Draft for public consultation

Climate-compatible development for Papua New Guinea

Second Draft – For Stakeholder Comment

Government of Papua New Guinea

March, 2010

ACKNOWLEDGEMENTS

This report was prepared by the Department of Environment and Conservation on behalf of the Prime Minister and Government of Papua New Guinea. It presents a revised view on Papua New Guinea's climate-compatible development, including opportunities for economic development, climate change mitigation and adaptation. The scientific understanding which underlies this study is still evolving, and remains imperfect for several important subject areas. Furthermore, a full greenhouse gas inventory for Papua New Guinea has not yet been completed. Consequently, estimates and extrapolations for our current carbon emissions have been made for some categories and sectors where data was incomplete or missing.

The Government would like to thank the many government, private-sector, development partner and NGO personnel who made important contributions to this report. Special thanks are due to the members of the technical working groups for REDD+, Adaptation and Low-Carbon Growth. The institutions consulted are listed below:

Within the government**,** the Office of the Prime Minister, the Departments of Treasury, Finance, National Planning and Monitoring, Forests, Mineral Policy and Geohazards Management, Petroleum and Energy, Agriculture and Livestock, Transport, Health, PNG Forest Authority, PNG Forest Research Institute, National Agricultural Research Institute, Mineral Resources Authority, National Disaster Centre and National Weather Service.

Beyond the government, the Asian Development Bank, AusAID, Australian National University, European Union, Institute of Medical Research, Institute of National Affairs, New Zealand High Commission, Oil Palm Research Association, PNG Forest Industries Association, PNG Sustainable Development Program, The Nature Conservancy, United Nations Development Program, University of Papua New Guinea, Wildlife Conservation Society, World Bank and World Wildlife Fund.

We would also like to thank McKinsey & Company who contributed data and analysis to this report. Technical appendices containing this data and analysis are available on request from the Department of Environment and Conservation.

EXECUTIVE SUMMARY

Papua New Guinea is committed to developing a thriving economy, a fair and happy society and a sustainable environment, as set out in our Vision 2050. Achieving this vision means increasing per capita GDP by a factor of three by 2030, implying an annual GDP growth of approximately 7% per year, well beyond the historic rate of 3-4%. While this is an ambitious target, we can achieve this increase in economic growth through the development of traditional sectors like agriculture, mining and forestry and newer ones like natural gas, services and tourism. We can succeed in these sectors; we have the necessary natural resources and we are developing the human ones.

Papua New Guinea has taken a global lead in seeking to combat climate change, particularly by proposing measures to activate the carbon abatement opportunity offered by preserving tropical forests. Deforestation and forest degradation are major contributors to greenhouse gas emissions, through large-scale logging and the conversion of forests into agricultural use. These activities continue because the value of forests as carbon sinks and a source of livelihood have not been fully recognised by market mechanisms. Together with other rainforest nations, we are working to create a mechanism for Reducing Emissions from Deforestation and Degradation, enhancing carbon stocks and managing forests sustainably in developing countries (REDD+). REDD+ will enable developed countries to pay for the ecosystem services provided by Papua New Guinea and other developing countries. The Copenhagen Accord of December 2009 recognised the fundamental role of REDD+ in climate change mitigation and makes substantial funding available for the first time, starting with a commitment of USD 3.5 billion globally for the period 2010-12. In total, funding of USD 30 billion will be made available for the 3 year period to support the implementation of mitigation and adaptation actions in developing countries in line with their national development strategies. This recognition marks a broader shift in the terms of the climate change debate, in which there must be an alignment between climate change and economic development.

For our own part, we are committed to mitigating domestic greenhouse gas emissions. Vision 2050 envisages low-carbon economic development, with an aspirational goal of carbon neutrality by 2050. Preliminary analysis suggests that emissions could be reduced by up to two thirds (compared with a Business As Usual growth scenario) by 2030, at an average estimated cost of approximately USD 4/t of carbon dioxide equivalent. This reduction can be achieved through large-scale abatement measures such as changing forestry practices, increasing agricultural yields and shifting to renewable power sources. Some of these measures will require significant investment in building infrastructure now to

support a low-carbon growth path over the next 40 years. REDD+ mechanisms are expected to be an important source of the necessary funds, but in order to access these funds we will have to develop an effective and transparent institutional framework to manage them. We will also need to develop technical and managerial capacity for activities such as Monitoring, Reporting and Verification (MRV) of agreed emissions reductions. REDD+ is also expected to provide a significant boost to conservation, protected areas and biodiversity; specific policies for these areas will be developed by the Department of Environment and Conservation under its policy for Environmentally Sustainable Economic Growth (ESEG), which complements this strategy.

Besides mitigating greenhouse gas emissions, we need to shape our development to be more climate-resilient. Our people and economy are already vulnerable to climate-related hazards. Even with global action on mitigation, climate change already in train will exacerbate some of these hazards, such as coastal and inland flooding. It will also introduce new hazards through gradual shifts in malaria prevalence and agricultural yields. Protecting our people and economy from these risks requires a thorough understanding of the nature and the size of the problem and the best ways to tackle it here in Papua New Guinea. Preliminary analysis suggests that the average cost of coastal flooding could increase from USD 20 m per year to USD 90-100 m by 2030 and the economic loss due to malaria from USD 130 m to USD 210-250 m per year, thanks to the interaction of climate change with the increased value of assets at risk as a result of economic growth. Cost-effective adaptation measures could avert 65-85% of these losses. International support will be required to carry out further analysis, build capacity, develop pilot programs and scale up the selected measures.

Climate-compatible development will require broad cooperation across all elements of Papua New Guinean society. We are preparing to reshape our national institutions so that we are able and ready to implement climate-compatible development. Beyond government, the refinement and successful implementation of the climate-compatible development strategy will require strong coordination and collaboration with private sectors and NGOs, as well as technical and financial support from the global community. Most importantly, the strategy will only work if local communities are involved in its design, support its implementation and share in its benefits.

In the coming months and years, the government will move to implement climate-compatible development, starting with the following priority actions:

- Climate change mitigation, adaptation and low-carbon growth need to be incorporated into national development planning. Policies in other sectors will also have to be reviewed to ensure they are climate-compatible.

- Further research and analysis will be required in some areas, such as developing a comprehensive greenhouse gas inventory and enhancing our understanding of climate risks.
- Many aspects of climate-compatible development require existing institutions to develop new capacities and ways of working. International support will be necessary to help develop these capacities.
- A new institution will have to be created to take charge of climate change policy at the heart of government in the post-Copenhagen reality. The Prime Minister has announced that this office will be the Office of Climate Change and Development, replacing the Office of Climate Change and Environmental Sustainability. A high priority for this institution will be to develop Monitoring, Reporting and Verification (MRV) system, fund disbursement mechanism and benefit-sharing models that ensure benefits accrue equitably to resource owners.
- Pilot programs will be required to enhance the knowledge base, identify the most effective institutional arrangements, test the new policies and build capacity.
- A large-scale consultation exercise will need to be launched to involve local communities and landowners in critical elements of the strategy, especially arrangements for benefit sharing

The Copenhagen Accord recognizes that mitigation and adaptation to climate change are inseparable from economic development. Papua New Guinea welcomes this and is now taking steps to ensure climate-compatible development for its entire people.

1. THE CONTEXT FOR PAPUA NEW GUINEA'S CLIMATE-COMPATIBLE DEVELOPMENT

Papua New Guinea enters its 35th year of independence as a vibrant democracy with enormous economic and social potential. Our geographic, biological and cultural diversity are without parallel. After a period of stagnation, the economy has been growing rapidly over the last several years, and is poised to continue on this path, thanks to abundant natural resources and increasing foreign direct investment.

In spite of its natural wealth, the nation faces enormous challenges to human development and service delivery, especially in rural areas. Approximately a third of the population is estimated to fall below the international poverty line of an income of USD 1.25 per day and more than half our adult population remains illiterate.

Papua New Guinea is taking the lead in combating man-made climate change. As a developing country, Papua New Guinea has low greenhouse gas emissions from housing, transportation and industry. However, it is also a rainforest nation, where some 80% of the population live in rural areas heavily depend for their livelihoods on the forests and on shifting cultivation that takes place on forest lands. Consequently, emissions from Land Use, Land-Use Change and Forestry (LULUCF) are relatively high. The government has recognised climate change as the foremost global challenge of the 21st century and is leading efforts to combat it internationally through programs such as REDD+. It is also planning steps to adapt to the increased risk that natural hazards and ecosystem changes implied by climate change pose to the country.

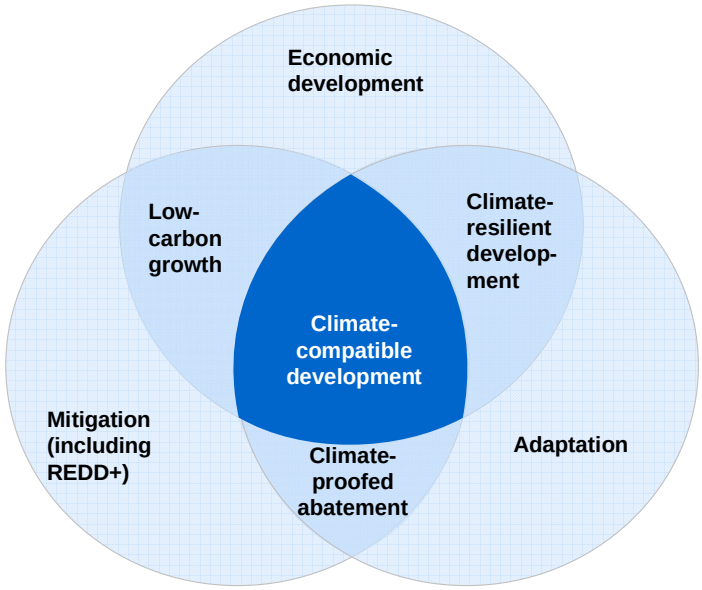
The nation is therefore moving towards climate-compatible development, combining economic development imperatives with climate change mitigation and adaptation measures. Exhibit 1 shows how these objectives should be optimised jointly. Achieving climate-compatible development will require substantial changes to patterns of land use (especially in agriculture and forestry), a shift in the structure of the economy, and new government policies. It will also require a shift in the mindsets of actors in the government, private sector, non-profit sector and landowners: from short-term to longer-term, from exploitation to sustainable use and from seeing the natural environment as a constraint to seeing it as an enabler.

There are substantial benefits to climate-compatible development that go beyond its environmental consequences. Climate-compatible development has

the potential to broaden the base of the economy, reducing reliance on natural resource exports and enhancing the earning power of smallholder farmers and forest communities. Climate-compatible development can contribute to food security by enhancing agricultural productivity and to rural development through small-scale electrification, infrastructure development and service provision. Moreover, the global community is moving to recognise the ecosystem services provided by countries like Papua New Guinea. New sources of funding from REDD+ can be invested further in development. The rest of this report sets out the preliminary view on climate-compatible development in Papua New Guinea, outlines options and makes preliminary recommendations on priorities for action.

Exhibit 1

The components of climate-compatible development



2. ECONOMIC DEVELOPMENT UNDER A BUSINESS-AS-USUAL SCENARIO

2a. Economic situation and development aspirations

Papua New Guinea's economy is growing and is very likely to continue to do so. Still, we face the important challenge of reducing poverty and making growth more broadly based. We have a dualistic development model, in which a small resource-based sector generates foreign currency income but creates few jobs, while 85% of Papua New Guineans live in rural areas, mostly as smallholder farmers with very low cash incomes and limited access to public services. Data and experience inside and outside government suggests the following:

- **Economic growth has increased from 2–3% to 6–7% over the last decade,** driven by high commodity prices and rapid growth in the construction, telecoms and tourism sectors. This has allowed our Treasury to achieve budget surpluses from 2004 to 2008 and significantly reduce government debt from a high of 95% to approximately 50% of GDP in 2008. While other countries were forced to increase public debt as a result of the economic crisis, our fiscal position remains strong.
- **Growth should continue in the medium term,** thanks mostly to our extensive natural resources. The development of liquefied natural gas (LNG) exports over the next decade is expected to give a major boost to GDP. Continued development of the agriculture, forestry and mining sectors can also contribute.
- **However, Papua New Guinea still faces multiple development challenges.** Of the country's approximately 6.5 million people, over 90% are employed in the informal sector. Domestic and international surveys reveal widespread illiteracy, malnutrition, poor health and vulnerability to natural hazards, many of which will become more salient with climate change. Investment in non-resource sectors is constrained by Papua New Guinea's limited infrastructure, human capital and financial resources.

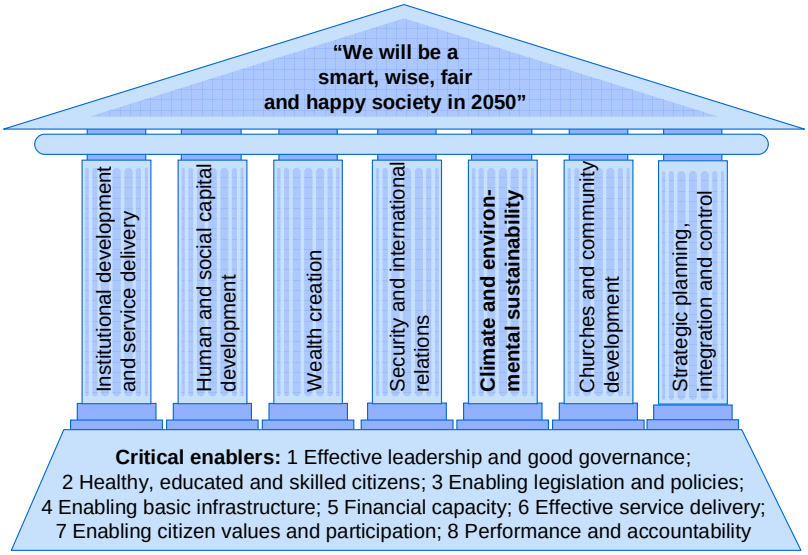
Papua New Guinea's vision for economic development is to triple GDP per capita by 2030. This ambitious target is captured within the government's Vision 2050, presented to the nation in November 2009, which outlines the country's long-term plan and interim objectives for the years 2020, 2030 and 2040.[1] The

[1] At the time of writing, the Department of National Planning and Monitoring had not yet published its Long Term Development Strategy (2010-2030) or Medium Term Development Plan (2011-15). However, the aspirations of these strategies are broadly consistent with those of Vision 2050 and this report

Vision targets 70% of the population to have access to electricity and 100% to have access to basic health and education services by 2030, along with a tripling of the road network and industrial production. Achieving these aspirations will require a five-fold increase in GDP, given that the population is forecast to increase from approximately 6.5 million to over 9 million by 2030. The components of Vision 2050 are shown in Exhibit 2.[2]

Exhibit 2

Papua New Guinea's Vision 2050 emphasises wealth creation, human development and climate and environmental sustainability



SOURCE: Vision 2050

2b. A Business as Usual scenario of economic growth

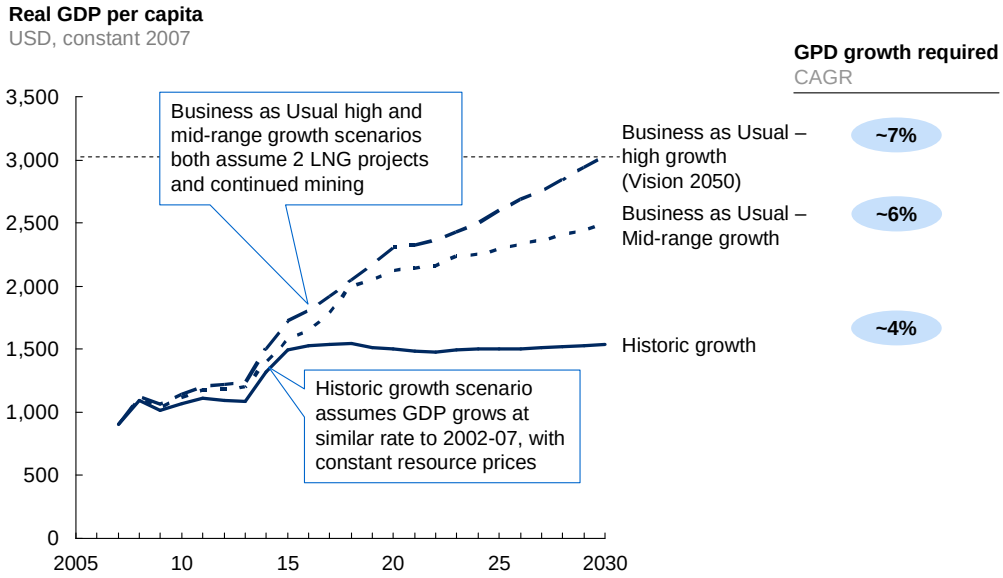
Achieving the GDP per capita goal of Vision 2050 (USD 3,000 by 2030) will require our GDP to grow at 7% per year, nearly twice its historic rate. In order to estimate a carbon emission baseline, we have taken this to be the high-end estimate of the economy's potential growth rate and developed historic growth and mid-range estimates using a bottom-up analysis of key economic sectors: their historic performance, potential and current trends. The historic growth scenario is comparable to economic performance in the period 2002-07

[2] Pillar Five in Vision 2050 describes an aspiration for carbon neutrality by 2050. However, achieving this neutrality would require the complete cessation of forestry and many commercial agricultural activities, along with large-scale afforestation and reforestation to sequester carbon. Carbon neutrality, while desirable, should therefore be seen as an aspiration and not a target of policy.

and incorporates one PNG Liquefied Natural Gas (LNG) project currently under development, while the mid-range and high growth scenarios assume two LNG projects and associated mining, industrial and service sector developments. These three scenarios are set out in Exhibit 3.

Exhibit 3

To achieve Vision 2050, the economy will have to grow by 7% per year to achieve a GDP per capita of USD 3,000 by 2030



SOURCE: Vision 2050, DNPM; Low-Carbon Growth technical working group

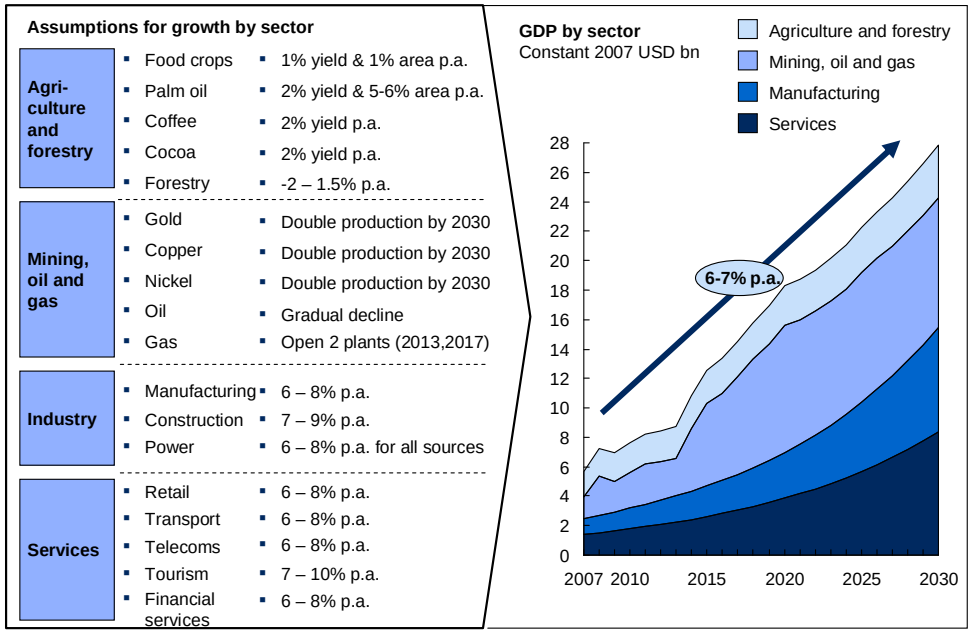
A Business as Usual (BAU) scenario should be ambitious but realistic. Based on extensive consultation throughout government , including the Department of National Planning and Monitoring, we have developed a BAU scenario that is a composite of the high and mid-range growth scenarios above. Business as Usual means that the government and private sector pursue major structural reforms to ensure rapid economic development, but do not take any measures to mitigate or adapt to climate change.[3] It should not be considered a full macroeconomic forecast, but is rather a composite of a mid-range and high-growth scenario that is broadly consistent with our vision.

The assumptions and sector composition of growth under the BAU scenario are set out in Exhibit 4, followed by a description of growth in each sector:

[3] The structural reforms envisaged by DNPM include land reform to 'unlock land for development', improvements in law and order, major investment in infrastructure through the ten strategic corridors and improved capacity in government and the private sector.

Exhibit 4

A Business as Usual development strategy will rely heavily on agriculture, mining, oil, gas and services



SOURCE: Vision 2050, DNPM; Low-Carbon Growth technical working group

- **Agriculture, fisheries and forestry** contribute 13-15% of GDP by 2030, down from 25-30% now:
  - **Agricultural and fisheries output** increase from USD 1.4 b to USD 3.3-3.6 b, accounting for 12-14% of GDP. This increase reflects increasing commercial cultivation of oil palm, cocoa and coffee, as well as increasing yields for staple crops[4]. The area under cultivation would remain relatively constant for all crops except oil palm, where a substantial increase is expected. Although temperature increase (0.2–0.7 degree Celsius) might have impacted yields for several crops, potential improvements in agricultural practices are expected to more than compensate for this. The scenario sees yields of smallholder farmers as increasing substantially; many would move beyond subsistence to produce a surplus for sale. Many challenges need to be overcome to make this happen: they include such as high transport costs, lack of extension funding, training, research, land disputes, limited access to credit, law and

[4] The increases in agricultural production envisaged under BAU are lower than those in the National Agricultural Development Plan (2007-16), which is considered highly ambitious. Large areas of forest have been allocated as agricultural leases; however, preliminary reports from the field indicate that few of these areas have been planted commercially to date.

order, disease (such as the cocoa pod borer) and reduction in commercial estate production.

- **Forestry** output increases from USD 250m to USD 350m (2.8 to 3.5 Mm3 of produced logs), accounting for ~1% of GDP.[5] The upper end scenario would be made up of 3.15m m^3 from commercial logging and 0.35m m^3 from one-off timber extraction from land cleared for commercial plantations (assuming that 90% of the commercial agriculture will be established primarily on forested land).

- **Mining (copper, gold and nickel)** remains a large contributor to GDP growth with 12-14% of GDP in 2030. To retain this share of the economy over the next 20 years, production would need to double from the current production (including the Ramu Nickel mine). This is economically feasible but would require extensive investment in exploration as existing reserves will be exhausted in 15–20 years.[6]

- **Oil and gas** accounts for 20-27% of GDP in 2030, the vast majority of this coming from exports of liquefied natural gas (LNG). This projection assumes a gradual decrease in oil production, an average energy price of ~USD 100 per barrel of oil equivalent and that both LNG projects currently under development enter production as planned. To date, no domestic consumption of the gas has been assumed, other than that required to power the compresser and other industrial sites.This assumption may have to be revisited in due course.[7]

- In the **industrial sector**, the BAU scenario sees the GDP contribution increasing from today's ~16% to 20-26%. Achieving this will require a rate of industrial growth of 6-8% per year, comparable to rates sustained over 20-30 years in Indonesia and Malaysia. The greatest contribution is likely to be from the construction sector, which is already growing at over 8% per year. Other areas likely to see further growth are the downstream processing of primary products (such as wood, coffee, copra and palm oil) and the power sector. Light manufacturing and assembly industries for export are likely to

[5] This figure is distinct from the annual exports, which are currently estimated at ~2Mm^3 by SGS, who verify export quantities for PNGFA. The export quantity of raw logs is likely to decline in line with PNGFA policy to process timber domestically

[6] Proprietary data from MineSearch and McKinsey & Company indicate that production costs for copper and gold in Papua New Guinea are in the mid-range of the global cost curve and thus competitive at prices up to 50% below the prevailing level in 2009 (e.g., gold production costs around USD 400/tr oz). Exploration and the development of new mines is therefore assumed to be viable. The environmental implications of these projects can be severe, however and thus a slower level of development may be preferable.

[7] Under UNFCCC carbon accounting rules, the emissions from burning the gas in the destination country are not included as part of PNG's national total

grow more slowly, reflecting relatively high energy costs, poor infrastructure and distance from world trading routes and markets.

- The **service sector** offers tremendous opportunities for growth in GDP. It offers important job creation opportunity for women and young people. Trade, retail and telecoms services could account for 25-31% of GDP in 2030. The tourism sector could also provide significant growth, although from a very low base, with the number of tourists increasing from 50,000 to 500,000 per year. Papua New Guinea has a large range of intrinsic tourism assets ranging from unique wildlife and pristine natural reserves, to a unique cultural heritage that could attract high value tourism.

The BAU scenario set out above will have a substantial impact on employment. While the large informal sector makes estimation difficult, the number of jobs in the formal sector is likely to almost triple from around 200,000 to over 500,000 in 2030. This will enable many people who currently work in the informal sector to move into formal employment. The sector composition of employment would change as follows:

- In the formal agriculture sector, the most rapid employment growth is likely to be in labour-intensive plantation industries like oil palm.
- Very few people are currently employed in mining, oil and gas, but this number will increase as a result of the LNG projects, each creating over 5,000 relatively highly skilled, highly paid jobs.
- In the formal industrial and service sectors, the most rapid employment growth will be in labour-intensive sectors like food processing, transport, retail and tourism.
- Employment opportunities in the informal sector will increase in line with urbanisation and the diversification of rural economies, but increasing numbers of informal sector retailers, transport operators and agricultural workers should be able to work in the formal sector and enjoy higher earnings and greater job security as a result.

2c. Forecasting emissions growth under BAU scenario

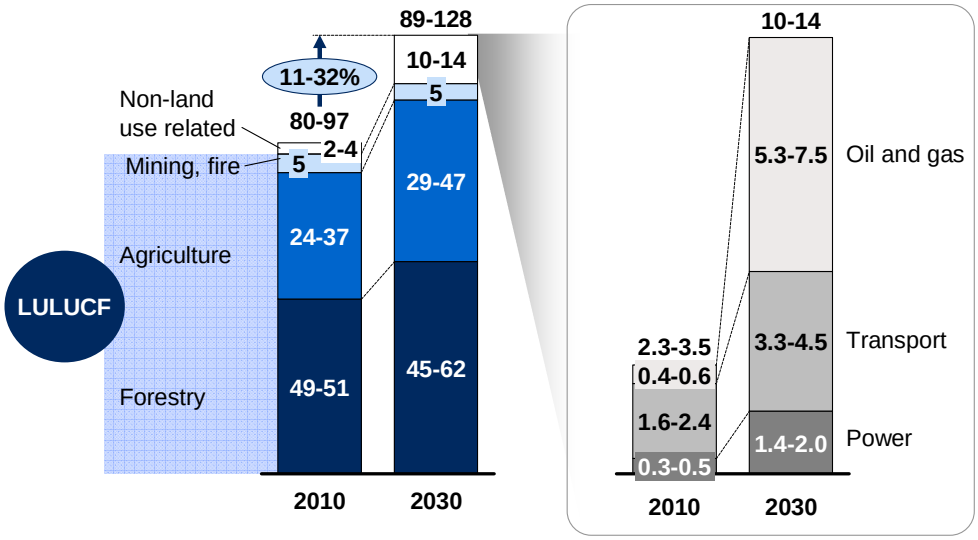
The growth path set out above is a carbon-intensive one. Greenhouse gas emissions would continue to increase, by up to 32% by 2030 under the BAU scenario (Exhibit 5). To estimate carbon emissions, data specific to Papua New Guinea has been used wherever available. In the absence of such data, international benchmarks and data from comparable tropical forest countries has been used as an approximation.

The methodology used for calculating emissions has been to identify the drivers of carbon emissions in various sectors and compute the annual GHG emissions from each activity. In accordance with IPCC guidelines, emissions from shipping, aviation and the burning of fossil fuels that are exported have not been included. For land use, land-use change and forestry (LULUCF) activities, a net approach is used (in line with IPCC guidelines) that calculates the change in time-averaged carbon stock (although this report considers above ground carbon only due to a lack of data and a global consensus on the dynamics of below-ground carbon). For example, emissions resulting from timber harvesting are calculated as the loss of carbon from primary forests compared to the time-averaged carbon stock of secondary forests, which includes biomass regrowth and loss after logging. The net emissions are all counted in the year of the activity taking place, using a "committed emissions" approach. Differences in carbon stocks in different regions of the country have been taken into account based on estimations of where such activities have taken place and are projected to occur.

Exhibit 5

GHG emissions are expected to increase by between 11 and 32% by 2030

BAU GHG emissions by sector
Mt of CO_2e/year



SOURCE: REDD+ technical working group

Current Land Use, Land-Use Change and Forestry (LULUCF) emissions are estimated at 80–97 Mt CO_2e p.a. and would increase by up to 32% by 2030 to 89–128 Mt CO_2e under a BAU scenario. LULUCF makes up 95% of Papua New Guinea's current emissions and several sectors have been identified

as the main drivers of deforestation and degradation: timber extraction, smallholder agriculture (expansion into forest and shortening of rotation cycle) and commercial agriculture (especially palm oil plantations). Under a BAU scenario, all of them will continue to represent the bulk of Papua New Guinea's GHG emissions by 2030, despite representing less than 20% of total economic value added.

- **Forestry emissions** will increase in line with the timber export volumes highlighted above, from 49–51 Mt CO_2e p.a. currently to 45–62 Mt CO_2e p.a. in 2030 (the wide range reflects uncertainty about future policy). This is based on historical rates of deforestation and degradation associated with logging, with an estimated 15% of area becoming deforested and the remainder degraded secondary forest after logging. It should be noted, however, that by 2030 the availability of commercially accessible forests will depend on the renewal of current FMAs (Forest Management Agreements). Furthermore, there is approximately three million hectares of primary forest yet to be acquired for various forest development options; much of this would become unavailable if the government allocates more of it to protected areas.
- **Agriculture-related emissions from land use and land-use change** will rise most significantly from 24–37 Mt CO_2e p.a. currently to 29–47 Mt CO_2e p.a. in 2030. Out of these numbers, most of the emissions come from deforestation and degradation caused by subsistence agriculture. Population growth and a shift into cash cropping among smallholders are direct and indirect drivers of encroachment into forests. Another emission source in this sector is commercial agriculture plantations (especially oil palm), which is estimated to grow by 5.0–6.0% annually. Subsistence-related activities other than agriculture, such as the collection of fuelwood are not currently major drivers of deforestation and degradation, as fuelwood needs are adequately covered from clearance of fallow land. It is estimated that current fuelwood need is ~3.8 m tonnes annually and it will grow to ~5.5 m tonnes in 2030. Using conservative estimates, there are ~13 m tonnes of fuelwood from the fallow land annually. But collection of fuelwood could play an increasing role, thanks to the growing population, urbanisation and a shift to more permanent agriculture.
- **Emissions from land-use change associated with fire, infrastructure development and mining** are expected to remain relatively constant at around 5 Mt CO_2e p.a. over this period. The majority of this is the result of ongoing damage to forest habitat in the Fly River catchment as a result of the Ok Tedi mining disaster, not the development of new infrastructure.

Other GHG emissions are still low relative to LULUCF, but would increase from 2.5–3.5 Mt CO_2e in 2010 to 10–14 Mt CO_2e by 2030, i.e., on a per person basis from 0.4–0.6 t CO_2e currently to 1.1–1.5 t CO_2e in 2030. These emissions would come from three main sources:

- **The demand for energy** is expected to more than triple within the next 20 years, reflecting the sort of association between GDP and energy use typical at our level of economic development. Given the country's access to large renewable energy sources, approximately 50% of additional power capacity would come from renewable sources (mainly hydro), even without additional low carbon incentives, while thermal plants would account for the rest – gas power stations and diesel generators at isolated villages that are not connected to the grid. Given their limited operating hours, diesel generators would only produce moderate emissions of 0.05 tons in 2030. In summary, the total emissions from the power sector would increase significantly from 0.3–0.5 to 1.4–2.0 Mt CO_2e in 2030, but would still remain low compared with the country's forestry emissions.
- The demand for **transportation fuel** could increase by a factor of three or four, as the number of vehicles will increase from approximately 155,000 in 2005 to more than 600,000 in 2030, thanks to increasing wealth, population growth and ongoing road construction and rehabilitation. This will result in emissions increasing from 1.6–2.4 to 3.3–4.5 Mt CO_2e by 2030.
- **Oil and gas production** is currently not associated with substantial emissions, but this will change when the LNG projects are fully operational mainly because of the energy used for compression of natural gas for pipeline transport and further liquefaction to LNG for sea transport. In addition, the upstream production process and flaring will generate further emissions. When both LNG projects reach full production, emissions are forecast to increase from 0.4–0.6 to 5.3–7.5 Mt CO_2e by 2030. This proportion could be increased if more of the gas were retained for domestic use or reduced if renewable energy sources could be found to compress the gas for transport and liquefaction.

Other sectors currently have very low emissions (less than 1% of the total); these include agriculture (direct emissions, excluding land use change), industry and buildings. Emissions from these sectors have therefore not been taken into account in building the BAU scenario. However, it is recommended that this situation be reviewed regularly. For example, a continued rapid expansion of the palm oil industry will make it necessary to forecast emissions from the use of fertiliser in plantations (an agricultural process), the burning of empty fruit bunches and the methane released by the palm oil mill effluent.

3. CLIMATE CHANGE MITIGATION THROUGH LOW-CARBON GROWTH

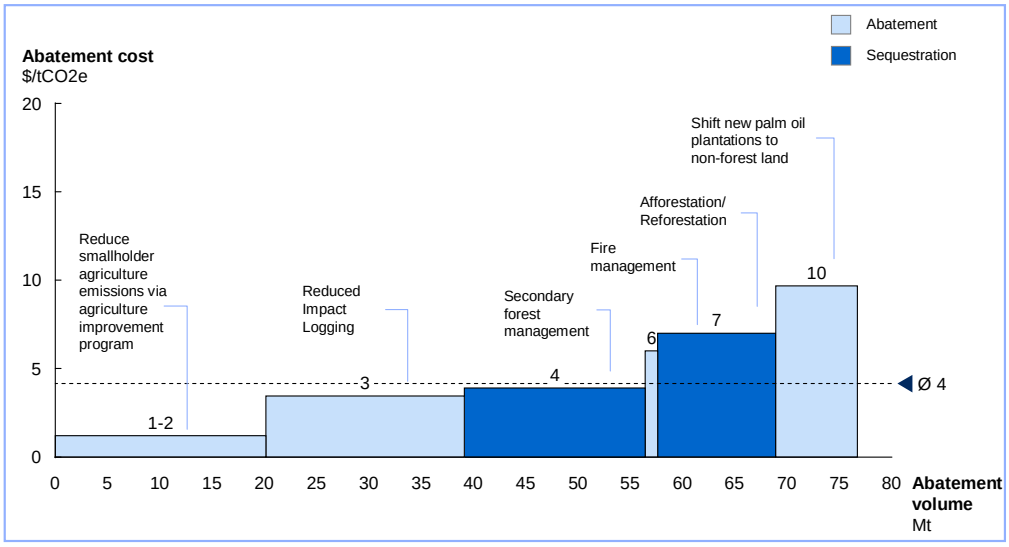
3a. Reducing emissions from deforestation and forest degradation and increasing forest carbon stocks (REDD+)

There are numerous technically feasible, cost-effective options for LULUCF emissions abatement and sequestration in Papua New Guinea. For every driver of deforestation and degradation there are multiple abatement options, including full abatement by stopping an activity, or partial abatement by reducing the carbon intensity of the activity. For example, most analyses (both government and academic) have been based on stopping agricultural use of forest lands entirely. Such an approach may have conservation benefits, but it is not strictly required for REDD+. In this report, our approach has been to analyse abatement measures that are broadly compatible with the continued development of the sector in question. Such measures, as captured in Exhibit 6, do not typically yield the full potential abatement, but they achieve very useful abatement while preserving economic growth. Costs have been calculated as program cost of the abatement, and where necessary, as the opportunity cost in USD per ton of CO_2e. Program cost estimates the additional costs of achieving the abatement while continuing the activity in a different manner. Opportunity cost refers to profit foregone from not undertaking an activity. At this stage in the analysis, these cost estimates should be seen simply as helping to create hypotheses about sequencing and prioritising abatement activities, and not as budgetary estimates. The sum of all abatement measures is up to 77 Mt CO_2e, at an average program or opportunity cost of around USD 4 per ton of CO_2e.

Exhibit 6

There is up to 77Mt of abatement potential in 2030 from programs tackling emissions from land-use, land-use change and forestry

2030 high GHG emissions scenario



Note: The curve presents an estimate of the maximum potential of all technical GHG abatement measures below USD 90 per tCO_2e if each lever was pursued aggressively, starting with the most affordable levers. It is not a forecast of what role different abatement measures and technologies will play. Assumes a 4% societal discount rate

SOURCE: McKinsey (2009); REDD+ technical working group

Emissions resulting from commercial timber extraction from primary forests could be reduced substantially by improving the sustainability of forest management. Preliminary estimates indicate that deforestation and degradation could be reduced by 50%, leading to a reduction in emissions by 14–19 Mt CO_2e p.a. by 2030, at a cost of USD 4/t CO_2e. This reduction would be achieved through a combination of two techniques: Reduced Impact Logging on primary forests and secondary forest management, which means improved post-harvest management of regrowth by applying silvicultural practices (such as shrub and climber control and replanting). While the current policy on timber extraction volumes and cutting cycles is based on principles of sustainable harvesting, it does not attempt to minimise the biomass removed, which is typically many multiples of the commercially extracted timber. Biomass removed includes trees felled to clear roads and trails for harvesting operations, and to provide materials for bridges, as well as trees damaged during the cutting and removal of commercial timber. The loss of carbon stock is extended where conditions are not conducive to forest regeneration. Continuing to harvest timber under a more rigorous application of sustainable forest management will require significant institutional strengthening, to educate and enforce best practices.

Compared with a complete halt in harvesting, Reduced Impact Logging allows the continued provision of timber for downstream processing, in line

with sector development plans, but in a way that improves biodiversity protection. Furthermore, this approach will improve the long-term viability of the timber industry, allowing forests to recover more rapidly and reducing the time required before viable timber extraction can recur in the same area. Other benefits of this approach are that forest communities will be able to continue to benefit from the roads and public services that are established through commercial logging and the increased employment opportunities created by the required monitoring and silviculture activities. However, there are several changes needed to make Reduced Impact Logging effective , such as infrastructure, institutions and behavioral changes. As an alternative, stopping logging would yield three times the reduction in emissions (45–62 Mt CO_2e p.a. by 2030) but at a higher opportunity cost of USD 8/t CO_2e. Applied at scale, this would have a negative impact on plans for downstream value adding activities and employment in the sector. The latter would however be offset by new employment opportunities created for local communities in forest conservation. There may therefore be reason to consider a combination of these two approaches.

Avoided deforestation from land clearances for establishing oil palm plantations equates to 5-8 Mt CO_2e p.a. at an opportunity cost of USD 35/t CO_2e. However, this full opportunity can be captured at significantly lower cost (~USD 10/t CO_2e) if oil palm plantations can be established on non-forested land, as the cost then represents only the foregone revenue from timber extraction in the initial land clearing and possibly some additional input costs or marginally lower yields. There are good prospects for this approach, with some projects already established on grasslands and degraded lands, such as in Ramu and West New Britain. According to PNG Oil Palm Research Association, in the next 5-10 years oil palm plantation will be mostly established in grasslands; however the limitation of grassland areas might push the oil palm plantations back to the forested land in 15-20 years. This situation will limit abatement potential of this sector. Further research should be conducted on this area.

The abatement potential from avoided deforestation and degradation from smallholder agriculture is an estimated 12–20 Mt CO_2e p.a. in 2030 at USD 1–2/t CO_2e.[8] This would be achieved through agricultural extension services to help the rural population increase productivity through improved soil management and other agricultural techniques and additional inputs (e.g.,

[8] The low cost of abatement reflects the relatively low cost of agricultural extension services provided at scale. Evidence from African countries (including Ghana, Ethiopia and Liberia) indicates that these services (including nurseries for new varieties) can be provided at a cost not exceeding USD 100 per hectare of land, with some additional cost for inputs if these are subsidised. Costs in PNG are likely to be somewhat higher, however, reflecting infrastructure constraints and the challenge of scalability

improved varietals and fertiliser).[9] Local agricultural research indicates that there is significant scope for productivity improvement, and indeed many appropriate technologies and varietals already exist. Capacity to disseminate knowledge, seeds and inputs is a major obstacle. Yield increases and soil management practices that allow for longer planting periods on the same plot of land will have a number of positive implications. Firstly, the pressure to encroach on forests to feed a growing population (~2% p.a.) or the increasing trend of adapting cash crops on land previously used for subsistence agriculture could be alleviated. If gains are substantial enough or it is possible to shift into more permanent agricultural practices, some of the land currently utilised for subsistence agriculture could be freed up for reforestation through natural regrowth, with the resulting sequestration presenting an additional source of livelihood for farmers through REDD+ credits. Such a scenario has, however, not been taken into account in the current analysis.

The abatement potential from changing smallholder agricultural practice represents a roughly 50% emissions reduction on the BAU scenario by 2030. Expert opinion suggests that this is already highly ambitious and any greater reduction would not be feasible, based on the difficulty of reaching all communities and achieving the necessary improvements, even over 20 years. The inaccessibility of many communities due to terrain and lack of infrastructure, variations in climatic and soil conditions, limited reach of existing extension services and complexity of changing behaviours are all factors which limit this potential over time. Given Papua New Guinea's long history of agriculture and adoption of new crops, it is reasonable to expect a gradual increase in yields of approximately 1% per year. However, substantial increases in yields and greenhouse gas abatement will require a transformation in the infrastructure and services provided to rural areas, as well as the capacity of farmers, extension agents and marketers. This area is therefore a high priority for further research, analysis and program development.[10]

Fire management could provide an average abatement potential of 1 Mt CO_2e p.a. of emissions at a cost of USD 6/t CO_2e by 2030. This volume represents an average over time; the reality is that the potential impact will be largely realised in El Niño years when Papua New Guinea is most prone to fires due to associated

[9] Conservations with NARI indicate that greater use of fertiliser and other inputs is not under serious consideration. More research is required into the feasibility of organic techniques (including green composting, the use of manure in certain areas and rotational practices) in Papua New Guinea

[10] The challenge of emissions reduction in the agriculture sector varies by region, crop and cultivation model: whereas permanent cultivation is common in the highlands, shifting cultivation models dominate in most lowland forest areas. Further research is required to confirm the potential of yield increases to reduce deforestation and degradation in different regions of PNG.

drought conditions. Cultural practices such as the use of fires for hunting and clearing fallow land will however make capturing these opportunities a challenge.

Better management of secondary forests to improve average carbon stocks over time could result in the sequestration of an estimated 17 Mt CO_2e in 2030 at a cost of USD 4/t CO_2e. This is based on ramping up silvicultural activities (e.g., enrichment planting, weeding and selective pruning to release tree growth and fire management) in logged areas from the current limited application to 130,000 ha annually in 2030 and will require a substantial change in capacity, timber industry incentives, policy, research and investment. As with sustainable forest management mentioned above, this represents significant employment opportunities for people in forest communities, who can be trained to assist with management of regrowth in logged-over (secondary) forests in their areas. This would typically continue for three to five years after the area has been logged, until degradation has been stemmed and the forest has begun to re-establish itself.

Afforestation and reforestation represent a sequestration opportunity of 10–11 Mt CO_2e in 2030 at a cost of USD 7/t CO_2e. This implies establishing forests on ~600,000–700,000 hectares of degraded lands or grasslands by 2030. The development of commercial plantations could also replace part of the need for commercial timber extraction from natural forests in the medium to long term. While this would yield less cumulative sequestration than natural reforestation, it may still be useful as a replacement for continued logging in natural forests.

Forest conservation also provides critical opportunities to protect the carbon stock and most importantly biodiversity from the threat of deforestation and forest degradation. Government of Papua New Guinea through DEC (Department of Environment and Conservation) is currently preparing a policy on Environmentally Sustainable Economic Growth (ESEG), which is complemtary to this strategy and includes provisions for forest conservation.

It is important to note that although the importance of afforestation/ reforestation and forest conservation have been acknowledged in the Copenhagen Accord, there is no legally binding agreement yet on the eligibility of afforestation/reforestation and conservation projects for REDD+ funding. If there is no threat to an area of land, because it is too steep for logging, uninhabited or designated a protection area, it may be difficult to establish it under REDD+, though other sources of funding may be available. It is therefore very important for Papua New Guinea to participate actively in the international discussions on the scope of REDD+.

3b. Greenhouse gas abatement in non-forestry sectors

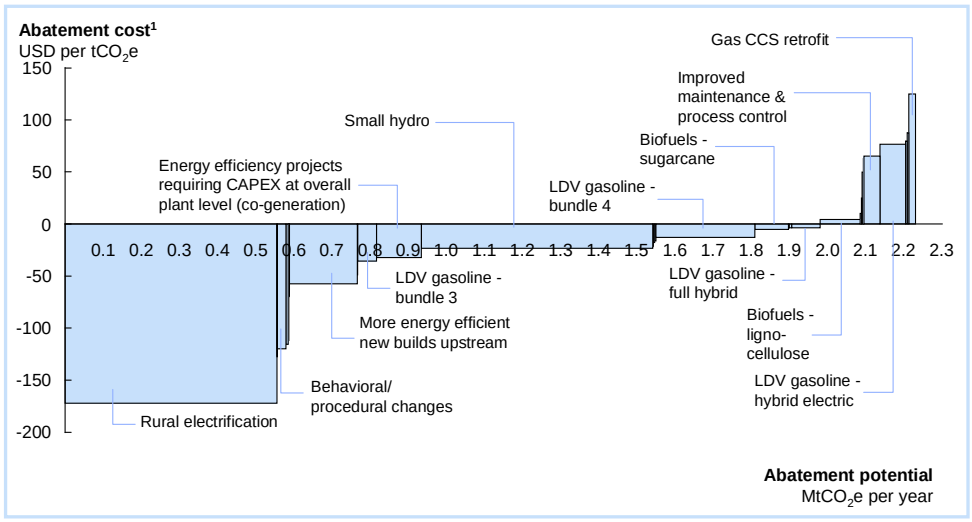
For the non-forestry sectors, emissions can be reduced by approximately 20%, i.e., ~2.2 Mt CO_2e in 2030 compared to BAU levels, mostly from the power sector. Approximately half the abatement potential (~1.2 Mt CO_2e) would come from a near total decarbonisation of the power sector at largely negative abatement costs (but at a substantial capital cost, approaching USD 200 m of investment required if rural electrification is included). This decarbonisation will also reduce indirect emissions from the manufacturing and service sectors as these sectors would rely on cleaner generation of energy. There are also interesting abatement opportunities in the oil and gas and transportation sectors. Exhibit 7 sets out the summary abatement opportunities; a sector breakdown follows.

Exhibit 7

Decarbonisation of existing sectors will reduce emissions by ~2 Mt CO_2e; these are mostly in oil and gas, power and transport

PRELIMINARY

Societal perspective; 2030



1 Cost assumptions from average of Rest of Developing Asia

SOURCE: McKinsey (2009); REDD+ technical working group

Emissions growth in power will be mainly driven by the tripling of installed capacity in the three grid-connected areas. Although Papua New Guinea's power sector already has a high share of renewable energy**,** there is potential to decarbonise it completely because renewable energy sources are so abundant:

- **Grid-connected areas**: In the grid-connected power system (Port Moresby, Ramu and Gazelle grids), 0.6 Mt could be saved at an abatement cost of USD -20/t CO_2e from additional hydro power capacity. This would leave the

new-built gas fired power stations as the largest emitters. It is theoretically possible to abate CO_2 emissions from projected gas-fired power stations through retrofitted carbon capture and storage, but this option would be prohibitively expensive compared with the other abatement measures.

- **Rural electrification:** In addition to the grid-connected power systems, rural electrification offers a very important opportunity of 0.6 Mt CO_2e. In a BAU scenario, large parts of rural electrification would be realised with diesel generators, as they represent a low up-front cost. However, there is scope to develop micro-hydro and solar photovoltaic generators to meet the same electricity demand, as these technologies have substantially lower operating costs and thus negative abatement costs over the lifetime of the asset. Additional financing and collection mechanisms need to be created to foster adoption and overcome the high investment needed for hydro and solar photovoltaic power.
- **Additional grid-connected hydro plants** are economically feasible, but require creative financing solutions to overcome the initial capital hurdle and avoid locking in carbon-emitting, inefficient power sources for 20–40 years. Further improvements in the costs and efficiency of micro-hydro and solar photovoltaic technology may allow the use of these technologies for rural electrification in the future.

Oil and gas production will be the biggest non-forestry source of emissions in 2030, though they offer limited abatement potential:

- **The oil sector offers a relatively small abatement potential (0.3 Mt CO_2e p.a.) but at negative abatement cost**, as there is scope for greater efficiency in the refinery and existing production sites and we expect production volumes to stagnate or fall.
- **The gas sector will become a significant contributor to GHG emissions in Papua New Guinea when the first LNG project comes on stream in 2013–14, but the sector's abatement potential is limited.** Firstly, given that the entire production, transportation and liquefaction infrastructure will be built over the next five years, it is likely to be built with GHG efficiency in mind. Secondly, there will be very limited potential for fugitive emissions (escaping from the pipeline in transit) given the short transportation distances currently planned. Further research is required into the abatement potential associated with the compression of the gas. For example, it may be possible to use renewable energy sources to power some of the infrastructure.

In the transport sector, abatement will depend on the gradual adoption of more efficient gasoline and diesel vehicles, but could be enhanced substantially by a shift to biofuels:

- **Nearly 0.6 Mt CO_2e can be saved at a negative abatement cost** mainly due to continuous efficiency improvements of internal combustion engines. Another 0.3 Mt CO_2e could be captured at a positive abatement cost by future efficiency improvements as well as hybrid and electric vehicles, but has not been included in the cost curve.
- **Biofuels can save approximately 0.2 Mt CO_2e**, based on sugarcane plus lingo-cellulose, but abatement costs are difficult to estimate because no resource assessment has been done for biofuel crops in Papua New Guinea. There are several potential fuels, including straight vegetable oil (SVO) made from coconut in coastal and island regions, jatropha (both as straight oil and methyl ester) and bioethanol made from sugar cane, cassava and sweet potato in highland regions, where low temperatures make the use of straight vegetable oils infeasible. Feasibility studies for some of these biofuels, including a full consideration of externalities (such as the potential effects on food crop production), are a high priority; if there are included, the full abatement potential from biofuels may exceed 1 Mt CO_2e.

Efforts to reduce emissions from palm oil agriculture and production have not been modeled as emissions are currently low. But as such emissions are likely to increase substantially, this should be another priority for the next phase of work.

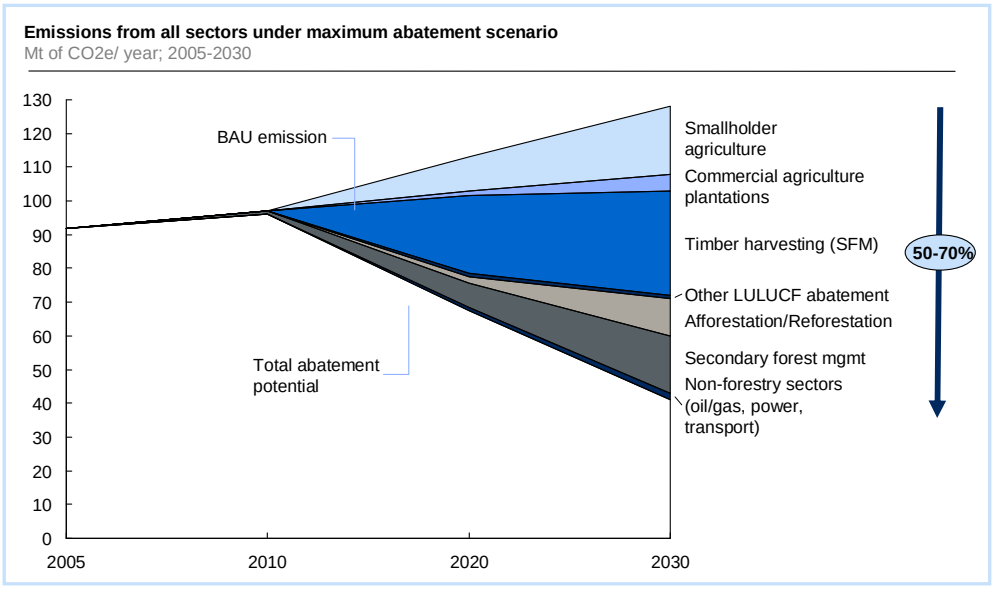
Other sectors were not analysed for emissions and abatement options, as the opportunities are likely negligible in comparison to the above mentioned sectors, and especially compared to the forestry sector. The mining sector, for example, was not modelled since Papua New Guinea does not develop coal resources, a source of significant emissions due to fugitive methane emissions. Emissions from deforestation caused by other mining activities (e.g., gold and copper) are accounted for in the forestry sector, while ongoing emissions from mining activities are small, especially as our remote mines often depend on renewable energy sources. The Lihir goldmine, for example, is supplied by a dedicated geothermal power plant.

3c. Moving onto a low-carbon growth pathway

Papua New Guinea will make great strides towards its stated objective of becoming carbon neutral by 2050 if it takes full advantage of technically achievable abatement and sequestration opportunities. Carbon neutral means that emission from all sectors should be compensated by carbon enhancement through afforestation / reforestation and carbon protection from forest conservation. The LULUCF sector in particular can make a substantial contribution, reducing emissions by up to 70% by 2030 compared with a BAU scenario.

Exhibit 8

Vision 2050 sets the aspiration of becoming carbon neutral by 2050; under a best case scenario, up to 70% of this can be achieved by 2030



SOURCE: McKinsey (2009); REDD+ technical working group

The abatement measures set out in Exhibit 8 would result in changes to the structure of the economy. These measures therefore need to be combined with existing plans for the development of the wider economy in a Low-Carbon Growth Plan, covering the decarbonisation of existing sectors and the development of new sectors that have low carbon emissions.

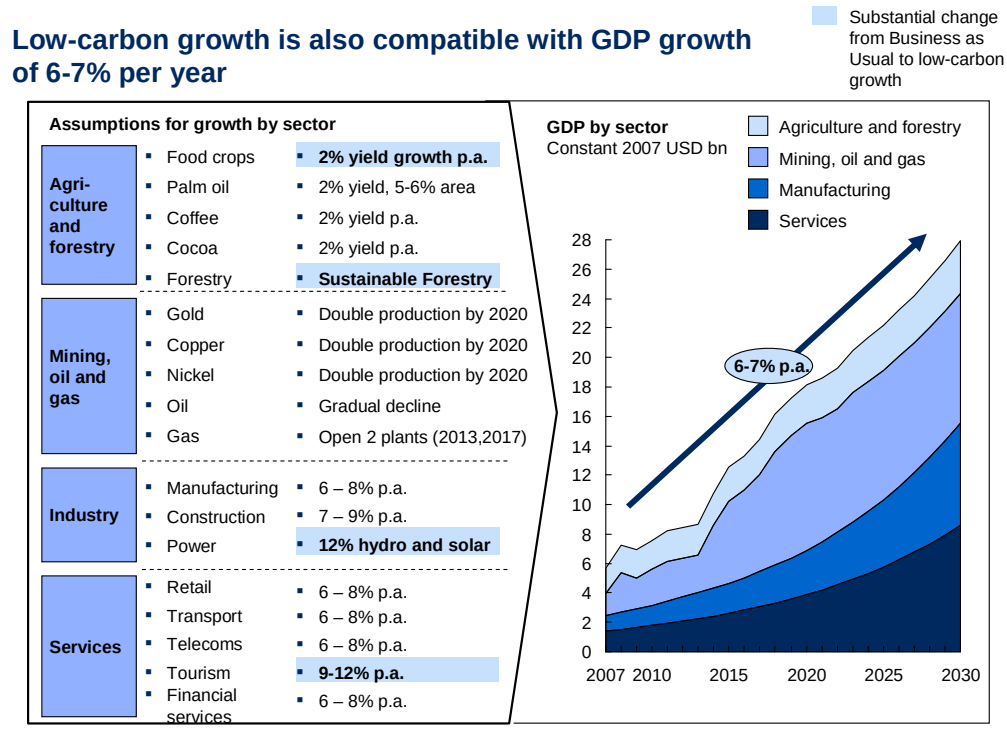
Preliminary analysis suggests that low-carbon growth can result in a similar level of GDP and employment to that achieved under BAU. The sector composition of GDP will change slightly, but GDP per capita would also reach about USD 3,000. Exhibit 9 sets out a potential growth path and sector composition of the economy under a climate-compatible scenario:

- In the **agriculture sector**, a combination of improved varietals and agricultural techniques such as soil management (which would allow for shorter fallow periods) could increase agricultural output by ~2% per year, reducing the pressure to extend the land under cultivation as the population rises. New oil palm plantations should be located on non-forested land, with irrigation and fertiliser provided if necessary.
- In the **forestry sector**, the universal enforcement of Reduced Impact Logging management in timber harvesting would result in the same overall volume of timber exports, but with much less associated deforestation and degradation and many more jobs created in the enforcement sector. Furthermore, a substantial increase in the area of afforestation or reforestation would act as a new carbon sink.
- In the **power sector**, the large-scale development of renewable energy would have little overall effect on growth, but the standard of living would improve in many rural areas as a result of rural electrification.
- The **tourism sector** would grow more rapidly than under BAU, thanks to the marketing advantage that Papua New Guinea's pristine environment would give it in the ecotourism sector.

Beyond its purely economic benefits, low-carbon growth promises superior social outcomes compared with BAU development. Increased productivity in the agriculture sector would enhance the food security, as well as the income, of rural families. Rural electrification would facilitate the extension and full operation of public services such as schools and health clinics. More high-skilled jobs would be created in the forestry and tourism sectors. Last but not least, reducing deforestation and degradation would ensure the biological diversity of Papua New Guinea's forests, capturing value far beyond their usefulness as a carbon store.

Exhibit 9

Low-carbon growth is also compatible with GDP growth of 6-7% per year



SOURCE: Vision 2050, DNPM, IMF; Low-Carbon Growth technical working group

The elements of this outline Low-Carbon Growth Plan need to be refined and incorporated into development plans for each sector and the national economy as a whole. Specifically, this includes Papua New Guinea's Long-Term Development Strategy (2010–2030), Medium-Term Development Plan (2011–15) and associated sector plans and policies. The structural shift towards low-carbon growth will take time to realise, and it is therefore critical that the pilot projects (chapter 3d) be accompanied by a simultaneous process of planning for the large-scale rollout of the most promising initiatives.

3d. Capturing the opportunities: Priorities and next steps

To maximise abatement opportunities and the transition to a low carbon growth path, early action is critical. This is important to avoid negative lock-in effects from decisions taken now, such as changing land use or building heavy oil- or diesel-fuelled power stations rather than hydroelectric ones. The impact of decisions taken now on land use, energy mix, transport and LNG infrastructure are cumulative, so starting abatement activities early would increase their overall impact. For example, establishing capacity for Monitoring, Reporting and Verification (MRV) of emissions cuts is a priority. Because REDD+ will be based on a pay-for-performance approach, no payments will be received until adequate MRV is in place.

Many of the initiatives proposed involve new technology, management and service delivery mechanisms in remote and diverse communities. Consequently, it is critical that these initiatives be piloted to assess their impact and feasibility and to learn lessons to ensure that they can be successfully rolled out across the diverse range of communities and environments in our country. Each pilot should incorporate a rigorous independent evaluation, conducted by experts from Papua New Guinea and overseas. Conducting the evaluations according to the latest international best practices (including randomised controlled trials and ongoing evaluation of impact) will enhance the credibility of the climate-compatible development strategy domestically and provide valuable lessons for other countries looking to follow our lead. There are two types of pilot projects that will be tested: sectoral and geographical pilot projects. Sectoral pilot projects aims to understand the different aspects of various REDD+ pilot programs, such as the MRV, fund disbursement, community engagement, capability building and benefit sharing mechanism. Geographical pilot projects aims to understand the dynamic of integration between different REDD+ pilot programs in certain REDD+ demonstration sites.

A number of sectoral pilot projects have been identified for REDD+ activities:

- Given the size of the potential abatement from **sustainable forest management** and the absence of data on the carbon impact and costs of **reduced impact logging and silvicultural practice** in Papua New Guinea, there is a need for pilot programs to establish comparisons with current practices. This includes total biomass removed or damaged, regeneration rates over time and additional inputs (e.g., labour and seedlings for post-logging enhancement planting and treatment) and their associated costs. Sample plots should be established in different regions and forest types and in sufficient quantities to ensure the results are statistically robust. The Forest Authority has identified the provinces of Milne Bay, West New Britain, Sandaun and Eastern Highlands for this purpose. The pilots will provide an opportunity to develop and test MRV methodologies, identify and test the benefit sharing mechanism and build capacity and capabilities (in both field measurements and remote sensing). They will run concurrently with initial results available within two or three years, following pre-and post-logging measurements and initial post-logging treatment. Results will then be combined with existing research on regeneration rates and costs associated with ongoing application of silvicultural practices. Total abatement potential and cost results will provide the basis to assess the feasibility of this abatement measure. In addition a full understanding of the costs will allow for the development of benefit sharing models.

- Research will also be required on **secondary forest management** to establish regeneration rates of biomass in areas that have been previously logged over when subjected to post-logging silvicultural practices. This research will provide baseline data for sequestration calculations for future activities. This will entail establishing and ongoing monitoring of sample plots in logged-over forests in different regions and forest types (same as above) and control areas. The outcome will verify abatement cost and provide a basis for the development of a benefit sharing model, based on an understanding of additional costs and labour required for improved management. Existing PNGFA and FRI capabilities should be utilised, but this research will also provide opportunities to develop new capacity in establishing plots and silvicultural practices. Government institutions also need to engage international NGOs that have wealth of knowledge and experiences on the ground.
- **Pilot plantations should be established for commercial crops** (i.e., palm oil) on non-forested land in various regions. This will help to determine suitability of different degraded land types, and create an understanding of yields and inputs such as fertiliser and irrigation infrastructure required. Knowing the productivity of such a plantation strategy will allow us to calculate opportunity costs of this sector strategy. Collaboration with the private sector will be important, and there is scope to build on existing projects here, including oil palm plantations that have been established on grasslands and other non-forest lands (e.g., Ramu). The outcome of the research should help determine whether the value of GHG abatement from moving commercial agriculture to non-forested lands is sufficient to justify a change in land-use policy.
- **Policy review on commercial agriculture** should also be considered, especially regarding the establishment of oil palm plantations. NGOs and many experts are reporting an increase in ‘agro-forestry’ projects that are supposed to combine agriculture and forestry in the same area; up to 2.5 m ha of agriculture leases have been signed. However, to date most of these projects have led to large-scale deforestation and forest degradation, without any agriculture or plantations being established. Therefore, commercial agriculture policy must be reviewed and strengthened so that all projects will provide optimal benefit not only to the investor, but also more importantly to the community and environment. In the short term, a moratorium should be imposed on all agricultural leases until this policy has been reviewed and enforcement mechanisms strengthened.
- **Papua New Guinea already has considerable expertise and data available from afforestation and reforestation.** Consequently, such

activities should start as soon as possible and be scaled up rapidly. The Forest Authority has identified Gomore (Rigo district) and Papa (Hiri district) as potential locations for this purpose. During the implementation, it will be important to test different approaches (e.g., spacing of trees, mix of species and monoculture) over a range of geographic and climatic conditions to determine the methods that offer optimal growth at minimal costs. Ongoing monitoring of sample plots need to be conducted in periodic reviews to continuously improve practices.

Two pilot projects are proposed as a high priority for other sectors:

- **Agricultural transformation of a suitable district or community** through research, farmer-led extension services, input provision and market development. The objective would be to double the output of marketable crops (and resulting cash incomes) over a five-year period, while ensuring that food security is maintained or enhanced. Rather than focusing on a single cash crop like palm oil or coffee, the pilot should demonstrate how yields can be increased in multiple crops simultaneously to increase smallholders' incomes and reduce their exposure to commodity price fluctuations. Another objective for the pilot would be to reduce emissions associated with clearing forest for agriculture by intensifying the use of existing plots. Executing the pilot will require close collaboration between local communities and the following institutions: Department of Agriculture and Livestock, Department of Lands and Physical Planning, Department of Works (for road maintenance and potentially construction to improve market access), Department of Transport, National Agricultural Research Institute (NARI), and provincial and district administrations. Most importantly, it will also require the active participation and support of local landowners and other influential members of the community will be essential.
- **Sustainable rural electrification through a combination of solar micro-hydro and photovoltaic technologies.** The objective would be to ensure that 50% or more of households and businesses in a suitable district or community have access to electric power for at least 12 hours per day and that critical community services (such as schools, health clinics and airstrips) have 24-hour access. The most important success factor for rural electrification will be to make it financially sustainable, by collecting user fees from the community that enable it to pay for part of the investment and ongoing maintenance in the micro-hydro plant or photovoltaic panels. This pilot will require close collaboration between the Department of Petroleum and Energy, provincial and district administrations, local landowners and the

private sector in the form of power and technology companies and financial services providers.

While further research is required in many areas, lack of detailed knowledge cannot become an excuse for inaction: rather, research should be integrated with the pilots through a continuous process of monitoring and evaluation. Where possible, pilot projects should be developed from an integrated, whole-community perspective. For example, a pilot agricultural extension project in a village trying to improve agricultural productivity could also test whether some of the land currently under shifting cultivation could be freed up for reforestation. In addition, the potential income generated could be used to finance the installation of solar or mini-hydro power in the village. Such an approach will require collaboration between various government departments and potentially partnerships with development partners, NGOs and private sector organisations. Such efforts will help to better understand how innovative mitigation actions could result in developmental benefits. In time, testing an integrated approach for an entire catchment area will provide an opportunity to test possible synergies, methods for aggregating carbon savings and arrangements for sharing benefits.

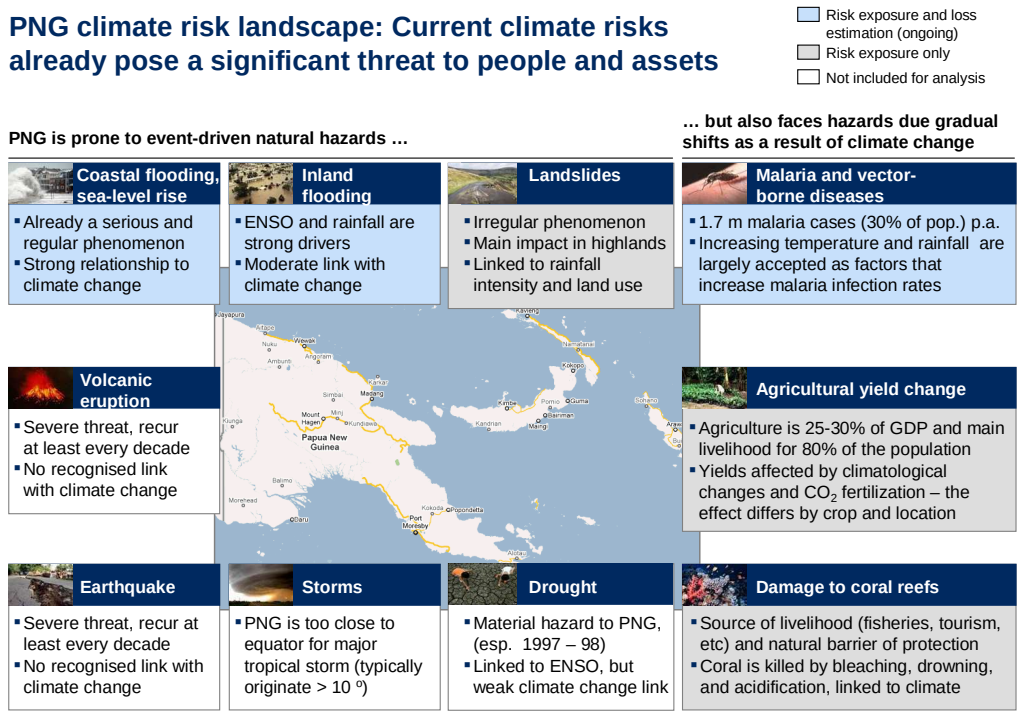
4. CLIMATE RESILIENCE THROUGH ADAPTATION

4a. Hazard identification

The natural environment already poses significant risks to Papua New Guinea today; hazards like coastal flooding, inland flooding and droughts take a severe toll on the people and the economy. Climate change will likely exacerbate some of these event-driven hazards and may also introduce new hazards due to gradual shifts in climatic conditions – most prominently, increased malaria penetration in the highlands, changed agricultural yields and damaged coral reefs. Throughout the country, natural disasters driven by climatic conditions[11] (i.e., excluding seismic and volcanic activity) as well as gradual shifts in climatic conditions disrupt daily life, cause damage to assets and infrastructure, destroy livelihoods, endanger cultural and ecological treasures, and kill or injure people (Exhibit 10).

Exhibit 10

PNG climate risk landscape: Current climate risks already pose a significant threat to people and assets



SOURCE: Adaptation technical working group

[11] Only climatic hazards were considered in this analysis. However, the methodology can also be applied to non-climatic, geophysical hazards, such as earthquakes and volcanic eruptions, which should be analyzed in later phases.

The six most serious hazards were selected based on their relevance to our country and their relationship with climate change:

- **Coastal flooding and sea level rise will affect coastal regions, mainly on the north shore of Papua New Guinea.** In the last 15 years and through four catastrophic flood events, coastal floods have affected some 8,000 people a year. On an annualized basis, the floods cause USD 10-20m of damage, displace 500 people and killed five. Rising sea levels worsen the effect of coastal floods and necessitated the evacuation of people from the Carteret Atolls and Duke of York Islands, as salinisation and flooding are damaging fragile communities and cultures, making these areas uninhabitable.
- **Inland flooding, driven by heavy irregular rainfalls, regularly affects valleys and wetlands in both lowlands and highlands.** The effects of inland flooding are amplified by steep inclines and deforestation. Based on 19 years of data, 22,000–26,000 people are affected annually by inland floods, displacing 6,000–8,000 and typically resulting in a few deaths each year. Public records estimate annual damage at USD 8–12m, a burden usually shouldered by the poorest people in the country. Changes in climatic conditions – both through increased average precipitation and increased extreme rainfall events - will strongly affect the impact of inland floods.
- **Landslides, triggered by increased rainfall intensity and land use changes, destroy vital assets in mountainous areas.** In recent decades, landslides have caused considerable damage to road infrastructure and remote communities. The effect of landslides is not well understood given the unpredictability and remote impact. At the same time, landslides have caused significant damage along the Highlands Highway, the sole lifeline for the highland communities and export businesses. At the time of writing, no recent estimates for the damage could be obtained. Changes in precipitation patterns and land use are likely to increase the number of landslides in PNG and this is therefore a priority area for further research and analysis.
- **Malaria severely affects our daily life, with 1.7m people infected every year.** About 60% of the population lives in high-risk malaria regions. Based on an estimated inclusive cost of around USD 80 per infection per year, malaria currently costs the economy USD 130m per year. In the last 20 years, climatic changes have worsened the effects of malaria; amidst rising temperatures, the parasite has established itself in regions like Enga, where it was not previously present. Additional rises in temperature over the next 20 years will introduce malaria to previously risk-free regions and could worsen the impact of malaria for the population now living in low-risk zones.

- **Variability in agricultural yields will affect many agricultural regions.** The highland regions are particularly sensitive to variability in agricultural yields as a result of change in climatic conditions. Three million highlanders rely on the sweet potato for around 70% of their diet. The sweet potato is highly sensitive to change in climate conditions. At present, climate-sensitive crops like sweet potato, coffee and cocoa have a crop-equivalent value of USD 0.7-0.9b, which means we have significant exposure to the yield consequences of climate change. These effects will be mainly shouldered by subsistence farmers, and who may need to look for an alternative crop replacing what has been their main source of calorie intake for over 300 years.
- **Sea temperature increase and acidification may over time destroy Papua New Guinea's coral reefs, the fifth largest in the world.** The economic value of these reefs is estimated at around USD 170 m p.a. today, Between 50,000 and 70,000 coastal inhabitants rely on coral reefs for their food, livelihoods and shelter. Reefs also contribute USD 95 m annually to GDP through fisheries and tourism, and avoid another USD 75 m in further coastal damage, due to the protection they provide from storms and loss of land. Comparisons with other countries with extensive coral reefs, such as Belize, suggests the GDP contribution of the reefs could ultimately reach USD 0.7-0.9 b per year. The greatest potential comes from the tourism sector (which only captures some 5% of that potential at present). The reefs offer other valuable services, such as climate regulation and genetic diversity.

Climate change will increase the expected losses associated with these hazards – the important question is how severely. Three IPCC scenarios [12](B1, A1B and A2) have been used to account for the full breadth of uncertainty of the climate change effect. While effective mitigation measures are crucial to curb climate change in the long run, IPCC models show that global warming out to 2030 is little influenced by the level of GHG emissions in the next 20 years, due to lags in the climate system. Hence, 2030 was selected as time horizon for the adaptation analyses. Depending on the scenario, temperature will increase by 0.2–0.7 degrees Celsius, rainfall will change minimally (by -0.9–3.4 mm), and sea level will increase 0.08–0.2m by 2030 under these scenarios. Economic development also increases expected losses, as the economic value of assets at risk grows. A growth rate of 7% per year has

[12] To date, the IPCC scenarios refer to the average effect of climate change on the whole of Papua New Guinea. However, NWS has recently acquired a LCM of the country with 20km horizontal resolution processed for the A1B scenario

been employed for assets, in line with the GDP growth forecasts in Vision 2050 and the forthcoming Long-Term Development Strategy.

For this preliminary report, the two hazards that are expected to cause most damage, coastal flooding and malaria, were analysed in more detail. The inland flooding hazard is also expected to cause substantial damage and is in the process of detailed analysis by the Adaptation Technical Working Group. Detailed analysis of the other two hazards is required to understand the total expected loss and will take place at a later stage.

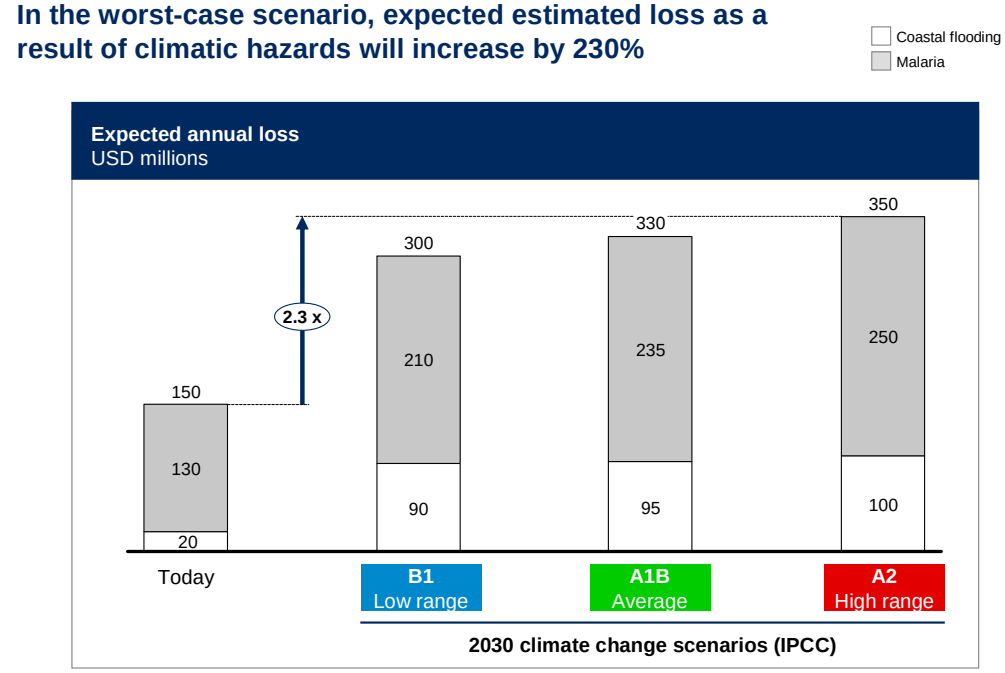
The total expected losses for coastal flooding and malaria are estimated to increase from USD 150 m today, to USD 300–350 m by 2030, thanks to a combination of climate change and the increasing value of economic assets:

- **Rising sea levels will increase the frequency** of severe coastal flooding. A 20cm rise, as assumed under the high climate change scenario, will almost double the frequency of a 100-year event to once in 50–70 years. This increases the expected annual loss from USD 20 m today to an estimated USD 90–100 m by 2030. Climate change will be responsible for USD 7–15 m of this annual loss by 2030. The remainder of the loss will be attributed to the increased value of assets due to economic development in flood-prone areas. Much of this loss originates from damage to high-value commercial assets in major port cities, whose value will increase with economic development. Swift action (e.g. zoning laws) is thus required to curb further economic development in these zones. Beyond the economic loss, flooding could affect up to 65,000 people directly by 2030. This does not include the impact of flooding on food security, through the destruction of crops caused by salinisation and groundwater contamination.
- **Rising temperatures may increase the malaria infection rate from 27% to 29–31%,** depending on the scenario – mainly due to a shift of endemic and epidemic malaria zones to higher elevations. Risk zones could shift upwards by 30–115m under the low and high climate change scenarios, respectively. In addition, the economic cost per case of introduction of malaria in previously risk-free regions could be up to 2.5 times as high as in the currently endemic regions (from USD 80 to USD 200) because of lower immunity and the disease taking more of an epidemic form, with substantial losses in economic activity. This increases the expected loss from USD 130 m today to an estimated USD 210–250 m by 2030. Climate change is responsible for USD 15–50 m on an annual basis. The remainder of the increased loss is due to a growing population in malaria risk zones, assumed to be 2.1% annually.

Exhibit 11 illustrates the consolidated expected loss contributed by both coastal flooding and malaria hazards.

Exhibit 11

In the worst-case scenario, expected estimated loss as a result of climatic hazards will increase by 230%



SOURCE: IPCC AR4, CSIRO, SEAFRAME, Expert interviews, press clippings, Academic literature, Meteorological data, NASA SRTM, CGIAR, ESRI, PNG RIS, PNAS, WHO, CDC, World Bank, PNG MRI, WRI; Adaptation technical working group

4b. Identification of effective adaptation measures

Adaptation measures from all sectors have been reviewed for malaria and coastal flooding, for the purpose of hazard mitigation and insurance of losses that cannot be mitigated. Based on research done by the Economics of Climate Adaptation Working Group, 40–65% of expected losses can be averted through cost-effective measures. Our findings suggest that Papua New Guinea can gain a benefit in the high range of these estimates. With sufficient community buy-in, we could reach as much as 85% of loss aversion through the application of measures in selected high-risk areas:

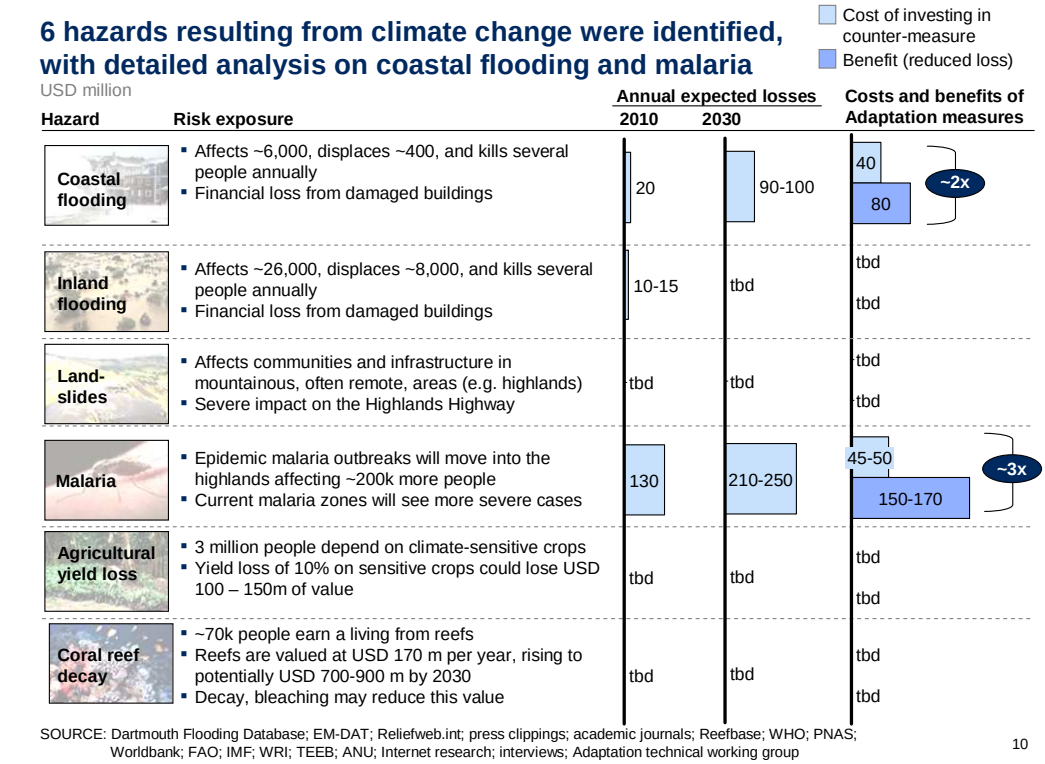
- **For malaria**, the most promising measures are: 1) ensuring continuous availability of artemisinin combination therapy (ACT) and rapid tests if treatment is needed, 2) distributing long-lasting insecticide treated nets (LLINs), and 3) conducting targeted indoor residual spraying (IRS). Distribution of these measures to all districts, especially to remote villages, is

critical for successful nationwide implementation. Furthermore, all measures should be accompanied by a clear educational campaign.

- **For coastal flooding**, the most promising initiatives are 1) community-based mangrove planting and monitoring, 2) building sea walls, preferably with locally available material, in residential and small-scale commercial areas where urgent action is required and 3) building dikes in high-risk, high-density economic areas (e.g., Wewak city). Suitable adaptation measures can differ strongly between the type of regions it aims to protect. Structural measures, such as sea walls and dikes, should be implemented where urgent action is required. Mangroves require at five to eight years of growth before becoming functional. In addition, particular attention should be paid to maintaining and reviving coral reefs, especially on the north coast and around flood-prone islands. Where structural measures are not cost-effective, insurance should be considered to better share and finance risk.

Exhibit 12 illustrates the low average cost-benefit ratio for cost effective adaptation measures for the two analyzed hazards.

Exhibit 12



Implementing these measures reduces the costs of climate risk from USD 140 m in the **best case** (USD 300 m expected loss, 85% cost-effective loss aversion, see Exhibit 12), and USD 200 m in the **worst case** (USD 350 m

expected loss, 65% cost-effective loss aversion) for coastal flooding and malaria. This 40–55% reduction in the costs of climate risk underscores the need for immediate action. If implemented in a timely manner, the costs of climate risk by 2030 break down as follows:

- **Residual loss** of USD 50 m in the best case (65% below today's level) and USD 120 m in the worst case (20% below today's level); in either case, cost-effective measures do not only fully eliminate the additional future expected loss, but do decrease Papua New Guinea's current exposure to both coastal flooding and malaria hazards. Insurance could be used to reduce expected loss further; further analysis is required to determine the costs and benefits of this for individual cases.
- **Cash costs of implementation** range between USD 80-90 m, assuming implementation at a cost-benefit ratio of about 0.35, based on a weighted average of both coastal flooding and malaria cost-benefit ratios.

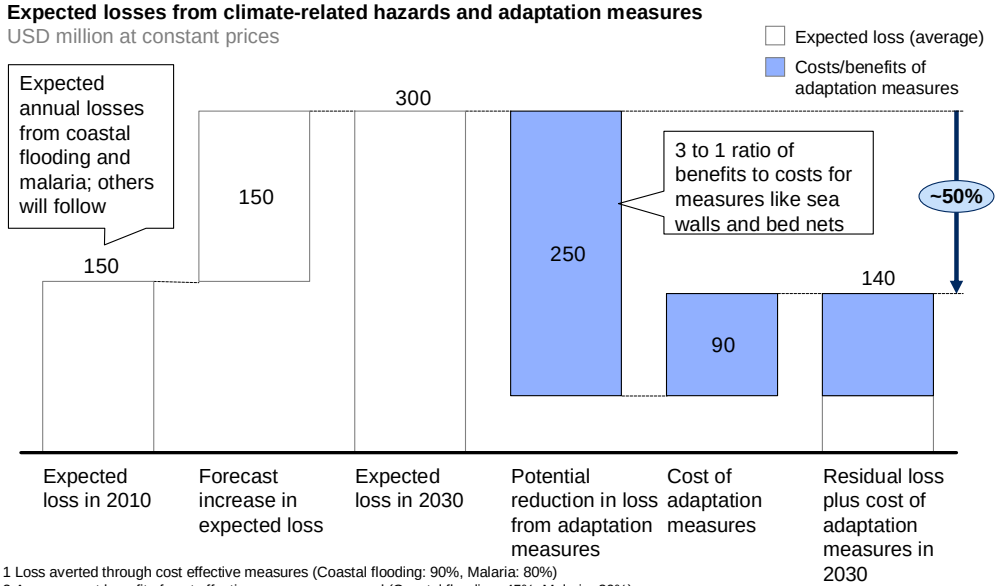
Exhibit 13

Losses are forecast to double by 2030, but timely investment in adaptation measures could reduce losses to current level BEST-CASE[3] EXAMPLE

COASTAL FLOODING & MALARIA

Expected losses from climate-related hazards and adaptation measures

USD million at constant prices



1 Loss averted through cost effective measures (Coastal flooding: 90%, Malaria: 80%)
2 Average cost benefit of cost effective measures assumed (Coastal flooding: 45%, Malaria: 30%)
3 Low-range expected loss, high-range cost effective measures, and low-range cost-benefit ratio

SOURCE: Adaptation technical working group

11

4c. Next steps: Pilot projects and implementation

Our national context poses obvious implementation challenges – not least the difficulties of access to remote, high-risk areas and gaps in our still relatively new and growing communication network. In addition, customary land

ownership patterns and ethnic group norms leave little precedent for populations to relocate. This constrains the set of adaptation measures available for localised hazards such as coastal flooding. The local applicability of adaptation measures will need to be verified as the climate-compatible development plan is translated into regional and sectoral action plans.

As with mitigation, testing the proposed adaptation measures through pilots is vital. Four pilot projects are proposed as a high priority to address the feasibility of the adaptation measures: two for each of the malaria and coastal flooding hazards. Pilot financing should ensure that communities have incentives to use funds responsibly. Equally, the pilots should be tailored to local customs. They should be monitored and evaluated regularly to ensure that lessons learnt are captured for the eventual scale-up. Lastly, the pilots offer a unique opportunity to identify best practices, as well as gain stakeholders' support.

Coastal flooding pilot projects

- **Community-based mangrove planting program in villages on the north coast and islands.** Small-scale mangrove planting initiatives are already in place at several sites along the south coast. The objective of this pilot is to test the viability of extend the reach of the existing project to other sites in the country by closely involving local communities. Local training sessions will be held around pilot communities to ensure easy access. These pilot sites will be located mainly on the North and East coast, as well as flood prone islands. Mangrove planting and maintenance techniques will be taught to one person representing his/her local community, and seedlings will be provided. Regular monitoring by trained staff is recommended to ensure the mangroves are maintained. The required investment to cover a 300 km coastline is expected to be ~USD 0.5m to train all communities and provide seedlings. The annual cost for the first five to eight years will range between USD 0.2m and 0.4m, depending on level of local NGO involvement. This pilot will also require close collaboration between research institutions (e.g., MIRC), provincial and district administrations, and local communities.
- **Protection of residential assets using low-cost sea walls.** The objective of this pilot is to protect valuable residential and smaller commercial assets from coastal flooding by using sea walls. Existing methods of building sea walls using local materials will first need to be identified. A selection of different methods are applied to pilot villages, chosen for their comparable flooding and asset risk. It is crucial that the pilot community expresses a willingness to implement sea walls according to the suggested method. The state of the sea walls needs to be monitored at regular intervals, as well as

the wall's ability to prevent coastal erosion and minimise flooding during flooding events. Marine engineers are required to help with material selection, sea wall positioning and structural monitoring. Achieving this pilot requires close collaboration between local communities and the Department of Transport, Department of Works, EI-PNG, Maritime Safety Authority, PNG Ports Corporation and provincial and local administrations.

Both coastal flooding pilot programs should be started around the same time. This will allow some communities to try both measures at the same time and test the synergies between planting mangroves and building traditional sea walls.

Malaria pilot projects

- **Distribution and communication of malaria prevention measures and treatment to remote villages.** The objective is to ensure access to two malaria prevention measures (i.e., IRS, LLIN) and a treatment option (ACT) in selected remote villages that don't currently have access to such health facilities. Pilot villages should be selected in the four main malaria risk zones to observe efficiency of adaptation measures by zone. For selected villages, important channels for distribution and communication need to be identified and considered for partnership. Possible channels include churches and national corporations, but should also include planned NARI outreach centres. The two adaptation measures need to be tested individually as well as in combination with each other in each village, to understand the synergies (i.e., IRS only, LLIN only, IRS+LLIN). Therefore, it is critical that malaria prevalence is tested before and during the pilot, preferably at a time with similar malaria activity (e.g., towards the end of the rainy season). Achieving this pilot will require close collaboration between the Department of Health, WHO, NARI, corporations, provinces and districts.
- **Partnership with large corporations for malaria prevention for their workers.** The objective is to implement malaria adaptation measures and communicate correct usage through active communication. LLINs should be provided to all workers, and all compounds should be treated with IRS. Working together with corporations allows pilots to be run in a controlled environment and ensure targeted communications. In addition, since communication and distribution takes place through a single interface, limited resources will be required to achieve this pilot. At the same time, the pilots require close collaboration between the Department of Health, WHO and the corporations as well as periodic monitoring.

5. WHAT IS REQUIRED FOR EFFECTIVE ACTION ON MITIGATION AND CLIMATE RESILIENCE

5a. Next steps for policy and institutional development

The government recognises that the **policy frameworks, institutional structures and capacity for implementing the climate-compatible development measures in this report are currently insufficient** and is taking measures to ensure that both are improved:

- Climate change mitigation, adaptation and low-carbon growth need to be **incorporated into national development planning**, including Vision 2050, the Long-Term Development Strategy and Medium Term Development Plans**.** This will require extensive coordination across all departments as well as with provincial and local governments. Policies in other sectors will also have to be reviewed to ensure they are climate-compatible.
- At the same time, **further research and analysis** will be required on issues where scientific understanding is limited. For example, a high priority will be to develop a comprehensive greenhouse gas inventory, including (but not limited to) emissions resulting from land use, land use change and forestry (LULUCF). Other priorities include assessing the results of previous pilot projects in Reduced Impact Logging and Sustainable Forestry Management (SFM) and innovative agricultural techniques and further analysis of climate-related hazards, such as inland flooding and the effect of rising sea levels and temperatures on coral reefs. International support (both financial and technical) will be crucial to ensure that the research is carried out in accordance with the latest international standards.
- **Many aspects of climate-compatible development require existing institutions to develop new capacities and ways of working.** For example, dealing with more frequent coastal flooding requires improved monitoring of weather conditions, better communication and more rapid disaster response. The implementation of forestry programs, such as for sustainable forest management (SFM) – reduced impact logging, will require new skills and capacity in forestry companies and regulators.
- **New institutional arrangements will be needed for other aspects of climate-compatible development, such as REDD+.** For example, a high priority will be to develop Monitoring, Reporting and Verification (MRV) system, fund disbursement mechanism and benefit-sharing models that ensure benefits accrue equitably to resource stewards and owners. In many cases, these institutions will require skills and capacities that do not currently

exist inside the country (and some of them not even outside). The new institutional arrangements should underpin the shift in mindset made possible by the Copenhagen Accord: that climate change is more than an environmental threat, but is also an opportunity for development.

- **Pilot programs will be required to enhance the knowledge base, test the new policies and institutional arrangements and build capacity**. Early pilots of mitigation and adaptation measures will allow lessons to be learnt to inform the scale-up of these measures. They will also deepen our understanding of which policies and institutional arrangements are most effective in the Papua New Guinea context.

As a first step, the Government is reforming its institutional architecture for climate change to reflect the reality post-Copenhagen. The Office of Climate Change and Environmental Sustainability is being disbanded and replaced by a smaller, more focused Office of Climate Change and Development which will take responsibility for all policy relating to climate change. The Department of Environment and Conservation will thus be free to concentrate on its role in environmental protection, regulation, natural resource management, biodiversity conservation and environmental monitoring. The Department's policy on Environmentally Sustainable Economic Growth (ESEG) will advance this agenda, which will eventually be taken up by a new Environmental Protection Agency.[13]

Effective action on climate change will depend on broad understanding and buy-in across the government and among our people. The change in mindset will start with increasing the awareness and understanding of both the risks and potential opportunities associated with climate change. This is likely to involve an extensive process of consultation, beginning at the national level, but rapidly devolving to provincial and district levels. A consistent message will be critical for these consultations. It should be stressed that **while climate change is a serious threat, it also represents an opportunity to move to a climate-compatible development path, which is not a path to easy riches, but has the potential to improve the lives of all hard-working Papua New Guineans**.

[13] Environmentally Sustainable Economic Growth is based on the principles of sustainability, including inter- and intra-generational equity, biodiversity and the precautionary principle. The concept of an Environmental Protection Agency is currently under development.

5b. International support required

Papua New Guinea is prepared to contribute to the world's pressing need to reduce global GHG emissions and is committed to embark on a climate-compatible development path. The next steps outlined in Section 5a indicate the steps the government is taking to make climate-compatible development a reality in the coming years. However, Papua New Guinea will also require support from the international community. To this end, we are requesting support from our partners in the Copenhagen Accord achieve the following objectives:

- **Technical and analytical support** for the research and analysis that will inform the evolution of our strategy for climate-compatible development and support its implementation.
- **Construction of institutional capacity** to develop and implement a viable REDD+ mechanism (MRV, fund disbursement, benefits sharing), to drive climate resilience based on a detailed analysis of how climate change will affect natural hazards (e.g., through asset and vulnerability mapping, and local downscaling models) and to co-ordinate mitigation and adaptation efforts across stakeholders from government, business and civil society.
- **Financial support in the short-term** to finalise the climate-compatible development agenda and to start building institutional capacity. Preliminary estimates suggest that this will cost USD 30 -50 m over the next 3 years for both adaptation and mitigation actions. Activities will include stakeholder consultation, a thorough policy review, design of institutional arrangements and subsequent institutional reform and development, capacity building (especially relating to MRV for REDD+), developing and conducting pilot programs, research and designing benefit sharing arrangements. Exhibit 14 provides some estimates for this, based on the Eliasch review conducted for the UK government, which provides cost estimates for developing countries depending on their size and complexity.

Exhibit 14

Preliminary estimates indicate that readiness activities will cost USD 30-50m over the next 5 years

HIGHLY PRELIMINARY

	Components of REDD+ readiness	Eliasch review estimate range USD millions	PNG cost estimate[1] USD millions	Rationale
Participation enablers	▪ Finalise strategy	0.2 – 3	~ 3	Will include research, pilots and policy review and development
	▪ Payment processing capacity	0.1 - 4	~ 2	Precedents for paying for resource exploitation but capacity required at scale
	▪ MRV capacity building	1 - 6	~ 4	Some existing field measurement capacity, but very limited remote sensing capacity
	▪ Stakeholder consultation	0.1 – 2	~ 2	Broad consultation required due to customary land ownership and limited government reach
Policy enablers	▪ Land tenure reform	0 - 16	~4	Extensive social mapping required
	▪ Institutional reform[2]	0 - 11	~8	New institutions and capacity required
	▪ Support services capacity building	0 - 8	~8	Significant extension capacity required locally
	▪ Land-use planning	0 - 8	~4	Local data and development plans required
	▪ Legislative reform	0 - 4	~2	Legislative reform to establish institutions
	▪ Treasury reform	0 - 4	~2	Required to manage flows of REDD+ finance
	▪ Forest law enforcement	0 - 1.6	¬1.6	Required to enforce SFM properly
	▪ Independent monitoring	0 - 4	¬2	Required to access donor funds

1 PNG values are estimated based on PNG existing capacity relative to benchmark "Range of cost estimate"

2 Includes training, education, organization design, IT systems, etc

SOURCE: Eliasch Review (2008), REDD+ technical working group

Beyond this, performance-based funding for REDD+ and financial support for other costs of mitigation and increasing the country's resilience to a changing climate are high priorities. While exact projections will follow from updating the figures in this report, the cumulative cost of capturing REDD+ opportunities up to 2030 could exceed USD 3.5 b, based on ramping up to an annual abatement of ~77Mt CO_2e at an average cost of approximately USD 4/t CO_2e. Therefore, although REDD+ is a promising idea with real potential benefits for Papua New Guinea and its people, financial incentives beyond existing overseas aid are a prerequisite for action over the next 3 years before ongoing performance based REDD+ funding can be ensured.

Climate change requires action at multiple levels: international agreements, national plans and local actions must complement each other. Papua New Guinea is already a leading player in international negotiations and for some time has expressed its commitment to local action. This report sets out our preliminary strategy and detail on the national action required. Refining the strategy and moving to implement it will be the next steps on the way to climate-compatible development for our country.

REFERENCES

Anderson, Tim (2006): “Oil palm and small farmers in Papua New Guinea”. Report for the Centre for Environmental Law and Community Rights on the economic prospects for small farmers in PNG’s oil palm industry

Angelsen, A. (1999): “Agricultural expansion and deforestation: modelling the impact of population, market forces and property rights”. *Journal of Development Economics*. 58. 185–218

Angelsen, A. (2008): “REDD models and baselines”. *International Forestry Review* 10(3): 465-475

Asian Development Bank (2009): *Asian Development Outlook*, chapter on Papua New Guinea. Manila: ADB

Australian Agency for International Development (2008): *Papua New Guinea-Australia Development Cooperation Strategy 2006-10.* Canberra: AusAID

Australian Department of Agriculture, Fisheries and Forestry (2005): “Improved timber inventory and strategic forest planning in Papua New Guinea”. Summary report from ACIAR project FST98-118

Australian Institute of Marine Science (2004). *Status of the coral reefs in Australia and Papua New Guinea.*

AusAID (South Pacific Sea Level and Climate Monitoring Project – 2007). *Pacific Country Report Sea Level & Climate: Their Present State -Papua New Guinea*

Barker, P. (2008): *Climate change, forests and carbon trading*. Institute of National Affairs, Port Moresby

Bourke, R.M. and V. Vlassak (2004): *Estimates of food crop production in Papua New Guinea*. Canberra: Land Management Group, Australian National University

Bourke, R.M. and T. Harwood ed (2009): *Food and Agriculture in Papua New Guinea.* Canberra: Australian National University ePress

Bourke, R.M. (2009): “The impact of subsistence agriculture on deforestation and contribution to greenhouse gas production in Papua New Guinea.” Unpublished report prepared for Department of Environment and Conservation

Bourke, R.M. (2006): “Sweet potato in Papua New Guinea”

Bryan, J., P. Shearman, J. Ash, J.B.Kirkpatrick (2010): “Estimating rainforest biomass stocks and carbon loss from deforestation and degradation in Papua New

Guinea 1972–2002: Best estimates, uncertainties and research needs". Journal of Environmental Management 91: 995–1001

Chandy, L. (2009): "Linking growth and poverty reduction in Papua New Guinea". Lowy Institute for International Policy analysis paper. Sydney: Lowy Institute

CSIRO and Conservation International (2009). *Sustainable Futures for Milne Bay*

CSIRO (2008). "Variability and trends in the Australian wave climate and consequent coastal vulnerability"

Davies, H.L. (2006): *Disaster. Reducing the effects of natural hazards in Papua New Guinea and the south-west Pacific.* Waigani: University of Papua New Guinea Press

Dartmouth University (2009). *The Dartmouth Flooding Database*

Delta Commission (2008): *Working together with water*

Department of Environment and Conservation (2010). *Environmentally Sustainable Economic Growth Policy (draft).*

Economist (2009): "Last gasp for the forest". 24/9/2009 edition

Economics of Climate Adaptation Working Group (2009): *Shaping climate-resilient development – a framework for decision-making*

Eliasch, J. (2008): *The Eliasch Review – Climate Change and Global Forests* London: HM Government

EM-DAT – Universite Catolique de Louvain (2009). *The International Disaster Database*

Filer, C. (2009): "Drivers of deforestation and forest degradation in Papua New Guinea". Unpublished report prepared for Department of Environment and Conservation

Filer, C. (2009): "Land rights and benefit sharing". Unpublished report prepared for Department of Environment and Conservation

Food and Agriculture Organization of the United Nations (2005): *Global Forest Resources Assessment: Papua New Guinea country report.* FRA2005/07. Rome: FAO

FAO (2002). *Global Agro-ecological Assessment for Agriculture in the 21st Century: methodology and Results* Rome: FAO

Fox, J.C., Yosi, C.K., Nimiago, P., Oavika, F., Pokana, J.N., Lavong, K, and Keenan, R.J. (2010). Assessment of aboveground carbon in primary and selectively-harvested tropical forest in Papua New Guinea. *Biotropica*, In press.

Fox, J.C., Yosi, C.K., and Keenan, R.J. (2009). Estimating CO_2 emissions associated with selective timber harvesting and oil palm conversion in Papua New Guinea. Report to the Papua New Guinea Department of Environment and Conservation. The University of Melbourne and Papua New Guinea Forest Research Institute. December 2009.

Gibson, John and Scott Rozelle (2002): "Poverty and access to infrastructure in Papua New Guinea". University of California, Davis: Working Paper 02-008

Government of Papua New Guinea (2005): *Medium Term Development Strategy*. Waigani: Ministry of Planning

Government of Papua New Guinea (2009): *Development Vision 2010-50*. Waigani: Prime Minister's Office

Government of Papua New Guinea (2000): *Papua New Guinea Initial National Communication*

Google Maps (2009). *http://maps.google.com*

Grieg-Gran, M. (2008): "The cost of avoiding deforestation". Update of the report prepared for the Stern Review of the Economics of Climate Change. London: International Institute for Environment and Development

Hayward-Jones, J. and S. Copus-Campbell (2009): "Tackling extreme poverty in Papua New Guinea: outcomes report". Sydney: Lowy Institute for International policy

Hoojier, A., M. Silvius, H. Wosten and S. Page (2006): *PEAT-CO2. Assessment of CO2 emissions from drained peatlands in SE Asia.* WL Delft Hydraulics report Q3943

Howes, S. (2009): "Cheap but not easy: the reduction of greenhouse gas emissions from deforestation and forest degradation in Papua New Guinea". *Pacific Economic Bulletin* 24(1): 130-143

Hunt, C. (2009): "The economics of land use change and associated greenhouse gas emissions in PNG." Report prepared for Department of Environment and Conservation

Hunter J. (2009): *"Estimating Sea-Level Extremes Under Conditions of Uncertain Sea-Level Rise"*

Intergovernmental Panel on Climate Change (2007): *Fourth Assessment Report*

International Monetary Fund (2009): “Papua New Guinea: selected issues and statistical appendix”. IMF Country Report No. 09/113

Johnston, P. (2004): *Pacific Regional Energy Assessment 2004: Papua New Guinea national report.* Apia, Samoa: SPREP

Kaluwin, C. (2008): “Understanding climate change: developing a policy for Papua New Guinea”. Occasional Paper no 1, National Research Institute, Waigani

May, R.J. ed (2009): *Policy making and implementation: studies from Papua New Guinea*. Canberra: Australian National University ePress

Marshall P. and Schuttenberg H. (2006). *A reef manager’s guide to coral bleaching.*

McKinsey and Company (2009): *Pathways to a low-carbon economy: Version 2 of the Global Greenhouse Gas Abatement Cost Curve*

Ministry of Agriculture and Livestock (2007): *National Agriculture Development Plan 2007-16*. Waigani: Ministry of Agriculture

Mueller, Y. et al. (2005): “Epidemic malaria in the highlands of Papua New Guinea.” *Am. J. Trop. Med. Hyg.*, 72(5), pp. 554–560

NASA (2000). SRTM 90m Digital Elevation Data from the CGIAR-CSI Consortium for Spatial Information

Overseas Development Institute (2007): “Issues and opportunities for the forest sector in Papua New Guinea”. Papua New Guinea Forest studies volume 1-3. London

Papua New Guinea Forest Authority (2009): *Papua New Guinea Forestry Outlook Study*. Asia-Pacific Forestry Sector Outlook Study II, Working Paper no. APFSOS II/WP/2009/19. Bangkok: Food and Agriculture Organization of the United Nations

Rahmstorf, S.: 2007, ”A semi-empirical approach to projecting future sea-level rise”. *Science* 315(5810), 368–370.

Rannells, J. and E. Matatier (2005): *PNG Fact Book*. Melbourne: Oxford University Press

ReliefWeb (2009). Relief Web natural disaster database. http://www.reliefweb.int

Sharp, P.T. (1982): “Highlands malaria: malaria in Enga Province of Papua New Guinea” *PNG Med J* 25: 253–260

Shearman, P. et al (2008): “The state of the forests of Papua New Guinea: mapping the extent and condition of forest cover and measuring the drivers of forest change in the period 1972-2002”. University of Papua New Guinea, Waigani

Shearman, P. et al (2009): “Forest conversion and degradation in Papua New Guinea 1972-2002”. *Biotropica* 41(3): 379-390

Shearman, P. and J. Bryan (2010): “A bioregional analysis of the distribution of rainforest cover, deforestation and degradation in Papua New Guinea.” *AustralEcology*, forthcoming

WHO (2009): *World Malaria Report 2009.*