developed countries (mainly Germany, USA, Spain and Japan) contribute around 80 percent of total renewable energy investments while developing countries (mainly China and India) make up the remaining share. China, India and Brazil are all now major producers of and markets for renewable energy, with China leading in solar, India in wind and Brazil in biofuels.⁷ China led new renewable investment in Asia, with investments of \$15.6 billion, mostly in new wind projects, and some biomass plants.

Fig. 1: 2008 Investments in Renewable Energy, billion US\$ (% change from 2007)



Source: New Energy Finance, UNEP SEFI;

Sources of investment for renewable energy currently come from a range of public and private funding. Some of the large public funds have included the German Development Finance Group (KfW), the World Bank Group, and the Global Environment Facility (GEF), which have primarily funded developing countries. The World Bank's Clean Technology Fund (CTF) finances large scale demonstrations, deployment and transfer of low-carbon technologies and totals about 5 billion US\$ in pledges to restructure the global economies. In addition, the European Investment Bank has been the leading public banking institution providing finance for renewable energy. Other sources of public financing include bilateral assistance agencies, United Nations agencies,⁸ and the contributions of recipient-country governments to development assistance projects.

Multiple policy initiatives exist for renewable energy. These include specific policy targets for renewable energy in many countries as well as power generation policies including feed-in tariffs, bio-fuel policies, solar-heating policies and rural electrification programs. Recently, European Union ministers agreed to set a target of 20% renewable power by 2020, and 10% biofuel use in transport fuels by the same date. Half of the US states now have renewable portfolio standards requiring utilities to use a particular proportion of renewable energy in the

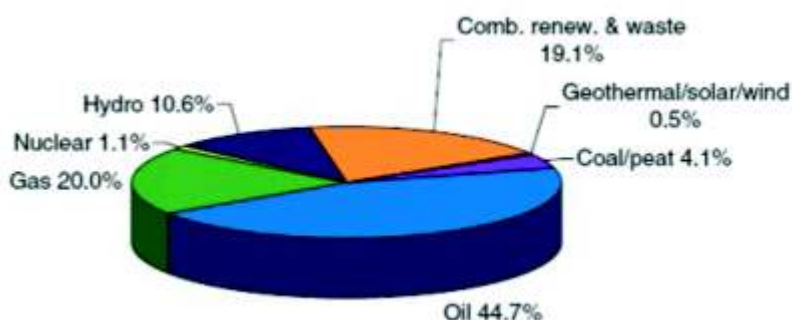
future. The US House of Representatives also recently passed the Wind Energy Research and Development Act of 2009, a bill that aim to improve the efficiency, reliability and cost effectiveness of domestic wind energy systems. In Asia, China has mandated that power firms must source 5% of their power from renewable sources by 2010; and the Indian state of Rajasthan has said that local utilities must purchase 9.5% of their energy from renewable sources by 2011-12. There have also been some bilateral and international initiatives, including most recently the International Renewable Energy Agency (IRENA) which was launched in 2009 and includes 137 signatory States⁹ among which many large developing countries. A global target of substantially increasing the share of renewable energy in global supply energy was set in 2002 at the World Summit on Sustainable Development in Johannesburg with a view to replace fossil fuels in the global energy matrix. In addition, regional initiatives like the EU's Environmental Technologies Action Plan (ETAP), launched in 2004, are helping to improve the development and to promote the wider use of eco-technologies.

Latin America and the Caribbean:

Current energy consumption in Latin America¹⁰ is around 30 EJ compared to some 450 EJ worldwide. While most of Latin America lives in urban areas (around 80 percent), the problem of access to energy is especially relevant for energy poor rural populations. It is estimated that more than 20 million people of Latin America's rural population is without access to modern energy forms and still relies heavily on traditional biomass.¹¹

Energy supply in Latin America is largely oil-dependent with substantial oil resources in Mexico, Venezuela, Colombia and Brazil. Natural gas is plentiful in countries like Argentina, Bolivia and Peru, but a good number of countries in the region have virtually no commercial fossil fuels and are dependent on imports. Large hydro is a major contributor to the energy profile in the region due to large existing resources. In addition, around 20 percent of Latin America's total primary energy supply comes from renewable sources,¹² mainly from sugarcane waste, biomass geothermal energy, and other renewable sources. The region exhibits immense diversity in terms of energy composition with countries like Brazil and Costa Rica having more than 50 percent of its total energy source from renewables while other countries have less than 10 percent. In addition, Brazil is the world's largest producer and exporter of biofuels, which domestically provide more than 25% of the Brazilian transport sectors' energy needs.

Fig 2: Primary Energy Supply in Latin America, 2006



Source: World Energy Outlook, OECD/IEA 2008

Total energy related investments in the region are currently in the range of 42 billion US\$ with renewable energy (including biofuels) constituting 15 billion US\$.¹³ A large share of energy-related investments in Latin America has historically come from public sector undertakings, in particular large state owned oil and gas companies. In addition, Latin America has been recently leading the growth in private sector investment in energy, although a large part of this has been spurred by public sector organizations either through divestures or through greenfield projects.¹⁴ Latin America receives low levels of FDI inflows into the energy sector compared with other emerging market regions,¹⁵ mainly due to government policies in many countries that act as barriers to flow of foreign aid. However there have been some successful examples of foreign aid directed towards renewable energy in the region like the "Increased Use of Renewable Energy Resources in Central America" (FENERCA) program in 2000 implemented in part by USAID. There have also been some examples of intra-regional financing with Brazilian companies playing an active role in other Latin American countries and former Portuguese colonies in Africa.

Legal, regulatory and financing schemes to foster and facilitate the use of renewables for electricity generation are at different stages of development in the Latin American region. Some initiatives with specific reference to renewable energy include: The Electricity Law in Bolivia, Law 10.848 in Brazil, Law No 671 of 2001 in Colombia which established the legal framework for sustainable energy, establishing responsibilities for the promotion of energy efficiency and renewable energy, and most recently a Law for the Use of Renewable Energy and for the Financing of Energy Transition¹⁶ in Mexico in 2008 which specifically regulates renewable energy and aims to substantially improve the legal framework for private investment in renewable energy projects. In addition, there have been a number of government initiatives including, the Program for Energy Development of States and Municipalities (PRODEEM) by the Brazilian ministry, that aim at delivering electricity to rural communities not served by the grid by means of locally available renewable energy resources. Other than renewable electricity, the use of bio-fuels has grown rapidly in the region, especially in Brazil which has mandated the blending of biofuels for 30 years under its 'ProAlcool' Program. The latter has been accompanied by a range of supporting policies including retail distribution requirements, subsidies and tax preferences for vehicles.

2. Future energy investments

What will drive investments?

Long-term scenarios of future energy use until 2100 have been developed at the International Institute for Applied Systems Analysis IIASA.¹⁷ Three alternate scenario storylines (A2r, B2, and B1) are formulated based on varying technological and socio-economic development paths using an integrated systems modeling framework (for further details on methodology and scenario storylines see Appendix). The large divergence in the scenarios in terms of technological change, energy systems and emissions profiles provide an indication of alternate technological pathways in the long-term. A number of climate stabilization levels have also been explored with these scenarios, from less than 2°C to more than 6°C above the pre-industrial level, at equilibrium. Table 1 lists the main outcomes of these scenarios in 2030¹⁸

Table 1: Range of Scenario outcomes for 2030

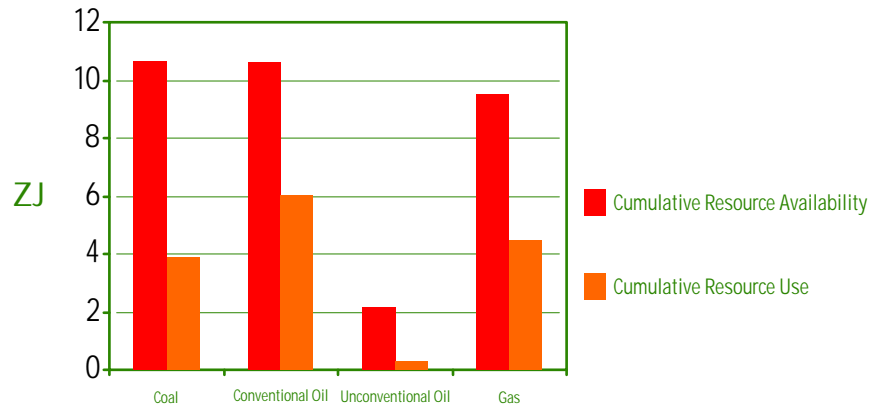
	2005	2030		
		Industrialized countries	Developing countries (of which Latin America)	Total
Population, 10 ⁹	6	1.4-1.5	6.5-7.5 (0.7)	8-9
GDP, 10 ¹² \$	45	50-60	37-60 (6-15)	90-120
PE, EJ	450	300-350	400-500 (50-100)	700-850
GtC energy	8	5-7	6-10 (0.6-1)	11-17

Global energy demand is estimated to be around 700-850 EJ in 2030. Population growth and GDP will be two key determinants of this increased energy demand. With the world's population estimated to be more than 8 billion by 2030 and the global economy growing equally as fast (although the current economic crisis could slow this growth), the demand for energy will increase exponentially. Most of the population growth will be concentrated in developing countries, in particular in Asia. While Latin America has low population growth forecast, the increase in demand particularly from Asia can be expected to significantly impact energy exporting countries in the region. Latin America's energy use is expected to grow exponentially and the rate of this growth will be somewhere between 1.5-3.5 percent per year depending on prevailing economic conditions.

The scenarios indicate that conventional fossil reserves, and resources in general, will become more expensive and difficult to exploit but concerns about profitability and the environment are more likely to cause a future shift to other sources of energy than are absolute resource constraints. Although the extraction of fossil-fuels shows enormous potential growth with the discovery and the development of more oil and gas fields, as well as an increase in so called 'unconventional' resources like shale oil and tar sands, fossil fuel use is below resource availability in all the scenarios looked at, thus indicating that resource scarcity while being an important limiting factor is not necessarily the only determinant of fossil fuel use. The increase in oil and gas prices as conventional resources get scarce is found to be a significant factor in determining the competitiveness of biofuels in the long-term. This will have wide-spread implications for Latin America and while some negative impacts can be

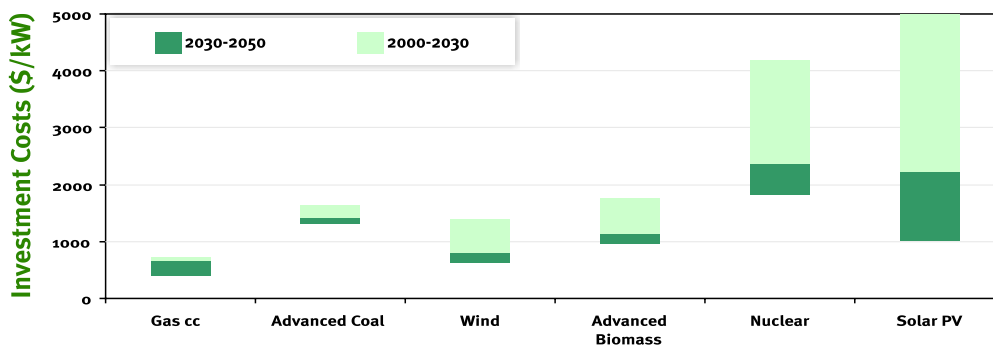
expected for the oil and gas sector in oil exporting countries. The ability of these countries to successfully implement policies that jump-start investments into alternative fuels can be a major factor in determining the extent of the impact.

Fig. 3: Fossil Resource Availability and Use, 2000-2050, ZJ



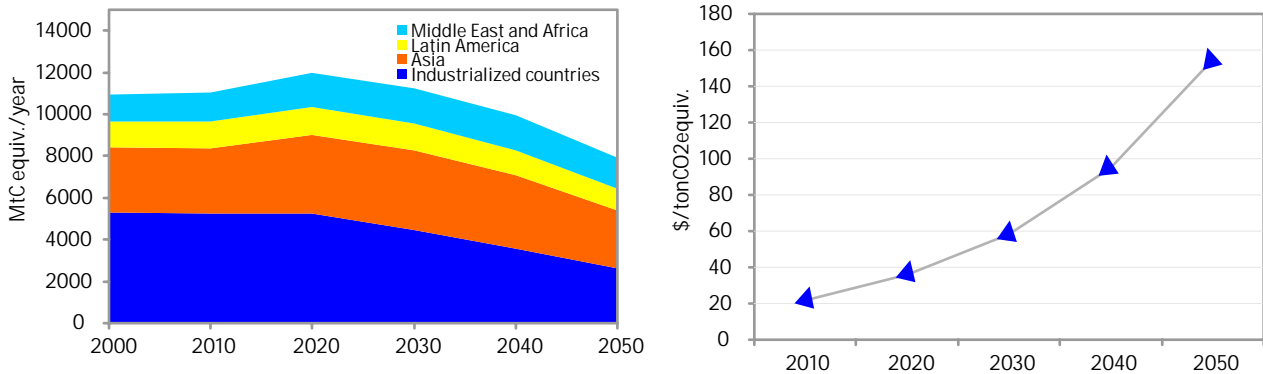
Technological development through innovation will play a vital role in both the improvement and increased deployment of existing and new technologies. Assumptions about the pace and direction of technological change are scenario dependent, but in general significant cost declines are envisioned in the future, thus taking as given the availability of R&D, technology transfer and deployment rates that will be necessary for these cost declines to result. Renewable energy technologies in particular have experienced an enormous learning effect in the past decade and currently in many parts of the world. Technologies like wind power are proving to be quite competitive with fossil fuels and this trend is expected to continue.

Fig 4: Estimated Range of Electric Technology Costs, (\$/kW)



Current and future policies both at the national and international level will be a major driver of future energy system investments. These will include national policies on energy security policies that promote access to energy and clean air quality. Policies on climate change will be important to scale-up the extent of low carbon technologies and provide the necessary momentum for the uptake of these technologies. For example, climate policies that stabilize global mean temperature levels at 450 ppm¹⁹ would require that greenhouse gas (GHG) emissions peak in 2020 and then start to decline, thus implying that developing countries would need to be involved in significant GHG reductions in the next two decades. While GHG emissions from Latin America are not expected to be as high (around 8% of global emissions in 2030) as compared to other large developing countries like China (over 20 % of global emissions in 2030), a climate policy stabilizing CO₂-equivalent concentrations at 450 ppm would still imply 30-50 % of reductions of CO₂ emissions from the energy sector (compared to a no climate policy scenario) for the region. The increasing price of carbon under a climate regime (estimated at around 70 US\$/ton CO₂ equivalent in 2030) will be the main driver for increased investments in many low carbon technologies.

Fig 5: Global GHG emissions and Carbon price, B2_450 ppm scenario



How much will be needed, when and where?

Global cumulative energy system investment needs until 2030 are found to be of the order of 28-38 trillion US\$, depending on technological uncertainty, and the extent of climate policy in place. Stabilization of climate change at 450 ppm would require annual investments of less than 2 trillion US\$ in 2030 (both in supply capacity and demand side efficiency), around 2% of estimated GDP.²⁰ Almost half of these investments would need to be available in developing countries, with Latin America requiring annual energy sector investments of around 180 billion US\$.

Table 3: Investments for a B2_450 ppm scenario, in 2030, trillion US\$

	IIASA	IEA*	McKinsey**
Annual Supply side Investments	1.5-1.8	1.5	
Annual Demand side investments	0.3-0.5	0.280	
Total	1.8-2.3	1.8	0.5-1.1
Share of GDP %	~2%	2%	0.6-1.4

*World Energy Outlook, 2008

** McKinsey Annual Report, 2007

Ensuring access to energy for all will necessitate additional investments. While evaluating the actual range of such estimates is difficult, initial calculations indicate that provision of energy supply to those who are currently without access to electricity and cooking fuels would require investments of between 100-400 US\$ per person, thus bringing total investments to around 0.2-1 trillion US\$ of annual investments in 2030.²¹

Thus meeting goals of limiting climate change to 2oc and ensuring access to energy will require annual investments of 2-3 trillion US\$ in the 2020-2030 period, less than 3% of the estimated GDP in 2030. Assuming that capital markets will grow relative to GDP, this indicates that future economic growth will make the investment requirements for new technologies and fuels attainable and shortage of capital may not necessarily pose a constraint to continued investments in the energy sector. However enabling the right kinds of investments to be made available early on will be critical to ensure that long-term climate goals can be met cost-effectively. The issue is namely that low carbon strategies have generally lower energy systems investment but higher end use one. The total systems cost are thus useful additional information.

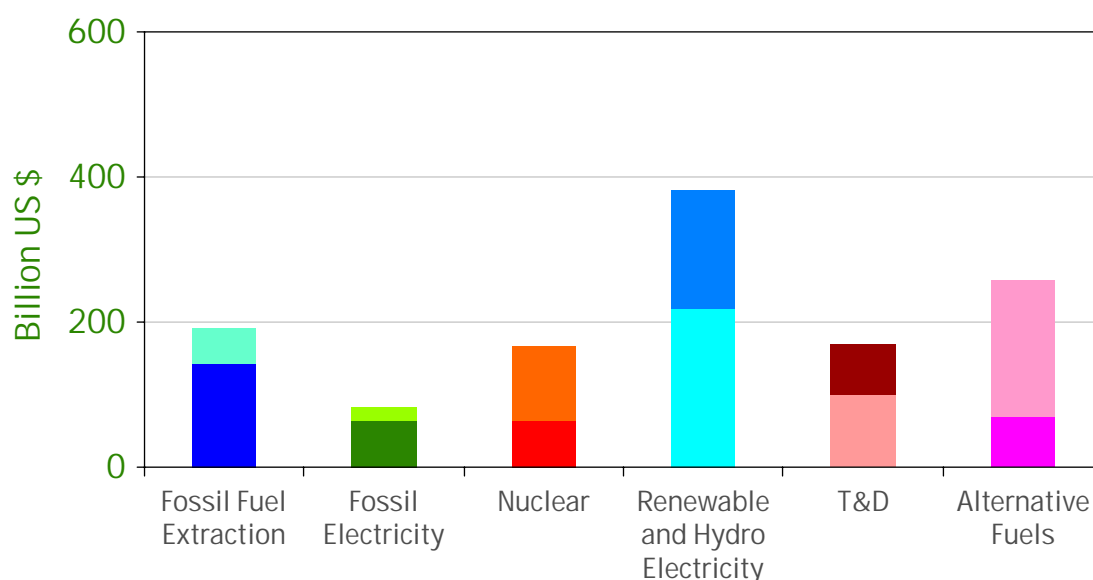
While the transition to a low-carbon pathway will involve a large-scale response across many sectors, two principal areas where investments would be critical in the next two decades are discussed below.

Low Carbon Energy Supply (including Renewable Energy):

Energy supply options both fossil and non-fossil will need to be completely restructured to be able to deliver large-scale clean and low carbon energy to dispersed populations.

In the electricity sector, investments will be needed in both replacing existing capacity, particularly in developed countries where many fossil-based power plants are aging as well as towards installation of new capacity globally. Total investments needed in the electricity sector are estimated to be around 18 trillion US\$ in the period 2010-2030.²² Fossil based electric generation will need to address issues of air quality and greenhouse gas emissions, thus paving the way for advanced coal generation technologies like super-critical boilers and integrated gasification (IGCC). In addition, carbon capture and sequestration will need to be a part of future fossil energy systems if specific climate mitigation policies are in place and given the long life times of power plants, these investments would need to be made early on. Investments into nuclear and hydro power are important investment opportunities, although public attitudes will greatly determine the extent of the expansion.²³ Annual investments in renewable electricity are in the range of 400 billion US\$ - a threefold increase from current levels.

Fig 4: Annual Global Supply Investments, 2030, B2_450 ppm scenario, billion US\$

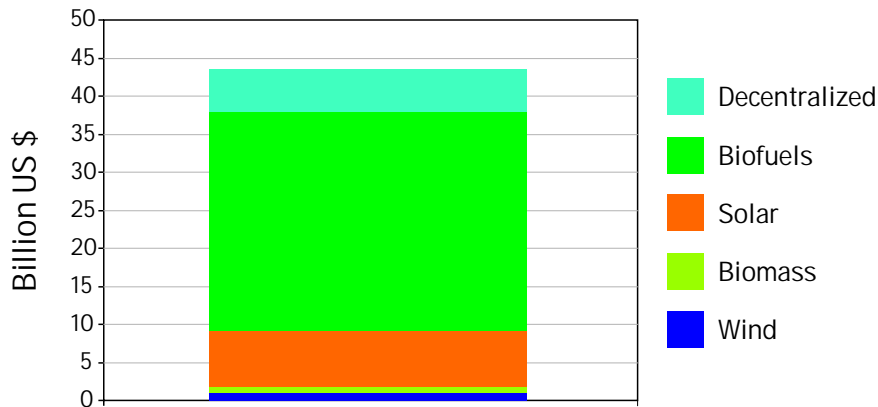


The scale-up in renewable energy will also bring with it a need for infrastructure related investments into 'smart' electric grids that can cope with decentralized, fluctuating supply. In addition, energy storage will become necessary to effectively integrate renewable supply into systems that are capable of continuous electric supply.

In the transportation sector, investments into biofuels represent an important strategy to offset GHG emissions and meet growing global fuel demands. Cumulative investment needs into biofuels are estimated in the range of 1.5 trillion US\$ over the 2010-2030 period, indicating a massive scale-up of current investments but the long-term sustainability of large-scale biofuels supply systems will depend on ensuring food security in developing regions.²⁴

For Latin America, investments in renewable energy including biomass, will need be more than 80 billion US\$ in 2030. A large part of these investments would need to occur in decentralized electric systems and biofuels, but centralized options like wind, solar and biomass will also be significant.²⁵ There will need to be a massive increase in biofuel supply from Latin America both to fulfill growing global demand as well as the escalating demand within the region itself. The trade benefits in terms of the increase in export revenues will be a major factor in fuelling this growth.

Fig 6: Annual Investments in Renewable Energy in Latin America, B2_450 ppm scenario, 2030, billion US\$



Energy Efficiency

Demand side investments into energy efficiency are seen to constitute an important part of a low carbon strategy, especially in the next two decades and investment needs are less than 300 billion US\$ annually. Investments into demand side technologies can occur already in the next 10 years and provide a cost-effective mitigation option. The low costs and comparatively high internal rates of return on many of the options involved make this an attractive market opportunity for investors.

Recently, many countries have realized the importance of demand savings in an overall energy strategy. While China is leading energy efficiency investments in developing countries, significant potential exists in other countries including those in Latin America by adopting affordable, existing technologies to improve their energy efficiency. A low carbon (450 ppm strategy) would imply that annual investments in demand savings in Latin America would need to be around 20 billion US\$²⁶, and could result in not only in significant CO₂ reductions but also lead to lower supply side investments, thus resulting in significant cost savings.

3. Securing Low Carbon Investments

How will we get there and who will pay for it?

Firstly, there will need to be new models of development financing. The recent economic crisis has provided an opportunity for rethinking of public finance mechanisms for clean energy. The main reasons that have motivated this specific inclusion of low-carbon measures in the national stimulus packages include revival of the economy through creation of “green collar” jobs; increasing concerns on energy security and increasing consensus on the urgency to respond to climate change.²⁷ The investments and policy measures included in the green economic plans should help stabilize investment activity in the short term and hopefully will contribute to continued upward investment trends once the financial crisis subsides. However the extent of the 'green' stimulus package when viewed globally is around \$200 billion US\$, indicating that they will not be sufficient to meet the challenge of the low carbon transition. The stimulus packages must be accompanied by a range of public finance mechanisms that include a range of innovative approaches like providing loan guarantees; co-investing in viable strategically important renewable energy projects; raising new finance through 'green bonds'; and developing new products for both institutional and retail investors. Bi- and multi-lateral banks will also have an important role to play in this regard.

Secondly, private sector participation is crucial. It is important that public finance catalyse larger flows of private sector resources, especially from the leading corporations to complement the effort of start-up firms and venture capitalists who have been driving the low carbon sector so far.

Thirdly, carbon markets will be essential. While global carbon markets will be the most effective in enabling technological transitions, regional initiatives will also be important. There has already been some action in this regard with the European Union's goal of linking the EU Emissions Trading System with the cap-and-trade systems being developed in other industrialized countries to form an OECD-wide international carbon market by 2015. In addition, the US government has indicated its support for a national cap and trade and NAFTA partners (US, Canada and Mexico) have committed to integrating continental emissions trading market. There will need to be a stronger push for regional and possibly global prices on carbon to speed up the uptake of low carbon technologies

Fourthly, technology will need to be at the forefront of the policy debate. While there has been a recent move towards increasing R&D in low carbon energy (for example, funding for climate-relevant research has been substantially increased to 9 billion EUR in the EU's Seventh Framework Programme (FP7) covering 2007-2013), a massive scaling up of worldwide activities in R&D on renewables including efficient use of energy is necessary. In addition, options to scale up technology deployment levels would need to be clearly defined. One option could be a continuation of current efforts like the Joint Implementation (JI), Clean Development Mechanism (CDM), GEF and other crediting mechanisms. However there would need to be a revision of some of the problems currently surrounding these mechanisms.²⁸ Mexico has proposed a global 'Green Fund' defined as a non substitutive but complementary scheme to the Kyoto Protocol that aims to expand the scale of global mitigation efforts and enable the participation of all countries. Alternatively there has also been a proposal for a new international technology financing scheme²⁹ that acts as a central clearing point for technology funding. In addition to international efforts, bi- and multi-lateral technology exchange mechanisms will be increasingly important. Local investors in energy-rich regions like Latin America will need to consolidate their leadership and expand their role as direct foreign investors in other regions.

Last but not least, favourable long-term national policy agendas will be necessary in many countries to support the transition to clean energy technologies. This will not only be necessary to provide support for public sector financing but also to provide a clear signal to private investors, thus enabling sustained investments. For Latin America, this will mean the need for stable and inclusive economic policies that will enable it to make the transition to a low carbon development path and participate effectively in the international debate.

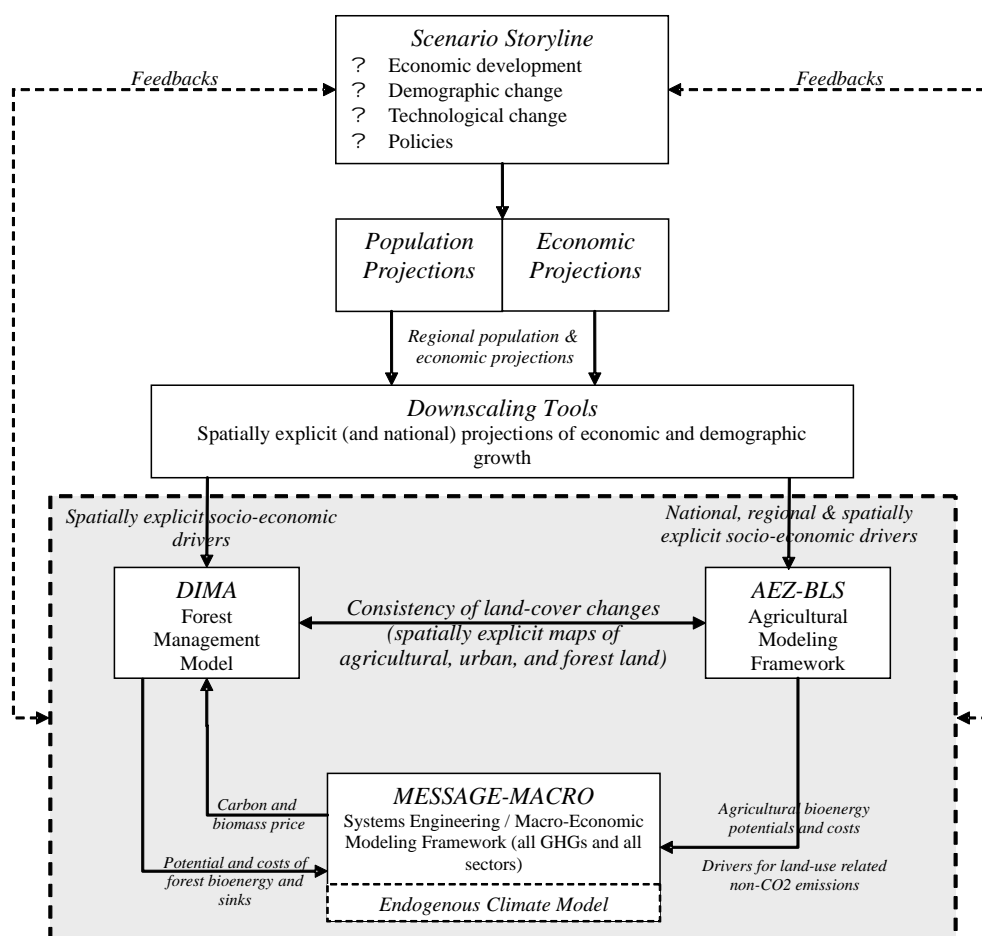
Appendix

Modeling Framework

This analysis is based on the MESSAGE-MACRO model (Messner and Strubegger, 1996). The model's current version, MESSAGE IV, provides global and sub-regional information on the utilization of domestic resources, energy imports and exports and trade-related monetary flows, investment requirements,³⁰ the types of production or conversion technologies selected (technology substitution), GHG and pollutant emissions (CO₂, CH₄, N₂O, SF₆, CF₄, HFCs, SO_x, NO_x, Black and Organic Carbon), inter-fuel substitution processes, as well as temporal trajectories for primary, secondary, final, and useful energy. The model configures the evolution of the energy system in ten year time steps and determines how much of the available technologies and resources are actually used to satisfy a particular end-use demand, subject to various constraints, while minimizing total discounted energy system costs.³¹

MESSAGE has recently been used in an integrated modeling framework and has been linked to various other models to provide a better representation of economic, land-use and forest sector interactions. The principal results comprise the estimation of technologically specific multi-sector response strategies for a range of alternative climate stabilization targets (for full description see Riahi et al. 2007). The link to a detailed land-use and forestry model ensures that food demand is met when considering land use for bioenergy and forestry purposes.

Figure 2.1 IIASA Integrated Assessment Modeling Framework



Scenario Storylines³²

A2 (A2r)

The A2 storyline describes a very heterogeneous world with a continuously increasing global population and the resulting 'high population growth' scenario adopted here is with 12 billion by 2100. Economic development is primarily regionally oriented and per capita economic growth and technological change is more fragmented and slower than in other scenarios. Supply structures and prices of both commodities and services remain different across and within regions. This reflects differences in resource endowments, productivities, and regulatory priorities (e.g., for energy and food security). The more limited rates of technological change translate into lower improvements in resource efficiency across all sectors. This leads to high energy, food, and natural resources demands, and a corresponding expansion of agricultural lands and deforestation. Energy supply is increasingly focused on low grade, regionally available resources (i.e., primarily coal). The resulting energy use and emissions are consequently highest among the scenarios with carbon emissions that approach 20 Gt by 2050 and close to 30 Gt by 2100 (compared to 8 Gt in 2000).

B1

The B1 storyline describes a convergent world with a low global population growth that peaks in mid-century and declines thereafter (to some 7 billion by 2100), but with rapid changes in economic structures towards a service and information economy, with reduction in material intensity and the introduction of clean and resource efficient technologies. The emphasis is on global solutions to economic, social and environmental sustainability, including improved equity per capita GDP growth is the highest of the scenarios analyzed. Combined with the assumed global availability of clean and high-efficiency production technologies for food, raw materials, energy, and manufacturing, differences in resource and environmental productivities are reduced significantly, which leads to comparatively low levels of GHG emissions even in the absence of dedicated climate policies. Carbon emissions, peak, at some 10 Gt by 2050 to fall below current levels thereafter (5 Gt by 2100), with the progressive international diffusion of rapidly improving post-fossil technologies.

B2

The B2 storyline describes a world in which the emphasis is on local solutions to economic, social, and environmental sustainability. The B2 scenario is characterized by 'dynamics as usual' rates of change and world population growth is assumed to reach some 10 billion by 2100. The economic growth outlook in B2 is regionally more heterogeneous, with per capita income growth and convergence assumed to be intermediary between the two more extreme scenarios A2r and B1. Given a more modest technology outlook, resource endowments and differences in income levels result in only slowly converging differences between domestic and international demands, productivities, and prices. The resulting food, energy, and resource demands and corresponding GHG emissions are consequently also intermediary between the two more extreme scenarios A2r and B1. Global carbon emissions, rise initially along historical rates (to some 13 Gt by 2050), but growth would eventually slow down (14 Gt by 2100) as progressively more regions shift away from their reliance on fossil fuels, a twin result of technological progress in alternatives and increasing scarcity of easy-access fossil resources.

1. More recent scientific publications that support the two degrees Celsius target include the European Commission Scientific Expert Group on Climate Change, International Scientific Steering Committee, the World Bank's Development Report and so on. International bodies including the G8 have further supported this.
2. IEA, 2009
3. Green Economy, The New Big Deal, UNEP 2009
4. All values are in 2007 US\$
5. Renewables Global Status Report, REN21 2009 Update
6. Around 140 billion including large hydro
7. Global Trends in Sustainable Energy Investment 2009, UNEP SEFI and New Energy Finance
8. Some examples include the Asian Development Bank (ADB), the European Bank for Reconstruction and Development (EBRD), the Inter-American Development Bank (IDB), UNDP, UNEP, the United Nations Industrial Development Organization (UNIDO), Denmark (Danida), France (Ademe and FFEM), Germany (GTZ), Italy, Japan (JBIC), and Sweden (SIDA)
9. State as of 24 September 2009
10. 'Latin America' refers to Latin America and the Caribbean throughout this paper
11. IEA, 2002
12. ECLAC, UN Economic Commission for Latin America and the Caribbean, Report 2003, World Energy Outlook, OECD/IEA 2008
13. IASA estimates, Global Trends in Sustainable Energy Investment 2009, UNEP SEFI and New Energy Finance
14. A greenfield project is one which involves constructing on unused land where there is no need to remodel or demolish an existing structure. Such projects are typically offered by the government to private sector for development.
15. IFC 2007, UNCTAD FDI Indices
16. Ley para el Aprovechamiento de Energías Renovables y el Financiamiento de la Transición Energética
17. These scenarios used here are described in Scenarios of long-term socio-economic and environmental development under climate stabilization. Technological Forecasting and Social Change (Special Issue: Greenhouse Gases - Integrated Assessment), 74(7):887-935 [2007]. There have been numerous earlier scenario efforts at IASA including Nakicenovic, N., O., Davidson, G., Davis, A., Grubler, T., Kram, E., Lebre La Rovere, B., Metz, T., Morita, W., Pepper, H., Pitcher, A., Sankovski, P., Shukla, R., Swart, R., Watson, D., Zhou: 2000, Special Report on Emissions Scenarios, Summary for Policy Makers; Riahi K, Gruebler A, Nakicenovic N (2007). More recently IASA is involved in the Integrated Assessment Modeling Consortium (IAMC) and the Global Energy Assessment (GEA).
18. These results include a wide range of baselines (A2r, B2, B1) and climate stabilization levels (450-1000 ppm CO2 equivalent). While uncertainty in the next two decades is somewhat limited, the scenarios diverge considerably in the longer-term
19. The B2_450 scenario is seen to have a 80% chance of staying below 2oC. For further details see Rao S, Riahi K, Stehfest E, van Vuuren DP, Cho C, den Elzen MGJ, Isaac M, van Vliet J (2008). IMAGE and MESSAGE Scenarios Limiting GHG Concentration to Low Levels. IASA Interim Report IR-08-020 .
20. This corresponds to around 400 billion US\$ in additional annual investments as compared to a 'no climate policy' case
21. As an example, the UNDP number shows a total of 268 billion US\$ in total. WEO 2004 has a figure of additional costs of 200 billion US\$ for access to around 500 million people.
22. IEA estimates around 17 trillion \$ in electricity sector investments
23. No policy constraints assumed in this analysis for nuclear power
24. This analysis includes a land-use model that accounts for competition for land for food and ensures that that food demand is met globally. See Appendix for details of modelling framework
25. While investments into hydro power will continue to be important, there is not expected to be significant increase from current levels.
26. This corresponds with a recent Inter-American Development Report (IADB) report concludes that investments of around US\$17 billion in compact fluorescent lighting, energy efficient motors and other measures would produce significant cost savings.
27. UNEP SEFI Report, 2009
28. Renewable energy projects still account for only 24 percent of all expected CERs. The basic economic barrier that renewable energy projects face is the relatively higher electricity generation costs for renewable electricity, although the scale of the difference varies from technology to technology and from country to country.
29. UNFCCC Report on Development and Transfer of Technologies, 25 March 2009
30. The MESSAGE model is based on a social-planner with perfect foresight. There are no individual agents involved in investment decisions. Thus the model does not account for uncertainty in decision processes, market imperfections and transaction costs.
31. A 5 percent discount rate is used in the model
32. Summarized from Riahi K, Gruebler A, Nakicenovic N (2007). Scenarios of long-term socio-economic and environmental development under climate stabilization. Technological Forecasting and Social Change (Special Issue: Greenhouse Gases - Integrated Assessment), 74(7):887-935 [2007].

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