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UNEP RISØ CENTRE
ENERGY, CLIMATE AND SUSTAINABLE DEVELOPMENT

Danida Green Facility

Maldives
Low Carbon Development Strategy

Ministry of Environment and Energy
Republic of Maldives

Joergen Fenhann from UNEP Risoe Centre (URC) and
Marianne Ramlau consultant to URC.
June, 2014

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Executive Summary

This report presents the findings of a study funded by Danida to provide technical assistance to the Ministry of Environment and Energy (MEE) in preparing for a low carbon development strategy for Maldives having 2020 as its first target year. It estimates Maldives Greenhouse gas (GHG) emissions by 2020, identifies abatement opportunities and costs and provides input for strategic considerations for establishment of 2020-targets considering also the pledge for carbon neutrality made under the United Nations Framework Convention on Climate Change (UNFCCC).

The principal findings are as follows:

Baseline emissions

Maldives GHG emissions were estimated to increase from about 1.1 million tonnes carbon dioxide equivalent ($MtCO_2e$) in 2009 to about 2 $MtCO_2e$ in 2020. The two predominant emitting sectors are electricity generation and mobile emissions sources i.e. transport. They can be further divided onto sub-sectors and geography as follows:

Table 1 GHG-emissions by sub-sectors in kilo tonnes carbon dioxide equivalent ($ktCO_2e$)

Sources	2009-emissions	Share (%)	2020-emissions	Share (%)
Diesel for electricity (incl. captive systems)	589	52	1,109	56
Greater Malé Region	*179*	*16*	*332*	*17*
Outer islands	*127*	*11*	*240*	*12*
Resort islands	*283*	*25*	*537*	*27*
LPG and kerosene (for cooking)	94	8	215	11
Greater Malé Region	*9*	*1*	*28*	*1*
Outer islands	*28*	*2*	*77*	*4*
Resort islands	*58*	*5*	*110*	*6*
Fishery (diesel)	78	7	87	4
Greater Malé Region	*9*	*1*	*10*	*0*
Outer islands	*70*	*6*	*78*	*4*
Transport	334	30	557	28
Domestic aviation	*51*	*5*	*97*	*5*
Road transport	*57*	*5*	*93*	*5*
Marine transport, passenger and goods	*154*	*14*	*250*	*13*
Marine transport, tourists and leisure	*69*	*6*	*112*	*6*
Hulhule airport ground transport operations	*3*	*0*	*6*	*0*
Other sources	37	3	0	0
Total	1,133	100	1,968	100

Looking at the 2020-projections for diesel for electricity, Liquefied Petroleum Gas (LPG) and kerosene the resort islands were expected to nearly become as great emitter as Greater Malé Region and outer islands all together. Resorts islands were forecasted to emit 647 $ktCO_2e$ versus 677 $ktCO_2e$ jointly from outer islands and the Greater Malé Region.

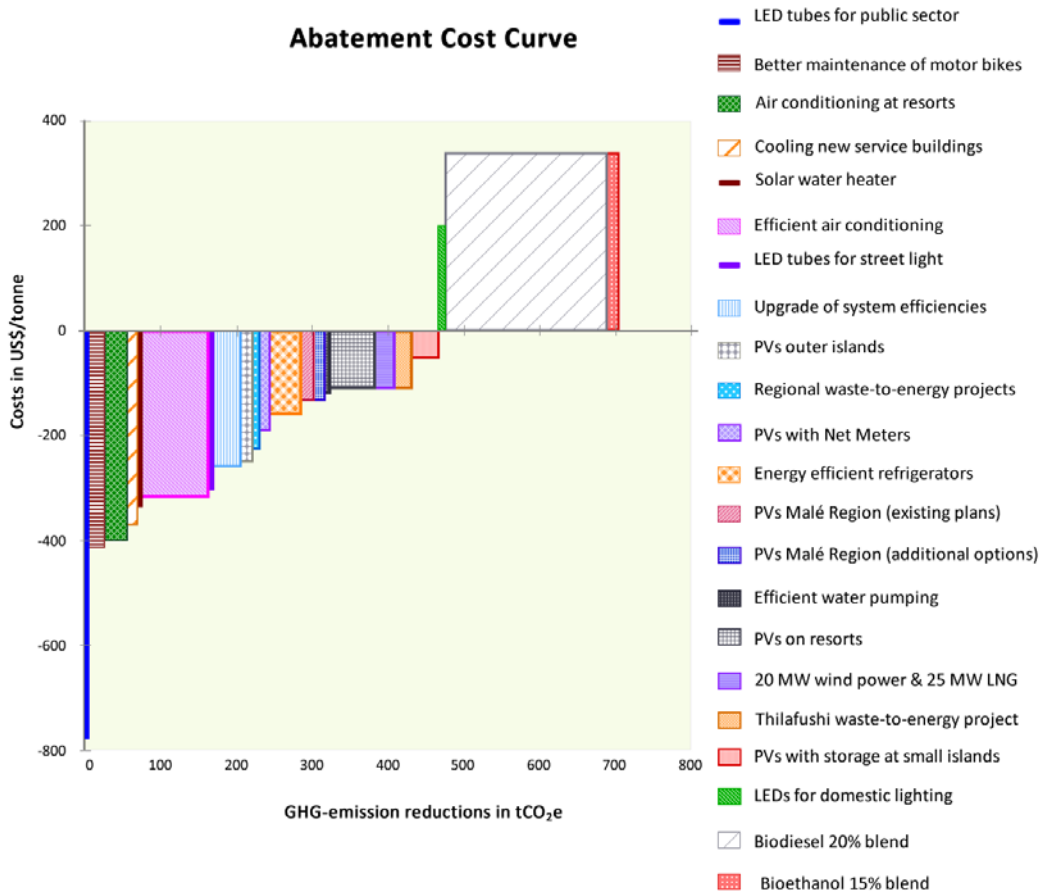
Total projected emissions from mobile sources excluding fishery were 557 $ktCO_2e$. The largest emitter within transport was found to be marine transport of passengers and goods between islands and the second largest was marine transport for tourists and leisure.

While electricity generation is the greatest emitter it also holds the greatest potential mitigation, whereas transport offers less emissions reductions considering the presently available technologies.

Abatement opportunities and costs

The abatement cost curve displays the potential abatements and attached costs of 22 mitigation options, listed at the right hand side in the figure below. Options with negative abatement costs are found below the x-axis. Negative abatement costs means that there will be net-savings to the Maldivian economy compared with projected emissions in the Business As Usual (BAU) scenario and measured as discounted lifetime costs divided over discounted lifetime mitigation of GHG-emissions. All but three options came in with negative abatement costs.

Figure 1 Abatement Cost Curve



With the options investigated, Maldives could bring its GHG-emissions down to between 1.3 $MtCO_2e$ and 1.5 $MtCO_2e$. It corresponds to capping emissions for the entire economy at between 114% and 134% of the 2009-emissions level, but it would require imposing more stringent caps at some sectors. Following caps by sectors could be suggested as 2020-targets for a low carbon development strategy without relying on net-costs measures:

Table 2 Mitigation by sectors in $ktCO_2e$, exclusive options on blends of bio fuels

Sector	2009-emissions	2020-BAU emissions	2020-cap through mitigation	Emissions cap relative to 2009 emissions level
Grid electricity	262	489	152	57%
Resorts electricity	283	537	451	159%
Transport	331	557	532	161%
Hulhule airport excl. transport fuels	13	25	25	192%
Captive systems at outer islands	19	36	36	189%
Desalination (Greater Malé Region)	12	22	22	183%
Fishery excl. LPG and Kerosene	82	87	87	106%
LPG and kerosene	94	215	215	229%
Other	37	0	0	
Sum	1133	1968	1520	134%

There may be even larger net-savings at hand with available technologies since behavioural changes in end-uses offering additional savings were not quantified for the analysis of this report, except for options on switching to energy efficient electrical appliances and on more fuel efficient motor bikes through improved maintenance. Also, for the resort sector there could probably be reached an even higher level of renewable energy (RE) integration with net-savings, than was considered here.

Supportive measures

In order to cap domestic emissions as suggested, effective institutional home(s) of underlying regulatory and supportive interventions would be required. For the short term target (2020), interventions are required towards grid electricity in particular, whether public (inhabited) islands grids or resort islands grids.

Out of total investment requirement of US$ 850 million for all options, capital costs requirements of total nearly US$300 million were found for the options envisaged suitable for project financing and implementation by Independent Power Producers (IPPs) under Power Purchase Agreements (PPAs) and Feed in Tariff (FIT) regimes. In addition to this, capital costs requirements of totally US$228 million were found for the options envisaged for implementation by power utilities on their own, namely grid upgrades and full transformation of small power grids to solar PV with storage. Hence, power utilities play a key-role for the success of a national low carbon strategy including for attracting investors. Further detailed strategic work is required on how to support utilities in fulfilling this role for instance through capacity building and training of staff, but also through removal of regulatory barriers for investors and establishment of supportive (funding) mechanisms, as relevant.

The tourism sector would also have to play a vital role in particular the resort sector for which capital requirements of US$173 million were estimated for the potential mitigation found, notable all net savings options. How to strike a proper balance of government oversight, regulatory measures and voluntary commitments by the tourism sector requires further considerations, but is seems essential that the national low carbon development strategy prescribes relevant low carbon development targets for the resort sector, develops mechanisms for monitoring, reporting and verification (MVR) and supports awareness and capacity building of the sector. Whether facilities or mechanisms for financial support would be necessary requires further considerations.

Carbon neutrality

In order to stay with - and ultimately comply with - the politically binding pledge for carbon neutrality by 2020 made by Maldives under the UNFCCC, Maldives would need to offset the remaining domestic emissions as a one-off exercise.

The findings indicated that once mitigation of some say 450 $ktCO_2e$ is secured the marginal abatement costs would come at net costs and notable at net costs exceeding current offset prices. This suggested the target for offsetting to be at 1.5 $MtCO_2e$ if carbon neutrality is to be attained at the lowest possible costs.

At the moment opportunities available to Maldives for acquiring offsets are limited to voluntary cancellation of Certified Emissions Reductions (CERs) and to Voluntary Emissions Reductions (VERs) originating from projects registered under the Clean Development Mechanism (CDM). Offsets under these project standards are currently offered at the carbon markets at prices ranging from less than one US dollar per tonne to around 6 dollar per tonne. Given a target of say 1.5 million tonnes offsets, offsetting could cost between US$1.5 million and US$9 million. While this may be viewed as an unsustainable spending to the Maldivian economy of much needed foreign currency, net savings achieved from mitigation of domestic emissions would likely more than pay-off the costs of offsets and abandoning the pledge holds the risk of Maldives losing creditability internationally as a party to the UNFCCC and perhaps as an attractive destination for international climate funding.

In order to hedge against exposure to significant costs increase that potentially could derive from a new global climate agreement, offsetting should preferable be secured as soon as possible. While the government through the appropriate governmental institution should play a strong oversight role including agreeing with project standards, project types, geographical focus and desirable development impact, the offsetting programme could be outsourced to offset providers.

Institutional arrangements

A low carbon development strategy including possibly sub-strategies for domestic mitigation and offsetting requires a creditable and effective institutional home mandated to take on the oversight role and to detail and streamline the implementation of the strategies. This is envisaged to include *inter alia* MRV, awareness and capacity building, development of detailed implementation strategies, development of supportive mechanisms, and monitoring of financial flow for implementation.

Abbreviations

AAU	Assigned Amount Units
ADB	Asian Development Bank
ASPIRE	Accelerating Sustainable Private Investments in Renewable Energy Programme
CAPEX	Capital expenditures
CDM	Clean Development Mechanism
CFL	Compact Fluorescent Lamp
CoP	Coefficient of Power
COP	Conference of the Parties
ERU	Emissions Reduction Units
FIT	Feed in tariff
GACMO	Greenhouse Gas Costing Model
GHG	Greenhouse gas
HCFC	Hydrochlorofluorocarbons
HFC	Hydrofluorocarbons
IPCC	International Panel on Climate Change
IPP	Independent Power Producer
JICA	Japan International Cooperation Agency
km	Kilometres
$ktCO_2e$	Kilo tonnes carbon dioxide equivalent
ktoe	Kilo tonnes oil equivalent
kW	kilowatt
kWh	Kilowatt hours
LCMR	Low cost must run resources
LED	Light-emitting diodes
LNG	Liquefied Natural Gas
LPG	Liquefied Petroleum Gas
MEE	Ministry of Environment and Energy
MOTAC	Ministry of Transport and Communication
MTCC	Maldives Transport and Contracting Company
Mt	Million tonnes
$MtCO_2e$	Million tonnes carbon dioxide equivalent
MVR	Maldives Rufiyaa
MW	Megawatt
MWh	Megawatt hours
MWSC	Malé Water and Sewage Company
NAMA	Nationally Appropriate Mitigation Action
NEAP	National Environment Action Plan
NSSD	National Strategy for Sustainable Development
OPEX	Operating expenditures
POISED	Preparing Outer Islands for Sustainable Energy Development Programme
PPA	Power Purchase Agreement
PV	Photovoltaic
RE	Renewable energy
SAP	Strategic Action Plan
SREP	Scaling Up Renewable Energy Programme
tCO_2e	Tonnes carbon dioxide equivalent
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
URC	UNEP Risoe Centre
VERs	Voluntary Emissions Reductions
WTE	Waste to energy

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The study work was conducted from October 2010 to March 2014 and comprised a number of study missions.

The contribution from Zammath Khaleel and Akram Waheed of the MEE was highly appreciated not least the extensive validation of data, the provision of insights into the Maldives country context and the review of previous drafts. The team furthermore wishes to express its thanks to all the stakeholders in Maldives that kindly contributed valuable input.

Introduction

This report presents an overview across sectors of potential mitigation of GHG-emissions attainable for Maldives in the short term and the social costs attached with such mitigation. The analysis builds upon most recent energy balance data and draws also on results achieved in previous studies on integration of renewable energy in island power systems and on potential savings in electricity demand.

Initially the report in chapter 1 discusses how to understand carbon neutrality in the context of Maldives pledge under the UNFCCC as clarity was needed on outreach and implications of the pledge made in 2010. Hence, the low carbon development strategy needs to consider these issues.

Chapter 2 summarises the main findings of the study to justify and inform a national low carbon development strategy. It suggests caps for domestic emissions by 2020 as per the findings of the abatement cost analysis and estimates the costs for offsetting remaining emissions in order to comply with the carbon neutrality pledge.

Chapters 3 to 8 walks through sources of GHG-emissions and abatement opportunities in all sectors: grid electricity (public and resort sector); desalination; energy services of other sectors (fuel for cooking, warehouses, construction, fishery, agriculture); transport and; waste. Some of the mitigation options described in these chapters were selected for further abatement costs analysis as presented in chapter 9. Chapter 9 first presents the GHG-inventory for 2009 and the business as usual projection for 2020 established by this report as this is the baseline emissions trend a low carbon development strategy should target to reduce. Then key findings of the abatement cost analysis are summarized followed by a walk through the 22 mitigation options covered by the analysis.

Abatement costs were analysed with a spreadsheet model developed by URC and made available to the MEE for continued work. Annex A to this report gives information on the spreadsheet model including its underlying technical assumptions and assumptions on fuel prices. Finally, it provides an example from the analysis on how mitigation options were analysed by the model.

1 Carbon neutrality

1.1 Introduction

The aim on carbon neutrality by 2020 is essentially an emissions cap target capping eligible greenhouse gas (GHG) emissions in 2020 at zero. To demonstrate compliance domestic emissions can be established *inter alia* by use of guidelines for GHG-inventories applied under the United Nations Framework Convention on Climate Change (UNFCCC).

Carbon neutrality does, however, not necessarily mean reducing domestic net GHG-emissions to zero. Carbon neutrality may also be reached by offsetting domestic emissions with non-domestic emissions reductions. For instance, the Kyoto-Protocol offers such offsetting opportunities to developed countries for compliance with their legally binding emissions caps and it is expected that new market mechanisms will be established as a part of a new global climate agreement in 2015. Such new mechanisms may provide for offset opportunities for Maldives.

Till now, national policies in Maldives provides for little guidance on how to understand the policy statements for carbon neutrality including whether offsetting is considered a valid option. The national strategy on carbon neutrality should therefore help ensuring that implications of choosing different approaches are well understood. Maldives is a party to the UNFCCC and has under the convention communicated the goal for carbon neutrality. Regulatory framework conditions derived from this should not least be understood and considered for the national strategy.

In this chapter policy statements in national policies were first resumed to present how the carbon neutrality goal so far has been incorporated into governmental policies. This was followed by an interpretation of how to understand Maldives pledge for carbon neutrality in the context of the UNFCCC and a new international climate agreement.

1.2 Policy statements

The goal on carbon neutrality was stated in several governmental policies and following policy documents, strategies, actions- and investments plans make reference to the goal:

- The third National Environment Action Plan (NEAP) 2009-13 (2008)
- The Strategic Action Plan (SAP) 2009-2013 (2009)
- Maldives National Strategy for Sustainable Development (NSSD)(2009)
- Maldives National Energy Policy and Strategy (2010),) and
- Maldives Scaling Up Renewable Energy Programme (SREP) Investment Plan, 2013-17 (2012).

The submission to the parliament of a bill on reaching carbon neutrality by 2020 was envisaged by *inter alia* the 3rd NEAP, but has so far not occurred and none of the current policies provides for a strategy for carbon neutrality covering the entire economy and all GHG-emissions sources and sinks.

Targets for emissions caps by sources or sectors were generally not incorporated in current policies except for the energy and the transport sectors. For these sectors statements for

becoming carbon neutral by 2020 (Maldives National Energy Policy and Strategies 2010) and milestones in the form of quantitative mid-term targets were also set out.

For the energy sector milestones were as follows:

- By 2015, 50% of electricity generation should be based on renewable energy (NSSD and 3rd NEAP)
- By 2020, final energy consumption should be reduced by 7.5% (from 2010 level) by means of efficiency improvements (NSSD)

For the transport sector mid-term quantitative targets were as follows:

- By 2015, biofuels are to reach 10% of transport fuels possibly increasing to 20% in 2020 (NSDD)
- By 2015, reduce the transport sector GHG emissions by 25% (3rd NEAP. Base year was not established).

Given the absence of any further indications of emissions caps or other quantitative benchmarks by gasses, sources or sectors, the goal on carbon neutrality was for the present analysis understood to be an economy-wide goal which shall apply for the total 2020-GHG-emissions made up by all domestic emissions sources and sinks equivalent with those to be reported in national inventories under the UNFCCC.

1.3 Carbon Neutrality in the context of the UNFCCC

1.3.1 Present commitments

The new global climate agreement to be concluded in 2015 and to enter into force in 2020 at the latest will essentially address post-2020 emissions and thereby succeed the Kyoto-Protocols second commitment period ending ultimo 2020. The new agreement is supposed to become legally binding for all parties to the UNFCCC, but its legal form (a protocol another legal instrument or an agreed outcome with legal force under the UNFCCC applicable to all parties) is yet to be decided and it may not comprise legally binding national emissions targets for each party.

Hence, the Kyoto-Protocol is presently the only instrument under the UNFCCC by which parties take on legally binding commitments to limit emissions. Parties with obligations under the Kyoto-Protocol to cap emissions are developed country parties (i.e. parties included in Annex-I to the UNFCCC) having ratified the Kyoto-Protocol and its amendment for the second commitment period. The second commitment period concerns emissions in the eight-year period from 2013-2020. Parties to the protocol can use offsets generated under the Clean Development Mechanism (CDM) to partly offset these domestic emissions and thereby comply with their obligations.

With the agreement on the second commitment period reached at the 18th Conference of the Parties (COP) in Doha in 2012, negotiations within the UNFCCC on legally binding commitments for pre-2021-emissions were formally closed and will not be revisited in the further negotiations on a new climate agreement. Still, efforts under the UNFCCC striving for increased ambitions for emissions reductions by 2020 continue[1] since the aggregate emissions level from present commitments by parties is not on track to keep global warming below 1.5-2.0 degrees Celsius. These efforts may lead to new pledges for deeper

[1] Workstream 2 under the Ad Hoc Working Group of the Durban Platform for Enhanced Actions

cuts in 2020-emissions, but they will not result in new offsetting mechanisms under the UNFCCC targeting pre-2021-emissions since such negotiations essentially closed with the agreement on the Kyoto-Protocol's second commitment period. This is important to note, since Maldives may likely be reliant on offsets to meet its pledge for carbon neutrality by 2020.

Pledges related to 2020-emissions referred to above stems from the Copenhagen Accords at COP 15 in 2009. Hereby a number of developing countries including Maldives agreed to implement mitigation actions in the context of sustainable development and subsequently communicated to the UNFCCC their commitments and/or mitigation actions, termed Nationally Appropriate Mitigation Actions (NAMAs). These submissions vary greatly - from mitigation actions at project level to economy-wide emissions reductions objectives. They also vary in terms of conditions attached – from unconditional to subject to provision of financial support or provision of a new global climate agreement. The Copenhagen Accords was also agreed to by some developed countries, by which they committed themselves to implement economy-wide emissions targets for 2020 relative to 1990-emissions levels.

Commitments by developing and developed countries made pursuant to the Copenhagen Accords are not legally binding, but they are politically binding pledges[2] put forward under the Convention and Maldives pledge for carbon neutrality should be considered in this context. The pledge is not and will not be inscribed in a legal binding agreement under the UNFCCC, given that the new global climate agreement will concern commitments on post-2020 emissions and Maldives commitment is to achieve carbon neutrality by 2020.

1.3.2 Maldives pledge for carbon neutrality

Pursuant to the Copenhagen Accords, Maldives submitted to the UNFCCC its pledge for achieving *"carbon neutrality as a country by 2020"*[3]. While indicating its intention to seek international support for implementation, *"Maldives submission of its present mitigation actions is voluntary and unconditional"*. Accordingly, it was understood for the present analysis that carbon neutrality by 2020 was pledged for unconditionally i.e. regardless of the outcome of the negotiations on a global climate agreement.

Maldives national submission was a commitment to an economy-wide emissions target by 2020 at zero. While this obviously requires mitigation actions to achieve, information on actions to be implemented has not yet been submitted to the UNFCCC. In general, mitigation actions are to be reported in biennial update reports, but these reports are not due yet[4] and Maldives has so far not made use of the opportunity to submit NAMAs to the UNFCCC secretariat, neither for requesting international support for implementation nor

[2] Note also that National submissions pursuant to the Copenhagen Accords are considered communications under the UNFCCC and later decisions by the COPs make reference to the information report referenced as: FCCC/AWGLCA/2011/INF.1 which compiles the same communications.

[3] See Annex 1 in the submission by Maldives where – under the heading "National Appropriate Mitigation Actions" – actions are stated to be "Achieve carbon neutrality for the country by 2020". The submission can be found at http://unfccc.int/meetings/cop_15/copenhagen_accord/items/5265.php

[4] First biennial updates report by developing countries is due in December 2014, however, for LDCs (Least Developed Countries) and SIDS (Small Island Development States) upon their discretion.

for recognition by the UNFCCC[5]. Accordingly, Maldives has so far not provided any information to the UNFCCC on how carbon neutrality is supposed to be achieved.

In this regard it is important to note that ”carbon neutrality” is not a fixed term in the UNFCCC terminology and Maldives is yet to make available to the UNFCCC clarification on accounting methods that will be considered appropriate by Maldives to demonstrate compliance. The key issue to this, is how to account for domestic emissions reductions, Maldives may wish to transfer for instance for the compliance market (i.e. under the CDM), as it would potentially make a big difference, if such emissions reductions could not be accountable towards Maldives pledge for carbon neutrality.

1.3.3 Offsetting options under the UNFCCC

Offsets used towards the pledge should preferable meet standards acceptable under the UNFCCC i.e. either be eligible for compliance under the Kyoto-Protocol or recognized for compliance under a future post-2020 climate agreement. Presently there is no such offsetting mechanism available to developing country parties, but they may come along as part a global climate agreement. Given this, offset options eligible to Maldives comprises:

- Voluntary cancellations of CERs (Certified Emissions Reductions) and
- Potentially, new market-based mechanisms.

The Kyoto Protocol is not designed for offsetting domestic emissions of developing countries. Transfers of CERs, ERUs (Emissions Reduction Units) and AAUs (Assigned Amount Units) between national registries are allowed only between countries participating in the second commitment period of the Kyoto-Protocol i.e. Annex I countries. As a non-Annex I country, Maldives can hold CERs in the CDM-registry only from activities to which it is a project participant, which essentially means from activities hosted by Maldives. Obviously, CERs stemming from Maldives would not help offsetting domestic emissions of Maldives.

However, voluntary cancellations of CERs upon request from Maldives would be eligible to Maldives for offsetting. In voluntary cancellation, project participants cancel CERs they are holding in the CDM-registry (in turn for payment). While cancellations does not appear in the national registry, if any to which the requester (buyer) belongs, the UNFCCC keeps track with cancellations and publishes at the UNFCCC webpage information on purpose/beneficiary of the cancellation. This should probably satisfy documentation requirements to offsets acquired by Maldives for the purpose of fulfilling the pledge for carbon neutrality. Again, cancelled CERs must obviously not originate from CDM-activities in Maldives.

Under the new global climate agreement market mechanisms eligible for offsetting emissions of developing countries will likely emerge. Negotiations are expected being concluded in 2015 for a new agreement to come into effect in 2020 at the latest. If new mechanisms will be given a prompt start and Maldives could wait for them coming into operation, they could become relevant to Maldives.

Note that there is presently no such thing as an agreed end-of-compliance date for pledges put forward pursuant to the Copenhagen Accords and Maldives can therefore assumable fix

[5] NAMAs not submitted to the UNFCCC NAMA-registry for the purpose of seeking international support can be submitted to the registry for the purpose of recognition. The latter is termed “domestically-supported NAMAs”.

the date as appropriate to allow for using offsets generated under new offsetting mechanisms.

With regard to offsets from the voluntary market, VERs (Voluntary Emissions Reductions) are in the general context of the UNFCCC not suitable for meeting pledges since they are not recognized under the UNFCCC and applicable for compliance under the Kyoto Protocol[6]. On the other hand no COP-decisions and UNFCCC-rules are currently governing which types of offsets would be eligible for meeting 2020-pledges by non-Annex I countries pursuant to the Copenhagen Accords. Therefore, Maldives could likely decide to use offsets from the voluntary market without violating any agreed decision *albeit* it would not be in line with the founding principle of having the UNFCCC to oversee the environmental integrity of emissions reductions used for complying with UNFCCC-commitments.

Still, offsetting through VERs originating from projects/programmes registered under the CDM but issued for emissions reductions occurred before the crediting period starts would probably be acceptable.

1.3.4 Reporting and accounting methods

Developing countries are required to report biennially their national GHG-inventory on domestic emissions and removals. Biennial update reports shall also comprise description of mitigations actions (e.g. quantitative goals and progress indicators) and their effects (e.g. estimated emissions reductions) as well as information on participation in international market mechanisms. Accounting rules to be followed by developing countries on imports and exports of offsets are, however, not addressed by the reporting requirements or elsewhere in the UNFCCC-rulebook.

Developed countries will also be required to report on their mitigation commitments and those with commitments under the second commitment period of the Kyoto-Protocol are in addition required to report on their accounts for compliance with their commitments for 2013-2020. Biennial reports shall describe the use of international market mechanisms in achieving quantified economy-wide emissions reductions targets "including relevant accounting rules, taking into consideration any relevant decisions of the COP, where appropriate". This suggests that offsets acquired by developed countries can count towards the country's economy-wide 2020 pledges equivalent with the accounting rules governing commitments under the second commitment period of the Kyoto-Protocol.

Hence, the present UNFCCC-rulebook does not prevent emissions reductions generated in a developed country and sold as offsets to a developed country to be accounted for by both countries. Those shortcomings may likely be addressed under a new global climate agreement and new rules could perhaps even come into effect in due time to govern also accounting for compliance with pledges for 2020-emissions. However, till then, it will rely on the discretion of Maldives how to treat potential double counting.

Strictly speaking Maldives is not required to report on the progress in achieving carbon neutrality since carbon neutrality is a pledge, not a mitigation action (NAMA). Nevertheless, MEE intends to report on carbon neutrality including participation in international market mechanisms and use of offsets, if any. The MEE expects to submit the Maldives 2nd National

Communication in 2014 and to submit update reports biennially. Accordingly, reporting on compliance with the carbon neutrality pledge will likely be addressed in Maldives biennial update report scheduled for 2022 at the latest.

1.3.5 Implications of using conservative accounting principles

To prevent double counting, any offsets Maldives may acquire (buy) to achieve carbon neutrality should be countable only to Maldives and not towards the pledge or a future legally binding commitment of the country from which the offsets originates. There could for instance be a risk of acquiring CERs for voluntary cancellation that potentially could stem from domestically-supported NAMAs since there is currently no safeguard build in to avoid this. Many developing countries have for instance not excluded participation in the CDM from the NAMAs they have pledged for under the UNFCCC.

Furthermore, transfers of emissions reductions (units) out of Maldives account to be used against other countries pledges, should be treated in Maldives account as emissions (i.e. they should be added to the domestic emissions account), not as emissions reductions. This effectively means that Maldives cannot generate emissions reductions for transfers out of its account without balancing with offsets, if carbon neutrality is to be reached.

Say for instance domestic emissions in Maldives by 2020 will be capped at zero and emissions reductions of one million tonnes of carbon dioxide equivalent ($MtCO_2e$) will be generated and transferred (sold) to another country. Despite actual domestic emissions in Maldives would be zero, Maldives would not have reached carbon neutrality due to the exports of emissions reduction units. Maldives would in this scenario itself have to acquire $1MtCO_2e$ offsets in order to achieve carbon neutrality without participating in double counting.

The double counting issue and its implications for the national carbon strategy have already emerged. A bilateral agreement between Maldives and Japan on cooperation in achieving emissions reductions in Maldives was announced in 2013. The intention was to have the emissions reductions internationally recognized. Emissions reductions vintage-2020 achieved from Maldives emissions sources and transferred to Japan under such agreement should not be counted towards the pledge of Maldives. They must therefore be compensated for by Maldives through offsets if the carbon neutrality pledge is to be fulfilled and if Maldives wishes to maintain the highest environmental integrity regardless of the present shortcomings in UNFCCC-rulebook. Though the impact of carbon leakages from emissions reductions transferred from Maldives would be insignificant on the global scale, emissions reductions occur only once and should be accounted for only once under the UNFCCC.

1.4 Key-findings

In summary, following were key-findings to inform the national low carbon development strategy:

Domestically, carbon neutrality was targeted for by numerous (primarily sector) policies but it has not been attempted to be consolidated by the parliament through legislation as an overarching economy-wide goal for Maldives.

Still, Maldives has given a politically binding pledge to the parties to the UNFCCC for achieving carbon neutrality by 2020. The pledge concerns economy-wide emissions in 2020

i.e. all domestic sources and sinks. The pledge was put forward without reservations for a new global climate agreement, but absence such new agreement, the road to compliance for Maldives will likely become much more difficult. For instance options for offsetting under the UNFCCC would narrow down to voluntary cancellation of CERs and perhaps to VERs from projects registered under the CDM.

Unless otherwise decided by the COP, end-of-compliance date can be fixed upon Maldives own discretion. For the true up, domestic 2020-emissions shall be established as per relevant rules and guidelines. There are no restrictions on vintages of issued offsets applicable for true up. They can originate from pre- or post-2020 as appropriate and available in due time to account for true up.

Also, as for now it is up to Maldives own discretion to take measures to avoid potential carbon leakages attached with offsets as this is presently not governed by reporting requirements and accounting rules agreed to under the UNFCCC. Such measures should target for:

- Avoid acquiring voluntary cancellation of CERs and/or emissions reductions (units) under new offsetting mechanisms, that originate from mitigation actions potentially also counted towards 2020-pledges of the host country or counted towards post-2020 commitments under a new climate agreement

- For true up, treat domestic emissions reductions (units) vintage-2020 transferred to another country for compliance under the UNFCCC as emissions adding to domestic emissions, not as emissions reductions. This will increase Maldives need for offsets.

It would be difficult for Maldives to step down from the carbon neutrality pledge, but the argument can be made that the pledge strictly speaking applies to domestic emissions in 2020 only and not to subsequent years. The pledge under the UNFCCC can accordingly be considered met if domestic emissions in 2020 only (not subsequent years) plus exports of emissions reductions units vintage-2020 minus imports of offsets (all vintages eligible) equal zero.

When evaluating pros and cons of offsetting it should be considered that staying with the pledge already made is a matter of national credibility in the international process. Thus an option for consideration could be to offset net emissions of 2020 only and submit to the UNFCCC a separate post-2020 domestic emission reduction target as “contribution” to the new climate agreement.

In the 19th COP to UNFCCC held in Warsaw, parties were invited initiate work on their national contributions and communicate the same to UNFCCC in the first quarter of 2015. The decision 1/CP19 does not prescribe the nature of the contribution other than it should help achieve the ultimate objective of the convention stipulated in Article 2 and it should be clarified and transparent. The decision however does not indicate that the contribution be of mitigation. It could be mitigation commitment or targets, financial commitment or targets or any other instrument or tool which could be committed or pledged or offered by any party to aid in the implementation of the final objective of the convention. This present Maldives an opportunity to present clear and more concrete contribution to the new 2015 agreement in comparison to what was given in COP15 at Copenhagen.

2 Strategic Considerations for Low Carbon Development

2.1 Justification

Maldives is a country where the impact of global climate change – in particular rising sea level – could become a serious threat to livelihood and burden the economy. For Maldives not least, a new global climate agreement with sufficiently high levels of commitments is much needed.

Domestic emissions and hence the impact on global warming of avoided emissions from a carbon neutral Maldives are insignificant on the global scale, but it is believed to be in the interest of Maldives to maintain high national level of ambitions for capping domestic emissions. This is both true with regard to post-2020 emissions and with regard to staying with the pledge already made for 2020-emissions.

Stepping down from the pledge for carbon neutrality by 2020 indeed bears the risk of losing international credibility. Staying with the goal for carbon neutrality for 2020 on the other hand implies spending much needed foreign currency on offsetting which may be viewed as unsustainable costs. In the global perspective this may, however, not be true. This is because Maldives should first reduce its need for offsetting to the largest extent possible, which ideally means that all domestic abatement opportunities with costs lower than the market price of offsets should be tapped first. In this way Maldives spent its resources in a highly sustainable way by reducing emissions where it globally is cheapest to do so.

Still, offsetting on its own does obviously not contribute directly to the Maldivian economy the way domestic mitigation does and in this sense costs for offsetting could perhaps be considered as better spent on mitigation of domestic emissions sources. Given the concern over cost constraints and dependency of the economy on fuel imports, it is believed to be difficult to obtain support for a more permanent offsetting scheme for achieving carbon neutrality also of post-2020 emissions, but as a one-off to fulfil the already made pledge, offsetting domestic 2020-net emissions will be needed.

The need for offsets by 2020 can, however, decrease quite significantly by mitigating domestic emissions with technologies well proven in similar environments viz. by hybrid diesel-solar Photo Voltaic (PV) systems, PV-battery systems, improved supply and demand side management, energy efficient electrical appliances and switch to biofuels. There is plenty of “low hanging fruits” and in the tourism sector and the grid electricity sector in particular, economically very attractive mitigation options that provides for net savings to the Maldivian economy compared with Business As Usual (BAU) were found from the analysis of this report.
Apart from the energy sector, mitigation options are also available in other areas including sustainable waste management including sound management of landfill sites and recycling, green transport management with low emission and energy efficient vehicles, green tourism including the promotion of eco-tourism.
Benefits to the Maldivian economy could even be valued higher than what was done for this analysis. Diesel fuel savings will for instance also lead to avoided damage costs from pollutants, new technologies will help diversify the energy supply and reduce dependency on fuel imports and not least will diesel fuel savings reduce the need for foreign currency in energy supply. The issues of security in supply and dependency on foreign currency were believed to be of particular concern for a small and open economy like Maldives. Moreover,

access to climate funds presents opportunities for technology transfer, which supposedly would otherwise not occur in the same scale, if at all.

A national strategy for low carbon development and its quantitative mitigation targets should be developed with the above in mind. While a low carbon development strategy may be triggered from international developments on the global climate scene including from the carbon neutrality pledge already made internationally, such strategy makes a lot of sense for a variety of other reasons and could potentially help strengthen the Maldivian economy. A low-carbon development pathway for Maldives will need to be a guiding principle and strategy to turn our challenges to opportunities that will in turn allow us to move towards sustainable economic growth and environmental sustainability with the objective of mitigating GHG emissions.

While it was recommended not to give up the carbon neutrality pledge at this point in time, Maldives should clarify internationally that the unconditional pledge applies merely to 2020-emissions and that a separate submission under the UNFCCC on post-2020 emissions will be made in support for a new global climate agreement.

2.2 Setting the 2020-target for low carbon development

The outset for this analysis on technical-economic mitigation options was the outlook for 2020 with focus on developing a strategy for what to be achieved on the short-term. Provided that the short term target is to attain carbon neutrality by 2020 at the lowest possible compliance costs, the low carbon development strategy is proposed to be composed by two sub-strategies both supporting the common goal of carbon neutrality: a sub-strategy addressing mitigation of domestic emissions and a sub-strategy targeting offsetting. The two will have related and likely moving targets. Since offsets are supposed to fill in the gap, the target for offsets should be defined from the quantified target set for domestic emissions reductions. On the other hand, the target for capping domestic emissions should be just as much as would be the least cost option compared with offsetting. Hence, quantification of such sub-strategy targets should both take abatement costs and offset costs into consideration.

2.3 Sub-strategy for domestic emissions mitigation

2.3.1 Sector targets

Marginal abatements costs were analysed for this study indicating potential mitigations by 2020 achievable at what costs. Baseline emissions were projected to be 1968 $ktCO_2e$ in 2020. The cost curve suggested as much as 24% of projected baseline emissions to be mitigated by measures providing for net savings for the Maldivian economy. Climbing from 24% to 36% of baseline emissions came in with net costs mitigation measures and notable at net costs higher than current offset prices. However, if considered as an integrated package of measures, net-savings options seems to more than pay off the net-costs measures and emissions can be capped at 1266 $ktCO_2e$ (64% of projected baseline emissions) with overall annual net savings.

Table 3 Summary table abatement costs

Mitigation option	Abatement costs	Capital costs	Annualized costs	Mitigation in 2020	
	US$/$tCO_2e$	US$ million	US$ million per year	$ktCO_2e$ per year	Fraction cumulative
LED tubes for public sector	- 784	0	- 0.8	1.1	0.1%
Better maintenance of motor bikes	- 413	0	- 10.0	24.3	1.3%
Air conditioning at resorts	- 398	4.7	- 12.7	31.8	2.9%
Cooling new service buildings	- 369	1.8	- 4.6	12.4	3.5%
Solar water heater	- 323	0.7	- 0.8	2.5	3.7%
Efficient air conditioning	- 313	9.6	- 27.7	88.5	8.2%
LED tubes for street light	- 292	0.1	- 0.6	2.2	8.3%
Upgrade of system efficiencies	- 260	61.1	- 11.2	43.2	10.6%
PVs outer islands	- 252	42.4	- 3.7	14.7	11.2%
Regional waste-to-energy projects	- 228	10.4	- 2.2	9.5	11.7%
PVs with Net Meters	- 189	42.0	- 2.2	11.9	12.3%
Energy efficient refrigerators	- 158	41.2	- 6.6	42.0	14.4%
PVs Malé Region (existing plans)	- 133	45.0	- 2.1	15.8	15.2%
PVs Malé Region (additional options)	- 133	45.0	- 2.1	15.8	16.0%
Efficient water pumping	- 117	14.5	- 0.9	7.6	16.4%
PVs on resorts	- 108	167.4	- 6.3	58.2	19.4%
20 MW wind power & 25 MW LNG	- 105	97.3	- 2.8	26.5	20.7%
Thilafushi waste-to-energy project	- 68	57.8	- 1.6	23.1	21.9%
PVs with storage at small islands	- 52	167.1	- 1.8	35.3	23.7%
LEDs for domestic lighting	199	42.4	1.7	8.5	24.1%
Biodiesel 20% blend	336	0	71.6	213.0	35.0%
Bioethanol 15% blend	337	0	4.9	14.6	35.7%
Total		850.3		702.4	

Yet, the above does not capture the combined impact of interrelated measures such as end-use savings, power system efficiency improvements and RE-integration. This is because each power sector mitigation option was always compared with the same baseline grid emissions factors and projected electricity demand for 2020. Due to this, the marginal abatement cost curve may slightly over-estimate the aggregate mitigation potential and hence abatement unit costs for options affected. In order to take this into account, the combined impact of demand and supply side options for grid electricity in outer islands and Greater Malé region, for resorts islands and for bio fuels were also assessed. This suggested 2020-emissions to be capped at 1288 $ktCO_2e$ if mitigation with biofuels is pursued or otherwise at 1520 $ktCO_2e$.

GHG-emissions of this magnitude would correspond to capping emissions at 114% - 134% of the 2009-level. However, an emissions cap target for the entire economy at this level would require imposing differentiated caps since some sectors offers greater mitigation than others. The abatement costs analysis indicated following emissions caps by sectors to be achievable with the options analysed when taking the combined impact into account:

Table 4 Mitigation by sectors in $ktCO_2e$

			Excl. bio fuels options		Incl. bio fuels options	
Sector	2009	2020 BAU	2020 cap	Relative to 2009-level	2020 cap	Relative to 2009-level
Grid electricity	262	489	152	57%	124	46%
Resorts electricity	283	537	451	159%	361	128%
Transport	331	557	532	161%	451	136%
Hulhule airport excl. transport	13	25	25	192%	20	153%
Captive systems outer islands	19	36	36	189%	29	152%
Desalination (Malé Region)	12	22	22	183%	18	147%
Fishery excl. LPG and Kerosene	82	87	87	106%	70	85%
LPG and kerosene	94	215	215	229%	215	229%
Other	37	0	0		0	
Sum	1133	1968	1520	134%	1288	114%

Mitigation through introduction of 20% biodiesel blends and 15% bio ethanol blends was envisaged as a country wide measure i.e. affecting all consumptions of diesel and petrol. These options came in at net costs and may be viewed as less attractive to pursue under a carbon neutrality target as they are more expensive than offsetting and do not provide for foreign currency savings. On the other hand bio fuels would help reduce other major pollutants like particulate matter, hydrocarbons, sulphur oxides and carbon monoxide and thereby it may help reduce damage costs to the economy.

When the combined impact of other options was accounted for biofuels were assessed to lead to mitigation of another 232 $ktCO_2e$ distributed among sectors as presented in the table above.

2.3.2 Investment requirements

While the abatement costs analysis indicated that mitigation could be achieved at net savings, realizing these would require considerable capital costs until 2020. The overall capital costs were found to be in the magnitude of US$850 million (discounted and in 2013-price level), but is should be noted that some costs estimates were attached with considerable uncertainty[7]. For energy efficiency options, the estimated capital costs presented incremental costs that are the extra costs of acquiring energy efficient technologies compared with conventional technologies as in the baseline. For the electricity supply side options, the capital costs calculations did not consider that the proposed new electricity generation capacities would eliminate or at least postpone investments in renewal of generation capacities or in capacity additions in the baseline.

Interventions for scaling up renewable energy (RE) for grid electricity as per the SREP Investment Plan were understood to be envisaged for implementation under Power Purchase Agreements (PPAs) between power utilities and Independent Power Producers (IPPs) to purchase tariffs established as per new Feed in Tariff (FIT) regimes. Contrary to this, transformation of small islands power grids to PVs with battery storage was found by the SREP Investment Plan to be less attractive for this model. Accordingly, investments for these interventions were understood envisaged for financing from internal funds (and debt finance as appropriate) of power utilities.

[7] In particular the combined LNG and wind power project envisaged by STELCO and the outer islands power system upgrade.

In the table below, capital costs estimated for the 22 mitigation options were distributed on sectors and types of arrangement that supposedly should provide the capital costs required for the investments.

Table 5 Capital costs for investments by sector in millions US dollar

	Capital costs (2013-price level)
Independent Power Producers - hereof waste-to-energy	297.8 68.2
Power utilities	228.2
Other public sector	2.2
Residential sector	149.7
Resorts	172.8
Total	850.3

Capital costs of nearly US$ 300 million were estimated for the mitigation options in public power generation supposedly suitable for e.g. project financing and implementation by IPPs. The hybrid project on LNG and wind power envisaged by STELCO and waste-to-energy projects were included together with the mitigation options on PVs at utility scale under FIT regimes.

Under the current ownership and operation of islands power systems investments within grid upgrades and fully transformation of small islands grid to PVs with storage, will likely have to be held by the power utilities on their own including through debt financing. Capital costs required for these options amounts to US$228 million.

Within other public sectors were found mitigation options in service buildings and street lighting which were understood to be financed from public budget allocations for such services. Capital costs requirements were found to be US$ 2.2 million.

Capital costs requirements for resorts were found to be around US$173 million and the remaining US$150 million is from domestic end-use sector and includes PVs under net metering scheme. Note, that the only net cost option in energy efficiency - domestic LEDs on its own accounts for US$42 million.

2.3.3 Supportive measures

Transformation from being an economy entirely dependent on fossil fuels import would take time and strategic planning and alignment of government, public and private sectors. It would also require a combination of regulatory measures, creation of incentives for private sector, capacity building and awareness to raise demands for low carbon technologies. Enhancement of the Maldivian resource base through e.g. scholarships in targeted areas also seems essential. While barriers and ways to overcome were not studied in depth for this report, it is recommended for the further work on detailing the national low carbon development strategy to address how to strengthen regulatory measures and provide adequate incentives supportive for the transformation to a low carbon economy. For such further strategy work, it may be useful to consider the following:

Public utilities and RE investments

Power utilities have a key-role to play in tapping the potential mitigation at hand in the field of supply side and demand side management (DSM) and in attracting investments required in new generation capacities from renewable energy. In order to prepare power utilities to

fulfil this role there seems to be a need for enhancement of the capacity of power utilities *inter alia* in fields of: upgrading of existing infrastructure to improve efficiency and accept greater share of renewable; development and cost benefit analysis of projects on low carbon/new technologies and; contract/PPA negotiations with investors/IPPs.

It was understood that there is also a need for mechanisms tailored to attract renewable energy investments. There are for instance issues of provision of risk guarantee for investors - which is an issue for attracting larger and foreign investments primarily, but there is also a need to address how domestic investors increasingly could be engaged.

End-use sectors

Numerous previous studies have already found areas where national regulation needs to be strengthened in order to tap the potential energy efficiency improvements and savings in end-use sectors. For this report, taking the building code to the next level by incorporation of energy performance standards was found to be of outmost importance and urgency together with awareness raising and capacity building on energy efficient/low carbon building design and building construction targeted architects, urban developers and planners, building contractors etc.

Also it appeared evident that the considerable potential savings by dissemination of energy efficient electric appliances currently lacks support for their realization and should be targeted dedicated efforts, whether be tax exemptions for energy efficient equipment, awareness raising and advocacy of energy efficient technologies, capacity development of retailers on communicating product information to customers or development and implementation of energy efficiency standards for electrical appliances.

The tourism sector

As a significant contributor to Maldives GHG-emissions, the tourism sector plays a key role for the success of a national low carbon development strategy and the draft 4th Tourism Master Plan deserves appreciation for proposing to introduce targets for resorts low carbon development.

Use of smart appliances including energy saving appliances and power control devices and use of renewables will all help in a low carbon development strategy for the resort sector. Also encouraging tourists to recycle waste would also help to reduce emissions

How to strike a proper balance of regulatory measures and voluntary commitments by the tourism sector requires further considerations, but is seems essential that the national low carbon development strategy prescribes relevant targets for the resort sector whether be for renewable energy integration, relative caps on fossil fuel usage or caps on GHG-emissions. Accordingly, baselines for emissions trends needs to be explored as well as development and implementation of monitoring mechanisms to current practices. Like for public utilities, awareness and capacity development of the tourism sector - in particular the resort sector - was found to be relevant *inter alia* in fields of new technologies and techniques, economic/financial analysis and implementation of low carbon projects including monitoring, reporting and verification (MRV) techniques associated with low carbon emissions projects. The feasibility of introducing more advanced mechanisms such as emissions trading schemes for the tourism sector needs first to be subjected a thorough analysis addressing issues like the risks of exercising market power and of not attaining a liquid market due to rather few market players and limited volume of transactions envisaged for such cap and trade system. Alternatively, other market tools such as tax reductions and and eco branding would encourage GHG emission reduction activities within the Market.

Other sectors

Transport was found to cause greater emissions than public grid electricity generation and it will develop to become an even more predominant sector for GHG-emissions in the future assuming that net-saving mitigation options in grid electricity will be tapped. Awareness on this was found to be little in general and there seems to be challenging tasks ahead for government institutions, transport/urban planners and transport service providers to reduce the rate by which emissions from transport are forecasted to grow. First of all baseline trends and mitigation options should be better understood as basis for setting low carbon development targets for instance for public transport service providers and developing detailed strategies including regulatory measures as relevant.

Over the long-term there is a need to have a human resource development strategy and introduce low carbon and green development concepts into the curriculum
An emission standard in maritime transport through an inspection and maintenance system is also needed.

There is also a need to have a low carbon infrastructure development strategy through which

- Introduce and design walkable cities providing comfortable pavements
- Design roads to accommodate cyclists
- Green building designs and use of energy efficient materials
- Use of renewable energy and energy saving appliances in buildings

Waste is also a problematic area for GHG emissions. There is a need to have sustainable waste management strategy to

- Address landfill sites through environmentally sound technology
- Promote waste to energy technologies
- Control of import of second hand goods and vehicles

2.4 Sub-strategy for offsetting

2.4.1 Quantified target

The relevance of a sub-strategy for offsetting obviously relies on the decision on whether to stay with the pledge for carbon neutrality by 2020, which in this report was assumed to be the case.

The quantitative target for offsetting depends on projections for domestic emissions by 2020 as offsetting is to fill in the gap to reach zero net-emissions. However, it may also take into account the marginal costs of domestic mitigation versus the costs of offsets. Hence, the guiding principle could be to purchase offsets once the marginal costs of additional domestic mitigation exceed the offset price.

The abatement costs analysis indicated that once mitigation of some say 450-500 $ktCO_2e$ is secured the marginal abatement costs would come at net costs and notable at net costs exceeding current offset prices. This suggests the target for offsetting to be at least 1.5 $MtCO_2e$. Still, it should be stressed that the portfolio of domestic mitigation options explored for this analysis is very preliminary and should further be carefully evaluated to validate if domestic emissions by 2020 actually would likely reach the potential target as indicated by the analysis. On the other hand, there may also be additional net-saving

mitigation options not explored presently, not least in the tourism sector at resort islands. Hence, the quantified target for offsetting could change accordingly.

2.4.2 Offset prices and costs of offsetting

At the moment opportunities available to Maldives for acquiring offsets are limited to CERs for voluntary cancellation and to VERs originating from projects registered under the CDM. Prices of CERs for the compliance market are currently less than one US dollar per tonne but there is no information in the public domain on prices of CERs purchased for voluntary cancellation. Still, CERs for voluntary cancellation may likely be available at the same low prices as appears for CERs in the compliance market.

The voluntary market is much less liquid and less predictive than compliance markets and prices vary among project standards under which the offsets are issued. The average volume weighted price of VERs reported from market players in 2012 was US$5.9/t (Bloomberg 2013). The most appropriate for Maldives with regard to offsets from the voluntary markets would be to acquire VERs from projects registered under the CDM i.e. VERs vintages stemming from prior to the CER crediting period. Such VERs (or CDM-offsets) constitutes, however, an insignificant share of the 2012-transactions in the voluntary market (less than 1% of transacted volumes) and the average price of VERs gives therefore little information on prices attainable in the CDM-offset segment of the voluntary market.

As a current price range for further considerations on offsetting, prices between one and six dollars per tonne may be expected. Given a target of say conservatively 1.5 Mt offsets, costs of offsetting would be in the range of US$1.5 million and US$9 million.

It is tempting to compare this value with savings that can be tapped by pursuing options for domestic mitigation. For instance the 15 MW solar PV programme in Greater Malé Region would alone lead to lifetime net savings for the Maldivian economy exceeding the estimated budget needed for purchasing 1.5 Mt offsets with the current low prices in the carbon markets.

The offsetting strategy should take into consideration the developments in negotiations for a new global carbon agreement as this may likely provide for new markets mechanisms eligible for developing countries for acquisition of offsets. It may, however, also lead to considerable price increases in the compliance markets due to increased levels of commitments as well as in the voluntary markets. This suggests Maldives to secure offsets as soon as possible.

2.5 Institutional home

The low carbon development strategy requires a creditable and effective institutional home(s) mandated to take on the oversight role and to detail and streamline the implementation of the strategies. This is envisaged to include *inter alia* MRV, awareness and capacity building, development of detailed implementation strategies, development of supportive mechanisms, and monitoring of financial flow for implementation.

While the government should play a strong oversight role also in the offsetting, the offsetting programme itself could be outsourced to offset providers. The governmental oversight of offsetting should address environmental integrity including agreeing with project standards, project types, geographical focus and desirable development impact, as

well as transparency and verification of acquired offsets aligned with standards prevailing under the UNFCCC.

2.6 Recommendations for follow-up

The analysis of this report is believed to fill in some gaps in terms of assessment of what is possible and feasible for Maldives regarding country wide mitigation of GHG-emissions and striving for less dependency on fuel imports. Still, there were constraints in the underlying data which is an area recommended for improvement in order to strengthen the basis for continued work in updating and sophisticating the energy balance, the GHG-inventory and projections of baseline emissions trends, which could all provide valuable input to the further strategic planning for low carbon development and as needed for a mitigation target commitment which Maldives could present as its contribution to an international climate agreement due to be agreed next year (in 2015).

3 Mitigation from grid electricity generation

3.1 Sector Brief

Diesel for electricity generation for public grids is one of the most significant sources of GHG-emissions. According to the energy balance diesel used for grid electricity generation corresponded to 25% of the primary energy demand of Maldives in2009 leading to GHG-emissions of 265 $ktCO_2e$. Add to this 285 $ktCO_2e$ from electricity generation at resort islands. In the BAU scenario for 2020 the significance of electricity generation in the energy balance was projected to largely sustain.

As per policy statements the electricity generation sector is to become carbon neutral by 2020 and renewable energy in electricity generation is targeted to reach 50% by 2015. These are indeed ambitious targets. Electricity is almost exclusively produced by diesel generators and distributed in isolated grids. Island grids are generally not interconnected. Some industries and business operate their own diesel gen sets as backup during periods of grid power shortages or since they are not connected to a grid. Electricity supply at resort islands are captive systems based on diesel generators. Overall installed capacity is about 245 MW (2010) divided into 120 MW at inhabited islands (49%), estimated 105 MW at resorts islands (43%) and 20 MW at industrial islands (8%).

Throughout the country, thermal efficiencies of grid connected diesel generators were understood to vary from 28% to 39%. The highest overall system efficiency found is 35% wheras down to 15% is found at some small and very small islands[8]. Except for Greater Malé Region with distribution losses of 7-8%, technical losses in distribution are 10% at the minimum, but upto 30-40% losses can be found in distribution networks.

Fuel costs of electricity generated by diesel generators are taken by the MEE to vary across the country from US$0.31/kWh electricity produced toUS$0.46/kWh (averages per islands grids) which suggests PV to be an economically attractive substitue at least to operating diesel generators for base load during day time. Hence, dependent on size and location of PV applications, levelized costs of electricity (LCOE) generated from utility PV installations have for this analysis been assessed to vary between US$0.21/kWh electricity and US$0.29/kWh.

In order to support that the competitive advanges of PV actually translates into increased dissemination of PVs, a variety of measures are planned for by the MEE to attract investments. This include Feed-in-tariff (FIT) schemes targeted utility PV-applications and Net Metering targeted residential PV applications. With Maldives SREP Investment Plan the most comprehensive plan so far was launched for supporting renewable energy investments for Greater Malé region and for a selection of outer islands. A total of 26 MW installed capacity from renewable energy technologies was planned for. Solar and waste-to-energy (WTE) is likely to be the most predominant renewable energy source to take up and to a lesser extent wind power and perhaps imported biomass.

[8] SREP Investment Plan

Levelized costs of electricity

The key measure used in the present analysis to identify attractive GHG-mitigation options was abatement costs, but levelized costs of electricity (LCOE) were also determined for some of the identified mitigation options. LCOE are discounted lifetime costs divided by discounted lifetime electricity generation. It is a measure often considered being useful in policy making and planning for prioritization of electricity generation technologies.

For the present analysis, LCOE were established for electricity generation technologies providing for GHG-abatement options compared with continued use of diesel generators for electricity generation in the Maldives. The LCOE calculations of these options considered: capital costs; operation and maintenance costs over the useful lifetime of the technology discounted by a social discount rate; and levelized over discounted lifetime electricity generation. The discount rate was set to 7%.

The LCOE of some technologies were s found to be competitive to electricity generation by diesel generators in the Maldives merely due to diesel fuel costs savings i.e. even when disregarding for the diesel reference scenario capital costs, maintenance costs and other operational costs. Accordingly, as LCOE were lower than avoided diesel fuel costs of diesel generators, these new technologies were taken to have the ability to provide savings to the Maldivian economy.

This may obviously not be true for any given application as there may be deviation for a particular case in the reference scenario or in the project scenario. The thermal efficiencies of the diesel generators assumed for the analysis relied on averages established from data provided by operators of islands grids – data which, however, has some uncertainty attached.

Moreover, thermal efficiencies of generators vary along the load curve and one unit of diesel generation capacity is not necessarily replaceable with one unit of generation capacity from an intermittence source like solar. Thus, the competitiveness of the new technologies depends highly on the scale of deployment and the load duration curve of a given islands grid. On the other hand, the project scenario may also for a given application postpone or eliminate capital costs in new diesel generators. This was not assumed being the case for the RE-options studied in the present analysis. Moreover, it should be noted that more extended methods may provide additional insights into the costs and benefits of different mitigation options. For instance if damage costs attached with emissions of pollutants were considered too, the diesel generator reference scenario would probably prove to be even more costly for instance due to health costs attached with emissions of sulphur dioxides and particulate matter.

Therefore, while the LCOE presented by this report is useful for general comparison with marginal costs of diesel generators, it should be kept in mind that it cannot replace analysis needed for specific power grids, neither for the purpose of assessing social costs of different scenarios nor for the purpose of assessing financial feasibility.

The experience in use of wind energy is very limited to Maldives, as there have been a limited number of pilot projects (wind-solar-diesel) only established on remote islands in around 2006[9]. The main reason for the lack of limited wind projects could be due to the

[9] Detailed information on these projects such as performance of turbines and information on operational issues is, however, not made available to the MEE/MEA.

fact that quality wind data is very limited. Moreover, NREL satellite measurements show variations in annual average wind speeds from North to South of the country. However, under a complementary resource mapping program from ESMAP, wind measuring stations are planned to be installed in selected regions in order to collect long-term high quality wind data. Wind is nevertheless understood by the MEE to be viable in smaller scales, which could complement PV-diesel hybrid systems and will be considered under the SREP programs.
When a USD370m worth projects were signed with international energy companies no quality wind data was available:
In 2009 a 75MW wind energy system in Gaafaru lagoon was started in collaboration with Falcon Energy without understanding of the wind resource. Later in 2011, the project was taken over by Chinese manufacturer XEMEC to install wind turbines generating upto 50MW and supplying Male' area with submarine cables.

3.2 Grid electricity in Greater Malé Region

In Greater Malé Region,[10] grid connected electricity generation capacities comprises the STELCO power houses at the capital island Malé and at the 5 other islands namely Hulhule (accommodating *inter alia* the airport for domestic and international flights and power managed by the Maldives airport company), Hulhumalé, Thilafushi, Villingili and Gulheefalhu. Thilafushi island accommodates waste management and industrial facilities which are served by captive power systems including one operated by STELCO. In addition to the STELCO diesel generators there are some rooftop mounted PV installations connected to the power grids in Malé and Villingili. Net electricity generation in 2009 was 217 GWh totally for all islands grids in the Greater Malé Region.

In the capital Malé, there is some 61.4 MW installed generation capacity from diesel generators. The peak demand of grid electricity is about 40 MW (Ministry of Environment and Energy 2013a). Since 2002 growth rates of peak demand were 10% and it has decreased to 8% since 2007[11]. New generation facilities to replace worn-out facilities and add generation capacity are needed in the coming years. Some 50 MW new generation capacity is needed over the next 10 years to cover peak demand estimated to reach about 80 MW in 2020 with the present growth rate. Due to constraints in available space in the capital island Malé, new facilities to serve the capital island may need to be placed in other islands. Interconnections of islands power systems would accordingly be needed. Interconnection of Malé with Hulhumalé and Villingili with Thilafushi was recommended in a pre-feasibility study in 2010 (SARI/ENERGY 2010), but Malé is yet not interconnected with any other island grid, neither are the other islands of Greater Malé region.

Thermal efficiencies of diesel generators were reported to be at 39% and distribution losses to be 7-8%, which was regarded as fairly acceptable levels unlike the situation in many outer islands. The challenge is therefore rather to find for the Greater Malé Region the optimum way of balancing supply and demand curves by paying due attention to reducing load demands while introducing large scale uptake of renewable energy sources.

[10] In this report Greater Malé Region refers to the 4 inhabited islands of Male, Hulhumale, Villingili and Gulheefalhu plus the industrial island of Thilafushi and the airport island of Hulhule.

[11] Data provided by STELCO to the MEE.

While STELCO has essentially not yet been into demand side management – such as reducing peak loads of end-user and/or shifting peaks to off-peak periods - the utility has recently obtained valuable experience with integration of PVs. Still, scale is limited and reaches totally some 1.4 MW installed capacity of PV[12] in Malé and Villingilli. For the Greater Malé region initiatives and major new projects in the pipeline include additional 39.9 MW generation capacities from renewable energy as follows:

- Waste-to-energy programme to establish up to 4 MW electricity generation capacities in Thilafushi to supply the utility grid and fully cover the electricity demand of the island. Time horizon for commissioning of the plant is 5-6 years.

- Malé region solar PV programme (packaged in ASPIRE component under the SREP Investment Plan) which comprises 11 MW for the capital of Malé and 4 MW for Hulhumalé. Time horizon is 5-6 years. FIT scheme is supposed to help spur investments required for this programme.

- STELCO is envisaging a wind/gas hybrid system with up to 25 MW LNG plant for base load and up to 20 MW wind power as will prove feasible once investigation of wind resources etc. is finalized. Such LNG plant would need being located outside the capital island Malé (probably at Thilafushi) and hence would require interconnections.

- It was recently (2013) being prepared to allow for net metering in the Maldives. Net metering is expected to help spur investments in residential PV installations. For the low carbon development analysis, net metering was assumed to potentially bring along 1.9 MW PV capacity additions to the Malé island grid by 2020[13]. However, shadowing from the increased number of high rise buildings have to be considered.

Renewable energies would accordingly possibly reach 42.3 MW in installed capacity while peak load demand for 2020 was forecasted to reach 80 MW for the Malé capital island grid alone and additional 10 MW peak load if the power systems in Greater Malé Region were considered as one system. As low-cost/must-run resources[14] these renewable energy applications would generate 107 GWh in 2020. This equals 27% of the annual grid electricity generation at 401 GWh projected for the BAU- scenario for Greater Malé region.

Therefore, while these initiatives are all important steps, they are not sufficient to reach 50% renewable energy of electricity demand as the nationwide mid-term target for 2015 suggests. In order to further move forward, alternative technologies to diesel generators in assisting renewable energy in day time operation, in serving loads outside day time

[12] Totally 652 kW under the STELCO Six Island PV Project under a Power Purchase Agreement (PPA) between STELCO and Renewable Energy Maldives including 294 kW in K.Villingilli. In addition about 775 kW PV installed at public roof tops in Malé with Japanese grants (project on Clean Energy Promotion in Male).

[13] This assumes that 30% of privately-owned houses in Malé each will be equipped with a PV system of 1 kWp.

[14] Solar PV, wind power and waste-to-energy were taken to be low-cost/must-run (LCMR) resources i.e. they will always be dispatched due to low marginal costs (operational costs) or because they are dispatched independently of daily or seasonal load of the grid.

operation and in provision of readily available reserve capacity due to the intermittency of PV(and wind power), remains to be explored. Alternative solutions may include:

- Inter-connection of islands grids in Malé Region;
- Extended use of renewable energy sources including by technologies other than PV;
- Storage technologies; and
- Substituting fossil diesel with biodiesel

In order to streamline the renewable energy projects one of the main activities of the SREP will include addressing the energy need of the greater Malé region through the development of an RE integration plan. This will involve installation of minimum 15 MW PV systems (as listed above) along with inter-island grid connections through submarine cables. Other RE options such as biomass, wind, ocean currents will be explored paired with complementary smart grid technologies which are expected to further make the power infrastructure more efficient.

For the purpose of the low carbon development analysis, the GHG-emissions impact of extended PV was assessed, namely additional 15 MW solar PV installed say for instance at warehouse rooftops at Thilafushi. Assuming that connecting Thilafushi with other islands in the Malé region would be needed in any case and thereby also in the reference scenario (due to space constraints in inhabited islands in Greater Malé Region for the capacity additions required to serve the 80 MW peak load), the 15 MW PV extension was assessed to help save net systems costs compared with capacity additions from diesel generators.

By adding another 15 MW solar PV to the portfolio of envisaged projects, installed capacity from renewable energy would increase to 57.3 MW all of which would be considered low-cost/must-run resources (LCMR). With such share of LCMR, storage technologies would perhaps need to be brought in adding to the overall costs[15] in particular if electricity demand in end-use at the same time is reduced significantly as the abatement costs analysis suggested.

Table 6 Existing PV and envisaged new projects for the Greater Malé Region by 2020

	Installed capacity (in MW)	Annual power generation (in GWh)	Annual mitigation (in $ktCO_2e$)
Existing solar PV in Malé and Vilingilli	1.4	2	1.5
Solar PV in Malé under SREP and by means of FIT	11	16	11.6
Solar PV in Hulhumalé under SREP and by means of FIT	4	6	4.2
Waste-to-energy plant in Thilafushi under SREP	4	32	23
Solar PV by means of Net Metering Scheme	1.9	3	2.0
STELCO wind power	20	26	18.9
Additional mitigation by 15 MW solar PV	15	22	18.8
Sub-total LCMR	53.3	107	77.1
STELCO LNG plant	25	21	5.9
Total		128	82.9
Total exclusive. existing solar PV		126	82.1

Note: For the mitigation estimate, thermal efficiencies in the BAU for diesel generators were assumed to be 37%. For other assumptions see Annex A.

[15] This was not investigated further. To determine this more information would be required on the power grids including load duration curves.

Switching from 100% fossil diesel to a 20% biodiesel blend was explored as part of the abatement costs analysis. Biodiesel blends will help reducing GHG-emissions attached with operation of diesel generators as needed in a future power system with high penetration of PV and possibly other renewable technologies with intermittency. There were extra costs attached with this option compared with use of fossil diesel due to the premium of biodiesel price. The extra costs translate into an increase in the costs of electricity by 29%.

3.3 Grid electricity in outer islands

Inhabited islands outside Greater Malé Region were in this report termed outer islands. In terms of islands grids at outer islands, this report counted 184[16] islands grids at outer islands.

Each outer island is served by its own power distribution system and inter-islands connections are generally non-existent[17]. STELCO operates 28 power stations in 26 islands. While FENAKA operates 146 power stations in 145 islands, there are 16 power stations operated in 16 islands by island councils and 3 power stations operated in 2 islands by private parties.

Islands grids have intentionally been developed to provide 24-hours of access to electricity for the entire population and a study from 2010 assessed installed generation capacity to be sufficient in general to cover the peak demand until 2020 for nearly all islands including maintaining sufficient reserve capacity for periods of maintenance and failures (SARI/ENERGY 2010)[18]. However, some island power systems are unreliable and poorly maintained leading to frequent power outages or less than 24-hours of supply due to technical failures or the price and availability of diesel fuel supplies. Installed capacity is often 2-3 times higher than peak load. This is explained by the substantial reserve capacity needed for maintenance but is likely also to some extent due to practices of inappropriate sizing when new generation capacities were acquired. Significant over sizing leads to running generators at inefficient part loads. Some studies reveals cases where it would be economically attractive – before end of technical lifetime - to bring in new and more efficient diesel generators better sized to meet the demand.

MEA informs that technical losses in distribution is 10% at the minimum but as high as 40% can be found stemming from poor technical quality of distribution lines. It was understood that these are purely network losses. The energy balance suggested end-use grid electricity demand in outer islands to have been 197 GWh in 2009, but no comprehensive and

[16] This number of 184 counts Addu City as two grids, namely one serving the island of Hulhumeedhoo and the second bundling S.Gan, S.Feydhoo, S.Maradhoo and S.Hithadhoo. The number of 184 also counts the 4 islands of Maahinna, Mukurimagu, Thundi and Mathimaradhou as one island grid, namely as L.Gan.

[17] But there are some examples. Addu central power stations supplies 4 inhabited islands which are interconnected. Feasibility studies are ongoing for interconnection of islands in Faadhippolhu Atoll (Hinnarvaru, Felivaru, Madivaru and Naifaru islands) and in Huvadnu Atoll (Thinadhoo, Kaadedhoo and Madaveli islands).

[18] The study projected load demands by islands based on 1996-census data and concluded that installed capacity as per 2010 is sufficient to cover projected 2020 demands plus 20% reserve in all provinces, except for the South Province, where 1 MW additional capacity would be sufficient to provide for a 20% reserve margin.

consolidated single set of data covering all islands was available for the abatement costs analysis. Therefore, in order to cover all inhabited island the analysis was built upon the underlying data used by the MEE for the SREP Investment Plan covering 107 islands outside Greater Malé Region (hereinafter referred to as the "SREP underlying data") as well as on the Energy Outlook for inhabited islands 2013 (Ministry of Environment and Energy 2013b). The 2013 Outlook publication collects data from 187 power systems of which the majority serves only one inhabited island[19].

According to the MEE diesel fuel costs of small and very small power systems are in the range of US$0.40-0.46 /kWh electricity produced. The LCOE of PV installations combined with battery storage to jointly cover 24-hours of electricity demand were with the prices used for the abatement costs analysis, found to be US$0.42 /kWh[20] i.e. within the range of avoided fuel costs from existing diesel generators. This is somewhat higher than what was found in the SREP Investment Plan. Still, with 100% transformation the solar and battery hybrid system will postpone or even eliminate investments in new diesel generators in the baseline scenario. LCOE of diesel generators taking capital costs in to consideration are therefore a better benchmark than avoided fuel costs for projects on 100% transformation to PV-battery systems.

3.3.1 Renewable Energy in outer islands

Experience with PV in outer islands stems from following projects:

- On GDh. Thinadhoo (large electricity consuming island) 300 kW PV installations mounted on public rooftops, expected to generate 500 MWh/year and decreasing diesel demand leading to emissions reductions of 270 tCO_{2e}/year. The project is entitled "Clean Energy for Climate Mitigation (CECM)" and is implemented under Maldives Climate Change Trust Fund;
- On Dhiffushi 40 kW PV installation implemented by KEPCO, funded by the government of Japan;
- On L.Gan and L. Fonadhoo 15 kW PV implemented by JICA and funded by the government of Japan and;
- Under the STELCO Six Island PV project: 64 kW on K.Guaridhoo, 78 kW on K. Himmafushi, 120 kW on K. Maafushi, 48 kW on K. Kaashidhoo and 48 kW on K. Thulusdhoo

There is no experience yet in Maldives with integrating renewable energies into diesel systems beyond 30% of the system peak load demand. The guidance of 30% as upper limit for ASPIRE of the SREP Investment Plan stems from concerns by STELCO over system reliability caused by fluctuations/variations in solar insolation. To further explore this, the feasibility of exceeding this threshold was recently studied for a small and a large island power system, namely the Gulhi and Thinadhoo islands (AF-Merchados EMI 2013b). The study results appear to challenge the 30% threshold as being conservative in particular for large power systems. Though the small power system in Gulhi island is more vulnerable, it was assessed for both cases that ramping capability of diesel gensets can cover the ramp

[19] Some serves more than one island. Addu City ii serves 4 islands, Gan in Laamu Atoll counts as one (not 4) and Hulhumalé counts also for Hulhule.

[20] This assumes conventional lead-acid batteries with a discharge of maximum 20% to achieve 10 year of lifespan of the batteries. Accordingly, the rated capacity of energy storage was 5 times the energy that is discharged.

rates of the PV installations. Hence, the hybrid solar-diesel scenarios developed for the two cases – which suggested PV beyond the 30% threshold - were evaluated by the study to not compromise security in supply[21] and they were also evaluated to lead to net costs savings. MEE informs that most recent studies for Thinadhoo island indicate that it is possible to achieve up to 50% of the daytime peak demand with proper control mechanisms.

The least cost options for electricity generation by diesel only and hybrid systems with PV were also studied for the two islands. The analysis relied on modelling of the power systems. It considered short and long run marginal costs of electricity by diesel generators, by solar PV and by optimized supply side management. One key result for the Gulhi island case which may give guidance on what to expect from small islands grids in the country was that annual diesel savings and hence attached GHG-emissions reductions at 19% are achievable by 2022 where PV accounts for 34% of peak load demand. The Thinadhoo case – where PV on average for the 10 year period studied accounts for 50% of peak load but varies from 39% to 71% - suggested that 22-36% of annual diesel consumption can be saved with an integrated approach to PV deployment and optimization of supply side management. The study also suggested savings to reach nearly 24% of annualized costs of the BAU scenario and 13% of the annualized costs of the Optimized diesel-only scenario. This may be an early indication on what to expect from interventions targeted islands sharing some of the same key-characteristics with Thinadhoo.

For outer islands, the SREP Investment Plan intends to provide for the following within a 5-6 years horizon:

- Fully transformation of diesel only systems to renewable power systems with battery storage in 10 islands with small power systems. Totally 2 MW installed PV-capacity is foreseen. The 10 islands transformation is packaged in POISED[22]. If found feasible, wind power may also be integrated;

- Power system upgrades such as sizing generators, installation of automatic controllers, and replacement of undersized and worn out cables etc. on about 15 islands to be ready for large scale renewable energy deployment. The power system upgrades are supported with funds packaged in POISED;
- Increase share of RE electricity up to 30% of total peak demand in about 30 islands. It comprises 15 islands with already rehabilitated power systems plus the 15 islands power systems supposed to be rehabilitated by POISED (see the previous bullet point). In total 3 MW installed capacity on PV and wind power is expected together with 2 MW waste-to-energy on selected islands, that is two large islands and one small island. FIT schemes are supposed to help spur private funding for the RE-investment together with various guarantee products packaged in ASPIRE[23]; and

[21] Still, micro systems are vulnerable – the study concludes - and solar forecast would be useful.
[22] Preparing Outer Islands for Sustainable Energy Development Programme, which is a programme under the SREP Investment Plan.

[23] Accelerating Sustainable Private Investments in Renewable Energy Programme, which is a programme under the SREP with a separate component for wind and PV (hereinafter termed ASPIRE-RE) and a separate component for WTE (hereinafter termed ASPIRE-WTE).

- Additional 129 islands will be considered under ADB funding for renewable energy combined with storage and ranging from 30% to 100% integration of renewable energy.

It was not entirely clear how interventions will be distributed among islands in particular the envisaged additional funding from the ADB. For the present analysis on mitigation options the additional ADB funding was understood to be targeted 129 islands, however, neither medium nor large islands. It was expected that small islands would be given priority over very small islands. Accordingly, the 95 small islands not otherwise targeted by interventions, were assumed being selected for the additional ADB funding, which leaves 34 of the very small islands as potential candidates for the remaining additional funds from ADB. The envisaged distribution of SREP interventions was summarized in the table below (3rd column).

The classification of islands according to size of islands power systems found in the table was in accordance with the categorizations used by the MEE for the SREP Investment Plan. The number of islands in each category was determined from data provided by the MEE for this analysis covering 107 outer islands (the SREP underlying data). Islands not included in these data were categorized according to their electricity generation reported in the Energy Outlook (Ministry of Environment and Energy, 2013b)[24].

Table 7 Distribution of interventions for RE among outer islands

Islands classifications	Nos. of islands	RE interventions (ASPIRE, POISED and potential additional ADB funding)	Nos. of islands without interventions	Options included in abatement costs analysis
Large Above 3 GWh/year	5	5 islands: • Kulhudhuffushi (WTE for water) • 2.S.Hithadhoo in Addu City (WTE for grid) • Fuahmulah (ASPIRE-RE) • Thinadhoo (ASPIRE-RE) • L.Gan (ASPIRE-RE)	None	3 islands in package with 12.1 MW distributed among 121 islands. 2 islands for WTE for grid
Medium 1 – 3 GWh/year	32	27 islands for 30% RE (ASPIRE-RE) (30 in total of which 3 are large islands).	5	32 islands in package with 12.1 MW distributed among 121 islands.
Small 0.250 – 1 GWh/year	106	10 islands fully transformed (POISED) by 2MW PV + battery 1 island for WTE for grid (.R.Vaadhoo under ASPIRE-WTE) Additional ADB funding for 30-100% RE for remaining 95 (98) small islands	None.	60 islands fully transformed by 12 MW PV plus battery. 1 island for WTE for grid 45 islands in package with 12.1 MW distributed among 121 islands.

[24] The 107 islands were distributed in the table according to the "SREP underlying data" despite, that there for some islands were found great discrepancies in the electricity generation data presented by the two sources of data. For several islands the Outlook 2013 data suggest moving some islands from small to medium size classification and also a few islands should move to a class with lower peak demand. It is also worth noting that for some islands data on fuel demand or electricity generation is obviously incorrect. In some cases efficiencies well above 40% were found and in some cases very low efficiencies were found suggesting that numbers are incorrect or that losses are even higher than the worst-case scenario envisaged by the MEA or that the figures reported does not take into account unmetered/un-billed electricity consumptions and that these are very high.

Very small Up to 0.250 GWh/year	41	Additional ADB funding for 30-100% RE for 34 small islands.	7	41 islands in package with 12.1 MW distributed among 121 islands
Total	184		12	184

Thus, funds allocated for SREP Investment Plan were expected to be able to reach nearly all outer islands and only five medium size islands and seven very small islands appeared to potentially remain uncovered. Due to lack of quality data covering all islands, estimating the GHG-abatement impact of the interventions is highly uncertain and so is estimation of remaining GHG-emissions that would need to be offset if carbon neutrality is to be obtained.

Still, from island data available (Ministry of Environment and Energy 2013b) solar PV integration at 30% was estimated to generate electricity corresponding to say in the order of maximum 13% of the annual electricity generation reported. Assuming that this would not lead to deviation in thermal efficiencies of diesel generators from present values, fuel consumption and hence GHG-emissions would not go below 87%. For comparison, the Gulhi island modelling study arrived at 19% fuel savings achievable by 2022 where 34% of peak load was covered by PV. The Thinadhoo modelling study arrived at 22-36% fuel savings with 50% peak load on average for the 10 year period studied (AF-Merchados EMI 2013b).

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For the abatement costs analysis following options were assessed (as can be found in the 5th column in the table above):

- 12.1 MW PV distributed among three large islands, 32 medium islands, 45 small and 41 very small islands (totally 121 islands and 0.1 MW PV per island on average). This is an extention of the ASPIRE heading for 3 MW PV at 30 islands by means of FIT-regime and various guarantee products etc. provided with funds commited under SREP. The additional ADB-funding targeted 30-100% PV deployment at 129 islands, was understood to potentially provide additional 9.1 MW solar PV capacity, hence a total of 12.1 MW. This total was estimated to generate 17.7 GWh electricity annually. This converts into primary energy demand of 55 GWh diesel given thermal efficiencies of diesel generators was set to be 32%.

- Totally 2 MW electricty generation capacity from three regional WTE-plants jointly generating 11.6 GWh electricity annually and hence substituting 36.3 GWh diesel fuel given thermal efficiencies of diesel generators at 32% for the reference scenario.

- Fully transformation of 60 small islands by installation of 29 MW solar PV and battery as storage. This is an extention of the POISED targeted fully transformation at 10 small islands through solar PV with batteries for storage. Annual electricity demand varies a lot among small islands. For the abatement costs analysis, the annual electricity demand in end-use by 2020 of 60 islands was assumed to be 34 GWh increasing from estimated 22 GWh in 2012[25]. With 20% losses in distribution,

[25] Estimated from ”SREP underlying data” and Energy Outlook 2013 (Ministry of Environment and Energy 2013b) for the 60 islands with the lowest annual demand of the islands in the small island group.

this end-use demand requires electricity from PV (and battery) of 43 GWh. If instead served only by diesel generators such end-use demand would require 134 GWh diesel in the BAU-scenario where overall system efficiencies were assumed to be 26% on average.

- The Net Metering Scheme will potentially also provide for dissemination of residential PV applications in outer islands. It was envisaged to lead to 8.58 MW installed capacity, electricity generation of 12.5 GWh annually and avoided diesel demand 39 GWh assuming thermal efficiencies of 32%.

With the above, 121 outer islands would reach RE deployment for at least 30% of the present peak load demand plus additional contribution from net metering. The remaing 60 islands[26] will reach 100% independency on diesel fuel for grid electricity by 2020. With this, annual electricity generation of totally 85 GWh by diesel generators is avoided by 2020 which would require 265 GWh diesel fuel in the BAU scenario.

Unlike Greater Malé Region, inter-islands connection in general is assumable not an economically attractive route to go – though it can not be ruled out in some exceptional cases. In order to further pursue low carbon development and carbon neutrality, options adding to the already planned interventions should therefore be further explored. This may be such as extended RE, storage technologies and fuel switching of diesel generators from fossil diesel to (blends of) biodiesel. Storage technologies also offers the possibility of extended integration of renewable energy. Bringing the outer islands power systems further towards low carbon development may not provide for net benefits for the Maldivian economy compared with the BAU path, but net costs can be reduced if the opportunities for optimizing supply and demand side management are utilized.

3.3.2 Supply side management in outer islands

Considerable diesel fuel savings can likely be achieved by improved supply side management in outer islands. Since they appear to be very attractive economically, these fuel costs savings should be pursued in any case also for islands grids not subjected on the short term for investments in renewable energy. Improved supply side management was also adressed by the National Energy Policy and Strategy (2010) in its call for “introduction of energy management plans and audit programme in electricity generation sector”.

(AF-Merchados EMI 2013b) found sub-optimal dispatch regimes to likely be prevalent in outer islands since load sharing between diesel gen sets are manually operated/syncronized. Considerable diesel fuel savings were therefore found to be obtainable if system operators introduce modern controllers for load sharing. With reference to the case of the Thinadoo island power system, diesel savings at 15% were assumed to be at hand and avoided diesel fuel costs were found to pay-back investments in automatic controllers in less than 6 months.

Besides optimizing dispatch regimes of existing diesel gen set stocks, the practice of investing in oversized diesel capacities should be avoided to the largest extent possible. The Thinadoo case modelling study suggested that the optimized diesel scenario allowing for

[26] The three islands targeted for WTE solutions under the SREP Investment Plan are additional to the mitigation options investigated for outer islands.

new efficient diesel genset better sized to meet demand, saves system costs of some 12% (operating expenditures (OPEX) and annualized capital expenditurs (CAPEX)) compared with baseline, where existing gen sets are used as much as possible.

Furthermore, load management (shifting loads e.g. from peak to off-peak periods or shifting night time loads to day time) may also help to allow for running diesel gensets at higher capacity factors and hence save diesel fuel. The Thinadoo scenario study incorporated shifting 10% of peak load to off-peak. However, the techno-economic opportunities depends stongly on the specifics of the individual power system, the composition of loads and development trends in peaks and off-peaks.

Reduction of techncial losses in distribution networks was apparently not considered in any of the above referenced studies and diesel and costs savings due to optimized supply demand management may therefore prove to be underestimated. Distibution losses are to be valued as generation costs (the value of one unit electricity lost in distribution equals the costs of generating one unit net electricity).

Fuel savings attached with upgrading grids combined with improving dispatch regimes in outer islands were estimated for the present report based on early experience gained from the 560 kW grid at Gan island (in Laamu Atoll). Folllowing the upgrade, overall system efficiency (i.e. fuel input divided over electricity delivered to end-user after losses in distribution) were understood to have reached 35%.

For the abatement costs analysis, the experience in reaching 35% system efficiencies obtained from L.Gan was extended to apply to all outer islands. The option was assessed to lead to annual diesel fuel savings of 16 million litres by 2020 provided end-use demands as projected for the BAU and entirely covered by diesel generators[27]. Hence, the 60 islands targeted full transformation to PV-battery system were not covered by this option.

3.4 Demand for grid electricity

Promotion of energy conservation and energy efficiency was one of the key-policies highlighted in the Strategic Action Plan (2008) and a target for 7.5% reduction in final energy demand by 2020 was set out in the National Strategy on Sustainable Development (NSDD 2009). Further to this, Maldives National Energy Policy and Strategy (2010) targeted energy conservation and energy efficiency improvements via a range of measures[28]. Existing policies already attempt to address many of the constraints the country faces in

[27] Considerable discrepencies were found between the "SREP underlying data"and the Energy Outlook 2013 with regard to data for determination of grid efficiencies. The calculations made for the abtaement costs curve took a top down approach as it relied on the energy balance data on fuel demand in outer islands, instead of the data reported island by island in the Energy Outlook 2013 and the "SREP underlying data". The calculation assumed average grid efficiencies of 26% (derived from thermal efficiencies of 32% as was used for the energy balance 2009 and from 20% grid losses) will increase to 35% in 2020 equivalent to the efficiency found in L.Gan after upgrade of grids and optimization of dispatch regimes.

[28] Measures included: development of an energy code to be incorporated in the building code applicable to all type of buildings; setting energy efficiency standards for governmental procurement and energy audits for all public buildings; targeting energy efficiency improvements in commercial sectors by awareness raising and "regulatory framework to drive improvements in the energy efficiency of commercial buildings and products" and use of fiscal instruments like tax and duty exemptions to support energy efficient equipment and appliances.

improving energy efficiency, but progress in some key areas is little. Electricity savings are not nearly fully utilized despite of their attractiveness financially as well as economically.

While the policy target is to reduce final energy demand by 7.5% in 2020, electricity demand in Maldives is expected to grow with more than 10% per annum unless the current development is changed. Not only will electricity requirements increase. Load curves will also become peakier in particular for island grids where connected cooling loads from air conditioners are likely to increase. For some islands, peak loads may grow by an even higher rate than the electricity requirement growth rate.

3.4.1 Demand side management

The National Energy Policy and Strategy (2010) called for "introduction of energy management plans and audit programme in electricity generation sector", but demand side management (DSM) is not mandatory for the power utilities and largely not exercised neither in Greater Malé region nor in outer islands.

DSM is both about flattering load curves and lowering electricity requirements. Loads can be reduced e.g. by switching to appliances with lower load demand or by eliminating non-essential energy services. This will also reduce electricity requirements. Merely shifting loads e.g. from peak to off-peak periods does not on its own decrease electricity requirements, but serves the purpose of saving overall systems costs i.e. operational costs and capital costs. Load shifting therefore also holds the ability of reducing GHG-emissions.

Load curves for inhabited islands have the highest peak from the morning to afternoon and a lower peak in the evening. For larger islands with urban centres, the peaks are typically steeper than for smaller islands. In hybrid solar-diesel systems without battery storage, PVs will cover day time base load operation assisted by diesel gen sets if needed, while night time operation will be by diesel gen sets. Shifting loads to day time, where they can be covered by PVs will therefore - other things being equal – reduce GHG-emissions attached with serving the load.

In systems fully transformed to PV with battery storage – as envisaged by the SREP Investment Plan for 10 small islands - storage capacity can be reduced if evening/night loads are switched to day time. Load shaving reducing the need for spinning reserve will help avoid GHG-emissions.

3.4.2 Load Management

Load management measures available for power utilities include advanced measures such as smart meters, but it may also include measures more easily available such as ripple controls and direct load controls, which, however, are likely only economically feasible for large loads such as sewage pumps, desalination plants, central air conditioning systems and ice making plants.

However, it was understood that the scale of savings in outer islands is limited because of relatively few such larger loads. Also in Greater Malé region only a few such large loads are connected to the island grids, namely primarily booster pumps for water distribution. Larger loads in Thilafushi are currently captive systems and may in future be connected to the grid. Decentralized air conditioning is the predominate technology used even for large cooling loads (80-100 TR) but if some of these -- for instance at hotels or large office buildings loads- were replaced with energy efficient central systems such loads could not

only be reduced, but also controlled with advanced load management measures. Energy audits in two hotels suggested air conditioning to be an interesting area to target for shaving night and morning peaks. The study (PricewaterhouseCoopers 2011b) found that that from 12% to 33% of load demand for air conditioning was avoidable by replacing conventional decentralized air conditioning systems with more efficient systems.

In Greater Malé region, electricity requirements in the evening and night hours stems from street/outdoor lighting, air conditioning, lighting and refrigeration in buildings accommodating commercial sector activities (shops, restaurants, hotels) and in residential buildings. Surveys on how load is distributed on energy services or sectors were not available, but office buildings appear to also contribute to the evening and night load demand in Malé. For example, an energy audit in a government office building complex in Malé found load in off office hours to be at least 1.5 times higher than required for the service necessary in night hours and in some hours up to 3 times higher. The non-essential loads were found to be controllable (eliminated) by switching-off the main feeder. This example suggests office buildings in Malé to be an interesting segment to target for load elimination.

3.4.3 Building Envelopes

Population density in the capital island Malé is very high and space constraints have resulted in construction of multi-storey residential, commercial and office buildings. Migration patterns from small islands will likely shift in the future to target other islands than Malé Greater Region as islands are developed with adequate social services etc. in accordance with policies on creating regional hubs for social services in the outer islands.

While there are indeed many ongoing, high rise building constructions in Malé, numerous upcoming land reclamations projects and harbour construction projects as well as ongoing development projects at land reclaimed in recent years, no prognosis on expected major developments in built up areas or floor areas were available for the analysis. Still, major development plans of residential and industrial complexes were believed to be an area of great importance to the low carbon development agenda and its stakeholders can potentially play a major role in the transformation of Maldives to a low carbon development economy.

Building developers were understood to have little incentives to secure energy efficient and low carbon building design since building envelopes are not required to meet a certain energy standard. Higher capital costs for energy efficient building envelopes may not be adequately reflected in the real estate market prices and developers receive no premium for buildings allowing for low energy operational costs during the lifespan of the buildings. Operational costs of energy services (cooling/air conditioning, lighting, pumps etc.) are thus passed on to the building occupants. Building occupants, such as tenants, on the other hand have little options to spur building owners/operators to improve energy efficiency e.g. by equipping new buildings with centralized cooling or hot tap water systems or by energy retrofitting existing buildings with adequate measures such as insulation, double glazing, tightening etc.

Though awareness has been increasing over the past few years, buildings occupants do not fully tap in on energy costs savings from replacement of inefficient equipment and from behavioural changes. This despite of energy efficiency improvements and energy savings representing attractive business cases, also for many options relevant for residential households and even with the current tariffs, which are heavily subsidised. Government

subsidies constitute some 60% of tariffs and the tariff methodology is currently being reviewed by MEA to determine tariffs that reflect better the actual costs of production. Introduction of more cost true electricity prices may increase incentives for some end-user groups to save electricity.

It was a stated goal in the National Energy Policy and Strategy (2010) to develop standards and regulations for buildings on energy and to incorporate an energy code in the national building code by means of compliance documents targeted energy efficiency issues, but this has yet to occur. Since 2008 a draft building code exists, but it can only be enforced once the building Act is passed in the parliament. Hence, there are currently no energy requirements to building envelopes. There is therefore a risk of continuing tying up the building stock to an unsustainable level for the lifespan of the buildings which could be 30 years at the minimum. The National Energy Policy and Strategy (2010) called for setting energy efficiency standard for government procurement. This may also be relevant for government procurement of buildings such as housing programmes.

Energy efficient building construction is generally known to be more cost efficient than improving energy efficiency through buildings retrofits. Still, economically feasible options for buildings retrofits likely exists but presently major building retrofits are neither subject to any energy code.

Due to lacking reliable data, it is difficult to even establish the baseline for energy demands derived from existing building construction practices in Maldives. Estimations on energy savings and GHG-emissions abatements from energy efficient design of new buildings and from energy efficient retrofitting of existing buildings would therefore also be highly uncertain. Cooling of buildings by air conditioning consumes a considerable amount of electricity and is, however, one example on end-uses which can be significantly reduced by integration of energy efficient design of the building envelope.

The up-coming Low Carbon Development Project implemented by the MEE and UNEP addresses some of these challenges. The project is targeted energy efficiency in the building sector by means of “an assessment and monitoring system for Energy Efficiency Roadmaps” and “new design parameters for Energy Efficiency and Low Carbon Energy Buildings”. Commercial-scale demonstration of technologies as well as formulation of policies for transformation of markets for energy efficiency and Low Carbon Energy technologies, are also supposed being covered by the project.

3.4.4 Lighting and electrical appliances

The National Energy Policy and Strategy (2010) called for a “*regulatory framework that will drive improvements in the energy efficiency of commercial buildings and products”* as well as for introduction of “*fiscal instruments like tax and duty exemptions to support energy efficient equipment and appliances”*.

Electrical appliances imported to Maldives carry the product information and energy labels applicable in their respective domestic markets and there is no minimum performance standard or energy labelling program required in order for commodities to access the Maldivian market. Accordingly, the retail sector and its customers are not presented with a uniform energy label but with various energy labels, if any such at all, and perhaps even with energy information only in Chinese. Absence energy labelling programmes it is difficult to spur a demand for energy efficient appliances even in government procurement such as envisaged in the National Energy Policy and Strategy.

Energy efficiency standards and labelling program for refrigerating equipment (chillers, lighting, air conditioners and refrigerators) was proposed in Maldives HCFC-phase out plan for 2020. Moreover, regulations are planned to be implemented in the next two years on energy performance labelling. This could eventually lead to the adoption of Minimum Energy Performance standards for these appliances and extended to other common household appliances.

Exemptions from import duties on certain renewable energy technologies have already been introduced from 2013. Duty exemptions are envisaged to become eligible for energy efficient equipment too, once energy efficiency labelling scheme will be implemented, expectedly by 2015-2016.

Lighting

Economically attractive options in shifting to energy efficient lighting do not only offer electricity savings but also options for load shaving. Three options were identified as least cost options to the Maldivian economy:

Compact Fluorescent Lamps (CFLs) were assumed to be widespread in Maldives including for residential use. Light-emitting diodes (LED) require less electricity than CFLs (around 40%). Import data suggested the stock of electrical bulbs to presently be renewed with nearly 573,000 CFLs annually, which was assumed to grow with 5.75% per year accordant with the growth expectations for electricity demand. If these were replaced with LED, annual savings in 2020 would amount 9.2 GWh electricity.

In street lighting there are untapped electricity savings and load shaving possibilities by replacing Sodium Vapour Lamps with LED tubes. A 100W LED tube saves approximately 60% of the electricity demand of a 250W Sodium Vapour Lamp. The 2200 lamps installed presently were assumed to increase according with the annual growth rate in electricity and in 2020 annual electricity savings by replacing Sodium Vapour Lamps with LED tubes were found to be 2.1 GWh.

Replacing conventional tubes for instance in public service buildings with LED tubes offers electricity savings and load shaving of estimated 44%. These savings will be tapped through the implementation of the Fahiali programme by which 70,000 tubes were granted by the Chinese government. Electricity savings would be some 1.3 GWh annually.

Air Conditioners

Unitary (decentralized) air conditioners – which are well suited for spot cooling such as wall mounted split types - are widespread. Energy audits suggested these conventional air conditioners to be common in public and commercial buildings in Maldives also in smaller islands. When it comes to residential housing, air conditioners in outer islands has not yet reached the same level of dissemination as in the Greater Malé region. For the Malhoos island a penetration rate of 10% only was found in 2010. Instead electrical fans were found to be common among households in Malhoos island (Kesterton 2010).

A recent study (PricewaterhouseCoopers 2011b) explored electricity savings in efficient air conditioning for a selection of public and commercial sector buildings. For large cooling loads the highest electricity savings were found in introducing centralized systems to replace decentralized systems.

Results from energy audits undertaken during the study in two hotels in Malé determined air conditioning to constitute 58% and 29% of the entire load of electrical appliances and lighting equipment installed in the two hotel buildings[29]. From data reported, annual electricity savings attached with centralized systems appeared to be between 24% and 33% respectively against 13% and 23% if replacing the current stock of conventional air conditioners with energy efficient decentralized units. Replacing conventional decentralized systems with more energy efficient systems (decentralized or centralized) also help shave peak loads as summarized in the table below.

Table 8 Annual savings by replacement of conventional air conditioners in hotels

	Hotel Mookai		Hotel Nalahiya	
	Load	Electricity	Load	Electricity
Conventional decentralized systems	94 kW equal to 58% of overall load of hotel		64 kW equal to 29% of overall load of hotel	
Savings by energy efficient decentralized systems	21 kW ~ 23% of BAU	89 MWh ~23% of BAU	8 kW ~ 13% of BAU	35 MWh ~ 13% of BAU
Savings by centralized system	33 kW ~ 33% of BAU (100kW)*	139 MWh ~33% of BAU	16 kW ~ 24% of BAU	65 MWh ~ 24% of BAU

*) Two units were not analyzed for the EE-decentralized system scenario but only for the central system scenario which explains the two different BAU values.
The table presents own calculations sourced by selected values presented in the report30.

An energy audit of the former Ministry of Housing and Energy (MHE) office building complex suggested annual electricity savings corresponding to 29% if the current stock of conventional air conditioners was replaced with decentralized energy efficient air conditioners, whereas 38% can be saved by introducing a centralized system. Air conditioning constitutes 44% of the entire load of the building. If a central system was introduced nearly 17% of the overall load of the building could be avoided and 12% could be avoided by replacing the conventional units with energy efficient decentralized units.

Table 9 Annual savings by replacement of unitary air conditioners in office building

	Load	Electricity
Conventional decentralized systems	44% of overall building load	
Savings by energy efficient decentralized systems	35 kW ~28% of BAU (124 kW)*	85 MWh ~29% of BAU (298 MWh)*
Savings by centralized system	47 kW ~38% of BAU (126 kW)*	114 MWh ~ 38% of BAU (302 MWh)*

*) One unit was not analyzed for the EE-decentralized system scenario but only for the central system scenario which explains the two different BAU values.
The table presents own calculations sourced by selected values presented in the report.

[29] The lower value of 29% may owe to the hotels wide use of inverter types air conditioners which is more energy efficient than conventional types.

[30] Values of cooling capacity in kW, CoP and energy input presented in the report were understood obtained during the audit from technical specifications appearing from installed systems. The values in the table were sourced from these readings and from the CoP values for efficient systems proposed in the report (PricewaterhouseCoopers 2011).

The entire stock of unitary air conditioners in Maldives was estimated to comprise some 76,000 units of which 66% was assumed being conventional types with low energy efficiency. If the entire stock were replaced with energy efficient units[31] estimated 97 GWh electricity could be saved annually by 2020. Assuming the extra costs of energy efficient ACs to be around 2000 MVR and tariffs for domestic users at 3 MVR/kWh , the pay-back period for an efficient unit is less than one year even for annual operational hours at 2100.

For the abatement costs analysis, the option of installing centralized air conditioning systems in new service buildings instead of energy efficient unitary types was analysed. Electricity saving and load shaving of 38% were found. Tapping this potential efficiency improvement for the 270,000 new floor square meters being approved in 2012 for construction would amount to electricity savings of 15.8 GWh annually.

For some cooling loads, the alternative solution to decentralized systems may be to introduce Vapour Absorption technologies sourced by waste heat from operation of diesel generators. Diesel generators exhaust gases at temperature of more than 400 degrees Celsius. Today, both STELCO and Malé Water and Sewage Company utilizes waste heat from the diesel generators to source their desalination plants. However, waste heat in flue gases could be further utilized for VAM (Vapour Absorption Machine) based centralized air conditioning provided that sufficient cooling demand is available in adjacent buildings (PricewaterhouseCoopers, 2011b). Dependent on availability of waste heat from power houses and desalination plants – considering future plans if any on RE uptake to generate electricity - VAM may prove to be at least as economically attractive for cooling loads in adjacent buildings as supplying air conditioning systems from the island power grid.

Refrigerators

Surveys suggested the vast majority if not all households to accommodate refrigerators (KEMA 2011a; Kesterton 2010)[32] and a study estimated the stock to count nearly 80,000 units in 2010 of which 70% was assumed being conventional refrigerators (PricewaterhouseCoopers, 2011b). For the abatement costs analysis the impact of switching to energy efficient types was investigated. If all new acquisitions – including for replacement of the present stock of refrigerators - over the coming years till 2020 were units consuming 65% of electricity demand by conventional refrigerators, annual savings would be 46 GWh at country level by 2020 provided that number of units increases with the growth rate expected for electricity generation. Assuming extra costs of an efficient refrigerator to be around 7700 MVR, the pay-back period would be below 3 years with domestic tariffs.

Electrical water heating

As with air conditioning residential buildings are usually not equipped with centralized systems for hot tap water heating. It was understood that hot tap water is not prevailing in residential sector, but the demand is likely to increase in particular in urban centres. Typically, individual systems like solar water heater or electrical heaters are used, but there was no estimation available on the rate of dissemination of electrical water heaters in households.

[31] This assumed the CoP of conventional types at 2.67 versus CoP at 4 for energy efficient types.

[32] (KEMA, 2011a) found every household in Thinadhoo to have a refrigerator whereas a field visit in Malhoos island in 2010 suggested 80% of households to have refrigerators. Malhoos island accommodates 600 inhabitants and is a small island power system (130 kW).(Kesterton 2010)

Energy audits in two hotels, suggested electrical water heating to constitute 33% and 58% respectively of the overall load of the entire electricity demand for lighting, pumps, air conditioning and water heating (PricewaterhouseCoopers, 2011b). No further data on water heating in hotels were available for the present analysis. There are presently some 20 hotels registered in Maldives.

The mitigation option of solar water heating as replacement for electrical water heating in hotels and at resorts was investigated for the abatement cost curve as presented in section 4.2 of this report.

Water Pumps

In outer islands, households are supplied with ground water from individual wells and also in Greater Malé Region households are supplied from wells with groundwater for toilet flushing. Some 49,000 households have their own water pump used for ground water pumping from wells. Assuming efficiency gains of energy efficient pumps to be some 60% over conventional pumps, the technical saving potential translates into about 7.3 GWh savings annually at country level.

In Malé in particular, there may also be untapped electricity savings in energy efficient pump types for booster pumps used by MWSC for supplying high rise buildings, but there was no data available suggesting the significance of such mitigation opportunity.

3.4.5 Behavioural changes

Studies[33] have confirmed that non-essential usages of electricity prevail in all sectors. Non-essential usages can often be eliminated by behavioural changes not requiring any costs besides costs of measures to make end-users change behaviour, like awareness campaigns, energy audits etc. Removal of subsidies available to residential users may help increasing the effect of awareness campaigns targeted elimination of non-essential usages in households. Examples on non-essential usages observed in various studies includes such as:

- Keeping (energy saving) lamps switched-on in day-light hours
- Running air conditioners for spot cooling of rooms and at the same time leaving doors open
- Temperature of air conditioners are set uneccesarily low (below 20 degrees) and not switched off eg. outside office hours or when rooms are not occupied.

For example an energy audit of the MHE building complex found that a substantial amount of energy is wasted due to standby losses as well as due to the running of non-essential appliances/ equipment in office off-/night-hours (PricewaterhouseCoopers 2011b). The load profile for the period from 7 PM to 8 AM (after office hours) revealed a variation from 12 kW to 27.5 kW against an estimated requirement for essential loads at 8 kW (for server, air conditioning of server, PABX and panel rooms). If this is representative for all office buildings at least 33% and perhaps considerable more (in this case up to 71%) of night time peak load in office buildings could be cut off in the Greater Malé region.

The previous mentioned energy audits in two hotels in Malé also revealed electricity saving opportunities by using electrical fans together with ACs in guest rooms and raising comfort temperature to say 20 degrees Celsius instead of 16. By this electricity savings equalling

[33] E.g. the Thinadhoo study (KEMA 2011a)

13% of the demand of conventional ACs and 17% of energy efficient ACs are achievable[34]. For rooms cooled with ACs but not already equipped with electrical fans, the payback period is less than two months according to the study.

3.4.6 Industrial loads

Presently, industrial loads connected to the grid are limited in Malé to smaller activities such as carpentries, metal works, cold storages, Maldives Port Ltd., pumps for sewage systems and booster pumps for water supply. Also in other islands of Greater Malé Region the industrial loads and hence ability for load management is limited. In Thilafushi it may change if industries in future will be connected to the grid rather than being served by stand-alone gen sets.

There are outer islands with particular dedicated industries such as fish processing, canning, bottling of water, ice making, etc. which have a significant power demand. However, in general all such installations uses power generated from their own genets installed at site.

3.4.7 Summary on grid electricity demand

Numerous studies have found saving opportunities in various segments of end-use including no-regret options and options showing very attractive business cases also for households. It is however highly uncertain to aggregate the potential savings - and their impact on the GHG-emission balance - at national or even island level. This is i.a. because some of the investigated saving opportunities are inter-changable.

One striking issue is, however, the significant saving potential related to cooling loads for buildings. With the current practice in building construction not paying due attention to reducing cooling demands, cooling will for many building functions continue to constitute the largest part of the overall electrical load demand of buildings. This is true in particular if the current practice of equipping buildings with decentralized systems continues to prevail. Energy audits of two multistorey, commercial buildings and one office building complex found connected cooling loads to be in the range from 29% to 58% of the entire electrical loads of the buildings. The audits also found that the electrical load for cooling at the minimum can be reduced to between 23% and 47% of the over all building load by replacing conventional air conditioners with energy efficient types. The electrical load for cooling could even be significantly further reduced with centralized air conditioner systems. While there is no solid survey for different types of residential buildings (multistorey, two-storey and semi-detached) reducing cooling demands and seeking energy efficient cooling technologies seems to be highly relevant for the low carbon development path not least for larger power systems serving urban centres.

Realizing these savings would not only make sense from point of view of consumers (with attractive payback periods of often less than one year) but also for power system operators as it helps save diesel costs and possibly helps avoid or postpone capacity additions. Tapping these potential savings to the largest extent possibly i.e. by introducing central systems whenever feasbile- may be of great importance for the GHG-emissions impact of power systems with extended integration of PV and where evening/night loads are to be covered by diesel generators, perhaps running on partial loads - or by storage technologies.

[34] Increasing temperature with 3.4 degree was assumed to reduce power load with 200 W/AC unit. Net savings (power demand of ceiling fans) are 140 W/unit.

Another interesting finding is the magnitude of non-essensial loads at night. Thus, it was found for an office building in Malé that load demand at night can be reduced with minimum 33% by switching off non-essential loads – notably merely by change in behaviour. There is no reason to believe that this is an exceptional case but the value of eliminating non-essiensial loads is poorly understood due to lack of data on the load composition at night in the Malé power system.

Large variations in peak power demand in small, outer islands were also noticed in some of the islands which often forces an additional genset to be installed and switched on during the peak hours and which usually runs underloaded, decreasing the fuel efficiency. This is observed for instance for peaks during Friday noon time, where most inhabitants do washing, ironing, use showers, etc. If instead such load were shifted to other times the load curve could be flattenend. Such load shifting could be a least cost measure as it helps avoiding unnecessary investements in additional capacity and improving fuel efficiency of the plant.

3.5 Summary on mitigation options

Costs savings attached with supply and demand side management of grid electricity are potentially significant. There exists many “no regret options” i.e. options that saves operational costs without requiring any capital expenditures and many options for which costs savings will pay back capital costs within a very short period of time. They do not only present much needed savings for the Maldivian economy, but also very attractive business cases including for households.

While current initiatives to provide framework conditions for RE-introduction in particular are important steps in transforming Maldives into a low carbon development economy much less reliant on energy imports than today, it is evident that carbon neutrality of grid electricity by 2020 would require significant offsetting to attain.

Table 10 Summary of mitigation options for grid electricity

	2020 - BAU	Mitigation options impact by 2020	2020 with mitigation
Annual grid electricity demand by end-user	Total 567 GWh from: • Greater Malé Region 369 GWh • Outer islands 197GWh	Savings of totally 179 GWh from: • Refrigerators (46 GWh) • Energy efficient unitary ACs (97 GWh) • Central AC in new buildings (15.8 GWh) • Solar water heating hotels (0.5 GWh) • Energy efficient water pumps (7.3 GWh) • LED for domestic lighting (9.2 GWh) • LED tubes for street lighting (2.1 GWh) • LED tubes for public services (1.3 GWh)	388 GWh
Annual primary energy demand by grid connected diesel generators	Total 1835 GWh from: • Greater Malé Region 1071 GWh • Outer islands 765 GWh	• Upgrades of outer islands grids to 35% overall system efficiency Diesel for 210 GWh electricity is replaced by new technologies from: • Greater Malé Region 104 GWh renewable incl. WTE • Greater Malé Region LNG plant 21 GWh • Outer Islands 85 GWh renewable incl. WTE	531 GWh
Annual GHG-emissions	489 $ktCO_2e$		152 $ktCO_2e$

Notes: Desalination was considered captive systems and hence not included in the above data for Greater Malé Region. Electricity for cold storage and canning were considered captive systems for outer islands and hence excluded from the above outer island data on grid electricity:

In summary, the demand side management mitigation options in end-use were estimated to potentially reduce end-use electricity demand to 418 GWh by 2020 equalling 70% of end-use in the BAU scenario with distribution losses of 8% in Greater Malé Region and 20% in outer islands. If outer island power systems were upgraded to reach efficiencies of 35%, this demand in end-use requires primary energy demand of 1108 GWh absence introduction of new generation technologies. Note that the mitigation option of power system upgrade refers to diesel only power systems by means of reducing grid losses and improving thermal efficiencies of diesel generators. The 60 small islands targeted full transformation to renewable were also supposed to comply with the target of 35% efficiencies after the transformation.

However, with mitigation options on the supply side by means of new electricity generation capacities (LNG and LCMR), this demand could decrease considerable. Accordingly, the combined impact of reducing end-use electricity demand, upgrading diesel only systems and introduce renewable energy and LNG could potentially reduce primary diesel fuel demand to 531 GWh by 2020 compared with 1835 GWh in the BAU-scenario. The LNG plant and the remaining diesel demand would lead to GHG-emissions of 152 $ktCO_2e$ of which the LNG plant counts for nearly 11 $ktCO_2e$. In the BAU-scenario GHG-emissions would be 489 $ktCO_2e$.

DSM and energy savings were thus found to potentially provide valuable contribution to decreasing dependency on diesel for electricity generation and should indeed be given high priority immediately. But even if opportunities are fully utilized for reducing electricity demands and for modifying load curves to better suit PV, some reliance on other sources of

energy will persists with the current projects envisaged. In Malé, there will remain to be loads in day time not coverable by PVs (given place constraints for large scale up take of PV) and also for most outer islands night time loads and readily available reserve capacity will still have to be served by diesel generators or other technologies.

The next steps down the route of low carbon development will clearly require increased system costs compared with withholding to fossil diesel fuel for peak operation and spinning reserve. Additional technological solutions to consider may include such as:

- Inter-connection of islands grids in the Greater Malé Region to utilize any space available for PV and to increase opportunities for modifying load curves of an extended power system.
- Extended integration of PV and wind as feasible. For grids where space constraints is an issue for large scale uptake it may be considered to integrate into future physical/urban planning and land reclamation projects, areas dedicated for such as utility scale PV installations or wind power
- Substituting fossil diesel with biodiesel. This may prove to be the least cost option for provision of spinning reserve
- Other renewable technologies for grid operation – such as biomass as well as renewable technologies suitable of shifting grid connected loads to off-grid loads such as deep sea cooling
- Storage technologies

The option of mitigation through introduction of 20% biodiesel blend was explored for the abatement costs analysis. If remaining primary energy demand of say 617 GWh was covered by 20% biodiesel blend instead of 100% fossil diesel, another 33 $ktCO_2e$ could be mitigated leaving some 142 $ktCO_2e$ for offsetting if carbon neutrality for grid electricity was to be attained.

4 Mitigation from electricity at resorts islands

4.1 Sector Brief

As per October 2012, 105 islands had been developed as resorts islands meaning that they are entirely dedicated for accommodation of tourist resorts. Additional 49 islands are leased for tourist resorts, but not yet developed (Ministry of Tourism, Arts and Culture 2012b). Resort islands are leased for periods of 25-35 years but leases can be extended to up to 50 years and even 99 years in certain circumstances. Planning, contracting, management and regulations of leases are the duties of the General Directorate of Tourism under the Ministry of Tourism, Arts and Culture. Resorts are required to have an environmental management system in place but monitoring of compliance with laws and regulations in fields of environmental protection is not enforced by the authorities, so resorts are essentially self-regulated. Electricity generation at resorts islands falls under the jurisdiction of the public services law so Maldives Energy Authority (MEA) seems to have unexplored options to promote low carbon development of resorts like portfolio regulation (target RE-uptake) and measures like energy audits and reporting.

Resorts are self-contained with regard to energy, transport, water, wastewater and waste management. The one-resort-one-islands concept which has governed the development of the resort segment of Maldives tourism sector implies that captive power systems prevail at the resorts islands.

Though a few resorts have pioneered with RE-technologies, electricity demands are largely met by diesel generators. Resorts accommodate approximately 105 MW installed capacity and peak demand is estimated to be 52 MW. Estimated thermal efficiency of diesel generators at resorts is 28% (Ministry of Transport, Housing and Environment 2010)[35]. Some resorts have combined heat and power units supplying heat for laundry service and likely also in some case hot tap water. Resort islands have their own desalination plants, which are also diesel fuelled probably connected to the grid of the resort and not as stand-alone systems. LPG is used for cooking and perhaps certain laundry services. Few resorts incinerate some of the waste fractions, however, without making use of the heat generated. Heating technologies used for hot tap water are the following: solar water heaters; waste heat from electricity generators and; electrical water heaters.

Diesel of 91 ktoe corresponding about one third of the gross diesel demand in Maldives was used for grid electricity generation and assumable desalination at resorts in 2009 leading to GHG-emissions of 283 $ktCO_2e$ which makes resort islands electricity generation the second largest single emitter after the transport sector. Note, that this does not include diesel demand for other activities of the tourism sector such as safari vessels, marinas (docks), hotels and quest houses[36]. Neither does it include consumption of other fossil fuels at resorts (LPG for cooking, kerosene, petrol for vessels, jet-skis etc.[37]).

[35] This was based on a survey conducted among 16 resorts.

[36] As of October 2012 MOTAC has registered 104 tourist resorts, 160 registered safari boats, 20 hotels and 26 guest houses (Ministry of Tourism, Arts and Culture2012b). Totally 26,800 beds were recorded.

[37] LPG and kerosene usages by resorts were considered ”stationary combustion” as per the IPCC guidelines for national inventories and were in this report dealt with in chapter 6. Use of fossil fuels

A tourism tax applies and since October 2011 also a Tourism Goods and Service Tax. It was raised to 8% as per January 2013. Fuels are not levied any taxes.

Resorts have so far been developed without any regulatory requirement to energy efficiency standards and integration of low carbon energy supply. The recent draft action plan attached to the draft 4th Tourism Master Plan for 2013-2017, called for a national low carbon programme for the tourism sector and targets for carbon neutrality by end of 2017 of at least 25% of the resorts (Ministry of Tourism, Arts and Culture 2012b). The plan also highlighted the need for an upgrade of sewage and wastewater disposal guidelines for resorts and new regulations to incorporate climate resilience and energy efficiency for all tourists establishments, and hence also for resort islands.

If say that electricity generation by resorts should met the same mid-term targets as set out for the energy sector in general, this would mean:

- By 2015, 50% of electricity generation should be based on renewable energy (NSSD and 3rd NEAP)
- By 2020 final energy consumption should be reduced by 7.5% (from 2010 level) by means of efficiency improvements (NSSD)

Given the projections for the tourism sector found in the draft 4th Tourism Master Plan (Ministry of Tourism, Art and Culture 2012a), the second bullet point is in particular a challenging task as targets here were set in absolute values. Thus, if the annual growth reaches nearly 11% as per the projections of the MOTAC, electricity demand in the BAU scenario would increase accordingly. Due to this, GHG emissions in the 2020 BAU scenario from fuel demands at resorts (excluding transport) would climb from projected 647 $ktCO_{2e}$ to 1071 $ktCO_2e$.

4.2 Reducing final electricity demand

In general, data on electricity generation and demand by resorts are scarce. A survey among 16 islands resorts suggested the following break-down of electricity demand (BeCitizen 2010):

Table 11 Electricity demand by services at resort islands

Type of service	Share %
Air conditioning	40
Refrigeration	10
Desalination	10
Lighting	10
Laundry	15
Water pumps	7
Electronics	3
Other	5

Note that desalination plants probably in most cases are supplied from the resort grid. Desalination plants were reported in the survey as being in operation 16-24 hours/day. Desalination by resorts was considered further in chapter 5 of this report.

by resorts for vessels, jet-skis etc. can be categorized as ”mobile combustion” as per the IPCC guidelines and were in this report dealt with in chapter 7.

A few resorts in the survey had solar collectors for heating. None had PVs for electricity generation. For some resorts electrical water heating is included in "Laundry". A few resorts had central systems for air conditioning and one resort had chiller air condition system from which the heat was used for generation of hot water. In general, air conditioners are set well above 20 degrees Celsius. One resort reported that waste cooking oil was used for biodiesel for off-road vehicles (for gardening), but electrical vehicles were understood to be widespread at resorts.

Proper demand side management of resorts likely offers no-regret options for energy savings and it was understood that energy costs in recent years have grown to constitute a fairly significant cost component which has helped spur the interests in diesel fuel savings. A recent audit in 3 resorts[38] revealed measures for electricity savings with payback period less than 5 years that would lead to savings in the range of 16%-37% of total electricity costs of the resorts.

For the abatement costs analysis, the option of replacing conventional air conditioners (unitary, decentralized ACs used in guest rooms) with energy efficient ACs was assessed. Assuming occupancy rate of 70% and daily usage of 14 hours, energy costs savings pays off the extra capital costs compared with conventional types within a few months. Potentially countrywide electricity savings were estimated to reach 40.6 GWh in end-use per year by 2020[39]. Another option identified for the abatement costs analysis was large solar water heaters. Assuming that 82 resorts (half of all resorts estimated to be active by 2020) installs solar collector with water tanks to cover part of the hot water demand instead of heating the water entirely with electrical boilers, annual electricity savings in end-use would be around 2 GWh by 2020. The extra costs for solar collector and water tank is paid back by diesel fuel savings within less than one year.

Accordingly, the two options were assessed to potentially cut 43 GWh of the estimated end-use electricity demand at resorts by 2020 at 516 GWh[40]. Assuming overall system efficiency of resort islands grids of 28% this would lead to savings in primary energy (diesel) at 165 GWh.

4.3 Large scale uptake of renewable energy

Least cost options for electricity (LCOE) generation vary greatly across resort islands. For new resorts coming along LCOE of hybrid solar-diesel or hybrid solar-LNG applications may very likely be a least cost option compared with diesel only systems in particular if buildings are designed in an energy efficient way reducing the need for energy storage and if proper control and load management are implemented.

Since resorts islands are isolated and resorts self-contained an integrated approach to energy, fresh water, wastewater and waste management may offer additional possibilities

[38] Cleaner Production Audit (CPA) by Allplan and Renewable Energy Maldives in 4 hotels and 3 resorts of Mookai Hotels.

[39] In 2012, number of beds at resorts was about 22880, which for the calculation was assumed to translate into one AC per bed. By 2020 number of ACs was assumed to have increased with 6% per annum as per the economic growth rate assumed for resort islands in the BAU 2020 projection of energy demand and GHG-emissions.

[40] This was derived from the 2009 energy balance assuming thermal efficiency of diesel generators of 28%, distribution losses of 9% and annual growth rate of 6%.

for not only low carbon development but also protection of scarce water resources and sustainable management of waste and waste water. For instance recycling grey water as well as increasing rainwater harvesting can minimize the need for water desalination and waste heat may be utilized for heating. Deep sea cooling may also prove to be attractive. For some resorts, cooling loads could perhaps be switched to off-grid loads by deep sea cooling.

For the abatement costs analysis, solar PV integration at resort islands was explored. LCOE by PV was found assessed to be US$0.25/kWh versus estimated diesel fuel costs by resorts islands of US$0.34/kWh electricity. According to the 2020 BAU projection, electricity demand in end-use at resorts were expected to grow with 6% per annum and total end-use electricity demand of resort islands was thus assumed to increase from nearly 272 GWh in 2009 to about 516 GWh by 2020. This translates into primary energy demand from diesel fuel of 2014 GWh assuming overall system efficiency of 26%. Some of this could be replaced with PV. Electricity generation of 73 GWh could be expected from 50 MW PV. The 50 MW estimated for 2020 equals 30% installed capacity in 2012 (33 MW) plus another 17 MW to keep up with expected growth until 2020[41]. This would cut 260 GWh of the diesel fuel demand (primary) assuming thermal efficiency of diesel generators at 28%.

The Embudu Village Resort Case

A recent case-study on the Embudu Village resort (AF-Merchados EMI 2013b) suggested the business case of large scale introduction of PV to be very attractive even for systems having substantial capacity surplus. Fuel efficiency of existing generators serving the resort is 0.28-0.31 l/kWh. Installed capacity is 1.8 MW and day time peak load at 450 kW under bed occupation rate of 80%. Evening peak load is 400 kW. Two scenarios were studied for the period 2013-2022. In the first scenario 500 kW solar is introduced assuming business-as-usual with regard to management of flexible loads. Already in 2014, 300 kW PV comes along as the least cost option and in 2019 the full capacity of 500 kW PV is reached. Diesel costs savings are 25%. Net savings in total systems costs are some USD 444,000 equivalent to 5.7% compared with the No-solar reference scenario. Assuming high solar CAPEX (space limitations may require installation of some of the PV panels in the lagoon) the uptake of solar is slower and the full 500 kW solar capacity is instead reached in 2021. Net savings are reduced to USD 86,000. In both cases, the GHG mitigation potential is estimated to be some 800 tCO_2/year once the full PV capacity is reached, but emissions reductions accumulated over the period is lower in the high solar costs scenario.

In the second scenario the 500 kW solar uptake from above (average solar CAPEX) is modelled assuming flexible load management, but without investments in new diesel gen sets better suited for the modified load. Here, diesel costs savings corresponds to 28% and net savings of total system costs to nearly US$ 657 thousand.

To help fully utilizing the opportunities of developing new resorts with due attention to energy and low carbon options, the MOTAC could incorporate low carbon energy options into the bidding documents and allocate marks for the same for awarding contracts for the development of resorts.

[41] Demand side management for instance switching to energy efficient ACs or large solar water heating described in the previous would help reducing peak loads and hence the need for installed capacity by 2020 may be over-estimated.

Large scale uptake of renewable energy among existing resorts may go via some of the same routes though it cannot take advantage of energy efficient building designs. Transforming existing resorts into carbon neutral or low carbon resorts may therefore imply higher relative costs compared with resorts additions. However, since the far greatest share of GHG-emissions from resort islands in 2020 will be due to already developed resorts, they too have to pursue the low carbon development route.

4.4 Summary on mitigation options

Since resort islands consumes a rather significant part of the country's demand for fossil fuels, resorts islands must indeed to a much larger extent than today become engaged in the low carbon development agenda. Several case studies and audits suggest that attractive options exist for reducing the demands of fossil fuels by resorts on the supply as well as the demand side. Still, for the purpose of informing a national low carbon development strategy it is uncertain what fuel demand savings to be expected at the aggregate level. For one reason because resort energy data found in the public domain is very few, but also because the economics in say for instance combined supply and demand side measures would be highly specific for a specific island resort case.

Nevertheless, transforming existing diesel only systems to hybrid PV-diesel systems is highly attractive for PV applications serving a certain level of day time loads. For the abatement costs analysis a level of PV integration around 30% of installed capacity was assumed to not requiring storage of electricity (e.g. batteries). Though considerable uncertainty is attached, the estimate is that not more than 13% of the annual diesel demand can be avoided by this level of PV integration. If say that resorts can also reduce electricity demands for cooling of guests rooms and demands of electrical water heating – as included in the abatement costs curve – electricity demand could be cut with 9% by 2020.

In combination these options will roughly reduce the diesel fuel demand with 21%, hence leaving the Maldives with a considerable amount of GHG-emissions to offset in order to reach the carbon neutrality pledge for 2020, unless further steps are taken by the resorts.

Table 12 Impact of abatement options for grid electricity at resort islands

	2020-BAU	Impact by options	2020-with mitigation
Annual electricity demand end-use (GWh)	516	- 43	473
Annual electricity generation by PV (GWh)	0	+73	73
Annual primary diesel demand (GWh)	2014		1693
Annual GHG-emissions ($ktCO_2e$)	537		451

Additional and economically attractive options on the demand side were believed to exist for instance in better management of cooling demands, which constitutes a major part of the electricity demands at resorts. Note that the diesel demand includes also demands for desalination and that some studies suggested attractive options for water savings as discussed in the next chapter. It may also for some resorts – for instance through further optimization of demand and supply management – be feasible to increase the share of PV beyond what is assumed for the abatement costs analysis, without adding storage capacity.

But as with outer islands it will at some point require storage technologies for resorts islands to move further down the low carbon development route or require switching from fossil diesel to biodiesel blends for the remaining loads. For some resorts, cooling loads

could perhaps be switched to off-grid loads by deep sea cooling. In any case, these options will increase the costs and may not provide for net savings.

The option of mitigation through introduction of 20% biodiesel blend was explored for the abatement costs analysis. If remaining primary energy demand were covered by 20% biodiesel blend instead of 100% fossil diesel, another 90 $ktCO_2e$ could be mitigated leaving some 361 $ktCO_2e$ for offsetting from resort power systems if carbon neutrality for resorts was to be attained.

In order to tap the mitigation potential a variety of measures seems to be needed and not least should data collection be improved and mitigation options better understood by both private sector and relevant regulatory institutions for the purpose of establishing baselines for GHG-emissions trends and prescribe targets relevant to mitigation. This could be targets for dissemination of renewable energy, for capping fossil fuel usage and/or for capping GHG-emissions. Awareness raising and enhancement of the capacity of the sector would be needed on e.g. economic analysis of low carbon projects, new technologies and techniques available and their implementation and on MRV techniques associated with low carbon emissions projects. Supportive and regulatory measures for consideration may furthermore include but not be limited to such as:

- Development and implementation of a mechanism for monitoring, reporting and verification of compliance with targets
- Establishment of a fund to facilitate enabling activities for such mechanism
- Possibly establishment of a fund/project development facility to facilitate investments in mitigation projects in the sector
- Improve the Maldives tourism sector branding as low emission to stimulate further growth of uptake of low emission technology by the market

5 Mitigation from desalination

5.1 Sector Brief

Fresh water is a scarce resource in Maldives. Ground water extracted from self-managed household wells is the traditional source of potable water. It was later supplemented by catchment and storing of rainwater as ground water resources were suffering from depletion due to over-abstraction and suffering from contamination. In late 1980's desalination of seawater for potable supplies was introduced in Malé and Kadholhudhoo and the Greater Malé region is today entirely dependent on desalination for all water supplies, except from toilet flushing, which is still supplied from wells.

In outer islands water extracted from wells is today suitable only for non-potable supplies due to levels of salinity and often contamination with sewage effluent. Potable supplies in outer islands are therefore largely reliant on rainwater harvesting and storing. As per 2011 about 90% of the outer islands were entirely dependent on rainwater harvesting for potable supplies (Ministry of Housing and Environment, 2011).

During dry seasons shortages in potable water supplies from rainwater storages occur in outer islands. Due to constraints in space available for extended water tanks more islands may in future turn to desalination. Presently, seven desalination plants for public water supplies are in operation in Maldives[42]. The water is piped for distribution among consumers connected to the system or at so-called water bays where water can be collected for free. For drinking supplies, bottled water is widespread in Greater Malé region whereas piped water is primarily used for washing, showers and cooking.

In addition to public water supplies, resorts and other commercial or industrial activities are engaged with desalination either for own use (e.g. fishery industry or power plants) or for bottling of water.

Data on presently installed desalination capacities and expected future growth were not available for this report.

5.2 Mitigation options

5.2.1 Demand side management

Saving opportunities for desalinated water likely exist in particular for public water supplies in the Greater Malé Region, in resort supplies and in some industries, but no studies provides for estimates on their significance.

Desalinated water for public water supplies in outer islands is apparently already used only for purposes requiring portable quality and not for purposes of washing, gardening, showering etc. Hence, there are hardly any available savings in desalinated water except from preventing leakages in piped systems. Greater Malé Region differs from this since public water supplies are used for all purposes by connected consumers except from toilet flushing and drinking.

[42] This does not account small desalination plants installed subsequent to the tsunami in 2004 to provide for security in water supplied for emergency situations and disasters. The small plants have a capacity of 10 cubic meter of water/day. They are apparently not being operated presently.

Major water loads for processing in industrial activities in Greater Malé Region and in outer islands are not connected to the public water supply network, but likely also offers opportunities for savings e.g. for usages of water for cleaning purposes.

Some resorts could likely save portable supplies including through prevention of leakages, if any in the water supply systems. There is however very little knowledge on the country wide potential on this. A recent audit at 3 resorts found water savings measures with payback periods of less than 5 years with costs savings corresponding to between 1% and 21% of the resorts total costs of water[43].

5.2.2 Supply side management

Desalination plants in operation in Maldives are mostly RO-based technologies supplied with electricity from stand-alone diesel generators. It was understood to apply also to desalination plants at resorts and for desalination plants supplying water for industrial use or for water bottling.

Public services

Sea water is desalinated for public water supplies in Greater Malé Region and a number of outer islands. It was understood that desalination plants for public water supplies are all membrane types based on reverse osmosis (RO). RO requires electricity to establish high pressures needed for the process. Companies running RO-plants for public water supplies also operate their own diesel generators for electricity supply for the desalination process. The grid is used for back-up but Malé Water and Sewage Company (MWSC) also generates electricity for the Malé grid during periods of grid power shortages.

It was understood that the desalination systems are designed to incorporate estimated demand for next 25 years. But the excess RO modules are put in operation only when demand increases.

MWSC has started installing PVs to partly cover the electricity demand of its desalination plants. Further to this some of its desalination plants have energy recovery, reducing the overall electricity demand for water desalination. Electricity demand per m^3 water produced is around 4.5 kWh for the largest systems in Maldives operated by MWSC.

There appears to be following options for the low carbon development of desalination plants:

- The best way forward for new desalination plants could be zero emissions desalination systems (i.e. PVs and desalination plant running only when solar energy is available or PV and battery storage allowing for 24 hours of operation). This would decouple desalination from fossil fuels.

- Alternatively, switch to being a grid connected load, which can be managed by the power station operator so the RO plant can be used for balancing the load and optimizing the load in the grid (i.e. used during periods covered with diesel generators running at partial loads). This can be achieved optimally with the use of smart grid system.

[43] Cleaner Production Audit (CPA) by Allplan and Renewable Energy Maldives in 4 hotels and 3 resorts of Mookai Hotels.

- The third option is to integrate water and power systems. However, this would require changing the existing systems completely and investing in new technologies and facilities. This option is only viable as mitigation if the integrated system is sourced from renewable energy.

Industrial applications

Some industries are self-supplied with desalinated water for process-water. This applies to fish processing industries, ice-making and bottling of water. There was, however, no data available on the countrywide installed desalination capacity by industries.

Still, industrial auto-producers of water in Maldives were understood to mostly use RO technologies and mostly supply the desalination plants with electricity from own diesel gen sets using the grid as back-up only. The desalination plant at STELCO power station in Malé is an exception. The technology used by STELCO for water used at the power station is of the Multi-Effect Distillation (MED) type. MED-technologies can be classified as thermal desalination as they require heat supply for the desalination process. The desalination plant of STELCO recovers heat from exhaust gases of the power station to source the desalination process.

Contrary to RO-types, distillation types are usually not stand-alone plants as they suit well for applications with nearby access to a heat source as the case with power stations. The conventional MED technology requires externally generated heat source with temperature at minimum 60 degrees Celsius.

While no data for Maldives was available, generic studies indicates that RO-technologies requires 3-5 kWh electrical energy/m^3 water product (depending on number of passes required to obtain sufficient quality of water product) while MED-technologies requires 1.5-2 kWh electricity plus thermal heat. If the thermal heat requirement can be fully met by recovering heat from exhaust gases, the MED-technology would actually offer GHG-mitigation over the RO-technology provided that the GHG-emissions intensity of electricity supplied are identical in both cases. Note, however, that relying on MED-technologies for future plants, makes desalination dependent on diesel generators (as MED technology is reliant on the waste heat as heat source) whereas RO-technologies requires only electricity, which could be partly or fully generated from renewable.

A recent study looked into the energy saving potential in Maldives of utilizing waste heat from diesel gen sets at power stations for water desalination by use of Low Temperature MED (LT-MED) technology (PricewaterhouseCoopers 2011b)[44]. However, most power stations were understood to not have demand for desalinated water as they contrary to the STELCO power plant in Malé uses air cooling and not water cooling. This option can therefore only decouple desalination from fossil fuel if the waste heat is sourced from renewable energy sources, such as bio fuels.

Resorts

Resorts are also dependent on desalination and operate their own desalination plants, but data was not available on technology-types and energy efficiency of desalination plants at

[44] The study suggested electricity demand to be 2 kWh/m^3 versus 5 kWh/m^3 of RO-based desalination. Using LT-MED instead of RO-technologies would save 5.7 GWh electricity annually in Greater Malé Region and 2.9 GWh electricity in outer islands according to the study.

resorts. Like public water supply, desalination technologies based on RO is probably the commonly used technology at resorts islands, supplied either from the resort island grid or as stand-alone plants i.e. sourced by stand-alone diesel generators and perhaps partly from PVs. Given the constraints on deployment of solar PV due to the often 18-24 hours of operation of desalination plants at resorts and perhaps space constraints, storage may provide for options to mitigate GHG-emissions attached with RO-based desalination.

6 Mitigation from energy services in other sectors

This chapter covers all IPCC prescribed sectors not covered in the previous chapters.

6.1 Fuels for cooking in residential and commercial sectors

The consumption of LPG and kerosene represents 9% of the energy demand according to the 2009-energy balance and was forecasted to grow by 12% p.a. due to increasing demand for LPG whereas usage of kerosene was foreseen to decrease significantly. The alternative option to LPG is to switch to electrical cooking and thereby increase demand for grid electricity and increase peaks. Replacing LPG for cooking with electricity will therefore at the moment hardly contribute to GHG-emissions reductions given also the low penetration of renewable energy in grid power systems.

In fact it might be the other way around for diesel fuelled power systems since overall energy losses including also losses by electric cooking equipment are higher than for gas fuelled cooking equipment.

6.2 Warehouses and transport supportive activities

Warehouses and the here included transport supportive activities were included for the purpose of comprehensiveness of the low carbon development analysis. In terms of national GHG-emissions inventories these activities relates to the IPCC sector 1.A.4.a commercial/institutional. In Maldives, these emissions sources are not very significant and consist mostly of captive power systems serving loads for such activities (as warehouses and airports).

Existing captive power systems at Thilafushi totals 4.4 MW (SARI/ENERGY 2010), all diesel-only systems. In future, the loads currently served by these captive systems will instead be connected to an island grid to which also the waste-to-energy plant supported under SREP will be connected as well as potentially upcoming PVs. Industrial loads in the industrial zone of Hulhumalé are also captive systems at the moment, but STELCO is supposed to extent its system at Hulhumalé and the industrial loads might then be connected.

In general small island grids do not have the capacity for industrial loads. In such cases it is preferable for industries to have their own captive system. The reason is that small generators runs at partial loads at much higher fuel efficiency (fuel demand in litres/kWh) compared to larger generators running at similar percentage loads[45] .

Deep Sea cooling for the International airport in Hulhule island is planned for with assistance from the government of Japan as a Joint Crediting Mechanism project. This is supposed to supply 2,500 refrigerant tons and avoid about 19,000 tCO_2e/year from diesel generators (Ministry of Environment and Energy 2013a). This specific project is, however, excluded from the abatement cost curve as there is little information available on its costs. The technology is not likely to be replicated in other airports around the country due to the small scale of those airports.

[45] Ref. to Alexander Schies , Fraunhofer Institute for Solar Energy Systems ISE, June 2013 – presentation Technological and Economic Assessment of PV-diesel hybrid solutions versus other technologies

6.3 Construction

Large building construction programmes and major infrastructure projects have be undertaken in recent years (including airport, harbours and several land reclamation projects) and many more are in the pipeline. The high level of activities is expected to continue and perhaps even grow.

Whenever supplied from the grid, electricity demand for construction is not accounted separately in statistics but is covered by the data collected on diesel demands of power stations. Energy demands in excess of grid electricity demands comprise i.a. diesel fuel for construction machinery and for pumping of sand (e.g. for land reclamation) etc. The fuel statistics are not yet able to separate these demands from the diesel fuel demand for transport purposes. Hence, diesel demands allocated for road and marine transport as per the 2009 energy balance covered also diesel consumption of construction machinery. Accordingly, mitigation options within the construction sector were covered by mitigation options of transport.

6.4 Fishery

Maldives fisheries industry is the main primary economic industry in Maldives. It is an industry with deep cultural and historical values. However, in the recent years there has been a sharp decline in the fisheries industry's contribution to GDP mostly due to stagnated growth of fisheries industry for the past decade. Even for the future there potential increased catchment of fish is limited and thus fuel demand was not expected for the 2020-projction to increase significantly. It is still considered as a major emitting economic activity due to its mobile combustion of fuels. The 2009-energy balance recorded the fuel demand for transport by fisheries vessels to be about 25 ktoe or 7% of the overall primary energy demand of Maldives.

The fisheries vessels in Maldives travel far and long for the catch and thus most of the emissions are for transport. In addition, due to long trips vessels also use energy for cooking as well as to some extent cold storing of fish catch. The mobile emissions in transport were already discussed in this report in chapter 7. In addition to those measures a mitigation option that could be considered is to install small PVs to supply the energy needs (electrical cooking and mini cold storage) the vessels may have in the open waters. The consumption of LPG and kerosene at fisheries vessels was determined to be less than 1 ktoe in the 2009-energy balance.

There are currently some 12 fish processing plants in Maldives, hereof are two located in the industrial zone of Hulhumalé. Both fish processing plants in Hulhumalé operate their own diesel generators and desalination plants for own consumption of electricity and water. This was understood to be representative for the majority of fish processing plants in Maldives. Major electricity loads consists of ice-making, freezing, cold storage and desalination. However, there are also ice-making and cold storage activities separate from fish processing. Major heat loads is for cooking and sterilization.

Ice-making requires electricity and in some instances also desalinated water. Ice-making plants and cold storage entities were understood to be electricity auto producers using the public grid as back-up. During periods of power shortage in the grid, the diesel gen sets of the plants may serve the grid. Alternatively to the current practice, the electricity /power required for ice making and storage can be derived from renewable energy sources like solar PV.

As per the 2009 energy balance, no diesel fuel demand in Greater Malé region for cold storage and canning was found and the demand for these activities in outer islands are determined to be 6.2 ktoe, which equals less than 2% of the overall primary energy demand of Maldives.

6.5 Agriculture

Agricultural activities occur in a few inhabited islands plus in some 10-20 islands dedicated to accommodate agricultural activities. Agriculture in the country comprises primarily growing of crops, however, it was understood that a few poultry farms exist too. Energy demands include diesel fuel for vehicles/machinery and pumping demand for irrigation, which at agricultural islands is sourced from small diesel gen sets since there are no island grids at these islands.

Water for irrigation was believed not to be desalinated. Organic waste from crops is composted. Information on animal breeding and manure handling was lacking but dependent on the manure treatment practices applied, emissions of methane or nitrous oxides may occur from animal breeding. However, the present level of emissions was considered to be insignificant and hence emissions from agriculture, other than emissions of carbon dioxide attached with fuel combustions, were assumed to be zero. The agricultural sector was not expected to grow, but to stay at the present level of activity.

Fuel statistics were not able to separate usages in agricultural sector from uses of fuels for marine or road transport. Hence, agriculture was in this report covered by mitigation options identified for marine and road transport with the predominately option relevant for agriculture being the introduction of biofuels blends. Additional mitigation options in agriculture could be to use solar PV or wind turbines to power pumps (for irrigation) as substitute for diesel generators. Organic waste and manure could be regarded as a source for generation of biogas potentially for domestic uses such as cooking and hence replacing either LPG used for cooking or electricity.

7 Mitigation from Transport

7.1 Sector Brief

Being a dispersed island nation transport is an integral part of life in Maldives. Historically, Maldivians have used sail boats to travel long distances and oars to travel short distances. In the 1970s Maldivian traditional way of transportation was changed with the introduction of mechanized boats and tourism. Overtime the mode of transport has changed completely to a fossil fuel based transportation mode. For this reason the transport sector is the second largest contributor to Maldives GHG-emissions after grid electricity.

Other than the broader policy of becoming carbon neutral by 2020, the specific policy goals assigned to the sectors are listed below.

- By 2015, biofuels are to reach 10% of transport fuels possibly increasing to 20% in 2020 (NSDD)
- By 2015, reduce the transport sector GHG emissions by 25% (3rd NEAP. Base year was not established).

Under the current government, Ministry of Transport and Communication (MOTAC) is the policy body and the Transport Authority is the regulatory body for the sector. Although both the Ministry and the Transport Authority are keen to find options and opportunities to reduce emissions from the sector, there is a severe lack of capacity and technical knowhow in the relevant bodies. It is also to be noticed, that the sector lacks a development master plan much less a sector specific policy document which address the emissions issues in the sector. The development of the sector is mostly driven by the demand of the end user. Thus the transport emissions are directly related to increasing economic activity in the outer islands. The transport emissions increased from 164 $ktCO_2e$ in 2003 to 334 $ktCO_2e$ in 2009 (excluding fishing boats). The transport activity emissions also contribute heavily to tourism, construction and fisheries industry in the Maldives.

In this report, the transport sector was sub categorized in land, marine and aviation and these are discussed in detail in the below.

7.2 Domestic Aviation

Domestic aviation in Maldives has been a considerably small sector in terms of energy consumption and GHG-emissions. In 2009 the contribution of domestic aviation or air transport was just 5% of total emissions in Maldives. In a historical context domestic aviation exhibited a low rate of increase with about 3-4% increase annually from 2001 to 2010 and it is closely linked with tourism activity. The domestic aviation sector has been relatively unchanged up until 2010. There were few DASH 8 and Dornier flights flying to four regional domestic airports in Maldives. These were Hanimaadhoo, Kahdhoo, Kadehdhoo and Gan. Catering for the resorts and tourists there were Twin Otter Sea Planes that flies to resorts from the main airport in Malé.

However, after 2010 the import of aviation fuel for the domestic aviation has increased. This can be mostly attributed to government policies of extending infrastructure for domestic aviation to include more areas of the Maldives in order to promote connectivity and other economic activities in those regions. Accordingly, two new domestic airports were in operation by end of 2011, viz. Fuvahmulah in the South and Maamigili in the West, and one airport in Dharavandhoo in 2012 and one in Kooddoo and Thimarafushi in 2013. There are plans to have an airport in Noonu atoll.

It can be foreseen that aviation fuel consumption will increase at a faster rate in the short term and then level out in the mid-term after market saturation. It was noted that due to the new regional airports tourists are increasingly switching to larger land based DASH 8 flights rather than going by sea plane. DASH 8 flights consumes less fuel per passenger than twin Otters Sea Planes, namely 4.3 litres per passenger to travel 100 km for DASH 8 versus 7.5 litres per passenger to travel 100 km for twin Otters Sea Planes. This was substantiated with increased number of passengers per flight from about 13 in 2009 to 24 in 2012. At the same time, it was observed that number of locals who travel by marine based transport to the islands near the newly built airports from and to Malé has reduced considerably, displacing a part of the emissions from marine transport to aviation.

In terms of mitigation, there is not much available for the aviation sector. The development of energy efficient and fuel flexible engines are mostly concentrated on large scale commercial airlines. The only options would likely be to increase efficiency in operation and maintenance including through improvement of capacity utilization (number of passengers per flight). In addition to this, careful planning and design of regional airport hubs could be done so as to reduce the number of flights.

7.3 Marine transport of passengers and goods

Sea transport has been the main mode of transport used by passengers and for goods between islands. There is a high traffic of goods and passengers between Malé and outer islands over the sea since Malé is the hub of economic activity in Maldives. Marine transport has proved a cheaper option for most customers in comparison to the aviation. In 2009, the initiation of decentralized development in transport infrastructure -a nationwide ferry transport system - was introduced. These ferries reduced the costs of transport between islands and consequently increased commuting between the islands.

The sea transport in the atolls for passengers and goods has risen from 9 ktoe in 2002 to nearly 50 ktoe in 2009. It is one of the fastest growing emissions sectors in Maldives. With estimated 155 ktCO_2e, which accounts for 12% of total emissions in Maldives, it has the highest emissions among the sub categories of transport.

MOTAC is working with different development partners to improve the sector and reduce the emissions footprint in the sea transport sector. However, so far efforts have not materialized in any mitigation activities. The difficulty seems to rest with lack of capacity of the authorities regulating the sector as well as with the limited options available in terms of marine technology that can be applied.

The goal outlined in NSSD on attaining 10% biofuels of transport fuels by 2015 and increase it to 20% by 2020 is a challenge considering also the prices of biofuels versus fossil fuels. However, technically 20% blends of biodiesel and 15% blends of bio ethanol are reachable with little or no capital investment in the sector. A policy directive to the main fuel importer to import 10% or 20% blends of biofuels would allow the transport sector to utilize this fuel and to reduce emissions of GHG. It would also help reduce other major pollutants like particulate matter, hydrocarbons, sulphur oxides and carbon monoxide.

This scenario for 2020 was explored for the abatement costs analysis. However, this would still leave the transport sector with a considerable need for offsets in order to achieve the pledge of carbon neutrality by 2020. Therefore a more aggressive target might need to be

set for the share of biofuels in transport sector for example by using exclusively biofuels in marine transport. Obviously, this comes at extra costs as it requires some modifications to the existing motors used in transport. Thus, such a target might be ideally set for a longer term of next 10 to 15 years.

In addition to non-fossil fuels, the sector needs to look in to possible energy efficiency measures to cut down the costs of transport. Especially in passenger transport, efficiency improvements seem to be at hand. Some measures of relevance were listed below.

1. More direct(short) routes for ferries
2. Careful design of an efficient ferry network within and among the atolls.
3. Building boats with efficient hulls and improve the boat building code to incorporate efficient designs and technology.
4. Optimizing the speed to get better fuel economy
5. Reduce idle time at the terminals or harbour
6. Use of more efficient motors
7. Sizing the boat to optimize passenger/load per litre of fossil fuel consumed
8. Incorporate renewables to supplement the diesel motors to reduce consumption

These measures would help reducing emissions, but it requires some further assessment to identify the potential of mitigation that can be achieved.

Case Study
Maldives Transport and Contracting Company (MTCC) is providing ferry services in the greater Male' region, with three major transport routes, i.e.

- Malé – Hulhumale
- Malé – Villingili
- Malé' – Thilafushi

Malé' to Hulhumale ferry runs every half hour and uses larger ferries with a capacity to carry 200 passengers. It carries on average 364,000 passengers monthly and the ferries have a fuel economy of 4.5 litres per kilometre.

Malé to Villingili ferry runs every 10 minutes and uses ferries with a capacity to carry 100-120 passengers. It carries on average 450,000 passengers monthly and the ferries have a fuel economy of 3.86 litres per kilometre.

Given the load of passengers between Malé and Villingili, MTCC could consider to switch to a larger ferry (capacity of 200) and changing the timetable to every 20 minutes thus carrying the same number of passengers. This would reduce the fuel consumption of that particular route with an estimated 22% corresponding to savings of 268 thousand litre of diesel and 667 tCO_2e annually.

7.4 Marine transport for tourists and leisure

Transport for tourism sector is also one of the key contributors to GHG-emissions in Maldives. It mostly consists of tourist transfers from airport to resorts, excursions and live-aboard vessels. This sector contributed with 69 $ktCO_2e$ in 2009 which accounts for 5.5% of

total emissions in Maldives. However, the growth of this particular sector has been slow mainly because the development of tourist resorts has taken place in regions away from the main airport. Thus the part of the transfer of tourist has changed from marine based transport to aviation, especially after the development of new airports.

The live-a-board vessels or safari boats also contribute to this sector. Since the number of vessels has only increased marginally in the past five years it seems reasonable to assume that GHG-emissions from safari vessels have also increased marginally during that period.

According to the draft 4th Tourism Master Plan (Ministry of Tourism, Arts and Culture 2012a) the most significant regulatory reforms required for the tourism sector in the environmental arena at present includes new environmental regulations for live-aboard vessels. The vessels use diesel to run the engine and diesel gen sets for electricity demands including for desalination. Mitigation options include solar panels and waste heat from the engine used for hot water. In addition solar power vessels could be used for short recreational trips. This has been tried out in Maldives with a diving boat. In many countries vessels have small PV or wind turbine installed to deliver power to electrical applications on the boats.

Obviously, this subsector also offers mitigation opportunities by switching to biodiesel.

7.5 Road transport Malé

In 2009, road transport in Malé accounted for 77% of the total road transport in Maldives. It contributed with an estimated 57 $ktCO_2e$ which constituted about 4% of the total emissions. That is an increase from 25.5 $ktCO_2e$ estimated for 2003. In the past, the rate of growth for road transport remained high, but due to congestion and straining the carrying capacity of Malé that rate has been reduced considerably to be below 5% per year.

Land transport in Malé is one of the emerging environmental issues in Maldives. Mainly the congestion of traffic and the effluents from fossil fuel based vehicles are degrading the urban environment in Malé. Therefore, mitigation of GHG-emissions in road transport would have multiple benefits. To address the congestion issue, the city council introduced bus services for public transport. This service has been rather popular even when the buses services struggle to keep to a set schedule. It has also proven difficult to further expand bus services due to traffic congestion.

There are many economically attractive mitigation options in fields of modal transfers which may also help solve congestion and improve urban life in Malé capital islands. The main challenge is to succeed in changing habits of motor bike and car users. Accordingly, it may also be politically sensitive to impose new regulation limiting traffic by cars and motor bikes and even to enforce existing regulation of parking.

Most of the road transport emissions come from petrol fuelled vehicles like motor bikes and cars which accounts for about 80% of the emissions. In 2012, for every 3.5 persons living in Malé there was one motor bike and one car for every 50 persons. It was also noted that most of these vehicles are old and inefficient. The road congestion further aggravates the inefficiencies. The fuel economy of these motor bikes was estimated to be 15km/l on average whereas the fuel economy for these vehicles estimated by manufacturer ranges from 35-55km/l. Thus there are potential improvements at hand with proper road management and through imposing specific standards on the vehicles.

The introduction of vehicles standards based of emissions and introduction of incentives in the form of reduced tax for efficient vehicles would further increase the mitigation efforts. It would also create an economically viable market for high end hybrid vehicles whose fuel efficiency was estimated to be about 2-3 times higher than current vehicles. Furthermore, the introduction of RE-based charging stations (or enough RE penetration in the grid) could increase plug-in hybrids thus reducing the emissions to a minimal, although the latter option requires large investments and would take time for implementation.

It was also suggested from the stakeholders that an effective mechanism needs to be in place to maintain the statistics of the vehicles as this would provide valuable information in the planning. Moreover, the current regulation about the testing for road worthiness needs to be revisited and the measures for non-compliance needs to be strengthened to ensure less emission by the vehicles.

As Hulhumale is one of the recently designed islands, the use of push bikes needs to be promoted on the island. More incentives needs to be in place as to promote and bicycle lanes needs to be introduced giving preference to push bikers.

Alternatively, in the short term in keeping with the policy statements on biofuels in transport, petrol-ethanol blends could be introduced for the vehicles. It was estimated that about 15% ethanol can be blended and used without having to modify the vehicles.

7.6 Road transport outer islands

Road transport in the atolls is considerably small in terms of energy consumptions and emissions. However, the decentralized development in the recent past has increased GHG-emissions from road transport in atolls. The emissions increased from 1.85 $ktCO_2e$ in 2003 to estimated 20 $ktCO_2e$ in 2012 i.e at a much faster rate than in Malé. So far the road transport in atolls does not face the issues that Malé is facing at the moment, but there is possibility of the same issues being replicated in some of the islands if the sector is not regulated.

Due to reasons described above it might be easier to implement some of the measures highlighted for Malé in atolls. Especially capping the number of vehicles per island, and introduce cost effective public transport for islands with higher demand for transport.

7.7 Summary on mitigation options

Transport sector is one of the major contributors to the GHG-emissions in Maldives but given the geographic uniqueness, there is a limitation of mitigation activities that can be carried out. Most of low carbon technologies developed in transport sector is for land transport which accounts for only about 5% of GHG-emissions in Maldives. The majority of transport activities is carried over the sea or air and mitigation options in technology developments for marine transport and aviation is limited as described above.

There exist limited capacity and commercial technology available in foreseeable future, but still the following list of possible mitigation activities could be carried out in Maldives.

- Cap number vehicles for islands
- Introduce emission standards and labelling for road transport
- Promote hybrid vehicles

- Promote the use of bicycles
- Promote electric vehicles including electrical bicycles and have RE based charging stations
- Promote vehicle free islands
- Promote vehicle free days
- Make experiments with pedestrian friendly route planning
- Switch to biofuels for transport
- Use of PV based engines for leisure and short marine trips
- More direct (short) routes for ferries
- Building boats with efficient hulls and improve the boat building code to incorporate efficient designs and technology
- Careful design of an efficient ferry network within and among the atolls
- Optimizing the speed to get better fuel economy
- Reduce idle time at the terminals or harbour
- Use of more efficient motors in transport vehicles/vessels
- Sizing boats/planes to optimize passenger/load per litre of fuel consumed

The proposed bridge connecting all islands in Greater Malé region holds a potential to scale up mitigation of transport in the region mainly due to modal change from the comparatively higher carbon intensive marine transport to land based transport. However, the mitigation potential can be fully realized if vehicles are converted to electric vehicles.

Mitigation through improved fuel economy of motor bikes was investigated for the abatement costs analysis. Assuming that fuel economy can improve from 15 km/l to 25 km/l through better maintenance demand for petrol by 2020 could decrease with 8.4 ktoe and emissions could drop with 24 $ktCO_2e$. This assumes a growth rate in transport demand by 4.5% per year and is a no-regret option as it requires no capital costs. Savings amounts to US$10 million annually.

The impact of introducing bio ethanol blend of 15% for the remaining demand of petrol was assessed to help reduce petrol demands with another 5.4 ktoe. This option comes at costs of US$4.4 million annually. Finally, by switching from diesel to 20% biodiesel blend 21.2 ktoe fuel would be saved by 2020. This comes with extra costs too, some US$76.3 million due to the difference in price of biodiesel and diesel.

Table 13 Impact of mitigation options within transport

	2020-BAU	Impact by options	2020 with mitigation
Demand for petrol (ktoe)	44.6	- 8.4 (fuel economy motorbikes) - 5.4(bio ethanol blend)	30.8
Demand for diesel (ktoe)	106.5	- 21.3(biodiesel)	85.2
Demand for JetA1 (ktoe)	32.4		32.4
Total demand (ktoe)	183.5		147.0
GHG-emissions ($ktCO_2e$)	556.6		450.5

In combination, these options would help reduce GHG-emissions from the transport sector by 19%. In order to become carbon neutral in 2020, there would remain GHG-emissions of about 450 $ktCO_2e$ from the transport sector that would require offsets.

8 Mitigation from Waste

8.1 Solid Waste

Waste management has been a growing concern in Maldives considering the limited land space and the fragile ecosystem of the country. The main methods of waste management are incineration (mainly in resorts), open burning, landfilling, or dumping into the sea (Census 2006).

The majority of the solid waste is collected and managed at Thilafushi island - an island dedicated for waste management and industrial activities). The waste collected here originates from Greater Malé region accounting for approximately 1/3 of the country's population as well as from nearby resorts.

In Thilafushi approximately half of the waste is openly burned while the other half is disposed as landfill (BeCitizen 2009). However, due to the salty nature of the soil and the salt water table being close to the surface, it was for this report assessed to be unlikely that it provides for proper conditions for anaerobic degradation and hence for methane emissions. Landfilling will stop in the future and emissions of methane, if any from existing landfills will decrease exponentially. The practice of open burning at Thilafushi may in previous time have lead to carbon dioxide emissions from fossil waste fractions such as plastic bottles and bags. However, such fractions were understood to a large extent to be recycled at least for waste stream that have come into Thilafushi for the past say 5 years.

As per the National Solid Waste Management Policy (2008) and Strategic Action Plan up to 7 Regional waste management facilities are planned for, which intend to demonstrate a sustainable solution with economic and environmental benefits. Conversion of waste into useable energy constitute a very attractive option in terms of addressing environmental/emissions concerns as well as managing waste, and hence is a value added solution. A pre-feasibility study supported by UNDP in 2007 suggested WTE technologies for incineration facilities to be viable for waste input of minimum of 15 ton/day. The waste statistics (Ministry of Transport, Housing and Environment 2010) shows a waste generation factor of 3.5 kg/bed/day in the resorts, and 0.86 and 0.98 kg/person/day in Malé and in outer islands respectively.

Currently there is a 4 MW WTE incineration facility being developed in Thilafushi. Electricity produced is expected to be delivered to the utility grid and to fully meet the electricity demand in the island and replace current electricity generation facilities. In addition to this, three regions are planned to be developed as WTE facilities from the SREP program under the FIT model. The following table describes the sites and the specific parameters for the WTE facilities.

Table 14 Planned waste-to-energy facilities

Site (Region)	Tonnes Per Day (TPD) of waste	Electrical Power Output of System (kW)	Annual Energy Production (MWh)	Annual Water Production (Litres/day)
Hithadhoo, Addu City (South)46	50	1000	5,500	94,500
HDh. Kulhudhuffushi (Upper North)71	20			75,500
Raa. Vandhoo (North)	50	1000	5,500	
Thilafushi (Greater Malé)	200	4000	20,000	

More regional waste management centres are expected to be developed in the future and such additional WTE facilities are envisaged to be developed based on the experience of the initial projects currently in the pipeline.

Assuming fossil waste fractions will be recycled, future incineration was for the 2020-projection of GHG-emissions expected not to lead to GHG-emissions. Furthermore, waste incineration at resorts was expected to not include fossil waste fractions, neither currently or in future.

8.2 Sewage

Practice in sewage management in Maldives consists of septic tanks at household levels. Septic tanks may allow for anaerobe conditions causing methane emissions, but these were taken to be negligible.

As for the waste water management in the country, Greater Malé Region has an established sewerage system which dumps the waste water to the ocean after treatment. Although a handful of islands in the outer atolls have similar sewerage systems, about 16% of the households in the outer islands have toilets connected directly to the sea and about 70% of the households have septic tanks (Census 2006).

Even though most of the islands have septic tanks, due to open ended structure, the salty water would seep into the system due to the open ended structure and hence anaerobic digestion was assessed to be minimal, resulting in negligible formation of methane. Moreover, for the case of sewerage systems and toilets connected to the open ocean, there would be little or no chance of sustained anaerobic digestion, hence no emissions.

Central sewage systems are increasingly coming along in outer islands and household sewage will accordingly increasingly be treated by central sewage plants. For this report, the treatment method at central sewage plants was not expected to lead to methane emissions, and switching from household systems to central systems will therefore mitigate methane emissions, if any from current practice.

[46] *Waste-to-Energy Study 2007* (IT Power 2007). The MEE expects these values to be higher compared to 2007 and to grow in futere. Therefore, Kulhdhuffushi is also likely to have electricity generation from waste, but it will be confirmed by SREP feasibility study in 2014.

9 Greenhouse gas emissions and costs of mitigation

9.1 Methodology

The GHG abatement costs analysis was made in following steps:

1) Establishing an energy balance as disaggregated as possible, based on the latest available data which was data from 2009. The energy balance was converted to a GHG-emissions inventory for 2009 by use of IPCC default CO_2 emissions factors.

2) Projection of the 2009 balances to 2020 in order to establish a baseline projection for 2020, the short term target year for the low carbon development strategy. As the 2020 projection describes the BAU scenario, energy services by 2020 were assumed to be produced and consumed with the same technologies and efficiencies as were assumed for the 2009-energy balance. For the 2020-projection growth assumptions used for Maldives national planning were taking into account.

3) Based on *inter alia* existing studies mitigation options in various sectors of the economy were identified (as presented in previous chapters 3 to 8) and 22 options were selected for further analysis by the "Greenhouse Gas Costing MOdel (GACMO), which is a spreadsheet model developed by the UNEP Risoe Centre (URC).

4) For each option selected, mitigation technology and baseline technology were identified and described in terms of capital costs, operational costs, energy demands and GHG emissions. These data were collected in GACMO and abatement costs per mitigation option were calculated accordingly. The model collects the results in a summary table, showing also aggregated results of all options like capital costs, abatement costs and annual abatement. Finally the model generates an abatement cost curve.

9.2 Greenhouse gas inventory for 2009

The MEE expects to submit the second national communication in 2014 which will include a GHG-inventory for 2011-data. Currently (as of March 2014), The Maldives 2009-carbon audit (BeCitizen, 2010) was the most recent GHG-inventory covering also other sectors than energy. The 2009-carbon audit was partly based on the Report on Energy Supply and Demand 2008-2009 (Riyan, 2010), which was the most recent national energy balance.

The 2009-inventory prepared for the analysis of this report was sourced from the 2009-energy balance (Riyan, 2010) and the Maldives' 2009 Carbon Audit report (BeCitizen, 2010). The inventory was prepared in a spread sheet model developed by the URC.

Table 15 2009 energy balance for Maldives

	Total ktoe	Jet A1 ktoe	Petrol ktoe	LPG ktoe	Kerosene ktoe	Biomass ktoe	Solar ktoe	Wind ktoe	Electricity generation ktoe	Electricity generation GWh	Thermal efficiency	Diesel for electricity ktoe	Diesel for transport ktoe
Total demand	361.4	17.1	27.5	33.8	1.7	0.5	0.2	0.0	60.6	704.3		190.0	90.7
Greater Malé Region	*56.9*			*3.1*	*0.2*	*0.0*			*20.1*	*233.6*	*0.37*	*53.6*	
- Households				3.0	0.1	0.0			9.0	105.0			
- Government buildings									3.4	39.3			
- Other public buildings									0.3	3.7			
- Industry, manufacture, commercial									5.9	68.9			
- Desalination									1.4	16.6	0.38	3.8	
- Vessels fishery	3.0			0.1	0.1								2.8
Outer islands	*51.7*			*8.7*	*1.5*	*0.5*			*13.2*	*153.7*	*0.32*	*40.9*	
- Residential buildings				8.1	0.9	0.5			6.7	78.2			
- Public buildings (schools, offices etc.)									4.3	50.6			
- Cold stores & canning									1.7	20.3	0.28	6.2	
- Manufacture									0.4	4.6			
- Vessels fishery	23.6			0.6	0.6								22.4
Resorts (excl. transport)	113.4			21.9			0.2		25.6	298.2	0.28	91.2	
Hulhule airport	5.3		0.1						1.6	18,8	0.38	4.2	0.9
Domestic aviation	17.1	17.1											
Marine transport (passengers, goods)	49.6												49.6
Marine transport (leisure, tourists)	22.9		11.1										11.8
Road transport	19.4		16.3										3.2

The second column of the energy balance in Table 15 shows that the total energy consumption in the Maldives in 2009 was 361.4 ktoe. The next columns disaggregate the total on fuels and sources recorded in Maldives. The contribution from solar was for water heating and the contribution from biomass was firewood for cooking. The diesel consumption was split into diesel used for electricity generation and diesel used for transport. Note that electricity generation values refer to values for electricity fed into the grid i.e. they are not equivalent with end-use electricity demands as they do not account for grid losses. The vertical axis of the table is disaggregated in four parts: Greater Malé Region; Outer islands; Resorts; and Transport, the latter however including also diesel for electricity at Hulhule airport.

Table 16 2009 GHG inventory for Maldives

Tonne CO_2e/Toe (IPCC):		2.99	2.90	2.64	3.01	0	0	0	3.10	3.10
	Total $ktCO_2e$	Jet A1 $ktCO_2e$	Petrol $ktCO_2e$	LPG $ktCO_2e$	Kerosene $ktCO_2e$	Biomass $ktCO_2e$	Solar $ktCO_2e$	Wind $ktCO_2e$	Diesel for electricity $ktCO_2e$	Diesel for transport $ktCO_2e$
Total domestic consumption	1132.6	51.1	79.7	89.1	5.0	0	0	0	589.2	281.2
Greater Malé Region	*174.9*			*8.2*	*0.6*				*166.2*	
- Households				8.0	0.3					
- Government buildings										
- Other public buildings										
- Industry, manufacture, commercial										
- Desalination									11.8	
- Vessels fishery	9.3			0.2	0.3					8.7
Outer islands	*154.5*			*23.0*	*4.5*				*127.0*	
- Residential buildings				21.4	2.7					
- Public buildings (schools, offices etc.)										
- Cold stores & canning									19.3	
- Manufacture										
- Vessels fishery	72.8			1.6	1.7					69.5
Resorts (excl. transport)	340.8			57.9					282.9	
Hulhule airport	3.1		0.3						13.1	2.9
Domestic aviation	51.1	51.1								
Marine transport (passengers, goods)	153.8									153.8
Marine transport (leisure, tourists)	68.7		32.2							36.5
Road transport	57.1		47.2							9.8
Other sources	*37.2*									
- Waste in Thilafushi	0									
- Waste outside Thilafushi	0									
-HCFC emissions	37.2									

Values for the GHG emissions inventory in Table 16 were determined by multiplying the energy amounts found in the energy balance with IPCC's default CO_2e-emissions factors for each relevant fuel as displayed in the top row of the table.

Sinks and emissions sources additional to use of fossil fuels were treated as follows for the GHG-inventory:

- Sinks were not estimated due to major data gaps. The majority of vegetation in Maldives appears at uninhabited islands, perhaps in the magnitude of 100-200 km^2 coastal vegetation, but there was no basis for estimating GHG-emissions removals from these sources for this report.

- GHG-emissions from waste sector were estimated to be negligible. Presumable 2009-methane emissions, if any from landfills were insignificant due to saline environment and open burning of waste were considered not to include fossil waste fractions. The practice of open burning was expected to cease up to 2020 and landfilling was likewise. For existing landfills, methane emissions, if any were assumed to decrease. For these reasons, emissions from waste sector were projected to be zero for 2020.

- Hydrochlorofluorocarbons (HCFCs) are not covered by the UNFCCC, but the Montreal Protocol which Maldives have agreed to. Still, the GHG-inventory prepared for the low carbon development study considers direct emissions of HCFCs as reported in the 2009 Carbon Audit (BeCitizen, 2010). Since the phase out of HCFCs were not supposed to lead to permanent applications of hydrofluorocarbons (HFCs), it was for the BAU 2020-projections assumed that use of HCFCs will be zero in 2020.

- With regard to GHGs other than carbon dioxide and methane such were estimated as non-existent (sulphur hexafluoride) or insignificant (nitrous oxides).

9.3 Projection for 2020 in the Business As Usual scenario

For the projection for BAU GHG-inventory by 2020 is was assumed that energy services in 2020 will be produced and consumed with the same technologies and efficiency as in 2009 but demands for energy services would be increased as per the assumed growth rate by sectors presented in the table below.

Table 17 Growth factors used in the BAU 2020 projection

	Annual growth	Multiplication factor
Kerosene	-19.17%	0.10
Resorts, Jet A1	6.00%	1.90
Petrol	4.50%	1.62
Diesel for transport	4.50%	1.62
LPG	11.83%	3.42
Fishery	1.00%	1.12
Electricity in Greater Malé Region	5.75%	1.85
Electricity in outer islands	5.75%	1.85

Note: The multiplication factor was derived from the annual growth rate applied for a period of 11 years (from 2009 to 2020). The same code colour by sector was used for the presentation of the 2020-projection as found in Table 18.

The growth rate assumptions were based on the following:

- Department of National Planning forecasts revenue from the tourism sector to grow with 5.1% p.a. until 2015 compared with 4.5% p.a. for the entire economy.

- As in the 2009 Carbon Audit Report it was assumed for the present 2020-projection that tourist arrivals will grow 6% per year implying an annual growth of fuel demands by resorts and for Jet fuel of 6%. The Carbon Audit growth rate (BeCitizen, 2010) was based on historical tourist arrivals. Note, that projections in the 4th Tourism Master Plan for 2013-2017 (Ministry of Tourism, Art and Culture, 2012b) imply growth rates at 10.97% and the alternative projection assuming that the target given by the MOTAC is reached was also prepared.

- Also as in the Carbon Audit it was assumed that kerosene demands will continue to decrease by -19.17% annually and that LPG demands will continue to increase by 11.83% annually. For the LPG growth rate it was expected that LPG increasingly will replace kerosene and biomass in outer islands.

- Department of National Planning projects revenue in fishery to decline with minus 5% p.a. but since the number of vessels was expected to increase a growth rate of 1% p.a. was assumed for the 2020-projection in this report equivalent with the Carbon Audit.

- The same growth in electricity of 85% from 2009 to 2020 was assumed for the entire country contrary to the Carbon Audit suggesting annual growth rate of 77% in outer islands versus 85% in Greater Malé Region.

- Petrol and diesel for transport were assumed to follow the National Planning Departments assumption of an annual GDP growth of 4.5% per year.

The energy balance for 2020 was found by applying the multiplication factors to the values of the 2009-energy balance.

Table 18 2020-projection of energy balance in BAU

Energy consumption	Total ktoe	Jet A1 ktoe	Petrol ktoe	LPG ktoe	Kerosene ktoe	Biomass ktoe	Solar ktoe	Wind ktoe	Electricity production ktoe	Electricity production GWh	Thermal efficiency	Diesel for electricity ktoe	Diesel for transport ktoe
Total domestic consumption	651.4	32.4	44.6	80.5	0.9	0.5	0.3			1318.3		357.6	134.6
Greater Malé Region	*109.6*			*10.4*	*0.1*	*0.01*			*37.2*	*432.2*	*0.37*	*99.1*	
- Households				10.3	0.01	0.01			16.7	194.3		44.6	
- Government buildings									6.2	72.7		16.7	
- Other public buildings									0.6	6.9		1.6	
- Industry, manufacture, commercial									11.0	127.5		29.2	
- Desalination									2.6	30.8	0.38	7.0	
- Vessels fishery	3.4			0.1	0.12								3.1
Outer islands	*107.0*			*28.5*	*0.7*	*0.5*			*24.5*	*284.4*	*0.32*	*77.3*	
- Residential buildings				27.8	0.1	0.5			12.4	144.7		38.5	
- Public buildings (schools, offices etc.)									8.0	93.5		24.9	
- Cold stores & canning									3.2	37.5	0.28	11.5	
- Manufacture									0.7	8.6		2.3	
- Vessels fishery	26.3			0.7	0.6								25.0
Resorts (excl. transport)	*215.1*			*41.6*			*0.3*		*48.7*	*566.1*	*0.28*	*173.2*	
Hulhule airport	10.0		0.2						3.1	35.7	0.38	8.0	1.8
Domestic aviation	32.4	32,4											
Marine transport (passengers, goods)	80.5												80.5
Marine transport (leisure, tourists)	37.1		18.0										19.1
Road transport	31.6		26.4										5.1

The projection for an energy balance for 2020 translates into a GHG-inventory as presented in the next table

Table 19 2020-projection of GHG-emissions

Tonne CO_2e/Toe (IPCC):		2.99	2.90	2.64	3.01	0	0	0	3.10	3.10
	Total $ktCO_2e$	Jet A1 $ktCO_2e$	Petrol $ktCO_2e$	LPG $ktCO_2e$	Kerosene $ktCO_2e$	Biomass $ktCO_2e$	Solar $ktCO_2e$	Wind $ktCO_2e$	Diesel for electricity $ktCO_2e$	Diesel for transport $ktCO_2e$
Total domestic consumption	1967.9	97.1	129.4	212.5	2.6	0	0	0	1108.9	417.5
Greater Malé Region	*335.1*			*27.5*	*0.4*				*307.3*	
- Households				27.2	0.0				138.2	
- Government buildings									51.7	
- Other public buildings									4.9	
- Industry, manufacture, commercial									90.7	
- Desalination									21.8	
- Vessels fishery	10.4			0.3	0.4					9.7
Outer islands	*316.9*			75.1	*2.2*				*239.6*	
- Residential buildings				73.3	0.3				*119.5*	
- Public buildings (schools, offices etc.)									*77.3*	
- Cold stores & canning									*35.8*	
- Manufacture									*7.1*	
- Vessels fishery	81.2			1.8	1.9					77.5
Resorts (excl. transport)	*646.9*			109.9					*537.0*	
Hulhule airport	30.9		0.5						25.0	5.4
Domestic aviation	97.1	97.1								
Marine transport (passengers, goods)	249.6									249.6
Marine transport leisure, tourists)	111.5		52.3							59.2
Road transport	92.6		76.6							16.0
Other sources	*0*									
- Waste in Thilafushi	0									
- Waste outside Thilafushi	0									
- Freon fugitive	0									

The result of the BAU projection was that Maldives 2020-GHG emissions would reach 1,968 $ktCO_2e$ coming up from 1,133 $ktCO_2e$ in 2009 according to the inventory on 2009-GHG emissions.

9.4 Costs of compliance through domestic mitigation

Chapters 3 to 8 walked through options for mitigation of domestic emissions in all key sectors of the economy and 22 options were selected for further analysis by use of the GACMO model. The table below summarises some key-results from the model calculations. It ranks the options by their abatement costs in descending order. Negative abatement costs express net-savings that is when discounted lifetime operational costs savings exceeds discounted capital cost. In order to arrive at the abatement costs, these discounted net savings were divided over discounted lifetime GHG-emissions.

Table 20 Summary of key-results from GACMO

Mitigation option	Abatement costs US$/$tCO_2e$	Capital costs US$ million	Annualized costs US$ million per year	Mitigation in 2020 cumulative $ktCO_2e$ per year	Fraction cumulative
LED tubes for public sector	- 784	0	- 0.8	1.1	0.1%
Better maintenance of motor bikes	- 413	0	- 10.0	25.4	1.3%
Air conditioning at resorts	- 398	4.7	- 12.7	57.2	2.9%
Cooling new service buildings	- 369	1.8	- 4.6	69.5	3.5%
Solar water heater	- 323	0.7	- 0.8	72.0	3.7%
Efficient air conditioning	- 313	9.6	- 27.7	160.5	8.2%
LED tubes for street light	- 292	0.1	- 0.6	162.7	8.3%
Upgrade of system efficiencies	- 260	61.1	- 11.2	205.9	10.6%
PVs outer islands	- 252	42.4	- 3.7	220.7	11.2%
Regional waste-to-energy projects	- 228	10.4	- 2.2	230.2	11.7%
PVs with Net Meters	- 189	42.0	- 2.2	242.1	12.3%
Energy efficient refrigerators	- 158	41.2	- 6.6	284.1	14.4%
PVs Malé Region (existing plans)	- 133	45.0	- 2.1	299.9	15.2%
PVs Malé Region (additional options)	- 133	45.0	- 2.1	315.7	16.0%
Efficient water pumping	- 117	14.5	- 0.9	323.3	16.4%
PVs on resorts	- 108	167.4	- 6.3	381.4	19.4%
20 MW wind power & 25 MW LNG	- 105	97.3	- 2.8	407.9	20.7%
Thilafushi waste-to-energy project	- 68	57.8	- 1.6	431.0	21.9%
PVs with storage at small islands	- 52	167.1	- 1.8	466.3	23.7%
LEDs for domestic lighting	199	42.4	1.7	474.7	24.1%
Biodiesel 20% blend	336	0	71.6	687.7	35.0%
Bioethanol 15% blend	337	0	4.9	702.4	35.7%
Total		850.3		702.4	

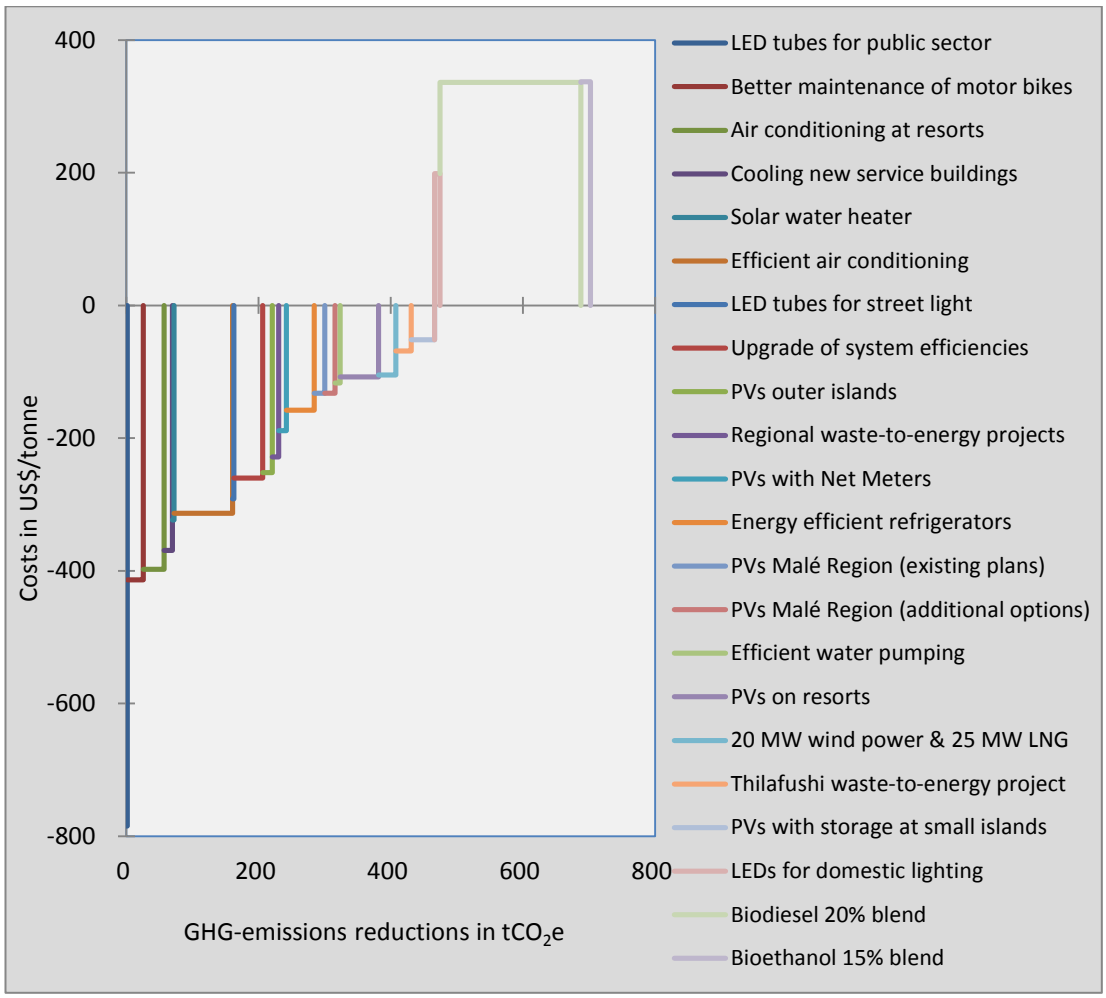
For options on the demand side, capital costs were established as the incremental costs. That is the extra capital costs of the mitigation technology compared with investments in the technology identified for the BAU scenario. Reinvestments, if any were discounted with a rate of 7%. For supply side mitigation options, capital costs in the reference scenario were not taken into consideration as it was conservatively assumed for the baseline scenarios that there would be no investments in renewal of diesel generators or in capacity additions.

The total capital costs requirements for the 22 mitigation options ("overnight costs") were found to be US$850 million (2013-price level). The "annual costs" values in the 3rd column multiply the abatement costs found (2nd column) with the annual (undiscounted) GHG-emissions reductions (4th column).

The cumulative abatement potential for 2020 was by the GACMO model found to be 702 $ktCO_2e$ equalling 36% of the projected BAU 2020 GHG-emissions of 1,968 $ktCO_2e$. However, the model does not account for interrelations and dynamics between various mitigation options. For instance grid efficiency improvements or dissemination of renewable in one option would in real life change the baseline for another option - for instance mitigation through reductions in electricity end-use - and thereby also change baseline fuel costs and resulting abatement costs. But such dynamics were not taken into account by the model. Therefore, except for the capital costs total, totals appearing from the summary table should not simply be taken as the overall achievable from all options. With regard to the cumulative abatement volume of 702 $ktCO_2e$ it seems to be slightly over-estimated as discussed in chapter 2 of this report.

Based on the values in the summary Table 20 the GACMO model draws an abatement cost curve as presented in Figure 2.

Figure 2 Marginal Abatement Cost Curve for 2020



The cost-curve shows that net-saving options (found below the x-axis) save an amount (annually in 2020) considerable larger than the net-costs options (found above the x-axis) but as discussed above the aggregate net savings of all options are lesser than indicated from the cost curve as the model does not account for dynamics across options.

The next sections walk through key-assumptions and results for the 22 mitigation options included in the abatement costs curve.

9.4.1 Renewable energy options

PVs Greater Malé Region

This referred to the Malé region solar PV programme involving installation of minimum 15 MW PV systems (11 MW for Malé and 4 MW for Hulhumalé) and implemented under a FIT-scheme. The programme is part of the SREP Investment Plan. Its realization may require inter-island grid connections through submarine cable.

For the abatement costs analysis capital costs for the solar PVs were considered only i.e. there was not assumed to be any investment in new diesel generators in the reference scenario. Capital costs of PVs were estimated to be US$3000 per kW or totally US$45 million for the scale of PVs envisaged. Useful lifetime of PVs was set to 20 years. The option came with negative lifetime abatement costs at US$133/$tCO_2e$.

LCOE was assessed to be US$0.21/kWh electricity versus avoided fuel costs by diesel generators at US$0.31/kWh electricity.

Additional PVs Greater Malé Region

For this option another 15 MW PV for utility scale was considered with the same assumptions as for the 15 MW solar PV program already envisaged under the SREP Investment Plan and hence the same level of abatement costs.

PVs under Net Metering

This option concerned solar PVs for residential applications under an upcoming net metering scheme as per new regulation agreed in December 2013. For this option 10,500 residential applications (corresponding to 30% of houses with private rooftops) of 1kWp each were projected by 2020. Capital costs of PVs were estimated to US$4000 per kW or totally US$42 millions. Negative lifetime abatement costs at US$189/$tCO_2e$ were found for this option.

PVs outer islands

For this option, solar PV installation of 12.1 MW was considered for totally 121 outer islands comprising three large islands, 32 medium size islands and 41 very small islands. This option was an extension of the 3 MW solar PV envisaged for 30 islands under the SREP Investment Plan by means of FIT-regime. The extension may be supported by additional ADB-funding understood to be targeted 129 islands with potentially 9.1 MW solar PV.

Capital costs for the solar PVs were considered only i.e. there were not assumed to be any investment in new diesel generators for the reference scenario. Capital costs of PVs were estimated US$3500/kW or totally US$42.4 million for the scale of PVs envisaged. Negative lifetime abatement costs at US$252/$tCO_2e$ were found for this option. For the BAU scenario thermal efficiencies of diesel generators at 33% were assumed.

LCOE for electricity by PVs were calculated to be US$0.25/kWh versus avoided fuels costs by diesel generators at US$0.46/kWh electricity.

PVs and storage at small outer islands

Under the SREP Investment Plan, 10 island grids are envisaged to be targeted full transformation to solar PVs with storage. For this option, this was extended to comprise totally 60 islands categorized as small islands. The annual end-use electricity demand of the 60 islands with presently lowest demands was estimated to be 34 GWh in 2020 with the growth rate assumed for electricity in the 2020-BAU energy balance projection. This estimated 2012 end-use demand was build upon a combination of the "SREP underlying data" and the Energy Outlook 2013. With the assumed current 20% distribution losses, this demand would require 43 GWh annually from PV. With estimated 1825 full time hours and a capacity factor for the PVs at 0.8, installed capacity from solar PV required to meet the projected end-use electricity demand would be 29 MW.

For storage it was assumed that on a daily basis half of the end-use electricity demand would occur during hours without solar insolation and therefore would need being covered from storages. Per kW solar PV, installed storage capacity of 10 kWh was needed to a price of 150 $/kWh, the estimated price of lead-acid batteries (IRENA 2012a). Since the battery lifetime was taken to be 10 years versus 20 years of the solar PV, one reinvestment in battery storage was taken into account.

Capital costs for the solar PVs and storage (batteries) were considered only i.e. there were not assumed to be any investment in new diesel generators for the reference scenario. Capital costs were found to be US$167 million. Negative abatement costs at US$52/t$CO_2$e were found. For the BAU scenario thermal efficiencies of diesel generators at 33% were assumed.

LCOE was calculated to be US$0.42/kWh versus avoided fuels costs by diesel generators at US$0.46/kWh electricity.

PVs on resorts

For this option integration of solar PV corresponding to 30% of installed capacity of resort islands grids was explored. The total installed generation capacity in the resorts was about 100 MW in 2012 and was expected to increase as per the growth rate assumed for the 2020-energy balance projection in this report. Accordingly, 30 MW was expected to grow to 47.8 MW by 2020.

Capital costs of solar PVs were estimated to be US$167 million. Useful lifetime of PVs was set to 20 years and negative abatement costs at US$108/tCO2e were found. For the BAU scenario thermal efficiencies of diesel generators at 33% were assumed.

LCOE was calculated to be US$0.25/kWh versus avoided fuels costs by diesel generators at US$0.34/kWh electricity.

Large solar water heater

In this option larger solar water heaters with electrical back-up were considered as replacement for electrical water heating at hotels and at resorts. For estimation of capital costs reference was made to solar water heater systems with 71 m^2 solar collector and

water storage tank of 9000 litre. Solar collectors were assumed capable to cover 50% of the energy required for heating the hot water consumptions.

Capital costs per solar water heater unit were assessed to be US$6.6 thousand or US$673 thousand totally. Capital costs for the reference technology (electrical boiler) were set to zero and operational costs were set to the production costs of electricity for large islands and for resorts islands respectively (weighted 50:50). For resorts islands electricity production costs were set to US$0.34 per kWh electricity consumed and the price for large islands were set to US$0.31/kWh.

Useful lifetime was set to 15 years and negative abatement costs at US$323/$tCO_2e$ were found.

In total 102 applications of large solar water heaters were projected for this option by 2020. This equals all the existing 20 hotels in Maldives plus half of the 165 resorts expected to be in operation by 2020.

20 MW wind power and 25 MW LNG

It was understood that STELCO is envisaging a wind/gas hybrid system with up to 25 MW LNG plant for base load and up to 20 MW wind power.

Capital costs for the wind power part were assumed to be US$2500/kW and US$850/kW for the LNG plant. Capital costs for interconnection cables were set to US$26 million. The overall investment costs were found to be US$97.3 million. Useful lifetime was set to 20 years and negative abatement costs of US$105/$tCO_2e$ were found for the hybrid system. LCOE for the wind/gas hybrid system was calculated to be US$0.25/kWh.

Capital costs for the reference scenario (diesel generators connected to the grids in Greater Malé Region) were set to zero and the operational costs were set to the electricity generation costs assumed for Greater Malé Region viz.US$0.31/kWh.

9.4.2 Waste-to-energy options

Thilafushi waste-to-energy project

This project on establishment of a WTE plant at Thilafushi with installed capacity for electricity generation of around 4 MW is envisaged under the SREP Investment Plan. For the abatement costs analysis an incineration plant at US$58 million in capital costs was considered (Ministry of Environment and Energy 2013a) and with annual operational costs at 5% of the capital costs. Capital costs for the reference scenario were set to zero and operational costs were set to the costs of electricity generation assumed for Greater Malé Region for the BAU-scenario i.e. US$0.31/kWh.

Lifetime of the plant was set to 20 years and negative abatement costs were found to be US$68/$tCO_2e$.

LCOE from the plant were found to be US$261/kWh. However, since the main purpose of the plant was understood to be to attain sustainable management of solid waste, the plant should hardly be benchmarked at the electricity generation costs since alternative options would likely be none-useful cooling of waste heat from the incineration.

Regional waste-to-energy projects

The projects on establishment of new regional waste facilities in Hithadhoo and Vandhoo are envisaged under the SREP Investment Plan. The two facilities are supposed to receive about 100 tonnes of waste per day and to jointly provide for 2 MW installed electricity generation capacity. For the abatement costs analysis costs estimates for the WTE plant at Thilafushi were down scaled to suit the waste incineration capacities envisaged for the two regional waste facilities. Capital costs for two plants were found to be US$10.4 million and annual operational costs to equal 7% of capital costs. Capital costs for the reference scenario were set to zero and operational costs were set to the costs of electricity generation assumed for medium outer islands for the baseline scenario i.e. US$0.34/kWh. Fuel demands in the baseline scenario were based on thermal efficiencies of diesel generators at 32%.

Lifetime of the WTE facilities was set to 20 years and negative abatement costs were found to be US$228/t$CO_2$e.

LCOE were assessed to be US$1.49/kWh electricity. However, the justification of the regional WTE projects is rather the concern over the present unsustainable management of waste in the country. Electricity from useful utilization of the waste heat from the waste incineration may therefore rather be seen as free good.

9.4.3 Energy efficiency options

Upgrades of system efficiencies

The present thermal efficiencies of diesel generators at outer islands were understood to be 32% on average and distribution losses to be 20%, hence leading to overall system efficiencies of 26%. Under the SREP Investment Plan upgrades of island grids at some 15 islands are envisaged in order to prepare for integration of renewable energies. This option on efficient generators and grids was an extension of the grid upgrades of the SREP Investment Plan.

Since integration of PV at a level corresponding to minimum 30% of installed peak demand was explored for all outer islands for the abatement costs analysis, this mitigation option targets islands power grids at all outer islands, except for the 60 islands subjected to full transformation to solar PV with storage (100% renewable). Hence, 124 islands were considered for grid upgrades.

The target was to reach overall system efficiencies of 35% by 2020. The reference for this target was the experience gained from the already implemented upgrade of the Gan island (Laamu Atol) grid. According to the MEE, the Gan grid of 560 kW peak load was upgraded to reach overall power system efficiency of 35% at capital costs of US$0.6 million. The upgrade was understood to have tapped efficiency gains with respect to both thermal efficiencies of diesel generators and distribution network.

Assuming capacity installed at all 124 islands eligible for upgrades to be 5.7 MW totally, overall capital costs required for this mitigation option were set to US$61 million. Note, that new diesel generators better sized to meet the demand were not included in the option i.e. neither capital costs nor fuel savings opportunities from new gensets.

The reference scenario was the BAU i.e. grids supplied with existing diesel generators and with the same efficiency as currently found. Capital costs for the reference scenario were

therefore set to zero and operational costs were set to the diesel fuel costs assuming thermal efficiencies of diesel generators at 32%.

The option was assessed to provide for negative abatement costs of US$260/tCO$_2$e.

Energy efficient air conditioning

For this option the Coefficient of Performance (CoP)[47]of energy efficient air conditioners was assumed to be 4.0 versus 2.67 for conventional unitary air conditioners that prevails in Maldives. The entire stock of unitary air conditioners in 2012 was estimated to comprise some 76,000 units of which 66% was assumed being conventional types with low energy efficiency. The useful lifetime of air conditioners was taken to be 5 years. For the mitigation option conventional types were envisaged being replaced until 2020 by energy efficient types. The projected stock of energy efficient types for 2020 was more than 74,000 units requiring incremental capital costs of US$9.6 million (i.e. the extra costs of energy efficient types compared with conventional types). Lifetime of ACs was set to 5 years and negative abatement costs of US$313/tCO$_2$e were found for this mitigation option.

Energy efficient air conditioning at resorts

This option builds on the same assumptions as above with regard to unit costs and CoP values, but operational hours were aligned with the occupancy rate at resorts of 0.70. Number of energy efficient air conditioners installed at resorts was projected to be nearly 36,500 given the expected growth rate for the tourism sector. Incremental costs were assessed to be US$4.7 million. Negative abatement costs of US$398/tCO$_2$e were found for ACs at resorts

Energy efficient refrigerators

For this option annual electricity demand of energy efficient refrigerators was assumed to be 0.3 MWh versus 0.86 MWh of conventional types. The entire stock in 2012 was estimated to comprise some 80,000 refrigerators of which 70% was assumed being conventional types with low energy efficiency. For the mitigation option conventional types were envisaged being replaced until 2020 by energy efficient types. The projected stock of energy efficient types for 2020 was 46,000 units requiring incremental costs of US$41.2 million. Lifetime of refrigerators was set to 7 years. Negative abatement costs of US$158/tCO$_2$e were found for this mitigation option.

LEDs for domestic lighting

It was assumed that that all domestically used bulbs are Compact Fluorescent Lights (CFLs) with a useful lifetime of 6000 operating hours equalling 3.3 years. In this option all CFLs were envisaged being replaced with Light-Emitting Diodes (LED) until 2020 consuming 40% less electricity than CFLs and with lifetime equalling 10 years. Based on import statistics on CFLs, number of LEDs in use by 2020 was projected to be nearly 875,000. The incremental costs (discounted) for this amount of LEDs were found to be US$42.4 million. Abatement costs were found to be US$199/tCO$_2$e and LEDs were accordingly the only investigated demand side option that came out with net mitigation costs.

LED tubes for public sector

This option looks into the impact attached with the donation from China comprising 70,000 LED tubes (termed the Fahiali programme). The evaluation was based on comparison of electricity demand of 16 Watt LED tubes with assumed lifetime corresponding to 21 years

[47] CoP is given by the cooling capacity divided by input power.

versus the electricity demand of conventional 36 Watt tubes with estimated lifetime of 1.5 years. The LED tubes were assessed spending 44% of the electricity demand of conventional tubes which equalled to annual net savings by 2020 of nearly US$1.1 million where all LED tubes were taken to be in use. This provides for negative abatement costs of US$784/t$CO_2$e.

Centralised cooling systems in new buildings

An energy audit for the former MHE building with nearly 2,000 m^2 floor area suggested the present 126 kW input power required for cooling as per the currently installed decentralized air conditioners to potentially be reduced to 79 kW with a centralized air conditioning system, thereby reducing the electricity consumption with 38%. In this option these audit results were applied to the 270336 new floor square meters that were approved for construction in 2012 as they were assumed to be constructed and in use by 2020. In the reference scenario these new floor square meters were taken to be cooled by unitary (decentralized) air conditioners in accordance with the prevailing practices, however, they were assumed to be energy efficient types and not conventional types. Lifetime was set to 7 years for both centralized cooling systems and decentralized air conditioners.

The incremental capital costs were assessed to be US$ 1.8 million. Negative abatement costs of US$369/t$CO_2$e were found for this mitigation option.

LED tubes for street lighting

In street lighting 100 W LED tubes saves approximately 60% of the electricity demand of a 250 W Sodium Vapour Lamps. There are around 2200 such applications of Sodium Vapour Lamps for street lighting including 1500 at harbours. For this option, LED tubes were envisaged for all 2200 applications plus for new applications required as per the growth rate assumed for electricity. Since Sodium Vapour Lamps were taken to have a useful life time corresponding to 5.5 years, 2.1 replacements of Sodium Vapour Lamps were projected in order to equal the lifetime of LED tubes, which was set to 11.4 years.

Negative incremental capital costs of US$ 70.1 thousand were found for all applications of LED tubes compared with Sodium Vapour Lamps. Negative abatement costs of US$292/t$CO_2$e were found for this option.

Note that the costs estimate is preliminary and costs savings over-estimated as costs of replacement of lamps were not taking into account.

Energy efficient water pumping

In outer islands households are supplied with ground water from individual wells and also in Greater Malé Region households are supplied from wells with groundwater for toilet flushing. Around 49,000 households have their own water pump using this type of ground water pumping from wells. In this option conventional pumps are envisaged being replaced with energy efficient pumps offering efficiency gains at 60% over conventional pumps. Number of applications by 2020 was estimated to have increased to nearly 74,500 applications as per the expected growth rate in electricity demand.

Incremental costs were estimated to be nearly US$14.5 million. Lifetime of pumps was set to 20 years. Negative abatement costs of US$117/t$CO_2$e were found for this mitigation option.

Water consumption in Malé was assumed to be 1 m^3/day and 2 m^3/day elsewhere.

9.4.4 Options within transport

Better maintenance of motor bikes

In 2012 there were about 36,000 motor bikes on Malé and about 10,000 motor bikes on other islands. Their estimated petrol demand was around 17 million litres which may grow to 25 million litres according to growth expectation for the transport sector. For this option energy consumption was assumed to decrease by means of improved maintenance. The present fuel economy of motor bikes was estimated to be 15 km/l on average. However, the fuel economy estimated by manufacturer ranges from 35-55km/l. For this option an average of 25 km/l was assumed to be within reach for all the motor bikes and with no extra costs. Annual net savings were found to be US$10 million leading to negative abatement costs of US$413/$tCO_2e$

Bioethanol 15% blend in petrol

This option aligned with the target set out in the National Strategy for Sustainable Development (NSSD) of 20% bio fuel in transport in 2020. In order to stay below the blend wall it was assumed that 15% of the projected 36.2 ktoe demand for petrol in 2020 was replaced by a 15% bio ethanol blend. The projected demand by 2020 stemmed from the BAU energy balance projection subtracted the estimated savings in petrol demand derived from the mitigation option on improved fuel economy of motor bikes.

According to the Agricultural Outlook 2013 (OECD-FAO 2013) the bio ethanol price was expected to remain unchanged until 2020, and according to the IISD (International Institute for Sustainable Development, 2013), the highest price in the period 2010-2012 was US$0.83/litre. It was therefore assumed that the biodiesel price will lie at around US$0.83/litre in 2020. However, 66% more ethanol is needed than petrol due to the lower energy density of ethanol.

It was assumed that there would be no incremental capital costs attached with introducing bio ethanol blend, whereas annual net cots was found to be US$4.9 million leading to net abatement costs of US$337/$tCO_2e$

9.4.5 Biodiesel option

Biodiesel 20% blend in diesel

This option aligned with the target set out the National Strategy for Sustainable Development (NSSD) of 20% biofuel in transport in 2020. For this option, the introduction of bio diesel was, however, envisaged for the entire diesel demand in all sectors. The projected 184.3 ktoe demand for in 2020 was replaced by 20% biodiesel blend. The projected demand by 2020 stemmed from the BAU energy projection subtracted estimated overall savings attained from all other options targeted mitigation from diesel fuel.

According to (OECD-FAO 2013) the biodiesel price was expected to remain unchanged until 2020, and according to (International Institute for Sustainable Development, 2013) the highest price in the period 2010-2012 was US$1.20/litre. It was therefore assumed that the biodiesel price will lie around US$1.20/litre in 2020.

It was assumed that there would be no incremental capital costs attached with introducing bio diesel blend, whereas annual net cots was found to be US$74 million leading to net abatement costs of US$358/$tCO_2e$.

9.5 Costs of compliance through offsetting

The abatement cost curve created from the GACMO suggested that 25% of projected BAU emissions can be mitigated with measures having negative lifetime abatement costs i.e. contributing with net savings. Increasing mitigation from 25% to 37% comes with net costs mitigation measures and notable at net costs higher than current offset prices. This means that it would be more cost efficient for Maldives to offset the remaining domestic emissions than to bring them to zero by further means of domestic mitigation actions.

Prices of CERs for the compliance market are currently less than one US dollar per tonne. There is no information in the public domain on prices of CERs purchased for voluntary cancellation which is one of the two options eligible to Maldives, but CERs for voluntary cancellation are likely available at the same low prices as appears for CERs in the compliance market.

The second offsetting opportunity available to Maldives is to purchase VERs from the voluntary market originating from projects registered under the CDM. The voluntary market is much less liquid and predictive than compliance markets and prices vary among project standards under which the offsets are issued. The average volume weighted price of VERs reported from market players in 2012 was US$5.9 per tonne (Bloomberg 2013). VERs (or CDM-offsets) constitutes, however, an insignificant share of the 2012-transactions in the voluntary market (less than 1% of transacted volumes) and the average price of VERs gives therefore little information on the prices attainable in the “CDM-offset“ segment of the voluntary market.

As a current price range for further considerations on offsetting, prices between one and six dollars per tonne may be expected. Given a target of say conservatively 1.5 million tonnes in offsets, costs of offsetting would be in the range of US$1.5 million and US$9 million which is far below the savings that can be tapped by pursuing the options for domestic mitigation explored for the abatement costs analysis.

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Annex A GACMO-model

Assumptions used for calculations by GACMO

Energy conversion - and fuel emissions factors

Annex Table 1 GHG-emissions factors and energy conversion factors

	Emissions factor	Conversion factors			
Fuel type	$kgCO_2/GJ$	Tonne	Litres	Toe	GJ
Fuel oil	77,4				
Diesel oil	74,1	1	1190	1.03	43.3
Petrol	69,3	1	1333	1.07	44.8
Kerosene	71,9				
LPG	63,1				
Natural gas	56,1				
Coal	94,6				
Lignite	110,0				
Biomass	0,0				
Bio diesel		1	1132	0.86	36.0
Ethanol		1	1324	0.65	26.8

Emissions factors stems from IPCCs default emissions factors. Energy conversion factors stems from http://www.iisd.org/gsi/sites/default/files/bf_uk_fqdmodel.pdf

Fuel prices and electricity generation costs

Fuel prices were conservatively assumed not to increase during the lifetime of the mitigation technologies explored. Calculations were made with fixed prices at 2013-price level.

Annex Table 2 Fuel prices

	Fixed fuel prices at 2013-price level					
	Diesel	Biodiesel	Petrol	LNG	Bioethanol	LPG
US$/litre	1.06	1.20	1.04		0.83	
US$/GJ	29.2	37.7	31.0	9.5	41.0	21.0

Baseline electricity generation costs were accordingly also assumed to remain constant for the periods considered and fixed at 2013-price level. The baseline electricity generation technology considered was diesel generators and electricity generation costs were established purely as the diesel fuel costs per unit net electricity generated from the diesel generators. The electricity generation costs (before grid losses) were obtained from the MEE as follows:

Annex Table 3 Fuel costs for net electricity generation

	Fuel costs per kWh electricity from diesel generators fixed at 2013-price level			
	Large islands grids	Medium islands grids	Small islands grids	Power grids of resort islands
US$/kWh	0.31	0.34	0.46	0.34

Fuel costs for resorts islands were set to the same level as medium islands grids as thermal efficiencies of resort islands were understood to correspond with the average value of thermal efficiencies of islands with power systems classified as medium systems.

Since calculations assumed the same values whether for mitigations on electricity supply side (such as PVs to replace electricity from diesel generators) or electricity demand side (such as more efficient air conditioners) and since these values were understood not to take distribution losses into account, costs savings of demand side options were likely underestimated. Accordingly, electricity generation costs measured per unit electricity delivered at the gate of end-users and thereby taking network losses into account would be higher than electricity generation costs measured per unit net electricity generated from diesel generators.

Grid electricity emissions factors

Grid electricity emissions factors were taken to remain unchanged for the lifetimes of the mitigation options considered for the analysis. Grid emissions factors applied to mitigation options on the supply side took thermal efficiencies of diesel generators into account and they were accordingly given as CO_2e-emissions per unit net electricity generated from diesel generators. Contrary to grid electricity costs, grid emissions factors used for options on the demand side took also grid losses into account. Accordingly, they were determined as CO_2e-emissions per unit electricity delivered at the gate of end-users (i.e. after accounting for distribution losses).

Thus, grid emissions factors were established from the IPCC default factor on CO_2e-emissions from fossil diesel fuel (74.1 kgCO_2e per GJ fuel), assumed thermal efficiencies of diesel generators in the baseline and assumed baseline grid losses. Following grid emissions factors were found:

Annex Table 4 Grid emissions factors and assumptions

	Greater Malé Region	Outer islands	Resort islands
Thermal efficiencies	37%	32%	32%
Grid losses	8%	20%	20%
Overall system efficiencies	34%	26%	26%
Supply side emissions factor in kgCO_2e/kWh electricity	0.72	0.83	0.83
Demand side grid emissions factor in kgCO_2e/kWh electricity	0.78	1.04	1.04

Other assumptions

Exchange rate US$: MVR was set to 15.42 MVR
Discount rate was set to 7%.

User Guide with example on spreadsheet for a mitigation option

The GACMO model is made in an Excel notebook. The model comprises a spreadsheet for each mitigation option plus the following four sheets:

- *Assumptions*, which contains the values shown in above Annex Tables 1 and 4 and which were used as default values in the calculations;
- *Energy prices,* which contains the default values for fuel prices and electricity generation costs given above in Annex Tables 2 and 3;
- *Main*, which contains a summary table collecting results from each of the spreadsheets on mitigation options and;
- *Graph*, which displays the Abatement Cost Curve of options selected for the curve.

In the below, the template for input values and results of calculations for a mitigation option was explained. The mitigation option on solar PVs in Greater Malé Region was used as example.

1 kW grid connected PVs in Greater Malé Region versus diesel fuelled power			
Costs in US$	Mitigation option	Baseline	Difference
Investment	3000		
Lifetime in years	20		
Levelized investment	283		283
Annual O&M	30		30
Annual fuel costs		453	-453
Total annual costs	313	453	**-139**
Annual emissions			Abatement
Fuel in tCO_2e	0,0	1.05	1.05
Other			
Total in tCO_2e	0,0	1.05	**1.05**
US$/$tCO_2e$			**-133**

General inputs:		
Discount rate	7%	
Baseline electricity costs	0.31	US$/kWh
Emissions factor	0.72	tCO_2e/MWh
Mitigation option: Solar PVs		
Investment in PVs	3000	US$/kW
Capacity factor	1825	full load hours
Efficiency factor	0,8	
Electricity production	1460	kWh/year
Annual O&M	1%	of capital costs
Baseline: Electricity from diesel generators		
Electricity production	1460	kWh

Electricity generation costs	0.21	US$/kWh

As indicated in the top row, the mitigation option was here defined as the installation of 1kW PV to reduce emissions from electricity from diesel generators.

The right hand side is for input values. Under *General inputs* default values for discount rate, baseline electricity generation costs in Greater Malé Region and grid emissions factor were taken from the sheets *Assumptions* and *Energy prices.* As they were all default values, cells were not colour coded..

Below in cells marked with yellow follows input values for the mitigation option: capital costs for PVs of 1kW; Operating and Maintenance (O&M) costs; annual hours of operation at full load (which gives the annual electricity generation when multiplied with the capacity of 1kW) and; the efficiency factor that reduced the output due to the high temperatures in the Maldives. Annual electricity generation from 1kW was accordingly calculated to be 1460 kWh. The same value for electricity generation in the baseline was inserted since baseline and mitigation option should deliver the same service.

The upper part of the left hand side shows costs of the mitigation option and the baseline respectively and calculates the net costs as the difference between the two. Negative values mean that the mitigation option provides for net savings i.e. baseline costs exceed mitigation costs. Positive values means that mitigation costs exceed baseline costs and there would accordingly be net costs attached with the mitigation.

In this example it was conservatively assumed that there would be no capital costs and O&M costs in the baseline (which is electricity generated by diesel generators), only fuel costs. Fuel costs were in this example determined to be equivalent to the baseline electricity costs as these were determined as fuel costs per unit electricity generated by diesel generators, here 0.31 US$ kWh as displayed under *General inputs.*

The value for *Levelized investment* is calculated by a formula available in excel by which investment costs (capital costs or "overnight costs") are levelized over the lifetime and discounted by a discount rate, here set to 7%. The lifetime of PVs was set to 20 years. Annual O&M costs in the mitigation option were in this example 1% of investment costs, whereas there will not be any fuel costs. Fuel costs for the baseline were determined as the electricity generation required by diesel generators (1460 kWh annually) at the baseline electricity unit costs.

In the bottom part of the left side annual GHG-emissions were calculated. In this example, the baseline only emits GHG and only from combustion of diesel. Hence, in this example the resulting abatement equals emissions in the baseline that were 1.05 tCO_2e. Abatement unit costs were subsequently found as annual net savings (found to be US$ 139) divided over annual mitigation, which is the key-result for the abatement cost curve. In this example abatement unit costs were found to be negative because baseline costs and baseline emissions exceed costs and emissions of the mitigation option. Accordingly, 1kW PV leads to net savings of estimated US$ 133/tCO_2e.

However, the solar PV programme of the SREP Investment Plan envisages installation of 15 MW. In order to scale up overall potential mitigation available from this option, number of units of 1kW inserted in the sheet *Main* under in the column *Number of units penetrating in 2020* were therefore 15,000.