The Converging World:
The social and environmental impact of convergence
UWE research output UWE-JPT#01

Dr Mark Everard

Associate Professor of Ecosystem Services

University of the West of England

University of the West of England

Research supported by the John Pontin Trust

A Bristol 2015 European Green Capital legacy project

Suggested citation:
Everard, M. (2015). *The Converging World: The social and environmental impact of convergence*. Research report UWE-JPT#01 by the University of the West of England (UWE Bristol) for the John Pontin Trust.

Contents

Executive summary

This study, led by the University of the West of England (UWE Bristol) and supported by the John Pontin Trust (JPT), aims to provide evidence of social impact (societal benefits, often expressed as social interest on investment or SROI, many of which are not currently marketed) from renewable energy and eco-restoration schemes led by The Converging World (TCW) Group.

The TCW programme has also been substantially supported by the John Pontin Trust (JPT).

The 'Brindia' (Britain-India) programme conceives 'Brindia' as a virtual country of two parts:

- South West England, spanning 9,200 square miles (23,800 km^2) and home to approximately 5 million people with cumulative annual emissions of 44.85 million tonnes CO_2 at approximately 8.97 tonnes CO_2 per capita; and
- Tamil Nadu state in southern India, covering 50,216 square miles (130,058 km^2) and home to over 72 million people with annual emissions of 111.86 million tonnes CO_2 (nearly three times that of south west England) at an annual mean of 1.59 tonnes CO_2 per capita (less than 1/5 the south west England average.).

Through partnering and conceptually linking these developed and developing world regions into one notional geographical unit – 'Brindia' – India's right to develop can be promoted on a lower carbon trajectory, whilst south west England's need to manage contributions to climate change can be promoted through cross-national partnerships as climate change impacts are geographically independent of where carbon emissions and sequestration occur. 'Brindia' therefore constitutes an ambitious, market-based project linking sustainability aspirations between south west England and Tamil Nadu. Already, the TCW Group (operating through a range of companies including operating branches in India) has 12.9MW of installed wind turbine capacity in Tamil Nadu, and is investing in eco-restoration of tropical dry evergreen forest (TDEF) as one of its programmes.

To generate evidence of social return on investment (SROI: taking account of the breadth of societal benefits many of which are not currently marketed) from TCW Group renewable energy and TDEF eco-restoration schemes, this study uses the ecosystem services framework. Specifically, it uses the classification of ecosystem services developed by the UN Millennium Ecosystem Assessment to assess the fullest possible range of benefits and potential disbenefits (disadvantages or losses) accruing to a diversity of people.

Ecosystem services are identified as the most appropriate framework for SROI assessment as: (1) distributional impacts on people occur through the shared medium of the natural environment; and (2) technology deployment and ecosystem management generates a set of benefits and disbenefits that are inherently interconnected and so it is important to assess them as an integrated set to avoid unintended negative outcomes, as well as recognising all potential co-benefits.

Assessment of both direct and indirect benefits, as well as potential disbenefits, arising from TCW Group renewable energy generation and TDEF eco-restoration schemes (Sections 2 and 3 respectively) has been addressed on an indicative basis, as quantification and monetisation were not possible within the bounds of this initial study. In summary:

- Direct and indirect benefits / potential disbenefits associated with TCW Group renewable energy generation include:
  - Improved access to water through powered pumping, though governance is required to avoid depleting groundwater resources.
  - Avoiding water use for traditional generation protects water resources.
  - Improved food and fibre/fuel security through water availability for irrigation.
  - Empowerment of women freed from the drudgery of traditional roles fetching water, fodder and fuel wood.
  - Protection of genetic, traditional medicinal and ornamental resources through reduced habitat conversion for traditional generation technologies.
  - Reduced climate-active gas emissions and impacts on microclimate and indoor air.
  - Contribution to improved landscape hydrology (flood and drought risks) and regulation of pest and diseases (human and stock) and pollination.
  - Displacement of alternative energy generation protects cultural values from the environment, though renewable energy resources need careful planning and siting.
  - Protection of natural processes underpinning ecosystem resilience and functioning.
- Benefits and potential disbenefits associated with TCW-funded eco-restoration of TDEF include:
  - Direct enhancement of quality, quantity and flows in the water system.
  - Enhancement of forest-sourced food, fuel and fibre, and forest-tolerant crops.
  - Support for species of genetic, medicinal and other uses, promoting local crafts and businesses, often led by women providing revenue and empowerment.
  - Regulation of global and local climate.
  - Buffering of storm energy, protecting crops and built infrastructure.
  - Improved regulation of pests and diseases (human and stock) and of pollination.
  - Buffering risks of soil and aquifer salinisation.
  - Providing visual and noise buffering, and restore culturally important landscapes.
  - Supporting forest activities generating pro-poor income, employment and training.
  - Enhancing natural processes underpinning landscape resilience.

These potential benefits do not arise without potential disbenefits. Sound governance and local involvement in planning is therefore required, for example, to avert insensitive siting of wind turbines or displacement of ecologically or cultural important sites through forestation.

The carbon dioxide (climate regulation) benefits of TDEF eco-restoration received particularly detailed scrutiny, including the consideration of both the costs of CO_2 sequestration directly through TDEF restoration and also when a proportion of operating margins from sales of renewable energy from TCW Group wind turbines is reinvested in TDEF restoration.

All calculated figures have to be regarded with caution as the published data upon which they are based are sparse; further research is needed to test illustrative calculated values.

- Annual CO_2 sequestration in restored TDEF = 21,995.6 tCO_2 ha^{-1} $year^{-1}$ over a century.
- The costs of CO_2 sequestration based on the costs of TDEF restoration are:
  - £0.74 for 1 tCO_2 $year^{-1}$
  - £ 739.01 for 1,000 tCO_2 $year^{-1}$
  - £ 739,011 for 1 million tCO_2 $year^{-1}$

If a reinvestment of £100,000 is made in TDEF restoration (annual incremental additions of 6.15 hectares) **for each operational year** over scheme life (20 year depreciation of turbine and 100 year carbon sequestration in each block of TDEF until it reaches climax community), this yields:

- Lifetime carbon sequestration/avoidance of 270,605,880 tCO_2, of which:
  - CO_2 sequestration through TDEF restoration = 270,545,880 tCO_2 (99.978%)
  - CO_2 avoidance from the turbine = 60,000 tCO_2 (0.0.22%)

Dividing the installation cost of a 2.1 MW wind turbine (£1,575,000) by gross carbon sequestration/avoidance over scheme life with 20 years annual reinvestment of £100,000 in TDEF restoration (270,605,880 tCO_2) yields:

- Cost per unit tCO_2 sequestered/avoided = £0.0058 £ per tCO_2 (0.58p per tCO_2)

The overwhelming contribution of TDEF restoration to the above value concurs with the findings of the 'Stern Review' that reforestation is one of the most economically efficient means to tackle climate change. The cost-effective figures above compare with a return of £26.25 per tCO_2 avoided over the 20 year depreciation life of the wind turbine alone.

TCW Group is working to implement measures to secure these benefits on an enduring and transparent basis, including for example the vesting of land purchased for TDEF eco-restoration in trust with public beneficiaries of the 'Brindia' partnership.

Climate regulation benefits constitute just one of a broad linked set of ecosystem services – by majority non-market and also unquantified within this focused initial study – arising from and likely to increase the cumulative significance of SROI outcomes arising from TCW Group renewable energy generation and eco-restoration activities. These benefits support sustainable development aspirations and commitments at Tamil Nadu state level as well as internationally. All 17 of the UN Sustainable Development Goals (SDGs) are supported by aspects of 'Brindia' investment.

When climate regulation and cost calculations for TCW Group investment in wind turbines and reinvestment in TDEF eco-restoration are related to implications for aspirations and commitments by Bristol City, the south west of England and the wider UK, investment in Tamil Nadu represents a highly cost-efficient pathway to reducing overall emissions and delivering a range of linked ecosystem service co-benefits.

The calculated figures below are all illustrative only; all need further research to underpin them with solid evidence. Additional evidence will consolidate a transparent business case.

The 123 hectares of restored TDEF resulting from reinvestment of operating margins over the 20-year depreciation lifetime of a wind turbine will sequester:

- Annually, approximately 2.7 million tCO_2 $year^{-1}$.
- Cumulatively, approximately 270 million tCO_2 as each annual area matures to climax.

In simplistic terms, this 270 million tCO_2 cumulative total is approximately equivalent to total Bristol City-wide emissions over a century of approximately 255 million tCO_2.

A capital fund for installation of a 2,1 MW wind turbine in Tamil Nadu used to generate funds for annual TDEF eco-restoration might illustratively represent:

- Investment in an initial year of £3:60 for each of Bristol City's 440,000 population; or
- A one-off £7:88 supplementary charge on rates for an assumed 200,000 rate-payers.

Simplistically extending these same broad approximations to the 5 million people of south west England, annual reinvestment of £100,000 from operating margins from each of **ten turbines** into TDEF restoration would sequester approximately 2.7 billion tCO_2 over a century in a total of 1,230 ha TDEF, roughly balancing the total emission of 2.9 billion tCO_2 by the population of south west England over a century. Calculations can be extended to UK scale with a proportionate increase in uncertainties.

They can also be applied at institutional scale (universities, businesses, municipalities and other organisations), particularly those with carbon reduction obligations. Taking the University of the West of England (UWE) as a Bristol-based example, UWE's approximate cumulative total UK carbon dioxide emissions of 35 million tCO_2 over a century might be met by a £189,000 contributory investment in turbine installation from which reinvestment of operating margins would sequester that quantity of carbon dioxide.

Similar calculations can be made for investment on behalf of individuals to sequester their likely carbon emissions over life. There are many linked assumptions in deriving such a figure, making calculated values highly uncertain. A purely indicative, highly uncertain value of £1:50-£2:57 per person emerges from highly extrapolated calculations.

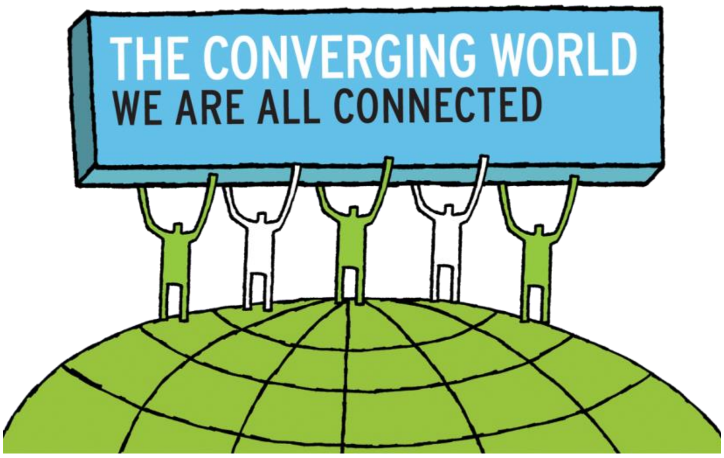
Investment in renewable energy and reinvestment in eco-restoration in Tamil Nadu is economically efficient for the notional 'super-region' of Brindia. Gross carbon dioxide emissions for Brindia as a whole are reduced in the most rapid and cost-efficient way. These investments also help Tamil Nadu develop on a lower-carbon pathway, and the wider spectrum of ecosystem service co-benefits represent pro-poor development and resource and livelihood security.

Key conclusions and recommendations from this study are summarised below from their full articulation in Section 8 (conclusions in black font and recommendations in purple).

Precis of key conclusions and recommendations
(Recommendations in purple)

- A diversity of both direct and indirect benefits, and some potential disbenefits, arise from TCW-sponsored renewable energy generation.
    - Recommendation: Prioritise and quantify a range of the more significant benefits.
- A diversity of benefits, and some potential disbenefits, also arise from TCW-sponsored TDEF eco-restoration.
    - Recommendation: Prioritise and quantify a range of the more significant benefits.
- Reinvestment of operating margins from wind energy generation into TDEF eco-restoration makes a substantial and long-lasting contribution to carbon dioxide sequestration/avoidance.
    - Recommendation: Review carbon sequestration figures calculated for TDEF restoration.
- TCW renewable energy and eco-restoration schemes address a range of sustainability goals, many of which are included in the UN Sustainable Development Goals (SDGs).
    - Recommendation: Promote contribution of TCW programmes to SDGs.
    - Recommendation: Seek means to upscale and outscale the TCW approach.
    - Recommendation: Present evidence in simpler terms to communicate to partner bodies.
- The TCW approach is more sustainable and equitable than India's industrial development goals.
    - Recommendation: Dialogue with Indian government about Sustainable Development Goals.
    - Recommendation: Dialogue with legislators/regulators to facilitate uptake of TCW approach.
- There is a compelling case for continuing TDEF eco-restoration for climate and other benefits.
    - Recommendation: Strengthen the case for TDEF restoration by quantifying wider benefits.
- Significantly beneficial climate and wider ecosystem service outcomes are likely to accrue from eco-restoration of linked habitats (mangroves, tank and wetland systems, hill slopes, etc.).
    - Recommendation: Research required into benefits likely to arise from restoration of Tamil Nadu's other natural habitats (particularly mangroves, tanks, wetlands and hill slopes).
    - Recommendation: Prioritise and build a business case for investment in their restoration.
    - Recommendation: Explore potential benefits from habitat restoration in UK partner region.
- Significant co-benefits accrue both to south west England and the partner Indian region.
    - Recommendation: Develop further evidence of co-benefits to strengthen the business case.
- Careful management is required to optimise benefits and also to avert potential disbenefits.
    - Recommendation: Engage regulators and local people in steps to avert potential disbenefits.
- TCW has a compelling and positive story to tell about practical sustainable progress.
    - Recommendation: Involve media in communication of this positive story.
- Parallel progress with renewable energy and eco-restoration was not evident in SW England.
    - Recommendation: Promote renewable energy and eco-restoration in UK 'Brindia' region.

End of Executive Summary



The Converging World:
The social and environmental impact of convergence
UWE research output UWE-JPT#01

UWE BRISTOL
University of the West of England

1. Introduction to this study

This document outlines research funded by the John Pontin Trust (JPT) addressing the breadth of benefits arising from one aspect of The Converging World (TCW) programme: a twinning of the renewable energy and linked eco-restoration projects otherwise known as 'Brindia'. The wider TCW programme, also substantially seed funded by JPT, is outlined in Annex 1.

1.1 What is Convergence

To illustrate convergence, the 'Brindia' (Britain-India) project conceives 'Brindia' as a virtual country of two parts: south west England which hosts carbon-intensive lifestyles; and Tamil Nadu state, India, where implementation of low-carbon energy can promote sustainable development (see Figure 1).

Figure 1: Locations and extent of south west England and Tamil Nadu state, India

South west England (image from en.wikipedia.org)

Tamil Nadu state, India (image from en.wikipedia.org)

Some of the characteristics of these two constituent regions of 'Brindia' are:

- South West England is one of nine official regions of England, the largest such region spanning 9,200 square miles (23,800 km^2) and home to approximately 5 million people. It comprises the counties/unitary authorities of Gloucestershire, Bristol, Wiltshire, Somerset, Dorset, Devon, Cornwall and the Isles of Scilly. Assuming annual emissions of 8.97 tonnes CO_2 per capita[1], total annual regional emissions for south west England equal 44.85 million tonnes CO_2 (just over 8% of total UK CO_2 emissions).

[1] 8.97 tonnes CO_2 per capita figure from UN Statistics Division (UNSD, http://unstats.un.org/unsd/environment/air_co2_emissions.htm, accessed 9th September 2015), with total UK figure of 546.43 million tonnes CO_2 for the UK as a whole.

- Tamil Nadu is the eleventh largest state of India by area (50,216 square miles, or 130,058 km^2) and the sixth most populous state (72,147,030 people). Total emissions by Tamil Nadu state in 2008-2009 were reported as 111.86 million tonnes CO_2 (nearly three times that of south west England), though at only an annual mean of 1.59 tonnes CO_2 per capita[2].

Investors in south west England can support progress towards sustainable development across the virtual 'Brindia country' in a number of ways. A principal means is investment in renewable energy generation and habitat restoration in India as a most cost-effective means to reduce overall CO_2 emissions across Brindia. This cross-national partnership is valid as climate change impacts are geographically independent of where carbon is emitted or sequestered. Implementing these schemes in India can help this developing country make socio-economic progress on a sustainable pathway as well as 'offsetting'[3] the carbon emissions of south west England as part of its own sustainable development journey. 'Brindia' is therefore an ambitious, market-based project linking sustainability aspirations between south west England and Tamil Nadu state, India.

1.2 Key elements of the 'Brindia' programme and their context

One of the core activities under the 'Brindia' programme is installation of wind turbines in Tamil Nadu to promote low-carbon development, at the same time 'offsetting' emissions from south west England through investment products as one component of a wider package of restorative measures. The scheme is led from the UK by The Converging World (TCW) Group, which has operating branches in India (the network of TCW-linked companies is described in Annex 1). 12.9MW of installed capacity is already in situ under the scheme in Tamil Nadu. These wind turbines are capable of generating 25 million units (kWhr) a year (seasonally variable) of low-carbon energy as well as associated energy sales operating margins with a 20-year depreciation (and estimated life span of 25 years). (Further details of the business model and aspirations for turbine installation and operation in Tamil Nadu are provided in Annex 1.)

Whilst India's total CO_2 emissions are forecast to beat Europe's output in 2019[4], these emissions are distributed amongst a far larger population. Nevertheless, as extensively reviewed in an article in *The Guardian* in May 2015[5], India is pursuing an aggressive pace of exploitation of coal. National and international 'development-out-of-poverty versus environment' political forces behind India's goal of doubling or tripling its production of coal will make it the world's second largest carbon emitter, adding to India's contribution already to around 7% to the warming the world has seen so far. Jairam Ramesh, leader of India's delegation to the 2009 UN Framework Convention on Climate Change (UNFCCC) conference in Copenhagen in 2009, is quoted in *The Guardian* article as saying, "*It's a double whammy: the more coal we extract, the more forest we lose, and that too will add to global warming*". Air and water pollution from India's massive open cast mines is also contributing

---

[2] Confederation of Indian Industry. (2012). *Estimation of Tamil Nadu's Carbon Footprint (for stakeholder consultation)*. Confederation of Indian Industry, Hyderabad. (http://www.greenbusinesscentre.com/site/ciigbc/footprint.jsp, accessed 9th September 2015.)

[3] Offsetting is a term usually associated with independently verified carbon credits accredited to an internationally recognised scheme. This report uses the term 'offsetting' more loosely and generally refers to the amount of carbon avoided by the generation of electricity from renewable sources when compared with that of fossil fuels or the carbon sequestered by reforestation. It is then equated to the amount of carbon emitted in South West England as an 'offset'.

[4] Matt McGrath, M. (2014). China's per capita carbon emissions overtake EU's. *BBC News*, 21st September 2014. (http://www.bbc.co.uk/news/science-environment-29239194, accessed 15th November 2015.)

[5] Rose, D. (2015). Why India is captured by carbon. *The Guardian* [online], 27th May 2015. http://www.theguardian.com/news/2015/may/27/why-india-is-captured-by-carbon (accessed 10th July 2015).

to serious health concerns, which fall disproportionately upon the poor, particularly the Adivasi (tribal people), whom increasing energy generation targets are intended to lift out of poverty.

Fossil fuel, nuclear and renewables are all seen as part of a future energy mix in India. Solar generation is singled out for particularly rapid growth in India, whereas nuclear, which provides less than 5% of India's electricity, meets strong political resistance. India's Energy Minister, Piyush Goyal, announced $US100bn investment over five years to help India become a "renewables superpower", though with coal-fired electricity generation also undergoing "very rapid" expansion[6]. Against this backdrop of burgeoning energy demand and the opportunity to increase the low-carbon contribution to the mix, TCW plans to develop renewable energy (including wind and solar) contributing to installed renewable capacity in India.

Underpinning TCW programmes is recognition that, whilst the world is likely to exceed a global atmospheric concentration of 450ppm CO_2 under current trends before then 'converging and contracting', a longer-term aspiration that civil society could and should grasp is to return this to a level of 280ppm. ('Contraction and convergence' is posited as a solution to global climate change challenges, recognising that "…*the right to emit carbon dioxide is a human right and should be allocated on an equal basis to all of humankind*" with allocation of target shares of tolerable CO_2 emissions back-calculated allowing poor countries capacity to grow while developed countries, economically advantaged on the back of historic emissions, would contract per capita emissions, offering opportunities for trading in the interim before countries ultimately converge at a sustainable and equitable level of emissions[7].) This 280ppm aspiration, which will most likely not be politically led though will doubtless be politically welcomed if progress is made beyond mere stasis of concentration, is representative of pre-industrial air as it is close to the average of CO_2 measured and dated with high time resolution between the years 1,000 and 1,800 in an ice core from Law Dome, Antarctica[8].

Linked to the investment in wind turbines is bio-regional eco-restoration, initially of selected regionally characteristic forest but conceivably extending to other naturally occurring habitats including mangroves, tanks, wetlands and inland hill slopes. Forest eco-restoration provides carbon sequestration, employment and a range of linked, primarily benefits. Therefore, these initiatives not only offer the possibility to sequester carbon, but also to provide income and a range of other linked direct and indirect societal benefits.

[6] Carrington, D. (2014). India will be renewables superpower, says energy minister. *The Guardian* [online], 1st October 2014. http://www.theguardian.com/environment/2014/oct/01/india-will-be-renewables-superpower-says-energy-minister (accessed 10th July 2015).
[7] Meyer, A. (1990). *Contraction and Convergence: The Global Solution to Climate Change (Schumacher Briefings)*. Green Books, Cambridge.
[8] Etheridge, D.M., Steele, L.P., Langenfelds, R.L., Francey, R.J., Barnola, J.-M. and Morgan, V.I. (1996). Natural and anthropogenic changes in atmospheric CO2 over the last 1000 years from air in Antarctic ice and firn. *J. Geophys. Res*., 101(D2), 4115–4128, doi:10.1029/95JD03410.

1.3 About this study

This study is a targeted piece of research outlining aspects of social return on investment (SROI) from low-carbon energy investment and eco-restoration in Tamil Nadu. The research is carried out as a partnership between the University of the West of England (UWE) and the John Pontin Trust (JPT), providing evidence for The Converging World (TCW) to support convergence and the promotion and future evolution of the 'Brindia' approach of notional nations comprising developed and developing nations, regions or communities. It is envisaged that this small, targeted initial research programme will also constitute a stepping stone towards further mutually beneficial investment in an endowed chair at UWE supporting the expanding TCW programme.

The study includes two principal areas of ecosystem service assessment:

- Section 2: 'Benefits arising from TCW Group wind generation'; and
- Section 3: 'Benefits arising from selected TCW Group eco-restoration activities'.

Section 4 then summarises 'Cumulative benefits from reinvestment of TCW renewable energy operating margins into TDEF eco-restoration' (with calculations and assumptions in supporting Annexes)

Section 5 then turns to 'The contribution of TCW Group programmes to societal wellbeing', addressing market and non-market contributions to state, national and international aspirations and commitments.

Section 6 relates findings about climate regulation back to 'Implications for Bristol, south west England and UK decarbonisation'.

Section 7 addresses 'Investment for good'.

Finally, Section 8 draws out 'Conclusions and recommendations'

The above sections are supported by seven technical Annexes.

1.4 Characterising social return on investment (SROI)

Although there are published methods for tackling SROI, for example the seven principles published by Social Value International[9], it is in essence a flexible, principles-based method for measuring environmental and social values that are not currently reflected in conventional financial accounts[10]. This includes accounting for stakeholder views, and also valuing impacts that lack mainstream market values.

In assessing the fullest possible range of benefits – and as importantly ensuring that potential disbenefits are not overlooked – a rather broader framework is required. As many of these potential

[9] http://socialvalueuk.org/.

[10] The EU Accounts Modernisation Directive (Directive 2003/51/EC) came into effect for large- and medium-sized European companies in January 2005, requiring non-financial reporting particularly including analysis of environmental and social aspects necessary for understanding of the company's performance. A lack of reference in the Directive to how these factors should be reported means that this new requirement is not prescriptive, and these factors are not consistently reported.

benefits and disbenefits are vectored via ecosystems to people, we have selected the ecosystem services framework for this purpose. Ecosystem services are defined as "…*the benefits people obtain from ecosystems*" [11]. Specifically, we will use the UN Millennium Ecosystem Assessment (MA) classification of ecosystem services[12]. (Background information about ecosystem services and justification of choice of the MA classification is the subject of Annex 2). The MA integrated a wide range of pre-existing ecosystem service classifications as part of a new framework spanning four categories:

- Provisioning services: food, fresh water, biochemicals and other substances and energy that can be extracted from nature;
- Regulatory services: natural processes that regulate, for example, flows and quality of air and water, erosion, diseases and climate;
- Cultural services: non-material benefits derived from nature such as spiritual enrichment, tourism and recreation opportunities, and education and research; and
- Supporting services: processes such as soil formation, photosynthesis and the cycling of nutrients and water that maintain ecosystem functioning, resilience and capacity to keep producing other more directly utilised services.

All ecosystem services support different aspects of human wellbeing, the supporting services doing so largely indirectly by ensuring ecosystem integrity, health and capacity to produce other more directly exploited services. Importantly, the ecosystem services framework also emphasises that all are part of an interconnected system, serving as means to deduce how changes in ecosystem vitality and functioning resulting from technology choice and habitat management or use translates into an intimately connected network of social and economic benefits and disbenefits.

The MA framework of ecosystem services addresses both marketed and non-marketed services, best reflecting a breadth of direct and indirect impacts and a diversity of beneficiaries and their value systems. There is also an available assessment guide endorsed by UK Government (Everard and Waters, 2013, *Ecosystem services assessment: How to do one in practice*[13]) based on the MA framework.

[11] http://www.millenniumassessment.org/en/Synthesis.html.
[12] http://www.millenniumassessment.org/en/Synthesis.html.
[13] Everard, M. and Waters, R.D. (2013). *Ecosystem services assessment: How to do one in practice*. Institution of Environmental Sciences London. (https://www.the-ies.org/resources/ecosystem-services-assessment, accessed 15th November 2015.)

1.5 Valuing ecosystem services

Valuation of the diversity of ecosystem service benefits is clearly important if they are to be recognised and weighted in decision-making, including wise investment decisions. Today, many ecosystem services are largely excluded from markets, undermining the resilience of the environment and the benefits it provides as well as the wellbeing of those dependent upon them, with the global poor often suffering the most severe consequences.

Valuation of all ecosystem services is not within the scope of this initial study, although it does go into considerable detail about the costs and benefits of carbon dioxide sequestration and avoidance which form the principal drivers of the TCW business model at present. However, it is important to be aware that climate regulation is just one of an interconnected range of ecosystem services. As net societal benefit, including implications for the integrity and continuing functioning of ecosystems, can only be addressed when all ecosystem services are considered as an integrated system, it is important to acknowledge and subsequently to begin to quantify and value all ecosystem service outcomes in subsequent research.

Annex 7 provides considerable more detail on valuation methods for ecosystem services, also addressing the case for and against their valuation, practical valuation methods and tools noting some useful further information sources and examples of how ecosystem services have been valued in previous studies, with some reflection on further economic considerations.

2. Benefits arising from TCW Group wind generation

Ecosystem service consequences arising from TCW Group wind turbines comprise both direct and indirect benefits as well as potential disbenefits. Other than climate regulation implications (see Section 3nad Annex 5), these outcomes are NOT quantified or monetised within the limitations of this first phase of research.

Annex 3 comprises a series of Tables providing detailed 'ecosystem service by ecosystem service' consideration of the direct and indirect benefits and also potential disbenefits associated with TCW Group wind generation. Making this assessment on a systemic basis is important as all services are produced as a connected set. It has been common historic practice to focus only on single or a limited subset of benefits, whilst overlooking wider ramifications (such as energy or food production methods that are blind to their wider potentially negative consequences). However, to overlook the wider potential co-benefits of more sustainable practices (such as carbon sequestration, hydrological and fishery recruitment benefits arising from some nature conservation measures), or conversely the negative impacts on these linked services and their associated beneficiaries, is potentially inequitable and economically inefficient and can potentially destabilise the ecosystem from which these benefits flow.

The following section summarises key issues identified by the more detailed systemic analysis in Annex 3.

2.1 Summary of direct and indirect benefits and potential disbenefits arising from TCW Group wind generation

Ecosystem service consequences arising from TCW Group wind turbine generation in Tamil Nadu are analysed in a series of Tables in Annex 3. These detailed 'ecosystem service by ecosystem service' considerations make a balanced assessment of benefits, both direct and indirect, as well as potential disbenefits which can inform avoidance or mitigation during careful planning. Benefits and disbenefits are NOT quantified or monetised within the limitations of this first phase of research. However, an illustration of how benefits may be valued is the subject of Annex 7.

The following four Tables summarise key issues identified for each Millennium Ecosystem Assessment ecosystem service category: provisioning, regulatory, cultural and supporting services. (More detailed systemic analysis can be found in Annex 3.) Combined direct and indirect benefits are highlighted in green and cautionary notes to avoid potential disbenefits are highlighted in red.

Provisioning ecosystem services

Generation of low-carbon energy from TCW Group wind turbines makes a contribution to:
• Access to **fresh water** and for its use in production of **food** and **fuel and fibre** indirectly due to:
  o Energisation of groundwater pumping where energy is not available from other sources;
  o Savings in water resource availability where wind generation averts the need for water use in cooling (for thermal energy generation technologies) or hydropower generation;
  o Enhancement in trading of commodities were electronic communication is made possible by electrification; and
  o Empowerment of women freed from historic drudgery of spending much of their time gathering water, fuel wood or fodder in the absence of pumping energy.
• Potential avoidance of harm to habitats naturally supporting **genetic resources**, species of **biochemical, medicinal and pharmaceutical value**, or **ornamental resources** due to displacement of traditional, non-renewable energy production technologies.
 	
Access to energy for additional pumping of water carries with it the risk of promoting the over-pumping of receding groundwater, an increasingly important but over-exploited resource across India. This highlights the importance of promotion of effective governance – coherently across state and local levels – to balance exploitation and recharge of water resources to ensure sustainable management of the linked water-food-energy nexus.

Regulatory ecosystem services

Generation of low-carbon energy from TCW Group wind turbines makes a contribution to:
• **Air quality** as well as **microclimate**:
  o Directly, through averting emissions from coal, biomass and other combusted fuels; and
  o Indirectly through, avoidance of dangerous fumes in houses from biomass fuel burning for cooking.
• **Global climate regulation** through averting:
  o Carbon-intensive emissions from coal, biomass and other combusted fuels; and
  o Methane generation from large dams used for hydropower generation, which are emerging as one of the most globally significant contributors to global warming.
• Potentially, and in an indirect way, to **water regulation** in landscapes as wind farms may contribute to catchment porosity (as has been found for solar farms) and the energy they produce may offset impacts on catchment hydrology resulting from biofuel growth or mining of fossil fuels.
• Indirectly, regulation of **pests**, **diseases** (human and stock) and **pollination** where habitat beneath turbines on wind farms plays host to natural predators, breakdown processes and pollinators, or averts habitat loss for mining, biofuel growth or dam construction. In the context of dams, flow and habitat simplification resulting from water impoundment can be a major contributor to increased human and stock diseases in the tropics due to the proliferation of disease vectors, an effect that wind farms avoid.
 	
Few potential disbenefits are associated with wind power generation, though the issue of noise generation and visual intrusion by turbines is subjective and needs further exploration and, ideally, dialogue with those likely to be affected in proposed wind farm sites.

Cultural ecosystem services
Generation of low-carbon energy from TCW Group wind turbines makes a contribution to: • A range of cultural services – **aesthetics**, **recreation and tourism**, **spiritual**, **inspiration of arts**, etc. – in an indirect manner by potentially averting damage from traditional energy generation technologies. • **Education and learning** through enhanced access to lighting and digital communication to prolong accessible learning into hours of darkness. Perceptions of wind turbines are subjective, and may have some relevance for this range of cultural values. Careful siting, ideally in dialogue with local people, can help avoid or address mitigation measures for adverse interactions.

Supporting ecosystem services
Generation of low-carbon energy from TCW Group wind turbines makes a contribution to: • A range of supporting services – **soil formation**, **primary production**, **cycling of nutrients and water**, **photosynthetic oxygen production** and **provision of habitat** – where wind generation displaces traditional technologies more damaging to habitats and their ecosystem functions. Further review of the literature is required to address disruption of wildlife and natural functions by wind turbines, making use of an evolving science base that may, in future, inform more sensitive siting of turbines and also add further rigour to environmental impact assessment supporting applications to regulators and potential investors.

The Table above is a simplified summary of the more detailed analysis in Annex 3. Ecosystem service impacts are not quantified, this initial phase of research focused on taking a systemic view of benefits and potential disbenefits across the full spectrum of ecosystem services.

Many of these benefits and potential disbenefits are external to conventional markets, such as greater access to lighting for education and pumping energy freeing women from the drudgery of traditional water-carrying duties. Nonetheless, all have a degree of positive or negative impact on people's wellbeing, and so are germane to the overall contribution of wind energy generation to sustainable development. This also highlights a conflict between narrowly framed economic development and another, more ancient and holistic approach based on 'happiness' (or fulfilment of needs), as for example articulated by Norberg-Hodge[14] and also reflected in the Gross National Happiness (GNH) indicator in Bhutan as an alternative to the more globally pervasive, financially oriented Gross Domestic Product (GDP) model of progress. (Alternative economic models are considered in Section 7.)

Recognising this range of benefits across all ecosystem services, including non-market supporting services that retain the integrity and functioning of ecosystems vital for livelihood needs, is an essential part of decision-making about net value of renewable energy generation to the people of Tamil Nadu (with climate regulation benefits expressed globally).

[14] Norberg-Hodge, H. (2000). *Ancient Futures: Learning From Ladakh*. Rider, London.

2.2 Managing potential disbenefits arising from TCW Group wind generation

Not all benefits are realised without risk of direct and indirect disbenefits. By significant majority, these potential disbenefits – mainly relating to cultural perceptions and services and potential impacts on wildlife – are a matter for further study as well as dialogue with local communities to ensure sensitive siting so as not to harm culturally important sites. TCW Group wind farms are large systems, so better understanding of their impact on the landscape is a priority for further research.

A potentially significant disbenefit arises indirectly through the ways in which renewable energy may be used. Specifically, this relates to risks associated with the misuse of energy to over-pump aquifers, resulting in biophysical problems such as resource depletion or contamination by saline intrusion from the coastal zone, saline and sulphurous water rising up from deep groundwater, and equity issues such as denial of access to depleted groundwater by poorer people as those with the necessary resources pump progressively deeper. The situation is compounded by farmers being provided with free electricity in Tamil Nadu, resulting in many pumps being switched on permanently. This is a complex matter of governance, rather than a flaw in the source of energy, highlighting the need for effective governance of the water-energy-food nexus at both state and community levels.

The links between energy sources, availability and use with water systems and food-producing land and water bodies – an interconnected nexus of issues – requires far greater scrutiny and policy reform if sustainability is to be achieved. Land cover and use pose particular challenges as food-producing land – of which there is sufficient to feed the region – is displaced by quick-growing forestry (particularly alien monocultures such as *Casuarina* and *Eucalyptus* trees) or abandoned as younger people move to cities for employment. A vicious cycle can result as abandonment of traditional tank management, intercepting monsoon rainfall for year-round availability, is replaced with energised pumping of retreating groundwater which compounds problems with water, food and energy.

Tamil Nadu state government is keen to work towards regional self-sufficiency, with Pondicherry-based organisations such as the NGO PondyCAN[15] and the associated Sustainable Livelihoods Institute playing a leading role in local water dialogues with community leaders (particularly tank users associations) and water users as part of a wider sustainability strategy that links in to substantial local activism. Energy deflation may be part of the solution, as may putting the energy strategy on a renewable footing (including bamboo biofuel, solar and wind) and the restoration of landscapes to retain water and soil. Traditional herbal medicinal practices are also prominent in the region, which means that eco-restoration could also make a substantial contribution to progressing the perception of Pondicherry and Chennai as a 'healthy region'. The potential for both TCW-generated energy and eco-restoration to contribute to this agenda is substantial.

This can form part of a wider regional regeneration and climate change strategy. A geological profile of the region is already available, and mapping of micro-watersheds around tank systems in the Kaliveli catchment (in which the Nadukuppam forest is located) has been undertaken. However, more knowledge is required about recharge rates of aquifers and tanks. Revegetation of the now largely denuded surrounding hills, the headwater of catchments serving the water system, may also be a priority for water and soil conservation.

[15] pondycan@gmail.com

3. Benefits arising from selected TCW Group eco-restoration activities

TCW recognises that limited access to energy is inextricably linked to poverty. Depleting energy sources mean that those with little or no access to energy today may become even more disadvantaged in the future. Therefore, providing access to affordable, sustainable energy at village scale can play a key role in reducing poverty, as well as helping to make them energy-independent and more resilient[16]. Installed, village-scale renewable technology may also provide jobs, as local people can be trained to run and maintain the system. TCW research into sustainable energy for international development addressed meaning and ethics of energy access, and selection of energy delivery models accounting for the enabling environment, socio-cultural context, technology and value proposition choice and implementation model[17]. The research highlighted the many choices available to support energy access interventions in terms of the scale (off-grid, mini-grid, on-grid) of the system, and all other elements of the delivery model.

This research has also highlighted regeneration of much-degraded natural habitats as fundamental to securing the water systems and livelihoods of local people. Therefore, within the 'Brindia' project, there are longer-term plans to address eco-restoration across broad landscapes and covering multiple habitat types within water catchments including forest, tanks and wetlands, and mangrove systems[18].

Reductions in net carbon emissions to the atmosphere may be achieved through enhancement of natural carbon sinks. One of the most effective methods of reducing emissions is to allow or encourage the reversion of cropland or unproductive, degraded landscapes to another land cover, typically one similar to the native vegetation[19]. Forests are important in the global carbon cycle, forming a major sink for carbon, forest loss or degradation therefore representing a significant source of carbon remobilisation into the atmosphere. A wide range of studies have established that carbon sequestration by trees can provide relatively low-cost net emission reductions[20]. Afforestation and conservation of existing forests not only has the potential to mobilise private

---

[16] The Converging World. (2015). *Village-Scale Renewable Energy*. http://www.theconvergingworld.org/sites/theconvergingworld.org/files/village_scale_renewable_energy_0.pdf (accessed 15th November 2015).

[17] The Converging World. (2015). Sustainable Energy for International Development. *TCW Research Briefing*. http://www.theconvergingworld.org/sites/theconvergingworld.org/files/news/tcw_energy_access_for_development_one_pager_final.pdf (accessed 03rd December 2015).

[18] It may be possible to link this phase with eco-restoration research interests in Auroville, which reportedly includes an interest in 700,000 km^2 tropical dry forest, mangroves, tanks systems and salt pans. (Mark Everard may be able also to make relevant links with colleagues in Wetlands International, Delhi.)

[19] Smith, P., Martino, D., Cai, Z., Gwary, D., Janzen, H., Kumar, P., McCarl, B., Ogle, S., O'Mara, F., Rice, C., Scholes, B., Sirotenko, O., Howden, M., McAllister, T., Pan, G., Romanenkov, V., Schneider, U., Towprayoon, S., Wattenbach, M. and Smith, J. (2006). Greenhouse gas mitigation in agriculture. *Philosophical Transactions of the Royal Society B*, 363, pp.789-813.

[20] For example:

- Adams, R. M., Chang, C. C., McCarl, B. A. and Callway, J. M. (1993). Sequestrating carbon on agricultural land: A preliminary analysis of social cost and impacts on timer markets. *Contemporary Policy Issues*, 11, pp.76–87.
- Richards, K. M. R., Moulton, and Birdsey, R. (1993). Cost of creating carbon sink in the US. In: Proceedings of the International Energy Agency Carbon Dioxide Disposal Symposium (ed. Riemer, P.), Pergamon Press, Oxford, pp. 905–912.
- Callaway, J. M. and McCarl, B. (1996). The economic consequences of substituting carbon payments for crop subsidies in US agriculture. Environmental Resource Economics, 7, pp.15–43.
- Stavins, R. N. (1999). The costs of carbon sequestration: A revealed-preference approach. American Economics Review, 89, pp.994–1009.

capital to fund forest conservation, for example through existing REDD+ mechanisms[21] or where the benefits of TCW initiatives can be articulated to zero-interest or low-interest investors, but also bring about many other benefits related to forest ecosystem services. Notwithstanding some scepticism about the feasibility of international contracts making a major contribution to the control of greenhouse gases due to concerns about monitoring, enforcement and scientific uncertainties[22], the Kyoto Protocol recognised the benefits for afforestation and forestry protection through three potential 'flexibility mechanisms' for countries to meet the emission reduction target: joint implementation (JI); a clean development mechanism (CDM); and emission trading[23].

3.1 Tamil Nadu's tropical dry evergreen forest (TDEF)

For this initial exploratory research phase, just one habitat type – tropical dry evergreen forest (TDEF) – is selected.

Tamil Nadu covers an area of 130,058 Km^2, much of this area severely deforested over recent decades to provide for fire wood, agricultural land and other forms of development. Of particular interest is restoration of the tropical dry evergreen forest (TDEF) within the catchment, which is a mere fragment of its former extent and condition. Remaining TDEF stands also host culturally important meanings such as sacred groves.

Two hundred years ago, TDEF existed as a thin belt around 30 km wide and stretching for approximately 1,000 km along the south–eastern seaboard of peninsular India[24], from Vishakapatanam to Point Calimere. Historic indications are that the area in and around the Kaliveli catchment were heavily forested as recently as 1960, and that forests were formerly far more extensive. Little remains today of this important habitat, with perhaps 1.5 hectares of climax forest extant, a larger area now constituting disturbed forest and rather more now scrub jungle or degraded thorny thicket.

Successful TDEF restoration has been occurring at Pitchandikulam, around Auroville, since the 1960s. This has demonstrated the feasibility of eco-restoration of severely degraded land with recovery of an increasing range of native wildlife as well as associated herbal traditions, forest-based livelihoods and traditional and religious benefits such as enhancement of sacred groves.

3.2 TDEF restoration under TCW programmes

A more recent reforestation project is occurring at Nadukuppam forest, in the Kaliveli catchment in Tamil Nadu. Initial TDEF restoration is focused on an area of a little over 30 acres in extent, with more land available to buy and put into trust as the scheme progresses.

Phase one of the TCW-sponsored forest eco-restoration programme was launched to celebrate Bristol as Green Capital of Europe 2015, 100 acres equating to just over 400,000m^2 (or 1m^2 for the 400,000 people living in Bristol). A longer-term aspiration of the TCW programme is to support

[21] http://www.un-redd.org/AboutREDD/tabid/102614/Default.aspx

[22] Brown, K. and W. Neil Adger, W.N. (1994). Economic and political feasibility of international carbon offsets. *Forest Ecology and Management*, 68(2-3), pp.217-229.

[23] Ramachandran, A.S., Jayakumar, R.M., Haroon, A.B. and Arockiasamy, D.I. (2007). Carbon Sequestration: estimation of carbon stock in natural forests using geospatial technology in the Eastern Ghats of Tamil Nadu, India. *Current Science*, 92(3): pp.323-331.

[24] The Converging World. (2015). *Restoring the forest*. http://www.theconvergingworld.org/restoring_the_forest (accessed 14th November 2015).

forest habitat restoration projects in India as well as Bristol equating to 27,000 acres – the size of Bristol[25] – with an intent to continue to promote reforestation for forthcoming decades through reinvestment of funds generated by renewable energy schemes. The degraded forest area that is being restored is naturally tank-fed, and is linked to initiatives based at Auroville (key contact Joss Brooks).

The ongoing TDEF eco-restoration programme at Nadukuppam forest builds on long-standing (since the 1960s) restoration of formerly barren lands at Pitchandikulam on the Auroville Plateau. Forest restoration is known to contribute to a wide range of human benefits[26]. Joss Brooks (Pitchandikulam Forest Auroville[27]) notes that: "*TDEF (Tropical Dry Evergreen Forest) contains over 160 woody species of which around 70 are found within the pristine climax forest. The TDEF is predominantly composed of trees and shrubs that have thick dark green foliage throughout the year. Within this forest the number of species approaches 1,000, of which over 600 have a recorded use for mankind, either medicinally, culturally or in religious rituals*".

Nadukuppam forest is adjacent to 'Nadukuppam field' and Nadukuppam school. 'Nadukuppam field' is a women's collective set of businesses including herbal medicinal products and crafts linked to forest products, local employment of women in germinating and nurturing indigenous forest plants, as well as *Spirulina* growth for sale as a healthy dietary supplement. Nadukuppam school has an environmental programme permeating its learning programme, and is used as a model for many schools across Tamil Nadu state. The Nadukuppam forest eco-restoration therefore very deliberately links with associated economic, women's empowerment and educational development.

The Pitchandikulam Bio-Resource Centre (PBC) has established good relationships with the State Forest Board and Agriculture Department, which has aspirations to achieve reforestation as well as regenerate the linked tank systems. An important aspect of the ongoing reforestation programme is the creation of sustainable jobs for the economically marginalised, as well as education in local schools about the critical importance of the forest to local people, also known as social fencing.

The ecosystem service framework provides a basis for evaluating not merely the benefits of carbon sequestration, but also the wider suite of co-provisioning (for example employment, food, fuel wood), regulatory (water flows, microclimate, etc.), cultural (such as sacred groves and traditional landscapes) and supporting (habitat for wildlife, nutrient cycling, etc.) benefits arising from forest eco-restoration.

---

[25] The Converging World. (2015). *The Brindian Forest*. http://www.theconvergingworld.org/sites/theconvergingworld.org/files/brindian_forest_eco-restoration.pdf (accessed 13th July 2015).

[26] Shvidenko, A., Barber, C.V. Persson, R., Gonzalez, P., Hassan, R., Lakyda, P., McCallum, I., Nilsson, S., Pulhin, J., van Rosenburg, B. and Scholes, R. (2005). *Chapter 21: Forest and Woodland Systems*. In Hassan, R., Scholes, R. and Ash, N. (eds.), Millennium Ecosystem Assessment – Ecosystems and Human Wellbeing: Current State and Trends, pp.585-621. (http://www.millenniumassessment.org/documents/document.290.aspx.pdf, accessed 16th November 2015.)

[27] http://www.pitchandikulamforest.org/cms/content/view/23/31/

3.3 Summary of direct and indirect benefits and potential disbenefits arising from TCW Group eco-restoration of TDEF

Ecosystem service consequences arising from TCW Group-sponsored eco-restoration of TDEF in Tamil Nadu are analysed in a series of Tables in Annex 4. These detailed 'ecosystem service by ecosystem service' considerations make a balanced assessment of both benefits and potential disbenefits.

As for TCW Group wind generation, making this assessment on a systemic basis is important as all services are produced as a connected set. It has been common historic practice to focus only on single or a limited subset of benefits, whilst overlooking wider ramifications (such as energy or food production methods that are blind to their wider negative consequences). However, to overlook the wider potential co-benefits of more sustainable practices (such as carbon sequestration, hydrological and fishery recruitment co-benefits arising from some nature conservation measures), or conversely the negative impacts on these linked services and their associated beneficiaries, is potentially inequitable and economically inefficient and can potentially destabilise the ecosystem from which these benefits flow.

Again, apart from climate regulation (see Section 4 and Annexes 5 and 6), ecosystem service benefits are NOT quantified or monetised within the limitations of this first phase of research.

The following four Tables summarise key issues identified for each Millennium Ecosystem Assessment ecosystem service category: provisioning, regulatory, cultural and supporting services. (More detailed systemic analysis can be found in Annex 4.) Benefits are highlighted in green and cautionary notes to avoid potential disbenefits are highlighted in red.

Provisioning ecosystem services
Restored TDEF ecosystems make a direct contribution to: • **Fresh water** availability by regulating the quality, quantity and local recycling of water, enhancing its availability to people for beneficial uses (which can include both direct exploitation and indirect uses such as extra capacity for hydropower generation and cooling). • **Food security and food availability for trade**, both through direct cropping or shade-tolerant polyculture. • **Fuel and fibre resources for use or trade**, also through both direct cropping or shade-tolerant polyculture. • **Genetic resources**, such as rare breeds of stock or crops or promotion of regeneration of natural diversity of inherent genetic value. • **Species with medicinal properties**, particularly related to traditional medicine, or for which biochemicals can be exploited in other ways. However, location of forest planting has to be carefully considered to avoid displacing land already producing food, fibre or fuel, or pre-existing ecosystems containing important or unassessed genetic, biochemical or ornamental values. In Nadukuppam, this is not perceived as problematic due to the highly degraded, aridified nature of the pre-restoration landscape.

Regulating ecosystem services
Restored TDEF ecosystems make a direct contribution to:

- **Enhancement of air quality** through settling fine particulate matter and dust, and suppression of dust generation from formerly erosive land surface, and absorbing or breaking down other aerial pollutants.
- **Microclimate regulation** within and adjacent to the forest.
- **Global climate regulation**, primarily by sequestering carbon. (Although quantification is not the aim of this early phase of research, Annex 5 of this report addresses the calculations used to identify carbon sequestration potential of tropical evergreen dry forest eco-restoration as 21,996.6 tCO_2 ha^{-1} $year^{-1}$ over an assumed 100-year succession to climax vegetation).
- **Catchment hydrology** (timing and scale of water run-off, buffering of floods and droughts, etc.), including both surface and groundwater flows.
- **Buffering natural hazards** such as storm energy, potentially protecting buildings and other infrastructure and crops from damage.
- **Regulation of pests and diseases** of both humans and stock, by providing habitat for natural predators (or both pest organisms such as aphids and the vectors of disease) and microbial breakdown processes.
- **Erosion regulation** though securing of the soil surface, particularly where landscapes were formerly degraded. (Sheet and gulley erosion are significant regional problems on degraded lands in this part of Tamil Nadu.)
- **Water purification**, largely through the role of forests in slowing water flows and providing habitat for natural purification processes (physical, chemical and biological).
- **Pollination**, by playing host to pollinating organisms.
- **Regulation of soil salinisation** by restoration of more natural landscape hydrology.
- **Visual and noise buffering**.

Many of these regulatory benefits arise with no or few disbenefits, though the greater standing biomass of trees may increase potential for wildfires necessitating cautious management.

Cultural ecosystem services
Restored TDEF ecosystems make a direct contribution to:

- **Cultural heritage**, if appropriately planned and managed.
- **Recreational and tourism**, again if appropriately planned.
- **Aesthetic importance**, an increasing number of studies relating physical and psychological health to exposure to nature.
- **Spiritual importance**, including for example regenerating valued habitats (such as sacred groves) or species (e.g. Peepal and Banyan trees).
- Inspiration of locally important **artistic, mythological, folklore and other cultural expressions**.
- **Income, employment and training opportunities**, particularly where marginalised communities are involved through, for example, forestry management, cropping other forest products and wildlife management.
- **Educational and research opportunities**, both formal and informal.

These benefits generally have few associated potential disbenefits, provided that care is taken – ideally in dialogue with local people – to avoid displacement of sites with established spiritual, artistic, employment or other cultural importance.

Supporting ecosystem services
Restored forest ecosystems tends to make a direct and substantial contribution to **all supporting services** (processes within ecosystems that maintain or rebuild their integrity, functioning and capacity to produce other services) – particularly where it replaces degraded habitats – including: • Soil formation; • Primary production; • Nutrient cycling; • Water recycling; • Photosynthetic oxygen production; and • Provision of habitat. No disbenefits arise as habitat prior to forest eco-restoration is degraded rather than being another form of important habitat that will be lost on conversion.

The table above is a simplified summary of the more detailed analysis in Annex 4. Most elements are not quantified, this initial phase of research focused on taking a systemic view of benefits and potential disbenefits across the full spectrum of ecosystem services.

3.4 Further eco-restoration opportunities

The focus of this Section of the report is the range of ecosystem service benefits arising from restoration of a relatively small area of TDEF. Further eco-restoration opportunities include wider forest area, different locally appropriate forest types, as well as regionally representative mangroves, tanks, wetlands, hill tops and slopes.

The water system is of particular importance not merely due to its close interaction with forestry but as it is a major contributor to the vitality of ecosystems of inherent worth and also supporting a diversity of human needs including poverty alleviation. The Pitchandikulum Bio-Resource Centre (PBC: a partly government-supported solutions centre), based in the city of Auroville to the north of Pondicherry, has particular interests in water and the involvement of communities in mutually beneficial socio-environmental regeneration. PBC's prime focus is its home distinct, the Auroville bioregion, but learning is disseminated and sought from across India. The Pitchandikulum Bio-Resource Centre is a partner of TCW in eco-restoration. PVC also has good connections with the District Forest Office, which is seeking to identify and take action against illegal activities compromising the viability of the Kaliveli estuary and wider system, such as unconsented prawn farming.

Of particular interest is the Kaliveli system in which Auroville is partially located. The Kaliveli system is a triangular catchment stretching from Gingee to Marakkanam to the Auroville plateau, spanning an area of 740 km^2 (25,000 ha). Restoration of the Kaliveli catchment is a significant target at state level. The Kaliveli water body is the second largest in South India, located 18 km north of Pondicherry and extending for 28 km parallel to the coast covering a total area of 13,200 ha comprising: (1) the Kaliveli floodplain; (2) Uppukalli creek connecting the floodplain to the estuary; and (3) Yedayanthittu estuary comprising intertidal mudflats and salt pans. The water system of the Kaliveli is characterised by an intricate, ancient network of 225 tanks (mainly seasonal but some perennial) which, together with associated channels, have been pivotal to human settlements over hundreds of years. The Kaliveli wetland complex has been the study of a management plan[28].

The tank systems of Tamil Nadu have been suffering the same kinds of declines in quality, extent and loss of traditional collaborative management as witnessed across much of the rest of India and indeed the tropical world[29]. Privatisation and proliferation of tube wells contributes to poverty and inequities as people with more resources can access groundwater preferentially through mechanised pumping technologies, depressing groundwater levels and suppressing incentives for community-based management of common water capture technologies that have persisted for centuries as an adaptation to local conditions[30 31]. Rehabilitation of traditional groundwater recharge and other water harvesting techniques and the social infrastructure that supports them, including effective community-level agreements to avert symmetric access to groundwater resources that deprives others, is a necessary condition for the recovery of ecosystems and intimately linked socio-economic security and progress[32 33]. Given the critical role of water in arid and semi-arid environments, water management will have many additional co-benefits. Threats to poverty and equity arising from the decline in collective tank irrigation management have been identified as a particular threat in Tamil Nadu[34]. Water User Associations have been established in Tamil Nadu.

Another Pitchandikulum Bio-Resource Centre-driven project has been creation of the multifunctional Adyar Poonga wetland system in the urban setting of Chennai, a 58-acre wetland ecopark, in partnership with the Chennai Rivers Restoration Trust.

Ecosystem service benefits resulting from restoration of these additional habitat types warrants further research, and the extension of the characterisation of targeted reforestation addressed above also warrants further detailed study and quantification. All can make a significant contribution to the sustainability of the energy-water-food nexus of interconnected issues within which TCW is operating.

---

[28] Bhalla, R.S. (2011). *Conservation of the Kalivelli Wetand Complex: Towards a Comprehensive Management Plan*. Foundation for Ecological Research, Advocacy and Training (FERAL), Puducherry.

[29] Everard, M. (2015). Community-based groundwater and ecosystem restoration in semi-arid north Rajasthan (1): socio-economic progress and lessons for groundwater-dependent areas. *Ecosystem Services*, 16, pp.125–135. http://dx.doi.org/10.1016/j.ecoser.2015.10.011.

[30] Bardhan, P. (2000). Irrigation and cooperation: an empirical analysis of 48 irrigation communities in South India. *Economic Development and Cultural Change*, 48(4), 847-65.

[31] Kajisa, K., Palanisami, K., and Sakurai, T. (2004). Declines in the collective management of tank irrigation and their impacts on income distribution and poverty in Tamil Nadu, India, FASID Discussion Paper Series on International Development Strategies, No. 2004-08-005, Tokyo, Foundation for Advanced Studies on International Development.

[32] Palanisami, K. (2000). *Tank irrigation: revival for prosperity*. New Delhi, Asian Publishing Service.

[33] Everard, M. (2013). *The Hydropolitics of Dams: Engineering or Ecosystems?* Zed Books, London.

[34] Kajisa, K., Palanisami, K. and Sakurai, T. (2007). Effects on poverty and equity of the decline in collective tank irrigation management in Tamil Nadu, India. *Agricultural Economics*, 36(3), pp.347-362.

4. Cumulative benefits from reinvestment of TCW renewable energy operating margins into TDEF eco-restoration

Annex 6 uses stated data and assumptions (costs of TDEF conversion, cost and operating margins from turbine generation, etc.) to calculate a range of benefits arising from TDEF restoration including reinvestment of operating margins from renewable energy sales. See Annex 6 for full calculations and more detail on values deduced.

Note that the TDEF carbon storage figures derived from Annex 5 have to be regarded with caution as the published data upon which they are based are so sparse. If subsequent research modifies these values, this will impact on subsequent calculations in Annex 6 and the summary figures in Section 4 of the report.

4.1 Costs and carbon benefits of restoring TDEF

The costs of restoring one hectare of TDEF = £16,255 (land purchase + restoration activities).

Using a calculated annual carbon dioxide sequestration rate in restoring TDEF of 21,995.6 tCO_2 ha^{-1} $year^{-1}$ (Annex 5), this equates to costs of CO_2 sequestration of:

Unit of annual CO_2 sequestration	Cost in GB pounds sterling[35]
1 tCO_2 $year^{-1}$	£ 0.74
1,000 tCO_2 $year^{-1}$	£ 739.01
1 million tCO_2 $year^{-1}$	£ 739,011

4.2 Carbon dioxide sequestered/avoided from one-off reinvestment of turbine generation in one hectare of TDEF

If a one-off investment of £16,255 (11.6% of £140,000) is made from net annual income from a 2.1 MW wind turbine is made in restoration of one hectare area of TDEF, assuming a lag phase of a year for the start of sequestration, cumulative annual carbon dioxide sequestered/avoided over the first five years of investment are (for details see Table below):

- For each of years 2 to 5 = 24,995.6 tCO_2 $year^{-1}$.
- Cumulatively over a five-year horizon = 102,982.4 tCO_2.

4.3 Net carbon dioxide sequestered/avoided from one-off investment of £100,000 turbine operating margins into TDEF restoration

If a one-off reinvestment of £100,000 is made in TDEF restoration (6.15 hectares TDEF), assuming a lag phase of a year for the start of sequestration, cumulative annual carbon dioxide sequestered/avoided over the first five years of investment are:

- In years 2 to 5, annual CO_2 emissions are 138,272.94 tCO_2 $year^{-1}$.
- Over a five-year horizon, cumulative CO_2 emissions averted = 556,091.76 tCO_2.

[35] @ 100.7284 IN₹/GB£ (www.msn.com/en-gb/money/currencyconverter, accessed 13th November 2015).

4.4 Net carbon dioxide sequestered/avoided from reinvestment in TDEF restoration of £100,000 per turbine per operating year

If a reinvestment of £100,000 is made in TDEF restoration (annual incremental additions of 6.15 hectares) **for each operational year**, again assuming a lag phase of a year for the start of sequestration, cumulative annual carbon dioxide sequestered/avoided over the first five years of investment are:

- Between years 2 to 5, rising from 138,272.94 to 544,091.76 tCO_2 $year^{-1}$.
- Cumulatively over a five-year horizon = 1,367,729.40 tCO_2.

Extending the above assumptions over scheme life (20 year depreciation of turbine and 100 year carbon sequestration in each of the 20 x 6.15 block of TDEF [total 123 hectares] until it reaches climax community), this yields:

- Lifetime carbon sequestration/avoidance of 270,605,880 tCO_2, of which:
  - CO_2 sequestration through TDEF restoration = 270,545,880 tCO_2 (99.978%)
  - CO_2 avoidance from the turbine = 60,000 tCO_2 (0.0.22%)

4.5 Price per tonne of sequestered/avoided CO_2 from annual £100,000 reinvestment of turbine operating margins into TDEF restoration

Dividing installation cost for a 2.1 MW wind turbine (£1,575,000) by gross carbon sequestration/avoidance over scheme life for annual reinvestment of £100,000 in TDEF restoration (270,605,880 tCO_2) yields:

- Cost per unit tCO_2 sequestered/avoided = £0.0058 £ per tCO_2 (0.58p per tCO_2)

The overwhelming contribution of TDEF restoration to the above value concurs with the findings of the 'Stern Review' that reforestation is one of the most economically efficient means to tackle climate change.

The cost-effective figures above compare with a return of £26.25 per tCO_2 avoided over the 20 year depreciation life of the wind turbine alone.

4.5 The value of averted carbon to individuals and institutions

Against a theoretical maximum safe permissible 2.0 tonnes CO_2 per capita annual emission[36] [37]:

- India has an average 1.7 tonnes CO_2 annual per capita emission;
- China has an average 6.7 tonnes CO_2 annual per capita emission;
- The UK has an average 7.1 tonnes CO_2 annual per capita emission; and
- The US has an average 17 tonnes CO_2 annual per capita emission.

[36] Related to achieving global convergence to prevent a 2°C rise in mean global temperature.
[37] Source, World Bank: http://data.worldbank.org/indicator/EN.ATM.CO2E.PC/ (accessed 3rd December 2015)

Part of the global challenge to reach climate stability is for:

- The approximately 100 million global births annually to average no more than 2 tonnes CO_2 annual emissions per capita;
- The keep the Indian average under 2 tonnes CO_2 annual emissions per capita;
- For higher-emitting nations to contract their per capita figures; and
- For organisations to offset or mitigate their CO_2 emissions on the journey to contraction.

Recently, China and the US, together accounting for about 45% of the world's greenhouse gas emissions, have agreed to converge on a target of 14 tonnes CO_2 annual emissions per capita[38]. This represents a doubling for China and a 71% cut for the US from current per capita levels. However, whilst cross-national collaboration between a developed and a developing country are welcome, the 14 tonnes CO_2 per capita converged target still leaves a total population of approximately 1.7 billion people (1,373,200,000 in China[39] and 322,237,000 in the US[40]) to tackle an average reduction of 12 tonnes CO_2 annual emissions per capita, or a total reduction of 20.4 billion tonnes CO_2 annual emissions, if safe limits (global convergence to prevent a 2^{o}C rise in mean global temperature) are to be achieved.

Whilst limited wind power installation and associated habitat restoration in Tamil Nadu makes a contribution, there is a need to replicate this type of cost- and carbon-effective approach globally – in addition to a wide range of other innovations – if climatic sustainability is to be achieved.

The Brindia partnership – Bristol/south west England and Tamil Nadu – is a starting point that also proves the general principal, with supporting analyses, of what is possible through collaboration between developed and developing world regions. As carbon sequestration and avoidance though renewable generation amount to the same outcome for the global climate – albeit each generating a different signature of related ecosystem service co-benefits – it also offers transparent, enduring means for establishing a range of transparent, market-based control measures.

4.6 Securing the benefits of carbon sequestration

Compared to the UK (1st April 2013) carbon floor price (see Annex 5) of £16 per tonne of CO_2 applied to fuels used for power generation, CO_2 avoidance through investment in TDEF eco-restoration is highly cost-efficient from a carbon perspective alone, also yielding the wider network of beneficial ecosystem services addressed in Section 3 of this report.

However, if these benefits are to be enduring, and transparently so to potential investors, mechanisms must be found to secure the carbon sequestration and wider direct and indirect ecosystem service benefits arising from TDEF and other habitat restoration in perpetuity. The TCW Group is working to identify and implement such measures. Ownership of land purchased for eco-restoration can be vested in an Indian Trust. The deed for this may, for example, be held (in full or in part) by the people of Bristol as a secure legal way to found the inter-regional partnership.

---

[38] Nakamura, N. and Mufson, S. (2014). November China, U.S. agree to limit greenhouse gases. *The Washington Post*, 12th November 2014. (https://www.washingtonpost.com/business/economy/china-us-agree-to-limit-greenhouse-gases/2014/11/11/9c768504-69e6-11e4-9fb4-a622dae742a2_story.html, accessed 15th November 2015.)

[39] National Bureau of Statistics in China. http://data.stats.gov.cn/ (accessed 15th November 2015).

[40] United States Census Bureau. http://www.census.gov/popclock/ (accessed 15th November 2015).

Although this section of the report provides compelling evidence for the carbon sequestration benefits of TDEF eco-restoration (albeit based on the sparse published data for carbon sequestration in restored TDEF that is currently available), further research is required to:

- Locate or generate more data to substantiate of modify these conservative analyses;
- Address other appropriate natural habitats that may be beneficially restored (mangroves, hills, tank and wetland systems, etc.);
- Assess the net societal benefits produced by regenerated forest compared to the profitability of degraded fields that may be bought for TDEF restoration. (It is assumed that, at present, the value of these degraded fields for food, jobs, etc., is negligible compared to the direct and indirect benefits stemming from regenerated forests.);
- Further substantiate the emerging conclusion that restored forests are much more valuable for climate stabilisation – and their additional associated ecosystem service benefits – than the renewable energy generation infrastructure that is the primary subject of most international investment; and
- Bring in more economic expertise (be that academic, pro bono[41] or other) to verify or further analyse economic conclusions.

4.7 Additional benefits from other ecosystem services

Although the focus of this Section of the report is on significant and cost-effective climate regulation (CO_2 sequestered/avoided), it is important to contextualise this ecosystem service as just one of a linked set of ecosystem service benefits stemming from renewable energy generation and TDEF eco-restoration.

Further societal value derives from the wide range of broader associated ecosystem service co-benefits described (though not quantified) for both TCW Group renewable energy generation (Section 2; Annex 3) and TDEF eco-restoration (Section 3, Annex 4). Further research quantifying and, where feasible, monetising or otherwise valuing these broader values would further reinforce the benefit-to-cost case for activities promoted by the TCW Group, and their contribution to broader sustainable development goals.

4.8 Strategic solutions

The substantial collective sequestration/avoidance values and associated low costs summarised in this Section highlight how efficient TDEF eco-restoration is in comparison to wind turbine generation. Akin to the way that ‘flagship’ wildlife species can serve to prioritise nature conservation action favourable to the networks of habitats and species upon which focal charismatic species depend, so at present the ‘flagship’ ecosystem service of climate regulation can focus action also protective of the wide diversity of societally co-beneficial ecosystem services the significance of which currently has a lower public and political profile.

[41] For example, the http://www.probonoeconomics.com/ network.

5. The contribution of TCW Group programmes to societal wellbeing

As identified in preceding Sections, a wide spectrum of social returns, spanning both benefits that excludable (market) and non-excludable (for example publicly beneficial outcomes flowing from habitat restoration), accrues to society from the TCW Group programme of installing wind turbines and reinvesting operating margins in TDEF eco-restoration in Tamil Nadu.

5.1 Taking account of full societal benefits

Detailed consideration of ecosystem service outcomes forms the basis for assessing this broader total SROI, characterising the diverse and potentially cumulatively substantial societally beneficial outcomes – many of them are invisible to established markets – as a broader form of return.

Characterising, and ultimately as an ideal quantifying where possible, the benefits associated with the wider suite of interlinked ecosystem service outcomes from renewable energy generation and eco-restoration becomes important in demonstrating total returns on investment. Quantification was not possible within the scope of this short initial project, but is an important theme for follow-on research as a robust assurance for regulating and investing communities. (An overview of ecosystem services valuation is provided in Annex 7.) This in turn provides a foundation for taking a 'Sacred economics' approach[42], further justifying zero or low percent returns on investment (both topics expanded in Section 7).

All of these benefits are amenable to optimisation with clear-sighted planning, and also to potential positive feedback through reinvestment of scheme surpluses into renewable energy, eco-restoration and related beneficial schemes.

5.2 Contributions to societal aspirations and commitments

At least some of the broader suite of societally beneficial outcomes of renewable energy generation and reinvestment in eco-restoration mesh closely with already-established societal goals. These include as examples:

- Tamil Nadu State Forest Department reforestation aspirations;
- UK and Indian low-carbon trajectory aspirations;
- Indian government renewable energy plans as outlined in Annex 1;
- Corporate Social Responsibility targets; and
- Wider corporate 'Permission to Operate'.

Significant international aspirations and statements of commitment to which the TCW/Brindia programme can demonstrate its contribution include:

- Kyoto Protocol and subsequent climate emissions targets;
- Aspirations of the international community to cut natural forest loss in half by 2020 and strive to end it by 2030, cutting between 4.5 and 8.8 billion tons of carbon remobilisation annually

[42] Eisenstein, S. (2011). *Sacred Economics: Money, Gift, and Society in the Age of Transition*. Evolver Editions, New York.

(approximating that currently emitted by the United States) under the New York Declaration on Forests[43], a non-binding global pledge endorsed by more than 130 governments, companies (including thirty of the world's largest ones) and more than fifty influential civil society and indigenous organisations to restore 350 million hectares of deforested and degraded landscapes by 2030. Signatory nations with specific forest restoration commitments include Ethiopia, Uganda, the Democratic Republic of the Congo, Colombia, Guatemala and Chile[44].

- Millennium Development Goals (MDGs) and their successor Sustainable Development Goals (SDGs); and
- Poverty alleviation goals (most since September 2015 subsumed into the SDGs).

5.3 Contribution to the UN Sustainable Development Goals

Of particular significance in terms of the disparate market and non-market benefits of the Brindia project are their 'fit' with the UN Sustainable Development Goals[45], agreed by the international community in September 2015 and superseding the former Millennium Development Goals.

Some of the key ways in which Brindia outcomes link with SDGs are outlined in the Table below. Renewable energy-related benefits are indicated in blue, whilst those stemming from forest eco-restoration are flagged in green. (The SDG graphics below are those used by the UN.)

Sustainable Development Goals (SDG) with UN logos	Potential contribution of the Brindia programme
End poverty in all its forms everywhere	• Provision of energy to those formerly without access will help lift people out of poverty, for example through education, electronic communications, better access to education, and mechanised pumping of water[46 47]. • Eco-restoration of forests will further secure economic resources (such as food, water, other forest products) as well as providing training and employment.

[43] United Nations. (2014). *FORESTS New York Declaration on Forests Action Statements and Action Plans*. http://www.un.org/climatechange/summit/wp-content/uploads/sites/2/2014/09/FORESTS-New-York-Declaration-on-Forests.pdf (accessed 8th April 2015).
[44] Although the UNFCCC (http://newsroom.unfccc.int/nature-s-role/un-climate-summit-forests/) expresses this area as "…*greater than the size of India*…", it is not clear from websites whether India is a signatory.
[45] United Nations. (2015). *Transforming our world: the 2030 Agenda for Sustainable Development*. https://sustainabledevelopment.un.org/post2015/transformingourworld (accessed 10th November 2015).
[46] United Nations. (2010). *Energy for a Sustainable Future*. The Secretary-General's Advisory Group on Energy and Climate Change (AGECC), United Nations, New York. (http://www.un.org/wcm/webdav/site/climatechange/shared/Documents/AGECC%20summary%20report%5b1%5d.pdf, accessed 6th November 2015.)
[47] World Energy Council India. (undated). Energy Poverty Alleviation. World Energy Council India. (http://wecindia.in/webportal/index.php/studies/weci-studies/118-energy-poverty-alleviation, accessed 6th November 2015.)

2 ZERO HUNGER End hunger, achieve food security and improved nutrition and promote sustainable agriculture	• Provision of energy to those formerly without access will contribute to food security and nutrition by mechanised pumping of water, though this does need to be governed collectively within the renewable capacity of aquifers. • Eco-restoration of forests will further ensure food security and nutrition by direct harvesting of food, agroforestry, and income generation to purchase food[48].
3 GOOD HEALTH AND WELL-BEING Ensure healthy lives and promote well-being for all at all ages	• Provision of energy to those formerly without access will make a generic contribution to health and wellbeing through poverty alleviation and food security (as noted above) as well as enhancing opportunities for education and trade. • Eco-restoration of forests will also enhance healthy lifestyles and wellbeing through restoration of traditionally valued and exploited forest landscapes as well as more material benefits (food, timber and fuelwood, etc.)
4 QUALITY EDUCATION Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all	• Provision of energy to those formerly without access enables study into hours of darkness, as well as more reliable access to electronic learning media. • Eco-restoration of forests provides a basis for training and restoration of traditional values associated with forests, including for example passing on herbal medicine and forest food traditions.
5 GENDER EQUALITY Achieve gender equality and empower all women and girls	• Provision of energy to those formerly without access increases security for women and girls in the use of sanitation during hours of darkness (public safety is an underappreciated problem as young women have to leave their rural homes after dark[49]), extends their capacity to access education, and frees them from the drudgery of the traditional roles of women in gathering water and fuelwood. • Eco-restoration of forests contributes to gender equality through relieving limitations on resources such as fuelwood, and the burden of its collection. Evidence from women-centred business activities in the 'Nadukuppam field' demonstrates how forest restoration provides livelihoods for women's cooperatives.

[48] Note that Joss Brooks reports that over 600 of the nearly 1,000 species found in TDEF "…*have a recorded use for mankind, either medicinally, culturally or in religious rituals*". Equivalent figures are not available for edible products, but a significant proportion can be assumed.

[49] The Economist. (2014). Sanitation in India: The final frontier. *The Economist*, 19th July 2014. (http://www.economist.com/news/asia/21607837-fixing-dreadful-sanitation-india-requires-not-just-building-lavatories-also-changing, accessed 6th November 2015.)

 Ensure availability and sustainable management of water and sanitation for all	• Provision of energy to those formerly without access enhances access to mechanised pumping of water and for effective sanitation systems, including enhancing safety (particularly for women accessing sanitation facilities at night). Relief of pressures on water resources by avoidance of traditional energy generation technologies (cooling for thermal plants and hydropower) can also increase water available for sanitation[50]. • Eco-restoration of forests has a positive influence on the water cycle, enhancing the availability of water for healthy and other beneficial uses.
 Ensure access to affordable, reliable, sustainable and modern energy for all	• Expansion of energy generated by renewable sources, including provision of energy to those formerly without access, may contribute significantly towards this Sustainable Development Goal in helping people rise out of poverty. • Eco-restoration of forests provides fuelwood, and also natural cooling averting some energy demand.
 Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all	• Provision of energy to those formerly without access opens up a wide range of employment and wealth-generating opportunities. • Eco-restoration of forests also provides a range of economic opportunities ranging from forestry to cropping, traditional medicine and other skills.
 Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation	• Provision of energy to those formerly without access through wind-and solar-powered systems and associated infrastructure represents long-lived assets supporting sustainable industrialisation and innovation. • Eco-restoration of forests builds natural infrastructure, providing a range of economic resources if well managed.

[50] The Economist. (2014). Sanitation in India: The final frontier. *The Economist*, 19th July 2014. (http://www.economist.com/news/asia/21607837-fixing-dreadful-sanitation-india-requires-not-just-building-lavatories-also-changing, accessed 6th November 2015.)

10 REDUCED INEQUALITIES Reduce inequality within and among countries	• Provision of energy to those formerly without access potentially increases energy parity between societal sectors in Tamil Nadu, if allocation and charging is governed appropriately, as well as increasing developing world capacity in partnership with the developed south west of England. Restoring capacity to develop to those in India though low-carbon energy is an aspect of restoration of opportunity denied by historic, internationally asymmetric development patterns. • Eco-restoration of forests also increases parity in resource availability to different societal sectors in Tamil Nadu, as well as increasing developing world capacity in partnership with the developed south west of England. Regenerated ecosystems and services restore capacity to develop to those in India denied by historic, internationally asymmetric development patterns.
11 SUSTAINABLE CITIES AND COMMUNITIES Make cities and human settlements inclusive, safe, resilient and sustainable	• Provision of energy to those formerly without access offers enhanced security through lighting in vulnerable areas (as noted above access to sanitation for women in hours of darkness) and the rebuilding of equity of access to renewable resources. • Eco-restoration of forests contributes directly to resilience through the supply of a diversity of (particularly) regulatory and supporting services, as well as greater access to forest resources by all societal sectors. Improved buffering of both flood and drought water flows and of storm energy can protect remote assets such as urban, transport and energy infrastructure downstream in catchments.
12 RESPONSIBLE CONSUMPTION AND PRODUCTION Ensure sustainable consumption and production patterns	• Provision of energy to those formerly without access occurs on an inherently sustainable basis from renewable generation, though governance of energy use will be required to ensure that this resource (and the other resources to which is promotes access) is used sustainably. • Eco-restoration of forests also occurs on an inherently sustainable basis, though governance of use, sharing and positive management will be required to ensure that the resource is shared and used sustainably.
13 CLIMATE ACTION Take urgent action to combat climate change and its impacts	• Provision of energy from renewable sources to those formerly without access contributes to a low-carbon trajectory of development, averting emissions from other traditional sources. • Eco-restoration of forests provides significant mitigation (primarily through carbon sequestration) and adaptation (mainly via regulatory services) to combat climate change.

14 LIFE BELOW WATER Conserve and sustainably use the oceans, seas and marine resources for sustainable development	• Provision of energy to those formerly without access does not make a direct contribution to this SDG. • Eco-restoration of forests enhances land-ocean interactions, particularly through water-vectored ecosystem services, for example providing enhanced freshwater flows to the coastal zone, reducing saline intrusion into groundwater, reducing run-off to the coastal zone due to increased erosion from deforested areas, and relieving pressure on exploitation of coastal and estuarine mangroves which serve important fish nursery and other services. Mangrove restoration may in future make a particularly significant direct contribution to regenerating coastal resources, livelihoods and regulation of interactions at the land-coastal interface.
15 LIFE ON LAND Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss	• Provision of energy to those formerly without access relieves pressure on mining, damming and other destructive energy conversion technologies that may contribute to degradation of terrestrial habitats. • Eco-restoration of forests directly rehabilitates forest ecosystems and their diversity of services, the benefits of which to people and wildlife ramify across other connected ecosystems (adjacent settlements, farmland, open landscapes, catchments and coastal seas) helping halt and ideally reversing biodiversity loss. Opportunities to restore more forest area, forests of different types and other regionally representative habitats also furthers this SDG through the linked sets of societal benefits that they support.
16 PEACE, JUSTICE AND STRONG INSTITUTIONS Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable and inclusive institutions at all levels	• Provision of energy from renewable sources to those formerly without access does not automatically promote greater inclusivity in resource access. Inclusive governance systems are also essential to ensure its sustainable and equitable use. Other TCW programmes (see Annex 1 for example include women's empowerment) seek to rebuild justice. • Eco-restoration of forests also promotes greater ubiquity and inclusivity in resource access. However, inclusive supporting governance systems are also required to ensure their sustainable and equitable management and use.

17 PARTNERSHIPS FOR THE GOALS Strengthen the means of implementation and revitalize the global partnership for sustainable development	• Provision of renewable energy, particularly to those formerly without access, makes direct contributions to the sustainable development agenda not merely in terms of the renewable basis of generation but also the empowerment of people, for which the effective operation of institutions at a variety of scales is essential. The international partnership between south west England and Tamil Nadu upon which the TCW programme is based reinforces and demonstrates potential replicable means to deliver global partnerships for sustainable development. • Eco-restoration of forests brings with it not merely increased resilience and scope for ecological recovery but also social and economic opportunity in the full intergenerational and systemic spirit of sustainable development as initially framed in 1987 by the World Commission of Environment and Development[51]. The international partnership between south west England and Tamil Nadu upon which the TCW programme is based reinforces and demonstrates potential replicable means to deliver global partnerships for sustainable development.

In summary, renewable energy capacity and eco-restoration of forests make significant and potentially quantifiable contributions to all SDGs (with the exception of a direct role for renewable energy generation in addressing Goal 14: *Conserve and sustainably use the oceans, seas and marine resources for sustainable development*).

[51] World Commission of Environment and Development. (1987). *Our Common Future*. Oxford University Press, Oxford: England.

6. Implications for Bristol, south west England and UK decarbonisation

Cautionary note: Figures in this Section must be treated with extreme caution. They are based on the indicative data (the best available within sparse literature) and stated assumptions behind calculations in previous Sections, extrapolated further using some generalised figures. Whilst this is valid for producing illustrative figures, the findings in this Section need testing and development through further research. Nevertheless, they indicate likely scales of benefits and opportunity.

Carbon dioxide sequestration/avoidance figures summarised in Section 4 (calculated in Annexes 5 and 6) are considered **in very approximate terms** for the people of Bristol City, south west England and the UK as a whole.

6.1 Implications for Bristol City

Bristol City has an approximate population of 440,000 people with mean per capita carbon dioxide emissions of 5.8 tCO_2 $year^{-1}$ (source: Professor James Longhurst), generating:

- Annual city-wide carbon dioxide emissions of 2,552,000 tCO_2 $year^{-1}$.
- Cumulative city-wide carbon dioxide emissions of 255,200,000 tCO_2 over a century.

The above figures ignore the conflicting contributions of likely population growth and anticipated reductions in per capita carbon intensity over the coming century.

Based on summary numbers in Section 4 (background calculations in Annex 6), the 123 hectares of restored TDEF resulting from reinvestment of operating margins over the 20-year depreciation lifetime of a wind turbine will sequester (21,995.6 tCO_2 ha^{-1} $year^{-1}$):

- Annually, approximately 2.7 million tCO_2 $year^{-1}$.
- Cumulatively, approximately 270 million tCO_2 as each annual area matures to climax.

In simplistic terms, the 270 million tCO_2 total TDEF sequestration over a century restored by annual reinvestment of £100,000 of operating margins from wind turbines during their 20-year depreciation period more or less equates to the 255 million tCO_2 hypothetically emitted by Bristol City, also over a century.

A capital fund of £1,575,000 for installation of a 2.1 MW wind turbine in Tamil Nadu with the TCW Group model (£100,000 annual reinvestment in TDEF over 20-year turbine depreciation) would approximately account for total city-wide emissions over a century, illustratively representing:

- Investment in an initial year of £3:60 for each of Bristol City's 440,000 population; or
- A one-off £7:88 supplementary charge on rates for an assumed 200,000 rate-payers.

Bristol City has made a commitment to cut carbon dioxide emissions by 80% cut by 2050. Extending the already substantial assumptions and extrapolations any further to model the implications for this target would be so uncertain as to be untrustworthy. However, it is immediately clear that inter-regional investment around the TCW Group/Brindia model would make a very much more cost-efficient contribution than traditional technical measures (house insulation, energy efficient appliances, smart grids, etc.)

The above assessments are illustrative only; all need further research to underpin them with solid evidence. Additional evidence will consolidate a transparent business case.

6.2 Implications for south west England

Extending these same **very broad approximations** to the 5 million people of south west England, assuming the same mean per capita carbon dioxide emissions of 5.8 tCO_2 $year^{-1}$ generates:

- Annual south west England carbon dioxide emissions of 29 million tCO_2 $year^{-1}$.
- Cumulative south west England carbon dioxide emissions of 2.9 billion tCO_2 over a century.

In very simplistic terms, reinvestment of £100,000 from operating margins from each of **ten turbines** into year-on-year TDEF restoration would generate approximately 2.7 billion tCO_2 total sequestration in a total of 1,230 ha TDEF (10 x 123 ha per turbine over scheme life) over a century. Given substantial uncertainties inherent in the sparse baseline data upon which calculations are based and additional assumptions applied, this is more or less equivalent to the 2.9 billion tCO_2 hypothetically emitted by the people of south west England in a century.

6.3 Implications for the United Kingdom

Extending this very broad approximation even more heroically to the 70 million people of the UK (approximately 65 million today rising to 75 million by 2050), assuming the same mean per capita carbon dioxide emissions of 5.8 tCO_2 $year^{-1}$ and also acknowledging a proportionate increase in uncertainties, generates:

- Annual UK carbon dioxide emissions of 406 million tCO_2 $year^{-1}$.
- Cumulative UK carbon dioxide emissions of 40.6 billion tCO_2 over a century.

Extending the logic of the above, possibly beyond breaking point, reinvestment of £100,000 from operating margins from each of **one hundred and fifty turbines** into year-on-year TDEF restoration would generate approximately 40.5 billion tCO_2 total sequestration over a century, more or less equivalent to the 40.6 billion tCO_2 hypothetically emitted by south west England in a century.

6.4 Implications at institutional scale

Taking the University of the West of England (UWE) as a Bristol-based example, the institution comprises approximately 35,000 people (staff and students combined) emitting very approximately 10 tCO_2 $year^{-1}$ (source Professor James Longhurst), generating:

- Annual UK carbon dioxide emissions of 350,000 tCO_2 $year^{-1}$.
- Cumulative UK carbon dioxide emissions of 35 million tCO_2 over a century.

Extending the logic applied to Bristol City above:

- This century-long total emission could be addressed by TDEF sequestration from 12% of the cost of turbine installation under the TCW Group model.
- If a turbine costs £1,575,000 to install, this UWE investment would therefore be £189,000.

This represents a cost-effective and transparent means for any institution – a business, university, municipality or other – to address their commitments as large emitters of climate-active gases.

It also brings with it the wide network of co-benefits arising as ecosystem service outcomes from wind turbine installation and TDEF eco-restoration recorded in this report.

6.5 What's in it for the individual?

On the basis of the above logic and rough approximations, it is also possible to consider a 'zero fund' (idea promoted by John Pontin, TCW/JPT as "*The gift loan that makes a world of difference*") to 'switch off' the carbon contributions of a child over their lifetime through a certificated contributory loan for investment in a turbine.

There are many linked assumptions in deriving such a figure, making calculated values highly uncertain. However, a purely indicative, highly uncertain value of £1:50-£2:57 per person emerges from highly extrapolated calculations in Box 6.1.

Box 6.1: Alternative values for a 'zero fund'

- The approximation in Section 6.1 of investment in an initial year of £3:60 for each person in Bristol City as a contribution to turbine installation, divided by 0.7 (a 70-year lifetime as a subset of the 100-year benefit of sequestration), yields a value of **£2:57**.

- An alternative basis for calculation is on the basis of a personal share of the £1,575,000 cost of turbine installation, based on a personal lifetime of emission 406 tCO_2 (70 years at the Bristol City average of 5.8 tCO_2 per annum) with payment at 70% of the benefit of 270 million tCO_2 achieved over a century from TDEF sequestration, yielding a value of **£1:50**.

Spare background data, bold assumptions and extrapolation from already uncertain calculations create a substantial uncertainty in any such highly extrapolated figures.

The figures above are entirely indicative, requiring much more further study. Once figures can be confidently calculated and verified, a 'zero fund' loan could then be certified to a nominated person (or institution), social return benefits achieved in their name with the loan returned to them on maturation of the investment period. Alternatively, the loan may be cancelled or reinvested into new schemes.

6.6 What's in it for investors?

TCW Group is working to establish transparent and robust models for zero- or low-interest loans by individuals and institutions, returning the societal benefits arising from climate regulation and other ecosystem services outcomes. Expanding on this range of potential investors is beyond the scope of this report (though the subject of an internal discussion document and ongoing exploration), but may include as working illustrative ideas:

- A 'zero fund' purchased by parents, grandparents, municipalities or others along the lines described above, for example as a 'Grandparent bond' through which elders can secure enduring offsets for their descendants;

- Cost-effective payment mechanisms for universities, businesses, municipalities or other institutions or individuals to invest in avoidance of carbon dioxide emissions in line with their obligations as large emitters, or as part of their elective corporate social responsibility (CSR); or

- Efficient means for countries to meet their international obligations under international protocols such as UNFCCC[52] the UN Sustainable Development Goals (see Section 5).

All of these benefits occur with related collateral ecosystem service benefits realised via the wider suite of interconnected ecosystem services that these measures generate, many of which may be quantified with further research.

6.6 What's in it for the people of Tamil Nadu?

There may be criticism of this approach from some quarters about making use of the substantially lower costs of carbon avoidance and sequestration in India as compared to installing or restoring similar infrastructure, and taking other carbon reduction measures, in Bristol/south west England.

Undoubtedly, the costs of carbon avoidance and sequestration are cheaper in Tamil Nadu, but that is exactly one of the central points of conceiving of 'Brindia' as a conjoined country. Gross carbon dioxide emissions for Brindia as a whole are reduced in the most rapid and cost-efficient way. That the investments in turbines and eco-restoration are in Tamil Nadu helps the state on its pathway to a lower-carbon form of legitimate development.

Even more significantly, the 'multiplier effect' of reinvestment in TDEF eco-restoration does not merely amplify overall carbon abatement but also generates multiples pro-poor development capacity through additional ecosystem service benefits ranging from provision of forest-based food, fibre and medicinal resources, stabilisation of water and soil resources, enhancement of sites and landscapes of spiritual, traditional and other cultural benefits, and also regeneration of the biodiversity and overall resilience of the bioregion. As demonstrated by women-centred businesses in Nadukuppam 'field', the historically most marginalised are thereby empowered and lifted out of poverty.

The potential to expand TDEF restoration also accords with both state and national reforestation goals, and could be further extended to regeneration of other currently degraded regionally appropriate habitat types. The beauty of the scheme is that it is a cost-efficient means to promote sustainable, low carbon development across the notional combined UK-Indian region with no losers (apart from possibly banks hoping to make narrowly financial profit from investments).

[52] The United Nations Framework Convention on Climate Change, www.unfccc.int

7. Investment for good

So what sort of person or institution would want to invest in benefits for which there may be no established market values and that accrue to society at large, as a form of 'collateral virtue', rather than maximising personal financial returns achieved through often uncounted 'collateral damage'?

7.1 Money and the market

Innovations in the manipulation of water and land, and their implications for the productivity of landscapes, have had a profound role in ushering in successive waves of cultural evolution since founding of the first recorded civilisation in Uruk, in the 'Fertile Crescent' of Mesopotamia during the Bronze Age around 5,300 BCE. Through these innovations, enhanced food productivity and security enabled the settlement and differentiation of successive civilisations liberated from the drudgery of foraging for food[53] [54]. With differentiation of societal roles came a need to develop tokens for the exchange of value as each emerging sector of society – agrarian, construction, religious, government, educational, etc. – made a distinct contribution to societal needs.

Since these socially connected origins, the accumulation of personal wealth, and later corporate wealth, on a competitive basis has seen a radical change in the use and meaning of money across what has become the developed world. Initially, markets based on supply of commodities and services retained much of their framing as a means for exchange around the meeting of diverse needs. That was to change with the innovation of speculation on future yields of crops, gambling on which technologies, products and companies would achieve breakthrough and which would succumb, and on the usury of the rich profiting from loans to poorer people and nations.

In contemporary industrialised society, money is used to make money. The rich lend to the poor, making profit from their struggle to meet their needs, both within and between nations. Much of international loans to developing nations are spent on servicing pre-existing loans to wealthier countries, the world's poor effectively subsidising the rich[55].

For the investor, profit no longer bears the 'history' of social and environmental implications entailed in its generation. The primacy of the essentially amoral market economy, partially constrained by regulation but still largely failing to account for its consequences for the long-term wellbeing of supporting ecosystems and distributional impacts on people, is today one of the primary contributors to environmental degradation, growing societal inequities and the declining resilience of the socio-ecological system.

7.2 Sacred economics

Charles Eisenstein posits a different sort of 'sacred economics', harking back to historic 'gift economies', recognising how money can and should be used to supply societal needs. Within this vision there is no expectation of repayment by the people to which money was supplied, but that money serves to help people address needs across society. This 'sacred economics' approach can be a driving force in the transition to a more connected, ecological and sustainable way of being if

[53] Everard, M. (2011). *Common Ground: The Sharing of Land and Landscapes for Sustainability*. Zed Books, London. 214pp.

[54] Everard, M. (2013). *The Hydropolitics of Dams: Engineering or Ecosystems?* Zed Books, London.

[55] Shah, A. (2007). Causes of the Debt Crisis. *Global Issues*, 3rd June 2007. (http://www.globalissues.org/article/29/causes-of-the-debt-crisis, accessed 16th November 2015.)

outcomes are measured not in terms of personal wealth accumulation founded on little more than usury, but instead in societal enrichment and ecological resilience that each of us internally may hold most sacred and meaningful despite the everyday tyrannies of the market system we have created[56]. Eisenstein sees this evolutionary step towards a new economy as already under way, for example in the form of the new 'social currencies' of various online ratings systems that are, by their very nature, public and symbolic of trust and gratitude. This form of new currency is also connected to its 'story', quite unlike a Pound, Euro, Dollar, Rand, Rupee or Yen that has no history and therefore no such accountability for the processes that generated it. The loss of homogeneity of money, and hence a growing capacity to bear its history, may be facilitated by increasing digitisation of monetary exchanges which can carry with them an audit trail, healing the formerly widening separation of profit from the consequences of investment.

Eisenstein's vision, which he characterises as transition to an 'Age of Reunion' in which it is possible to envisage an economy geared more closely to collective senses of beauty, equity and ecological restoration, may appear utopian and unrealistic. However, viewed dispassionately, a current market model that causes unaccounted but unsustainable damage with associated potential liabilities raises serious questions for those with resources and a concern for the consequences of their investment. The absurdity of contemporary markets was illustrated in a thought experiment by Nobel physicist Frederick Soddy in the 1920s, conjecturing that, had Jesus invested £1 at the then current interest rate, the profit would have equalled the world's weight in gold; this skewing of wealth to the most privileged due to the capacity of virtual wealth to grow *ad infinitum* whilst physical assets decay, concluded Soddy, could only result in debt cancellation, revolution or war. Today, the wealthiest 1% of Americans possess 40% of the nation's wealth whilst the bottom 80% own just 7%, meanwhile the wealth of the 225 richest people in the world nearly tripled in the six years to 2000 with their assets equalling the entire annual income of half the world's population, the top 1% of households in the US owning more wealth that the entire bottom 95%[57]. This magnitude of concentration of wealth by a privileged few at the expense of the increasingly marginalised many creates social instabilities, with hyper-consumption by the affluent coincident with the poor overusing and inadvertently degrading fundamental natural resources in a struggle to meet their basic needs. Market forces virtually wholly exclude most of the fundamental assets – the resilience and diversity of the natural world and its wealth of ecosystem services – that supports not only the long-term viability of the economy but of life itself. This contemporary market reality defies natural laws, at least during the limited period until natural limits and/or connected societal conflicts impose their own rebalancing through natural selection processes.

A more connected world view, in which sense of self and the weight of feelings, values and aspirations reshape conceptions of 'value', can progressively reform a system under which people have throughout history progressively allowed themselves to become subjugated[58]. When one begins to think in these terms, there is also a wide range of established and emergent steps towards a new economy evident beyond the 'social currencies' of ratings systems[59]. Ethical investment products and banks, such as The Co-operative Bank[60] based in the UK that will only trade with businesses conforming to an ethical policy published since 1992 (though the Co-operative Bank was not immune from the global financial 'crash' and needed to be bailed out by government funds), offer customers a choice to invest in a way that has greater accountability for social and environmental consequences. Bonds for community energy, such as those supporting installation of solar farms or wind turbines, also serve as market instruments with clear pro-environmental

[56] Eisenstein, S. (2011). *Sacred Economics: Money, Gift, and Society in the Age of Transition*. Evolver Editions, New York.
[57] Bruges, J. (2000). *The Little Earth Book*. Alastair Sawday Publishing C. Ltd.
[58] Eisenstein, C. (2007). *The Ascent of Humanity*. Panenthea Productions, Harrisburg, PA.
[59] Everard, M. (in press). *The Ecosystems Revolution: Co-creating the Symbiocene*. Palgrave PIVOT series.
[60] http://www.co-operativebank.co.uk/aboutus/ourbusiness/ethicalpolicy.

outcomes and returns to local people. Microcredit schemes too, in which very small loans (microloans) are targeted at impoverished borrowers (or those who are outside of the banking system) who typically lack collateral or a verifiable credit history, support entrepreneurship, contribute to helping people rise out of poverty and provide financial services for those typically excluded from established banking models. Microcredit schemes now represent a significant sector with an estimated 74 million men and women holding microloans totalling US$38 billion in 2009[61]. So too the rise of crowdsourcing, in which investment or effort is solicited from a large group of people, especially through online communities rather than via traditional profit-taking enterprises, to promote services or innovations of various sorts. An impressively system-challenging example here is the manner in which US President Barack Obama's first electoral campaign was substantially underwritten by 'grassroots' contributions from multiple small individual donors supporting the values and vision he not only espoused but had also published[62], as an alternative to the established model of big corporate sponsorship of presidential campaigns. A similar 'line of sight' between investment and consequence is also seen in the rise of peer-to-peer lending, in practice often realised as a form of crowd-lending, that cuts out the banking middle-men, also often offering borrowers a slightly lower rate of return for longer-term commitment. The same potential is seen in the increasing use of crowdsourcing for ideas by businesses to gather views by governments of all scales, and the potential of pervasive digital media to elicit a greater diversity of perspectives to inform policy decisions which, if not automatically geared to optimally sustainable outcomes nor free from capture by powerful vested interests, certainly offers opportunity for greater democratisation in the shaping of consequences.

Traces of this values-based redirection of investment can be seen in the grand philanthropic gestures of the industrial era that saw the establishment of municipal medical, library, artistic, educational and other institutions from which those in the industrial world still benefit today, albeit that these social improvement bequests were possible on the back of unprecedented wealth generated through practices with questionable impacts on ecosystems and people including the worst excesses of the age of empire. Arguably too, in an era of super-rich minorities, we may be experiencing a new age of philanthropy, in which various individuals with way in excess of the money necessary to support themselves are making available substantial sums for altruistic purposes. The prime example here is the *Bill and Melissa Gates Foundation*[63], the largest private foundation in the world, as of 31st March 2015 employing 1,376 people with a Foundation Trust Endowment of $42.9 billion and having paid out US$33.5 billion in total grants since inception. The 'Gates Foundation' was launched in 2000 by Bill Gates, the Microsoft multi-billionaire founder, and his wife Melinda Gates with the primary aims of enhancing healthcare and reducing extreme poverty globally, and also expanding educational opportunities and access to information technology across America. The Foundation applies business techniques to giving through a venture philanthropy model, which includes a willingness to experiment with novel approaches, focus on measurable results using mutually agreed metrics, fund on a multi-year basis and prioritise capacity building typically with a high degree of involvement between donors and their grantees. Such is the success of the Gates Foundation that, in 2006, Warren Buffett, then the world's richest person, pledged substantial sums from his fortunes spread over multiple years to be used as a matching contribution, doubling the Foundation's annual giving. Many large institutions too, from professional associations such as the UK's Royal Institution of Chartered Surveyors (RICS) to major businesses such as the America-based Ford Motor Group, operate separate research and/or development Trusts. These Trusts are numerous and disparate, each with its own focal priorities, yet cumulatively represent a model of

[61] MFI Benchmark Analysis. *Microbanking Bulletin*, December 2009 (Issue No. 19). http://www.themix.org/publications/microbanking-bulletin/2009/12/mfi-benchmark-analysis-microbanking-bulletin-december-200 (accessed 3rd November 2015).
[62] Obama, B.H. (2008). *The Audacity of Hope: Thoughts on Reclaiming the American Dream*. Canongate Books.
[63] http://www.gatesfoundation.org.

using money for variously framed environmental and social good, rather than for market-based return, therefore with some similarities to Charles Eisenstein's concept of 'sacred economics'.

7.3 Potential investors in zero-/low-interest loans to TCW projects

TCW is working to identify key constituencies (both individuals and organisations) potentially interested in making zero-interest or low-interest investments, the objectives and argument attractive to them, and some of the kinds of people and organisations that may be approached. This off-line activity is not a subject for this report.

It is anticipated that this research will provide evidence to influence the thinking and rigour of the wider sustainability agenda through bodies such as:

- The potential investor community, now informed by a more rigorous and transferrable approach to social return on investment;
- The World Bank and other international and national development and donor organisations for whom the 'sacred economics' case (achievement of social, environmental and linked economic uplift as a goal rather than purely financial returns) could be persuasively demonstrated by this example;
- Corporate CSR thinking, raising the bar with respect to rigour of assessment of likely impact; and
- Policy change (national and state governments, international agencies, etc.) where barriers are identified and characterised.

Positive cases for investment may also include, for example:

- The availability of tax breaks to businesses and/or individuals making a no- or low-interest loan; and
- How the Government of India announcement on Indian radio in May 2015 and as part of investment intended to help India become a "renewables superpower" (as outlined in the *Introduction* to this report) may create linked opportunities.

This needs then to bed into the investment model being developed by TCW, for example with options for 0% loans, low-interest loans, hybrid loans that start at 0% but may attract interest after an initial period, cancellation at the end of the loan as a means to 'make carbon disappear', potential for trading Carbon Offsets, etc.

8. Conclusions and recommendations

This study draws the following conclusions and associated recommendations (bullet points in purple font):

- A wide range of direct and indirect benefits, and also some potential disbenefits, arise from TCW-sponsored renewable energy generation, highlighting diverse and already significant progress in addressing sustainable development challenges.
  - Recommendation: Conduct further research to quantify, and ideally start to monetise or otherwise value, the more significant benefits arising from TCW Group renewable energy generation. These include a range of contributions, to be prioritised by TCW, to:
    - security of water, food and fuel/fibre supply;
    - commodity trading benefits;
    - empowerment of women;
    - protection of habitats supporting genetic resources, species of biochemical, medicinal and pharmaceutical value, or ornamental resources;
    - air quality, microclimate and global climate regulation; and
    - control of pests, disease transmission and pollination.
- A wide range of direct and indirect benefits, and also some potential disbenefits, also arise from TCW-sponsored TDEF eco-restoration, highlighting diverse and already significant progress in addressing sustainable development challenges.
  - Recommendation: Conduct further research to quantify, and ideally start to monetise or otherwise value, significant benefits arising from TCW Group TDEF eco-restoration. These include a range of contributions, to be prioritised by TCW, to:
    - security of water quality and quantity;
    - security of food, fuel/fibre, genetic resources and medicinal plants;
    - regulation of air quality and microclimate, catchment hydrology;
    - regulation of pests and disease transmission;
    - regulation of global climate;
    - regulation of soil quality and quantity;
    - economic opportunities, particularly pro-poor;
    - cultural benefits (spiritual, income and employment opportunities, tourism); and
    - ecological resilience.
- The significant contribution to climate regulation that reinvestment by TCW Group of operating margins from renewable energy generation into TDEF eco-restoration makes, as well as stimulation of a low-carbon trajectory of development, is the subject of more detailed analysis. Whilst conclusions in this study about carbon sequestration by restored TDEF have to be regarded as tentative, due to the paucity of published literature on TDEF carbon storage, carbon dioxide sequestration in restored TDEF was found to be particularly substantial compared to avoidance through wind turbine generation. In combination, reinvestment of a proportion of annual operating margins from wind generation into TDEF eco-restoration had a very substantial 'multiplier effect' on carbon dioxide reductions.
  - Recommendation: Undertake more research to validate or modify knowledge about carbon dioxide sequestration rates in restored TDEF, and build a model of compound return of CO_2 avoidance from initial packages of investment in renewable energy generation.

- Beneficial outcomes arising from TCW Group renewable energy and eco-restoration schemes address many of the sustainability goals reflected in national and international commitments, significantly including the internationally agreed UN Sustainable Development Goals.
  - Recommendation: Promote recognition of the contribution that TCW Group programmes have made, and can make, to the UN Sustainable Development Goals.
  - Recommendation: Seek support for this international linked renewable energy and eco-restoration approach to be upscaled (increased uptake) and outscaled (extended beyond the focal area).
  - Recommendation: Present the evidence base in this report in simpler terms to demonstrate to potential investors the socially beneficial returns stemming from the TCW Group approach, including how it can help partner bodies deliver their own commitments, goals and aspirations.
- The TCW approach already provides evidence that a low-carbon, locally beneficial approach to development is more sustainable and equitable than the current Indian government 'development-out-of-poverty versus environment' trajectory, including its substantial increase in coal production with associated climatic, forest loss and air quality threats.
  - Recommendation: Seek dialogue with the Indian government at a range of scales about an alternative sustainable and equitable pathway of lower-carbon development.
  - Recommendation: Promote dialogue with national and state legislators and regulators to promote greater coherence in the formal and informal policy environment better to facilitate, and to remove unintended obstacles to, sustainable outcomes from renewable energy generation and functional habitat eco-restoration at local scale.
- There is a compelling case for continued investment in eco-restoration of TDEF, in terms not merely of its contribution to carbon sequestration and microclimate regulation but also a far broader set of societally beneficial ecosystem service outcomes, many relating to restoring landscape hydrology, soil stability and fertility, and cultural values.
  - Recommendation: Undertake further research into ecosystem service outcomes to further reinforce the case for social return on investment in TDEF restoration based on a broader set of ecosystem service benefits.

- Significantly beneficial parallel climate regulation and wider ecosystem service outcomes are likely to accrue from eco-restoration of other linked habitats (mangroves, tank and wetland systems, hill slopes, etc.) within the target bioregion and more broadly across Tamil Nadu and India. This principle applies as much to India as to Bristol and the wider partner region of south west England.
    - Recommendation: Undertake further research into likely ecosystem service outcomes, significantly but not exclusively including carbon sequestration and its associated costs, to substantiate the case for net social return on investment in restoration of a range of local natural habitat types that may include mangroves, tanks, wetlands and hill slopes.
    - Recommendation: On the basis of the above research, prioritise and build a business case for investment in restoration of different natural habitat types in Tamil Nadu.
    - Recommendation: Extend analysis of potential benefits from habitat restoration to the partner Bristol/south west England bioregion (consistent with goals proposed by the UK's Natural Capital Committee[64] and their endorsement by UK government[65]).
- When findings about the TCW Group model of carbon sequestration through reinvestment of wind turbine operating margins into TDEF eco-restoration in Tamil Nadu are related to implications for decarbonisation of Bristol, south west England and UK, investment in renewable energy generation in Tamil Nadu as a partner region demonstrates a highly cost-effective pathway to overall carbon management. This partnership is co-beneficial to the Indian region through promoting a lower-carbon pathway of development and restoring the natural infrastructure of the bioregion securing livelihoods for local people.
    - Recommendation: Further develop the evidence of co-benefits to both south west England and Tamil Nadu, bolstering the emerging business case for inter-regional investments.
- Careful management is required to optimise benefits and also to avert potential disbenefits.
    - Recommendation: Develop a strategy, linking with the regulatory environment but also the views of local people, to avoid or mitigate disbenefits potentially arising from TCW schemes including:
        - Renewable energy generation to: develop guidance and coherent governance models appropriate to balancing exploitation and recharge of water resources accessed through powered pumping, and to avert or mitigate noise, visual intrusion and wildlife disruption.
        - TDEF restoration to: avert displacing land important for commodity production or for a range of cultural values, and to avert fire risk due to increasing tree biomass.

---

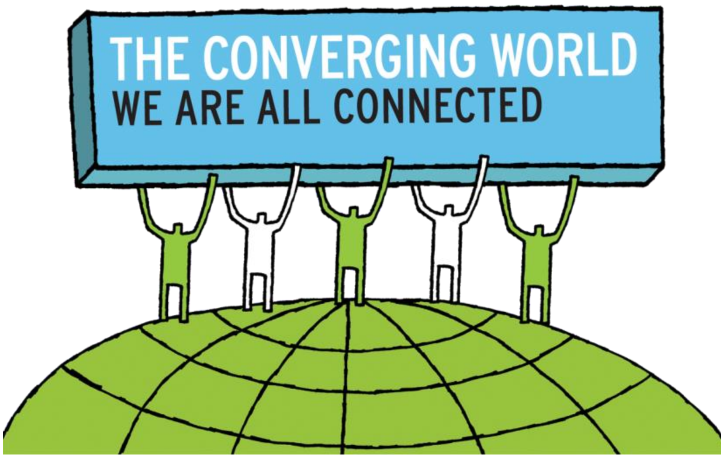
[64] Natural Capital Committee. (2015). *Protecting and Improving Natural Capital for Prosperity and Wellbeing: Third 'State of Natural Capital' report*. Natural Capital Committee, HM Government, London. https://www.naturalcapitalcommittee.org/ (accessed 16th November 2015).

[65] Defra. (2015). *The government's response to the Natural Capital Committee's third State of Natural Capital report, September 2015*. Department for Environment, Food and Rural Affairs, London. (*https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/462472/ncc-natural-capital-gov-response-2015.pdf*, accessed 16th November 2015.)

- TCW has a compelling and positive story to tell about a market-based, international approach to progressing sustainable development.
  - Recommendation: Involve media (written and broadcast) in communication of this positive story to promote TCW successes, attract additional support, and stimulate parallel evolution of schemes in other regions. A successful precedent here is publicity surrounding initiatives such as catchment/landscape regeneration in semi-arid north Rajasthan by the NGO Tarun Bharat Sangh[66], which has: elevated the profile of the organisation and initiative; increased funding from international sources; and demonstrated what is possible in terms of reversing long-standing linked cycles of socio-environmental degradation. Wider co-benefits from media presentation are to elevate in public consciousness the challenges facing the wider world, and thereby to promote transferrable lessons, upscaling and outscaling.
- Significant progress has been achieved on the basis of funding (largely from the south west England partners) on renewable energy generation and eco-restoration (in the target developing world region). However, no compelling evidence arose, at least from this tightly focused study, on proportionate parallel installation of renewable energy and eco-restoration in the south west of England.
  - Recommendation: Seek opportunities to influence the acceleration of renewable energy installation, eco-restoration and lower-carbon measures in Bristol/south west England as part of overall progression to sustainable development of 'Brindia'.

End of the body of this report

[66] www.tarunbharatsangh.in.



The Converging World:

The social and environmental impact of convergence

ANNEXES 1 to 7

UWE BRISTOL University of the West of England

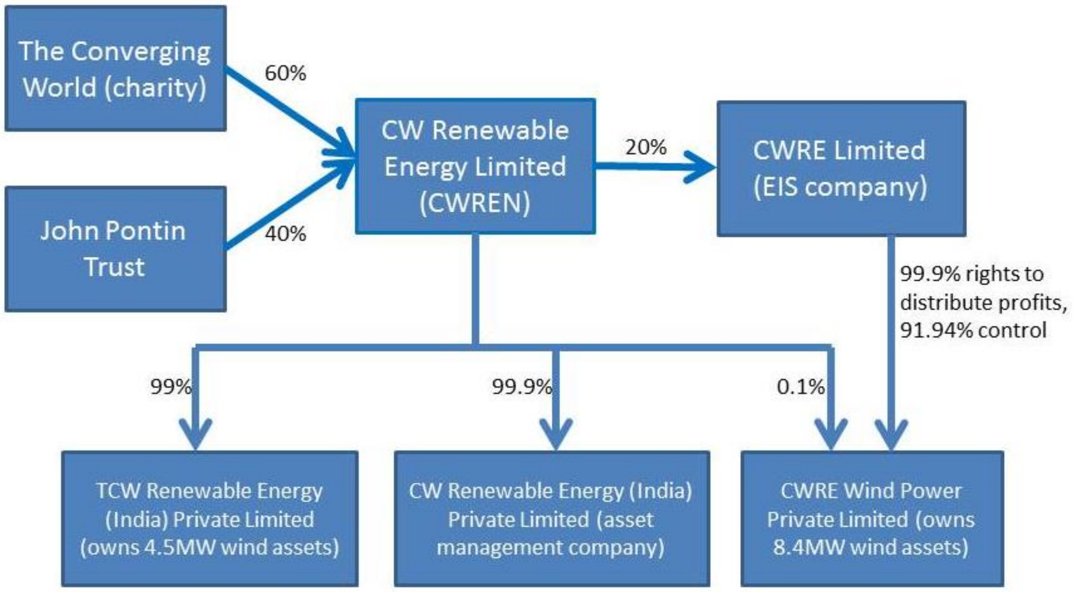
Annex 1: Background information on The Converging World (TCW)

The information in this Annex is confidential and relates to how the TCW/'Brindia' programme works financially, including its aspirations.

A1.1 About The Converging World (TCW)

TCW started in 2008 by installing its first wind farm (3MW) capable of generating 7 million kWhr and avoiding more than 6000 tonnes of CO_2 each year. Since then, TCW has increased its capacity to 13MW with the ability to generate nearly 25 million kWhr each year, avoiding more than 20,000 tonnes of CO_2.

The term 'TCW' or 'TCW Group' will be used to cover activities within a connected group of companies represented (as of 31st March 2014) below:



TCW programmes fall into three broad, interlinked categories, illustrated and described below:

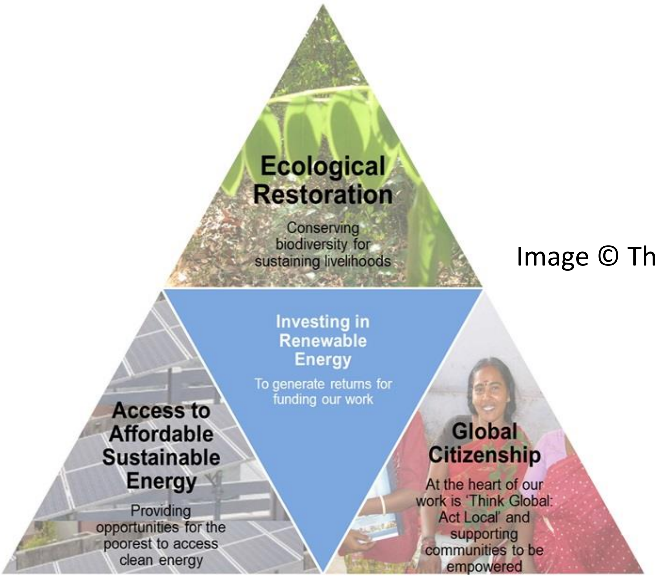


Image © The Converging World

- The **Ecological Restoration** strand of TCW work reflects that the biospheric integrity and continuing human wellbeing – including biophysical needs, economic goods and broader aspects of quality of life – depend upon functional ecosystems and a sustainable supply of ecosystem services. TCW is working with partners to restore tropical dry evergreen forest (TDEF) to sustain biodiversity and help support livelihoods for people earning less than $2 a day. To date, outcomes from TCW initiatives include the planting of more than 17,000 trees contributing to TDEF restoration with another 25,000 seedlings currently being nurtured for subsequent planting.

- The **Access to Affordable Sustainable Energy (AtASE)** strand of TCW work reflects that poverty and access to affordable energy are inextricably linked. Globally, over 1.3 billion people are without access to electricity, and 2.7 billion people are without clean cooking facilities. More than 350 million people in India are still without access to electricity. Providing sustainable and affordable options will help some of the most marginalised lift themselves out of poverty whilst preventing environmental damage from less sustainable energy sources. To date, TCW initiatives have: installed solar photovoltaics on an orphanage for girls in Mumbai; developed the TCW Energy Map, free to UK communities to help them understand their energy use and support informed decision making about the future of energy in their communities.

- The **Global Citizenship** strand of TCW work reflect that, at the heart of any environmental conservation or poverty alleviation programme, there must be a community which is enabled and empowered to help themselves in organising their own futures whilst recognising the impact of local decisions on the global community. 'Think Global; Act local' is a core principal underpinning all of the work of TCW. TCW initiatives to date include completion of its fourth year connecting children from a slum in Mumbai with children from Bristol. These children explore each other's cultures and learn about how the other community is impacted by various environmental issues. The children are encouraged and inspired to become young leaders and to implement solutions in their local community.

A1.2 Scheme ownership, investment and returns

The turbines in Tamil Nadu are owned by CWREWP Ltd[67] and TCWRE(I)[68]. As the scheme is in its early stage with substantial up-front investment, no profits are yet flowing back. However, profits are planned to be paid back as:

(1) reinvestment in more turbines and related low-carbon schemes including:

   a. More turbines planned with an approximate capital cost of around £700k per MW; and

   b. Investment in carbon sequestration schemes, such as forest planting. Forest planting is already occurring with 17,000 trees planted to date, albeit not yet from profits (as none have yet been made) but from other sources.

(2) returns to UK and other investors

The longer-term reinvestment model is flexible; up to 80% reinvestment in turbines is possible, which means that the scheme can go into positive feedback, financial returns increasing investment in new turbines thereby accelerating transition to a low carbon economy and pathway of development in India and 'offsetting' emissions for the south west of England.

However, a sizeable proportion (approximately £4.5 million assuming a conversion rate of IN₹100 to the £) of the capital costs of installed turbines was raised from Indian banks at commercial rates (typically around 13% interest paid back over 12 years). Consequently, much of current revenues from electricity sales produced by existing turbines goes into servicing the bank loan, resulting in a reduced excess and hence a slower pace of reinvestment in turbines. This is illustrated in A1.4 below.

A1.3 Accelerating positive feedback through zero/low interest investment

In order to accelerate the positive feedback effect, wherein operating margins from electricity sales is reinvested to increase the growth in decarbonised energy generation as well as investment in local forest reinstatement, TCW is exploring ways to break out of bank loans. The financial implications of this are projected in A1.5 below.

Ideas currently under discussion to achieve this include 'Grandparent funds', zero interest bonds, and other financial products for which the 'interest' is achievement of sustainability goals on the back of borrowed money, consistent with Charles Eisenstein's concept of 'sacred economics'[69]. To persuade potential investors, it is necessary to demonstrate with rigour the delivery of social benefits from the scheme.

The TCW team already has substantial expertise in assessing carbon savings and the potential for generation of Carbon Credits. The first 3MW of generation capacity under TCWRE(I) ownership are registered for Carbon Credits under the UN Clean Development Mechanism (CDM), a highly audited scheme that is generally regarded globally as the 'gold standard' and linked to the Millennium Development Goals (MDGs). However, the remaining 9.9MW of installed capacity can't be registered under the CDM as India no longer qualifies for wind farm based carbon credits because they do not pass the additionality test due to the level of internal rate of return.

[67] CWREWP owns 8.4MW. 80% of CWREWP capital is owned by a private investor, and 20% by TCW. TCW can only be a minor investor for three years from the point of its last investment, though TCW is aiming for 100% ownership by 2018.

[68] TCWRE(I) owns 4.5MW, which in turn is owned by TCW Group (60%) and the John Pontin Trust (40%).

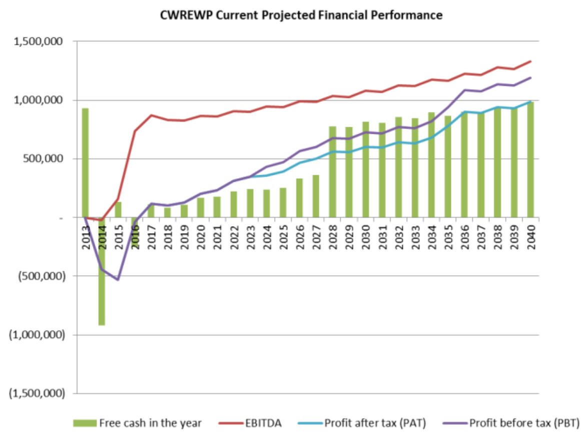
[69] Eisenstein, S. (2011). *Sacred Economics: Money, Gift, and Society in the Age of Transition*. Evolver Editions, New York.

The principal area in which UWE research can add value to the Brindia project is in characterising, and where possible quantifying, the **social return on investment (SROI)**. This will be important in terms of attracting a different sort of investor interested in longer-term societal and environmental benefits over and above single bottom line financial returns. For this reason, a level of rigour and transparency comparable to (and beyond) that in carbon markets becomes essential in substantiating these wider non-market benefits.

A1.4 Current projection with bank loan

The graph at Figure 1, produced by TCW, illustrates CWREWP Ltd projected financial performance.

Figure 1: Current projected financial performance from the 8.4MW CWREWP-owned turbines



The red line shows EBITDA (Earnings Before Interest, Taxes, Depreciation and Amortization), eliminating the effects of financing.

The purple and blue lines highlight actual profit (before/after tax).

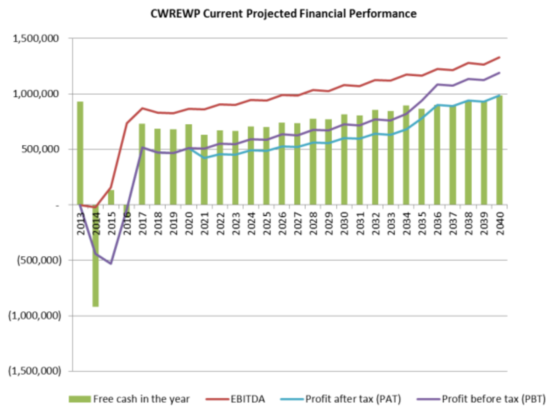
The space between the lines is the gap between returns with/without bank interest and repayments.

The total bank debt in the Company is just over £1.4m repayable over 10 years.

A1.5 Projection if bank loans were replaced with interest-free loans

Were the commercial rate bank loans to be substituted by interest-free loans with a planned repayment after ten years, this produces a rather different projection as illustrated in Figure 2. Under this zero-interest scenario, free cash available between 2016 and 2027 would be just over £7.5m (an increase of £5.5m relative to projections with bank interest) for available reinvestment, oration and other social-environmental initiatives. The graph does not include additional MWs of installed wind-generated energy.

Figure 2: Projected financial performance with transfer to zero interest loans on the 8.4MW CWREWP-owned turbines



£3.3m would need to be repaid in 2027 either as a refinance in the UK or from earning from additional MWs installed from some of the funds for reinvestment.

The proposed research would aim to provide underpinning evidence to give those potentially making loans the confidence that there were a related set of benefits into which to invest.

A1.6 Potential Indian government support

The CWRELTD team in Mumbai (Laxsmanan Natarjan: nl@cwreltd.com) has reported that Tulsi Tanti gave an interview in CNBC (the leading Business channel in India) on 26th May 2015 concerning renewable energy scope and prospects. In this interview, it was noted that:

- Government of India has planned 175 GW new installations of power generation by 2022. Out of which, the Suzlon Group (www.suzlon.com: the world's fifth largest wind turbine supplier) has planned 15 GW within 5 years comprising:
    - 10 GW – Wind onshore
    - 1 GW – Wind offshore
    - 4 GW – Solar
- Government of India promised support to achieve the target of 175 GW including:
    1. Lower interest rate
    2. 80:20 funding
    3. Long- term funding to the extent of 15 – 20 years
    4. Improving the health of SEBs
    5. Improving the grid infrastructure for evacuation of power

This can open up opportunities for support for TCW/CWRELTD schemes that may accelerate progress towards potential positive feedback in renewable energy growth and eco-restoration within the programme.

End of Annex 1

Annex 2: Ecosystem services and the UN Millennium Ecosystem Assessment framework

Ecosystem services are defined as "…*the benefits that people derive from nature*"[70]. As such, they are anthropocentric, but the diversity of services includes many that are far from simply utilitarian and relate to the integrity and resilience of ecosystems and their capacity to continue functioning and producing services.

Several models of the ecosystem service framework have been published. These range from early ecosystem service classification schemes (such as Dugan's 1990 classification of wetland 'goods and services'[71] and Everard *et al*.'s SWAMP model[72]) that tended to be habitat- and location-specific, though to more recent generic classifications.

A2.1 The UN Millennium Ecosystem Assessment framework

In order to compare a range of major habitat types across the world, the UN's Millennium Ecosystem Assessment[73] integrated a wide range of pre-existing ecosystem service classifications as part of a new framework spanning four categories:

- Provisioning services: food, fresh water, biochemicals and other substances and energy that can extracted from nature;
- Regulatory services: natural processes that regulate, for example, flows and quality of air and water, erosion, diseases and climate;
- Cultural services; non-material benefits derived from nature such as spiritual enrichment, tourism and recreation opportunities, and education; and
- Supporting services: processes such as soil formation, photosynthesis and the cycling of nutrients and water that maintain ecosystem functioning and resilience.

All ecosystem services within the Millennium Ecosystem Assessment classification support different aspects of human wellbeing, the supporting services doing so largely indirectly by ensuring ecosystem integrity, health and capacity to produce other more directly exploited services.

70 http://www.millenniumassessment.org/en/Synthesis.html.
71 Dugan, P.J. 1990. *Wetland Conservation: A Review of Current Issues and Required Action*. Gland (Switzerland): IUCN, 95 pp.
72 Everard, M., Denny, P. and Croucher, C. (1995). SWAMP: A Knowledge-Based System for the Dissemination of Sustainable Development Expertise to the Developing World. *Aquatic Conservation*, 5(4), pp.261-275.
73 http://www.millenniumassessment.org/en/Synthesis.html.

Table A2.1 reproduces the Millennium Ecosystem Assessment framework of ecosystem services, with selected, widely-used addenda, and a brief explanation of each of the services.

Table A2.1: The Millennium Ecosystem Assessment framework of ecosystem services, with some modification and explanation of services

Types of ecosystem services		**What is this ecosystem service all about**
Provisioning services	Fresh water	Fresh water available for use for a variety of purposes
	Food (e.g. crops, fruit, fish, etc.)	Food grown, harvested or otherwise provided
	Fibre and fuel (e.g. timber, wool, etc.)	Fibre (wood, wool, cotton, Kapok, etc.) and fuel grown, harvested or otherwise provided
	Genetic resources (used for crop/stock breeding and biotechnology)	Natural or rare strains of plants, animals and microorganisms, wild or domesticated, that could contribute genetic diversity for human uses (improving resilience of domestic animals and plants, etc.)
	Biochemicals, natural medicines, pharmaceuticals	Plants, animals. microorganisms or their parts and/or geodiversity with biochemical, medicinal or other related properties
	Ornamental resources (e.g. shells, flowers, etc.)	Plants, animals. microorganisms or their parts and/or geodiversity with ornamental properties
	Energy harvesting from natural air and water flows	Energy harvested from natural flows, such as via water wheels, turbines, etc.

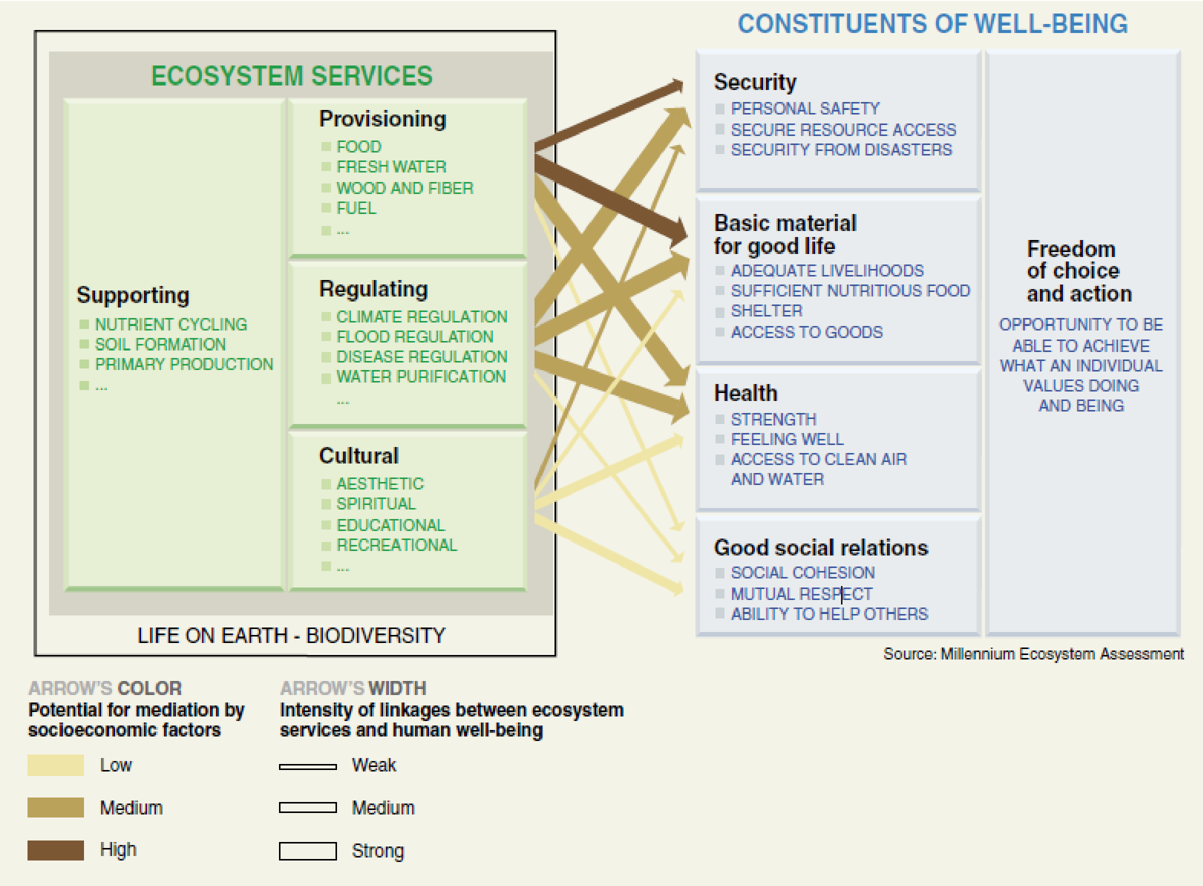
Regulatory services	Air quality regulation	Regulation of aerial pollutants or metabolisation of gaseous air pollutants, either as a source or a sink
	Microclimate: local climate regulation	Cooling, moisture or other benefits to the local air cell
	Global climate regulation	Storage and/or sequestration of carbon, including potential generation of methane and other greenhouse gases
	Water regulation	Hydrological behaviour (timing and scale of run-off, flooding, etc.), including both surface and groundwater flows
	Natural hazard regulation	Regulation, typically by complexity of habitat (trees, tall vegetation and surface topography, etc.), that absorbs or dissipates energy from extreme events (flood surges, storms, etc.)
	Pest regulation	Natural predation and other ecological processes that regulate pest organisms (mosquitoes, invasive species, etc.) or serve as a net source of pests (for example midges thriving in ponded water bodies)
	Disease regulation - human	Natural predation and processes that regulate organisms that may cause human diseases (microbes, disease vectors such as mosquitoes, etc.)
	Disease regulation - stock	Natural predation and processes that regulate organisms that may cause stock diseases (microbes, disease vectors such as snails, etc.)
	Erosion regulation	Natural processes, typically including permanent vegetative cover, that regulate the erosion of soils
	Water purification and waste treatment	Physico-chemical and biological processes resulting in the breakdown of organic, microbial and other water pollutants
	Pollination	Populations of pollinating organisms (wasps, bees, beetles, etc.) or natural processes (wind, water flows) contributing to pollination
	Salinity regulation	Processes regulating for salinisation of soils
	Fire regulation	Processes regulating for the spread of wildfires
	Noise and visual buffering	Regulation, typically by complexity of habitat (trees, tall vegetation and surface topography, etc.), that affords visual screening or the suppression of noise

Cultural services	Cultural heritage	Natural features of cultural importance, including via natural character and/or traditional uses
	Recreation and tourism	Natural features offering recreational uses, organised or informal, and/or wider tourism/ecotourism benefits
	Aesthetic value	Natural features with aesthetic benefits, including implications for adjacent houses or commercial developments
	Spiritual and religious value	Natural features with implications for spiritual and/or religious values, including traditional management practices with spiritual meanings
	Inspiration of art, folklore, architecture, etc.	Natural features with implications for the inspiration people gain – in terms of painting, creating music or other art, ways of designing and building – or relating to myths or other folklore
	Social relations (e.g. fishing, grazing or cropping communities)	Natural features linking local communities, such as cropping and farming, fishing, stock management, walking and jogging, birdwatching and photography, etc.
	Educational and research	Natural features serving educational purposes, organised or informal, ranging from school-level visits to university research and teaching
Supporting services	Soil formation	Natural soil accretion processes, including both sedimentation of mineral material and build-up of organic material
	Primary production	Photosynthetic processes producing organic matter and storing energy in biochemical form
	Nutrient cycling	Natural processes transforming nutrients (for example nitrification/denitrification or settling out particulate forms of nutrients)
	Water recycling	Natural processes that retain water in tight local cycles, such as capture of evaporated water by complex vegetation or topography
	Photosynthetic oxygen production	Photosynthetic processes producing oxygen
	Provision of habitat	Habitat supporting biodiversity, including rare and common species

A2.2 Contribution of services to human wellbeing

All ecosystem services contribute to human wellbeing end-points. All ecosystem services within the Millennium Ecosystem Assessment classification support different aspects of human wellbeing, the supporting services doing so largely indirectly by ensuring ecosystem integrity, health and capacity to produce other more directly exploited services.

Figure from MA of how maps to benefits:



Whilst other ecosystem service frameworks have been developed

A2.3 Other ecosystem service frameworks and the reason for using the MA framework

The Millennium Ecosystem Assessment framework is far from the only classification of ecosystem services. The MA framework integrated a disparate range of pre-existing classifications, often developed on a regional and habitat-species basis, and various subsequent reclassifications have since been developed. A subset of these includes:

- The Economics of Ecosystems and Biodiversity (TEEB) ecosystem services framework[74] is broadly consistent with that developed by the MA, comprising: Provisioning, Regulating, Habitat and supporting; and Cultural services.
- The Common International Classification of Ecosystem Services (CICES) developed from the work on environmental accounting undertaken by the European Environment Agency (EEA)[75] to

[74] http://www.teebweb.org/resources/ecosystem-services/.
[75] http://cices.eu/.

support revision of the System of Environmental-Economic Accounting (SEEA). CICES introduces international standardisation of ecosystem services for compliance with economic accounting methods, with three degrees of subdivisions from the three principal categories of: Provisioning; Regulation & Maintenance; and Cultural. (The Regulation & Maintenance category effectively merges the MA's Regulatory and Supporting categories.)

- The economic model of the UK National Ecosystem Assessment (UK NEA)[76], which relegates many less directly consumed services in 'primary' and 'intermediate' services that contribute to more directly exploited services that can be more confidently monetised, the argument being that these non-marketed services should not be valued as do so it to 'double count' their contribution to services that are directly exploited and marketed.

The importance of valuing in some manner all services, marketed and non-market alike, is elaborated in Annex 7. A primary reason for recognising and quantifying for weighing all services in decision-making stems from the fact that many externalities are associated with the full production costs of resources such that markets substantially distort the allocation of resources and hence the viability of productive systems[77]. For example, implications for soil fertility and structure, nutrient cycling, habitat for wildlife, carbon sequestration and a range of other non-marketed services during the production of farmed food and other traded commodity outputs are substantially omitted from market prices. Failure to recognise the contribution of these excluded services, particularly supporting and some regulatory ecosystem services, both to production of traded goods and to overall system functioning and resilience perpetuates their exclusion from decision-making at all scales. Indeed, key messages of the Millennium Ecosystem Assessment[78] [79], TEEB[80] [81] as well as national studies such as the UK NEA[82] highlight the substantial degradation of broad habitat types and their services through narrow exploitation for limited provisioning services.

For this reason, ecosystem services classifications subject to economic filtering must be treated with caution. This study therefore favours continuing use of the original MA classification of ecosystem services with commonly-applied addenda (such as the provisioning service of energy harvesting which is highly appropriate to wind power, the regulatory services of fire and salinity regulation and of noise and visual buffering, and the cultural service of educations and research).

---

[76] www.uknea.unep-wcmc.org.
[77] Ayres, R.U. and Kneese, A.V. (1969). Production, consumption, and externalities. *The American Economic Review*, 59(3), pp.282-297.
[78] Millennium Ecosystem Assessment. (2005a). *Ecosystems and Human Well-being: General Synthesis*. Washington DC: Island Press.
[79] Millennium Ecosystem Assessment. (2005b). *Ecosystems and Human Well-being: Wetlands and Water Synthesis*. World Resources Institute, Washington, DC.
[80] TEEB. (2010a). *The Economics of Ecosystems and Biodiversity: Ecological and Economic Foundations*. Edited by Pushpam Kumar. Earthscan, London and Washington.
[81] TEEB. (2010b). *The Economics of Ecosystems and Biodiversity: Mainstreaming the Economics of Nature: A Synthesis of the Approach, Conclusions and Recommendations of TEEB*. Earthscan, London and Washington.
[82] UK NEA. (2011). The UK National Ecosystem Assessment: Synthesis of the Key Findings. UNEP-WCMC, Cambridge. http://uknea.unep-wcmc.org/ (accessed 10th July 2015).

A2.4 Related sustainable development frameworks

A wide range of frameworks and systems models address sustainable development, each suited to different applications. These include, as a few better-known examples:

- The Ecosystem Approach[83], which sets broader geographical and socio-economic contexts within which to apply ecosystem services;
- UNEP Global Environmental Outlook (GEO), a 'living process' and open data repository serving as an integrative baseline to assess global megatrends with due consideration given to gender, indigenous knowledge and cultural dimensions. The GEO assessment is intended to lay the foundation for continued socio-environmental assessments across relevant scales, with a thematic as well as an integrated focus, enabling and informing societal transitions and the tracking of SDG targets and goals as well as previously agreed internationally environmental goals[84].
- Planetary Boundaries, developed by the Stockholm Resilience Centre and the Australian National University, which specify nine indicators defining a "*safe operating space for humanity*" that can be used by the international community, including governments at all levels, international organizations, civil society, the scientific community and the private sector, as a precondition for sustainable development[85].

The selection of the Millennium Ecosystem Assessment framework reflects its utility in translating ecosystem implications directly to an interconnected set of human wellbeing end-point, directly integrating environmental, social and economic factors.

End of Annex 2

[83] Convention on Biological Diversity: www.cbd.int/ecosystem.
[84] UNEP: http://www.unep.org/geo/pdfs/geo5/GEO5_report_full_en.pdf.
[85] Stockholm Resilience Centre. (2015). The nine planetary boundaries. (http://www.stockholmresilience.org/21/research/research-programmes/planetary-boundaries/planetary-boundaries/about-the-research/the-nine-planetary-boundaries.html, accessed 10th November 2015.)

Annex 3: Detailed analysis by ecosystem service of systemic outcomes from TCW generation activities

This Annex comprises a series of Tables providing ecosystem service-by-ecosystem service consideration of the direct and indirect benefits and also potential disbenefits associated with TCW Group wind generation.

A3.1Direct benefits arising from CWRELTD generation

Benefits stemming directly from carbon averted through renewable energy generation in Tamil Nadu extend locally, nationally, across to the UK as a partner nation/region, and globally.

Types of ecosystem services		What is this ecosystem service all about
Provisioning services	Fresh water	• No direct benefits perceived from wind turbine generation.
	Food (e.g. crops, fruit, fish, etc.)	• No direct benefits perceived from wind turbine generation.
	Fibre and fuel (e.g. timber, wool, etc.)	• Empowerment of women freed from historic drudgery of spending much of their time gathering fuel wood or obtaining water in the absence of pumping energy.
	Genetic resources (used for crop/stock breeding and biotechnology)	• Potential avoidance of harm to habitats naturally supporting genetic resources, but currently subject to mining of fossil fuels, growth of biomass fuel crops of upstream and downstream dam impacts.
	Biochemicals, natural medicines, pharmaceuticals	• Potential avoidance of harm to habitats naturally containing species with biochemical, medicinal and pharmaceutical application, but currently subject to mining of fossil fuels, growth of biomass fuel crops of upstream and downstream dam impacts.
	Ornamental resources (e.g. shells, flowers, etc.)	• Potential avoidance of harm to habitats naturally containing ornamental resources, but currently subject to mining of fossil fuels, growth of biomass fuel crops of upstream and downstream dam impacts.
	Energy harvesting from natural air and water flows	• Co-benefits from improved efficiencies through powered communications infrastructure.

Regulatory services	Air quality regulation	• Averts emissions from coal, biomass and other combusted fuels into local airspace.
	Microclimate: local climate regulation	• Averts localised emissions from coal, biomass and other combusted fuels. • Avoidance of dangerous fumes in houses from biomass fuel or waste materials burnt for cooking.
	Global climate regulation	• Averts global emissions from coal, biomass and other combusted fuels.
	Water regulation	• AREA FOR FURTHER STUDY: It is known that solar arrays can make a positive contribution to the hydrology of catchments through reduced compaction[86], and this may also be a feature of landscapes surrounding turbines though at present this has not been studied.
	Natural hazard regulation	• No direct benefits perceived from wind turbine generation.
	Pest regulation	• No direct benefits perceived, though possible benefit from averted mining and biofuel growth compromising populations of natural pest-regulating organisms (such as wasps predating on aphids).
	Disease regulation – human	• No direct benefits perceived, though possible benefit from averted mining and biofuel growth reducing habitats regulating human diseases and their vectors.
	Disease regulation – stock	• No direct benefits perceived, though possible benefit from averted mining and biofuel growth reducing habitats regulating stock diseases and their vectors.
	Erosion regulation	• No direct benefits perceived, though possible benefit from averted mining and biofuel growth exposing soil surfaces to erosion.
	Water purification and waste treatment	• No direct benefits perceived from wind turbine generation.
	Pollination	• No direct benefits perceived, though possible benefit from averted mining and biofuel growth reducing habitats supporting natural pollinators.
	Salinity regulation	• No direct benefits perceived from wind turbine generation.
	Fire regulation	• No direct benefits perceived from wind turbine generation.
	Noise and visual buffering	• No direct benefits perceived from wind turbine generation.

[86] Pisinarasa, V., Weib, Y., Bärringb, L. and Gemitzia, A. (2014). Conceptualizing and assessing the effects of installation and operation of photovoltaic power plants on major hydrologic budget constituents. *Science of the Total Environment*, 493, pp.239–250.

Cultural services	Cultural heritage	• No direct benefits perceived from wind turbine generation.
	Recreation and tourism	• No direct benefits perceived from wind turbine generation.
	Aesthetic value	• No direct benefits perceived from wind turbine generation.
	Spiritual and religious value	• No direct benefits perceived from wind turbine generation.
	Inspiration of art, folklore, architecture, etc.	• No direct benefits perceived from wind turbine generation.
	Social relations (e.g. fishing, grazing or cropping communities)	• May create new community groups as well as technicians associated with turbines.
	Educational and research	• Promotion of learning due to availability of lighting in the evenings and better access to digital media.
Supporting services	Soil formation	• No direct benefits perceived from wind turbine generation.
	Primary production	• No direct benefits perceived from wind turbine generation.
	Nutrient cycling	• No direct benefits perceived from wind turbine generation.
	Water recycling	• No direct benefits perceived from wind turbine generation.
	Photosynthetic oxygen production	• No direct benefits perceived from wind turbine generation.
	Provision of habitat	• No direct benefits perceived from wind turbine generation.

A3.2 Indirect benefits arising from CWRELTD generation

This section considers collateral benefits likely to arise from the availability of renewable energy from turbines and the wider systemic effects of averting other sources of energy generation (biomass, thermal, nuclear, hydropower, etc.)

Types of ecosystem services		What is this ecosystem service all about
Provisioning services	Fresh water	• Energisation of groundwater pumping by energy not available from other sources may enhance access to water for local communities. • There are potential savings in water resource availability versus water used for cooling by alternative thermal energy generation technologies (fossil fuel, nuclear) in this already water-scarce region. • There are potential savings in water resource availability versus hydropower generation in this already water-scarce region.
	Food (e.g. crops, fruit, fish, etc.)	• Energisation of pumping may enhance food production, and enhanced access to electronic communication may increase traded food values.
	Fibre and fuel (e.g. timber, wool, etc.)	• Energisation of pumping may enhance food production, and enhanced access to electronic communication may increase traded fibre and fuel values.
	Genetic resources (used for crop/stock breeding and biotechnology)	• No indirect benefits perceived from renewable energy generation.
	Biochemicals, natural medicines, pharmaceuticals	• No indirect benefits perceived from renewable energy generation.
	Ornamental resources (e.g. shells, flowers, etc.)	• No significant indirect benefits perceived from renewable energy generation, though enhanced access to electronic communication may increase traded ornamental resource values.
	Energy harvesting from natural air and water flows	• No indirect benefits perceived from renewable energy generation.

Regulatory services	Air quality regulation	• Avoidance of dangerous fumes in houses from biomass fuel burning for cooking.
	Microclimate: local climate regulation	• No indirect benefits perceived from renewable energy generation.
	Global climate regulation	• Displacement of carbon-intensive emissions is addressed above as direct effects. • Displacement of hydropower generation may also yield significant indirect benefits for global climate regulation. Though a simplistic assumption that hydropower is carbon-neutral is often implicit in political pronouncements, methane generation in deep anoxic water from vegetation inundated on dam filling and organic matter washed into or growing in tropical dams is 72 times more potent as a greenhouse gas than carbon dioxide although removed from the atmosphere rather quicker. Generally, this impact has been overlooked or assumed to be trivial, but peer-reviewed research[87] suggests that 104 +/-7.2 Tg (million metric tonnes) of methane are generated by large dams each year based on ICOLD (dams industry) inventories. Large dams around the world may be one of the single most important contributors to global warming, accounting for more than 4% of the total global warming impact of human activities[88] with large dams in India responsible for 19% of the country's total global warming impact[89]. • A CONTINUING RESEARCH NEED is to follow or influence how this overlooked impact is factored into future IPCC and carbon accounting findings and policies.
	Water regulation	• UNCERTAINTY: Averting mining of fossil energy resources or growing of biofuel crops will have a positive impact on catchment hydrology.
	Natural hazard regulation	• No indirect benefits perceived.
	Pest regulation	• UNCERTAINTY: Potential impacts for natural pest regulation arise from averting habitat lost to mining of fossil energy resources or growing of biofuel crops.
	Disease regulation – human	• Significant increases in transmission of diseases with insect vectors (such as Japanese encephalitis, bilharzia, Dengue Fever, West Nile Virus) commonly accompany river

87 Lima, I.B.T. et al. (2007). Methane Emissions from Large Dams as Renewable Energy Resources: A Developing Nation Perspective. Mitigation and Adaptation Strategies for Global Change, published on-line March 2007.

88 International Rivers. (2007). Press Release: 4% of Global Warming Due to Dams, Says New Research. International Rivers Network, 9th May 2007. (http://www.internationalrivers.org/node/1361).

89 South Asian Network. (2007). 19% of India's Global Warming emissions from Large Dams: Myth of large hydro being clean shattered (again). South Asian Network on Dams, Rivers and People, 18th May 2007. (http://www.sandrp.in/dams/India_Dams_Methane_Emissions_PR180507.)

		modification for hydropower generation in tropical climates[90], which may be averted if turbines produce energy as an alternative.
	Disease regulation – stock	• REQUIRING FURTHER STUDY: The probability of increased transmission of stock diseases with insect vectors (such as Bluetongue) is a possibility where rivers are dammed as an alternative power source, but this impact is not as intensively recorded as for human diseases.
	Erosion regulation	• No indirect benefits perceived from renewable energy generation.
	Water purification and waste treatment	• No indirect benefits perceived from renewable energy generation.
	Pollination	• UNCERTAINTY: Potential impacts for pollination arise from averting habitat lost to mining of fossil energy, growth of biomass fuel crops of upstream and downstream dam impacts.
	Salinity regulation	• No indirect benefits perceived from renewable energy generation.
	Fire regulation	• No indirect benefits perceived from renewable energy generation.
	Noise and visual buffering	• No indirect benefits perceived from renewable energy generation.
Cultural services	Cultural heritage	• UNCERTAINTY: Displacement of other energy generation techniques and associated supply chains may confer indirect cultural benefits (through averted damage).
	Recreation and tourism	• UNCERTAINTY: Displacement of other energy generation techniques and associated supply chains may confer indirect recreation and tourism benefits (through averted damage).
	Aesthetic value	• UNCERTAINTY: Displacement of other energy generation techniques and associated supply chains may confer indirect aesthetic benefits (through averted damage).
	Spiritual and religious value	• UNCERTAINTY: Displacement of other energy generation techniques and associated supply chains may confer indirect spiritual benefits (through averted damage).
	Inspiration of art, folklore, architecture, etc.	• UNCERTAINTY: Displacement of other energy generation techniques and associated supply chains may confer indirect artistic benefits (through averted damage).
	Social relations (e.g. fishing, grazing or cropping communities)	• UNCERTAINTY: Displacement of other energy generation techniques and associated supply chains may confer indirect benefits so communities of various kinds though averted damage to habitats around which they associate.
	Educational and research	• Indirect benefits include opportunities for study of energy systems in technical, economic, social and environmental contexts.

[90] Everard, M. (2013). *The Hydropolitics of Dams: Engineering or Ecosystems?* Zed Books, London.

Supporting services	Soil formation	• UNCERTAINTY: Displacement of other energy generation techniques and associated supply chains may confer indirect benefits to all supporting services though averted damage to habitats and their functioning.
	Primary production	• UNCERTAINTY: Displacement of other energy generation techniques and associated supply chains may confer indirect benefits to all supporting services though averted damage to habitats and their functioning.
	Nutrient cycling	• UNCERTAINTY: Displacement of other energy generation techniques and associated supply chains may confer indirect benefits to all supporting services though averted damage to habitats and their functioning.
	Water recycling	• UNCERTAINTY: Displacement of other energy generation techniques and associated supply chains may confer indirect benefits to all supporting services though averted damage to habitats and their functioning.
	Photosynthetic oxygen production	• UNCERTAINTY: Displacement of other energy generation techniques and associated supply chains may confer indirect benefits to all supporting services though averted damage to habitats and their functioning.
	Provision of habitat	• UNCERTAINTY: Displacement of other energy generation techniques and associated supply chains may confer indirect benefits to all supporting services though averted damage to habitats and their functioning.

A3.3 Potential disbenefits arising from CWRELTD generation

In order to take a systemic view of outcomes from CWRELTD generation, both in terms of recognising potential impacts as well as then planning to avert or mitigate them, it is also important to consider potential disbenefits.

Types of ecosystem services		What is this ecosystem service all about
Provisioning services	Fresh water	• Risk of newly available energy being used to over-pump receding groundwater. Groundwater supports over 85% of India's rural domestic water requirements, the number of mechanised wells in India increasing in the last four decades of the twentieth century from less than one million to more than 19 million in the year 2000[91] with more than 22 million operational wells supporting the economy[92]. However, groundwater overexploitation is a pervasive problem. Overexploitation of groundwater has triggered mass movements of people from Rajasthan's semi-arid villages towards better watered regions[93],

[91] Jha, B.M. and Sinha, S.K. (2009). Towards Better Management of Ground Water Resources in India. *Bhu-Jal News Quarterly Journal*, 24(4), pp.1-20.
[92] Wani, S.P., Sudi, R. and Pathak, P. (2009). Sustainable Groundwater Development through Integrated Watershed Management for Food Security. *Bhu-Jal News Quarterly Journal*, 24(4), pp.38-52.
[93] Hills, E.S. (ed.) (1966). *Arid Lands: A Geographical Appraisal*. Methuen Young Books.

		Government of India statistics classifying more than 50% of Rajasthan's groundwater aquifers as overexploited ('dark')[94]. Groundwater depletion has serious implications, driving a negative spiral of interlinked ecological, social and economic degradation[95 96 97], representing a major threat to food security in India[98] putting a quarter of the nation's food harvest at risk[99 100]. In the light of this potential risk, precautionary formal or informal regulation of energised groundwater pumping is necessary. AREA FOR FURTHER STUDY: Open dialogue with Tamil Nadu State regulatory authorities about the linked water-food-energy nexus and its sustainable management.
	Food (e.g. crops, fruit, fish, etc.)	• No disbenefits observed from renewable energy generation.
	Fibre and fuel (e.g. timber, wool, etc.)	• No disbenefits observed from renewable energy generation.
	Genetic resources (used for crop/stock breeding and biotechnology)	• No disbenefits observed from renewable energy generation.
	Biochemicals, natural medicines, pharmaceuticals	• No disbenefits observed from renewable energy generation.
	Ornamental resources (e.g. shells, flowers, etc.)	• No disbenefits observed from renewable energy generation.
	Energy harvesting from natural air and water flows	• No disbenefits observed. Energy harvesting from air flows will not compromise other energy harvesting methods.

[94] Rathore, M.S. (2003). *Community based management of ground water resources: a case study of Arwari River basin*. Institute of Development Studies, Jaipur.
[95] Downing, R.A. (2002). *Groundwater: our hidden asset*. British Geological Survey, Nottingham, UK.
[96] Postel, S. (1999). *Pillar of sand: Can the irrigation miracle last?* New York, USA: W. W. Norton & Company.
[97] Vaidyanathan, A. (1996). Depletion of Groundwater: Some Issues. *Indian Journal of Agricultural Economics,* 51(1–2), pp.184–92.
[98] Kumar, M.D. (2003). *Food security and sustainable agriculture in India: The water management challenge*. International Water Management Institute, Working Paper 60. Columbo, Sri Lanka: International Water Management Institute.
[99] Seckler. D., Barker, R. and Amarasinghe, U. (1999). Water Scarcity in the Twenty-first Century. *Water Resources Development*, 15(1/2), pp.29-42.
[100] Singh, D.K. and Singh, A.K. (2002). Groundwater Situation in India: Problems and Perspective. *International Journal of Water Resources Development*, 18, pp.563-580.

Regulatory services	Air quality regulation	• No disbenefits observed from renewable energy generation.
	Microclimate: local climate regulation	• No disbenefits observed from renewable energy generation.
	Global climate regulation	• No disbenefits observed, though embedded carbon in turbine manufacture and associated infrastructure has to be assessed in calculating overall balances over life.
	Water regulation	• No disbenefits observed from renewable energy generation.
	Natural hazard regulation	• No disbenefits observed from renewable energy generation.
	Pest regulation	• No disbenefits observed from renewable energy generation.
	Disease regulation - human	• No disbenefits observed from renewable energy generation.
	Disease regulation - stock	• No disbenefits observed from renewable energy generation.
	Erosion regulation	• No disbenefits observed from renewable energy generation.
	Water purification and waste treatment	• No disbenefits observed from renewable energy generation.
	Pollination	• No disbenefits observed from renewable energy generation.
	Salinity regulation	• No disbenefits observed from renewable energy generation.
	Fire regulation	• No disbenefits observed from renewable energy generation.
	Noise and visual buffering	• AREA FOR FURTHER STUDY: The issue of noise generation and visual intrusion by turbines is subjective but needs to be addressed.
Cultural services	Cultural heritage	• NOTE: The subjectivity of perceptions of wind turbines may have some relevance for cultural values, but careful siting to avoid adverse interactions in valued sites is a sensible mitigation measure.
	Recreation and tourism	• No disbenefits observed from renewable energy generation.
	Aesthetic value	• NOTE: The subjectivity of perceptions of wind turbines may have some relevance for aesthetic values, but careful siting to avoid adverse interactions in valued sites is a sensible mitigation measure.
	Spiritual and religious value	• NOTE: Careful siting to avoid adverse interactions in spiritually important sites is a sensible mitigation measure.
	Inspiration of art, folklore, architecture, etc.	• No disbenefits observed from renewable energy generation.
	Social relations (e.g. fishing, grazing or cropping communities)	• No disbenefits observed from renewable energy generation.
	Educational and research	• No disbenefits observed from renewable energy generation.

Supporting services	Soil formation	• No disbenefits observed from renewable energy generation.
	Primary production	• No disbenefits observed from renewable energy generation.
	Nutrient cycling	• No disbenefits observed from renewable energy generation.
	Water recycling	• No disbenefits observed from renewable energy generation.
	Photosynthetic oxygen production	• No disbenefits observed from renewable energy generation.
	Provision of habitat	• AREA FOR FURTHER STUDY: Further study of the literature on disruption of wildlife by wind turbine fields is warranted to assess effects objectively. From this evidence base, siting of future turbines can be better-informed, as can be representation of the positive case to regulators and potential investors.

End of Annex 3

Annex 4: Detailed analysis by ecosystem service of systemic outcomes from TCW eco-restoration of tropical dry evergreen forest (TDEF)

This Annex comprises a series of Tables providing ecosystem service-by-ecosystem service consideration of the direct and indirect benefits and also potential disbenefits associated with TCW Group TDEF eco-restoration activities.

A4.1 Benefits arising from forest eco-restoration

Eco-restoration of forests brings with it a diversity of potential co-benefits.

Types of ecosystem services		What is this ecosystem service all about
Provisioning services	Fresh water	• Forest ecosystems make a direct contribution to the water system, in terms of quality, quantity and local recycling of water, enhancing its availability to people for beneficial uses.
	Food (e.g. crops, fruit, fish, etc.)	• Potential for establishment of forest-dwelling species that can be cropped for food (honey, jackfruit, etc.) or for polyculture within established forests (e.g. shade-loving crops such as coffee, plants using trees such as vanilla vines, etc.)
	Fibre and fuel (e.g. timber, wool, etc.)	• Potential for establishment of species that can be pruned or harvested for timber or other types of fibre (thatch, kapok, etc.)
	Genetic resources (used for crop/stock breeding and biotechnology)	• Potential for establishment of species of genetic value, such as rare breeds of stock or crop or promotion of regeneration of natural diversity of inherent genetic value
	Biochemicals, natural medicines, pharmaceuticals	• Potential for establishment of species with medicinal properties (particularly related to traditional medicine) or for which biochemicals can be exploited in other ways
	Ornamental resources (e.g. shells, flowers, etc.)	• Potential for establishment of species with ornamental uses, either informally of as part of trade
	Energy harvesting from natural air and water flows	• UNCERTAINTY: The degree to which protection of hydrology makes available extra capacity for additional hydropower generation is uncertain.
Regulatory services	Air quality regulation	• Settling particulate matter • Metabolising other pollutants • Dust control, both through settlement of dust form the air and also avoidance of dust generation from formerly erosive land surfaces
	Microclimate: local climate regulation	• UNCERTAINTY: Forest stands can influence microclimate within and adjacent to the forest, though the extent to which there are adjacent beneficiaries is uncertain.
	Global climate regulation	• Although quantification is not the aim of this early phase of research, Annex 5 of this report addresses the calculations used to identify carbon sequestration potential of tropical evergreen dry forest eco-restoration as 21,996.1 tCO_2 ha^{-1} $year^{-1}$.

	Water regulation	• Forestry improves hydrological behaviour (timing and scale of run-off, flooding, etc.), including both surface and groundwater flows. For catchment restoration elsewhere in India, community-based regeneration of groundwater and ecology was found to minimise drought consequences, including serious impacts and distress migration witnessed elsewhere in India, in a programme recognised by the India's president in 2000[101] [102] [103]. Further research is necessary to quantify specific hydrological impacts of TDEF restoration on catchment hydrology.
	Natural hazard regulation	• Forests naturally buffer storm energy, potentially protecting buildings and other infrastructure and crops from damage. The scale of benefits requires further exploration.
	Pest regulation	• Forests provide habitat for natural predators of pest organisms. To quantify this effect, better understanding of local cropping and pest issues is necessary.
	Disease regulation – human	• Secondary benefits for human health likely to arise from contributions to air quality, providing a means to quantify part of the benefits of air quality regulation. Further study is also needed to assess the scale of regulation of disease organisms and vectors in restored forests compared to open, degraded landscapes.
	Disease regulation - stock	• Secondary benefits for stock health are likely to arise from regulation of disease organisms and vectors in restored forests compared to open, degraded landscapes.
	Erosion regulation	• Restored forests, particularly where landscapes were formerly degraded, will regulate erosion of soils. (Sheet and gulley erosion are significant problems on degraded lands across Tamil Nadu[104].)
	Water purification and waste treatment	• Water quality improvements are likely to result from improved hydrology in forest systems.
	Pollination	• Forests provide habitat for pollinating organisms, though this is not easy to quantify remotely.
	Salinity regulation	• Improved hydrology though water-retaining forest landscapes, and displacement of water-intensive monoculture forestry and agriculture, can reduce pressure on abstraction reducing the tendency towards sol salinization from coastal intrusion and exposure of deep

[101] The Hindu. (2000). Hope in the midst of loss. *The Hindu* 25th June 2000. (http://www.thehindu.com/thehindu/2000/06/25/stories/1325041a.htm, accessed 13th November 2015.)

[102] Kumar, P. and Kandpal, B.M. (2003). *Project on Reviving and Constructing Small Water Harvesting Systems in Rajasthan*. Sida Evaluation 03/40, Swedish International Development Cooperation Agency. Stockholm.

[103] Sinha, J., Sinha, M.K. and Adapa, U.R. (2013). *Flow – River Rejuvenation in India: Impact of Tarun Bharat Sangh's Work*. SIDA Decentralised Evaluation 2013:28. Swedish International Development Cooperation Agency, Stockholm.

[104] Ramasamy, S., Govindarajan, S.T., Balasubramanian, T. (2005). Integrated study and identification of erosion prone areas in Vaigai irrigation system in Tamil Nadu. In: Ramasamy, S.M. (editor). Remote sensing in water resources, CAB Direct, pp.50-71.

		saline aquifers.
	Fire regulation	• No perceived benefit, though the propensity for native TDEF to spread fire versus monoculture *Casuarina* and *Eucalyptus* requires further exploration.
	Noise and visual buffering	• Greater vegetative complexity provides visual screening or the suppression of noise, though this may not be a significant benefit if these factors are not problematic in the locality.
Cultural services	Cultural heritage	• Reforestation can potentially enhance areas of cultural importance if appropriately planned and managed.
	Recreation and tourism	• Reforestation can potentially enhance areas of recreational and tourism importance if appropriately planned and managed.
	Aesthetic value	• Reforestation can potentially enhance areas of aesthetic importance if appropriately planned and managed. An increasing number of studies relate physical and psychological health to exposure to nature[105] [106], including studies that take a quantitative dose-response approach[107].
	Spiritual and religious value	• Reforestation can potentially enhance areas of spiritual importance if appropriately planned and managed, including for example regenerating valued habitats (such as sacred groves of trees) or species (e.g. Peepal and Banyan trees).
	Inspiration of art, folklore, architecture, etc.	• Reforestation can potentially enhance areas of cultural importance with associated mythology, folklore, etc., if appropriately planned and managed.
	Social relations (e.g. fishing, grazing or cropping communities)	• Reforestation and local involvement in forest management can create income, employment and training opportunities, particularly where marginalised communities are involved, through: ○ forestry management; ○ cropping other forest products (fruit, honey, etc.); and ○ wildlife management. • A potential learning model is the Working for Water programme in South Africa where vegetation management provides a basis for employment, skills development and liked biodiversity and water cycle benefits for historically marginalised communities[108].

[105] Pretty, J.N., Barton, J., Colbeck, I., Hine, R., Mourato, S., MacKerron, G. and Wood, C. (2011).Chapter 23: Health Values from Ecosystems. UK National Ecosystem Assessment. http://uknea.unep-wcmc.org/LinkClick.aspx?fileticket=S901pJcQm%2fQ%3d&tabid=82.
[106] World Health Organisation. (undated). *Ecosystem goods and services for health*. http://www.who.int/globalchange/ecosystems/en/.
[107] Cracknell, D., White, M.P., Pahl, S., Nichols, W.J. and Depledge, M.H. (2015). Marine Biota and Psychological Well-Being: A Preliminary Examination of Dose–Response Effects in an Aquarium Setting. *Environment and Behavior*, pp.1–28. DOI: 10.1177/0013916515597512.
[108] www.dwaf.gov.za/wfw.

	Educational and research	• Reforestation processes and re-established forests can provide diverse educational and research opportunities, both formal and informal, including field studies centres. They already do so at the Nadukuppam school adjacent to the Nadukuppam forest restoration.
Supporting services	Soil formation	• Reforestation tends substantially to enhance all supporting services, particularly where it replaces degraded habitats, building resilience and carrying capacity.
	Primary production	
	Nutrient cycling	
	Water recycling	
	Photosynthetic oxygen production	
	Provision of habitat	

A4.2 Potential disbenefits arising from forest eco-restoration

Systemic assessment of the outcomes of eco-restoration of forests also calls for structured assessment of potential disbenefits, the better to inform management. Exploration of potential disbenefits includes identifying 'unknowns'. These are assessed below.

Types of ecosystem services		**What is this ecosystem service all about**
Provisioning services	Fresh water	• UNKNOWN: Early establishment of trees may make demands on water, either piped or naturally occurring, that compete with other uses. The extent to which this occurs is unknown and requires further research.
	Food (e.g. crops, fruit, fish, etc.)	• UNKNOWN: Forest planting may displace food-producing land. The extent to which this occurs is unknown and requires further research. The long-term supply of food from forests versus farmed land also requires further study, taking account of the degraded nature of land that is being used for reforestation.
	Fibre and fuel (e.g. timber, wool, etc.)	• UNKNOWN: Forest planting may displace fibre- and fuel-producing land. The extent to which this occurs is unknown and requires further research. The long-term supply of fibre and fuel from forests versus farmed land also requires further study, taking account of the degraded nature of land that is being used for reforestation.
	Genetic resources (used for crop/stock breeding and biotechnology)	• UNKNOWN: Forest planting may displace ecosystems with important or unassessed genetic values. The extent to which this occurs is unknown and requires further research, recognising that most re-forestation occurs in

		degraded landscapes.
	Biochemicals, natural medicines, pharmaceuticals	• UNKNOWN: Forest planting may displace ecosystems with biochemically important values. The extent to which this occurs is unknown and requires further research, recognising that most re-forestation occurs in degraded landscapes.
	Ornamental resources (e.g. shells, flowers, etc.)	• UNKNOWN: Forest planting may displace ecosystems containing ornamentally important resources. The extent to which this occurs is unknown and requires further research, recognising that most re-forestation occurs in degraded landscapes.
	Energy harvesting from natural air and water flows	• No perceived disbenefit.
Regulatory services	Air quality regulation	• No perceived disbenefit.
	Microclimate: local climate regulation	• No perceived disbenefit.
	Global climate regulation	• No perceived disbenefit.
	Water regulation	• No perceived disbenefit.
	Natural hazard regulation	• No perceived disbenefit.
	Pest regulation	• No perceived disbenefit.
	Disease regulation - human	• No perceived disbenefit.
	Disease regulation - stock	• No perceived disbenefit.
	Erosion regulation	• No perceived disbenefit.
	Water purification and waste treatment	• No perceived disbenefit.
	Pollination	• No perceived disbenefit.
	Salinity regulation	• No perceived disbenefit.
	Fire regulation	• Great standing biomass of trees may increase risk of wildfires without cautious management.
	Noise and visual buffering	• No perceived disbenefit.

Cultural services	Cultural heritage	• Potential for loss of value if forests are replanted in places with established cultural importance, necessitating careful planning.
	Recreation and tourism	• No perceived disbenefit.
	Aesthetic value	• Potential for loss of value if forests are replanted in places with established aesthetic importance, necessitating careful planning.
	Spiritual and religious value	• Potential for loss of value if forests are replanted in places with established spiritual importance, necessitating careful planning.
	Inspiration of art, folklore, architecture, etc.	• No perceived disbenefit.
	Social relations (e.g. fishing, grazing or cropping communities)	• No perceived disbenefit.
	Educational and research	• No perceived disbenefit.
Supporting services	Soil formation	• No perceived disbenefit.
	Primary production	• No perceived disbenefit, forest eco-restoration enhancing rather than displacing biota.
	Nutrient cycling	• No perceived disbenefit.
	Water recycling	• No perceived disbenefit.
	Photosynthetic oxygen production	• No perceived disbenefit, forest eco-restoration enhancing rather than displacing biota.
	Provision of habitat	• No perceived disbenefit, as habitat prior to forest eco-restoration is degraded rather than another form of habitat that is lost on conversion.

End of Annex 4

Annex 5: Carbon sequestration in tropical dry evergreen forests (TDEF)

The carbon dynamics of forests differ significantly with forest type and location. A literature search – more research is necessary to more fully interrogate the literature including unpublished data – found only one significant publication dealing specifically with a forest type akin to Tropical Dry Evergreen Forest (TDEF) in Tamil Nadu. This study by Ramachandran *et al*. (2007)[109] used geospatial technology to assess carbon stocks in natural forest areas – including semi-evergreen forest which appears to be the most locally most appropriate forest type – of the Kolli hills, in the southern part of the Eastern Ghats in Namakkal district of Tamil Nadu. The study gathered data on biomass and soil carbon for different forest types and in different stages of degradation.

A5.1 Biomass carbon (above and below ground)

Biomass carbon (above and below ground) for semi-evergreen forest was estimated by Ramachandran *et al*. (2007) as contributing 22% of the total 2.74 Tg of carbon stored by five forest types (tropical broadleaved hill forest [semi-evergreen], southern dry mixed deciduous forest, secondary deciduous forest, southern thorn forest, and *Euphorbia* scrub forest) in the Kolli hills.

Biomass carbon density for semi-evergreen forests, the locally most appropriate forest type for TDEF, is approximately 0.60 TgC ha^{-1} (600,000 tonnes C ha^{-1}).

Obtaining comparative figures for carbon storage in the biomass of degraded tropical forests is more elusive, generic studies of tropical forests estimating average biomass carbon density of 63.33-156 tC ha^{-1} [110] and 70 tC ha^{-1} [111].

Taking a conservative approach, it is assumed that TDEF restoration can enhance:

- Biomass carbon storage from 156 tC ha^{-1} (the highest figure suggested for degraded tropical forest) to 600,000 tC ha^{-1}, a difference of 599,844 tC ha^{-1}.

Assuming a linear increase over a 100 year recovery period to climax community, this equates to an annual sequestration rate in TDEF of:

- 599,844 tC ha^{-1} divide by 100 ≈ 5,998.4 tC ha^{-1} $year^{-1}$.

This assumption is highly conservative: the evidence from Pitchandikulam forest is that climax TDEF has been achieved in a shorter timeframe (approximately 50 years), which would imply a higher sequestration rate, albeit a shorter lifetime.

---

[109] Ramachandran, A.S., Jayakumar, R.M., Haroon, A.B. and Arockiasamy, D.I. (2007). Carbon Sequestration: estimation of carbon stock in natural forests using geospatial technology in the Eastern Ghats of Tamil Nadu, India. *Current Science*, 92(3), pp.323-331.

[110] Bolin, B., Doos, B. R., Jager, J. and Warrick, R. (1986). *The Greenhouse Effect, Climate Change and Ecosystems*. SCOPE 29, John Wiley, Chichester.

[111] German Bundestag. (1990). *Protecting the Tropical Forests: A High Priority International Task*. Bonner Universitats–Buchdruckerei, Bonn.

Converting this to CO_2 equivalent (x44/12 for molecular weights of CO_2/atomic weight of C):

- 21,994.1 $tCO_2\ ha^{-1}\ year^{-1}$.

This figure must be regarded with caution as the published data behind it are sparse. More research is recommended to flush out more data – published or unpublished – to verify or modify this value.

A5.2 Soil organic carbon (SOC)

Soil organic carbon (SOC) is primarily concentrated in the upper 12 inches of the soil where it is readily depleted by anthropogenic (human-induced) disturbances such as land-use changes and cultivation[112] [113]. The potential of the pedosphere (the soil layer) to sequester carbon can play an important role in the overall management of C, and there is significant potential for increasing SOC through restoration of degraded soils and widespread adoption of soil conservation practices[114] [115]. Reforestation, and conversely deforestation, are particularly significant land use changes affecting soil organic carbon storage and CO_2 flux into the atmosphere[116].

Ramachandran et al. (2007) calculated mean soil organic carbon densities ($tC\ ha^{-1}$) in the top 90cm of evergreen forest soils in the Kolli Hills at:

Forest type	**Soil organic carbon density (t/ha) (0 to 90 cm)**		**Confidence interval (t/ha) (α = 0.05)**	
	Mean	**SD**	**From**	**To**
Very dense evergreen	274.06	175.57	159.35	388.76
Dense evergreen	233.65	193.92	89.99	377.31
Medium evergreen	143.02	54.85	105.01	181.03
Degraded evergreen	193.49	80.62	122.83	264.15
Total evergreen	184.00	123.13	139.19	228.82

[112] Post, W. M., Emanuel, W. R., Zinke, P. J. and Stangenberger, A.G. (1982). Soil carbon pools and world life zones. *Nature*, 298, pp.156–159.
[113] Tian, H., Melillo, J. M. and Kicklighter, D. W. (2002). Regional carbon dynamics in monsoon Asia and implications for the global carbon cycle. *Global Planetary Change*, 37, pp.201–217.
[114] Lal, R. and Bruce, J.P. (1999). Soil management and restoration for C sequestration to mitigate the accelerated greenhouse effect. *Progress in Environmental Science*, 1, pp.307–326.
[115] Albrecht, A. and Kandji, S.T. (2003). Carbon sequestration in tropical agroforestry systems. *Agric. Ecosyst. Environ*., 99, pp.15–27.
[116] Moghiseh, E., Heidari, A. and Ghannadi, M. (2013). Impacts of deforestation and reforestation on soil organic carbon storage and CO2 emission. *Soil Environ*, 32(1), pp.1-13.

There is a logical disconnection in the above data as 'Medium evergreen' has a lower recorded mean SOC concentration (143.02 tC ha^{-1} with SD of 54.85) than 'Degraded evergreen' (mean SOC of 193.49 tC ha^{-1}). However, the calculations in this study take a conservative approach, assuming that TDEF eco-restoration will elevate SOC condition from:

- 193.49 tC ha^{-1} (mean degraded evergreen) to 233.65 tC ha^{-1} (dense evergreen), a difference of 40.16 tC ha^{-1}.

Assuming a linear increase over a 100 year recovery period to climax community and maximum SOC, this equates to an annual sequestration rate of:

- 40.16 tC ha^{-1} divide by 100 ≈ 0.416 tC ha^{-1} $year^{-1}$.

Converting this to CO_2 equivalent (multiplying by 44/12), this equals:

- 1.53 tCO_2 ha^{-1} $year^{-1}$.

This value is highly conservative not merely due to assumptions about forest density but also as the baseline for planting at Nadukuppam is on degraded, effectively bare habitat devoid of trees rather than the 'degraded evergreen' SOC value used above as a baseline.

This figure also has to be regarded with caution as the published data behind it are so sparse. More research is recommended to flush out more data – published or unpublished – to verify or modify this value.

A5.3 Annualised carbon dioxide sequestration rates in restored TDEF

Adding together the figures above for biomass and soil CO_2 sequestration in restored TDEF (21,994.1 tCO_2 ha^{-1} $year^{-1}$ + 1.53 tCO_2 ha^{-1} $year^{-1}$) over an assumed 100-year recovery period yields:

- Annualised sequestration rate = 21,995.6 tCO_2 ha^{-1} $year^{-1}$.
- Cumulative sequestration over a century to assumed climax state = 2.2 million tCO_2 ha^{-1}.

Further research, seeking unpublished data to supplement sparse published data, would confirm or modify these figures. In particular, values for SOC storage appear relatively low.

A5.4 Pricing carbon

Carbon pricing is a complex matter. Two commonly-used methods are the 'social cost of carbon' and the 'shadow price of carbon'[117].

Social cost of carbon (SCC, or SC-CO_2) provides an estimate of incremental economic damages (negative externalities) associated with a small increase in carbon dioxide (CO_2) emissions, conventionally expressed in terms of one tonne per year. The SCC need to be incorporated into decisions on policy and investment options in government if these externalities are to be factored

---

[117] Defra Economics Group. (2007). *The Social Cost Of Carbon And The Shadow Price Of Carbon: What They Are, And How To Use Them In Economic Appraisal In The UK*. Economics Group, Department for Environment, Food and Rural Affairs, London. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/243825/background.pdf.

into decision-making. For example, a SCC of £20 per tonne of carbon dioxide would reflect that emitting an additional tonne of carbon dioxide today would have the same impact on society's expected welfare as reducing a representative consumer's consumption by £20 today. It reflects a theoretical willing for society to pay now, and therefore representing changes required in the economy as a whole, to avoid the future damage caused by incremental carbon emissions.
The market price of carbon differs in that it reflects the value of traded carbon emissions rights to those in the market given the constraints on supply of these rights to emit imposed by current policy (for example through the EU Emissions Trading Scheme). The market price of carbon is therefore more to immediate market and political priorities than a mechanism geared to actual effects.

The marginal abatement cost (MAC) of carbon reflects the cost of reducing emissions, rather than the damage imposed by creating emissions.

In the ideal world of perfect markets for damage to human wellbeing, the SCC, market price and MAC would be broadly equal. However, as the 2006 Stern Report highlighted[118], climate change represents the greatest market failure.

Ideally, the SCC should be geared to an optimum stabilisation goal such that MAC incentivises the necessary abatement for the world to achieve the goal. However, as the global climate stabilisation trajectory cannot be controlled by any one nation and also significant remaining uncertainties, UK government and many other governments have chosen to use a shadow price of carbon (SPC).

Shadow price of carbon (SPC) is a more flexible tool, based on the SCC but adjusted to reflect the policy and technological environment to inform policy decisions across government decision-making.

In 2007, UK Government adopted an SPC of £25/tCO_2e (approximately $US39/t$CO_2$e).

An additional difficulty with valuing the carbon benefits of measures is the fluctuating price and volatility of the agreed 'cost' of carbon with evolving understanding and political ambition. For example, on 1st April 2013, the UK introduced a new carbon floor price, which saw firms charged £16 per tonne of CO_2 for fuels used for power generation. The move was designed to provide a long-term price signal for low-carbon investors and will increase gradually every year to reach the Treasury's goal of £30 per tonne by the end of the decade, and £70 per tonne in 2030. However, this is currently only applicable to the power generation sector, and is significantly higher than the EU carbon price (which has been around €5/tonne in 2015[119]), threatening to undermine the Treasury's scheme. In late July 2015, UK environment secretary Amber Rudd defended announcement of a wave of cuts to support for green policies (cutting subsidies for solar energy farms and wind farms, scrapping the Green Deal of home energy grants, etc.) in favour of a claimed profit motive in developing green technology as the best way to tackling global warming, rather than tackling "…*the issue from a left-wing perspective*".[120] Analogously in India, intent to triple coal production also highlights political unwillingness to cost climate change on an objective basis, favouring short-term growth defined in narrow financial terms over consequences stemming from market externalities.

---

[118] Stern, N. (2006). *Stern Review on The Economics of Climate Change (pre-publication edition). Executive Summary*. HM Treasury, London. http://www.webcitation.org/5nCeyEYJr.

[119] http://carbontradexchange.com/

[120] Demianyk, G. (2015). Green-Cutting Government Is 'Greyest Ever' Say Environmentalists As Climate Change Minister Hits Out. *Huffington Post UK*, 24th July 2015. http://www.huffingtonpost.co.uk/2015/07/24/climate-change-secretary-amber-rudd-wind-farms-climate-change-anti-capitalist_n_7862998.html.

The UK's Department for Energy and Climate Change has produced a range of supplementary guides for calculating carbon value[121] [122] [123].

Given volatility in terms of knowledge about climate change but particularly given the politics of pricing carbon, the unmodified 2007 SPC is used here to determine value. It should be recalled that such valuations are illustrative rather than absolute, discrepancies in the cash figure being in all probability dwarfed by greater uncertainties about climate change trends and their wider impacts.

Given the substantial volatility and uncertainties of theoretical surrogate market prices ascribed to carbon, the approach taken in this study is to seek to root conclusions in actual prices (turbine investments, costs of TDEF restoration, etc.)

End of Annex 5

[121] DECC. (2011). *A brief guide to the carbon valuation methodology for UK policy appraisal*. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/41793/3136-guide-carbon-valuation-methodology.pdf.

[122] DECC. (2012). *Updated short-term traded carbon values used for UK public policy appraisal*. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/41794/6667-update-short-term-traded-carbon-values-for-uk-publ.pdf.

[123] DECC. (2012). *IAG spreadsheet tool for valuing changes in greenhouse gas emissions*. https://www.gov.uk/government/policies/using-evidence-and-analysis-to-inform-energy-and-climate-change-policies/supporting-pages/policy-appraisal.

Annex 6: Calculation of cumulative benefits from reinvestment of TCW renewable energy operating margins into TDEF eco-restoration

A significant climate regulation service is associated with TCW Group renewable energy generation from wind turbines, in addition to the wide range of broader associated ecosystem service benefits described (though not quantified) in Section 2 and Annex 3.

TCW plans include investment in TDEF eco-restoration based on proceeds from sales of electricity from wind turbines. The carbon dioxide sequestration rate annualised over 100 years for restored TDEF calculated in Annex 5, albeit a figure that must be treated with caution given the very limited published data from which it is derived associated assumptions, is a substantial value of 21,995.6 tCO_2 ha^{-1} $year^{-1}$. In addition to the climate regulation service associated with carbon sequestration, a wide range of other ecosystem service benefits arising from TDEF eco-restoration are described (though not quantified) in Section 3 and Annex 4.

This Annex calculates cumulative benefits from linked TCW Group wind generation and re-investment of proceeds in TDEF eco-restoration.

Note that the TDEF carbon storage figures derived from Annex 5 have to be regarded with caution as the published data upon which they are based are so sparse. If subsequent research modifies these values, this will impact on all calculations in this Annex.

A6.1Costs of TDEF restoration

The costs of TDEF restoration (source: Joss Brooks, Pitchandikulam Forest Auroville[124]) are:

- Tree density: 500 trees per acre
- Species mix: A matrix of species appropriate for native TDEF restoration
- Cost per 100 acres: IN₹ 15,916,000, covering:
  - Supply of seedlings (seedlings, manure, pit digging, transport, planting, mulching, bunding;
  - Personnel (foresters/maintenance workers, specialist supervision; and
  - Institutional overheads and contingencies.

Therefore, total cost of restoration activities (acknowledging that some lifetime forest stewardship cost may not have been included, an area for further research) are:

Per unit area[125]	Cost in Indian Rupees	Cost in GB pounds sterling[126]
Per acre	IN₹ 159,160	£ 1,580.09
Per hectare	IN₹ 393,279	£ 3,904.35
Per m^2	IN₹ 39	£ 0.39
@ 500 trees per acre (1,235 trees ha^{-1} or 0.1 trees m^{-2}), this equates to IN₹ 318.32 (£3.16) per tree		

[124] http://www.pitchandikulamforest.org/cms/content/view/23/31/
[125] 100 acres = 40.47 hectares = 404685.642 m^2
[126] @ 100.7284 IN₹/GB£ (www.msn.com/en-gb/money/currencyconverter, accessed 13th November 2015).

Adding in the purchase price of land for TDEF conversion @ £5,000 per acre (source: John Pontin, JPT/TCW), the total cost of restoring hectare of TDEF restoration = £16,255 (see Box A6.1).

Box A6.1: Total cost of restoring one hectare of TDEF

- Land purchase = £12,350 (£5,000 per acre @ 2.47 acres per hectare)
- TDEF restoration (see Box 1) = £3,904.35 (IN₹393,279)
- **Total cost = £16,255**

A6.2 Cost of carbon dioxide sequestration through TDEF restoration

Dividing total cost per hectare of (£16,255: A6.1) by annual CO_2 sequestration of 21,995.6 tCO_2 ha^{-1} $year^{-1}$ (Annex 5) yields the following costs (over assumed 100-year forest recovery horizon):

Unit of annual CO_2 sequestration	Cost in GB pounds sterling[127]
1 tCO_2 $year^{-1}$	£ 0.74
1,000 tCO_2 $year^{-1}$	£ 739.01
1 million tCO_2 $year^{-1}$	£ 739,011

A6.3 Net revenue effect of reinvestment of turbine operating margins into TDEF restoration

If TCW Group reinvests operating margins from renewable energy sales in any one year from turbines into TDEF restoration, net effects on surplus available for other TCW uses (interest payments, reinvestment in new turbines, other TCW schemes, etc.) are:

- For **reinvestment in one hectare of TDEF restoration** (£16,255; see A6.1 above) from net annual income from a 2.1 MW wind turbine (£140,000; see Box A6.2 below), this:
  - Represents a reinvestment of 11.6% of net operating margins from renewable energy sales; and
  - Leaves a surplus of £123,745 to support other beneficial uses.
- For **reinvestment of £100,000 in TDEF restoration** from net annual income from a 2.1 MW wind turbine, this:
  - Represents a 71% reinvestment of net operating margins from renewable energy sales;
  - Provides funds to restore 6.15 hectares of TDEF; and
  - Leaves a surplus of £40,000 to support other beneficial uses.

Box A6.2: Turbine generation, operating margins and CO_2 avoided

The following starting assumptions were provided by John Pontin (JPT/TCW):

- Each 2.1 MW turbine generates 4 million units of electricity annually
- Revenue from electricity sales (conservatively) are 5p per unit
  - The above figures imply total annual electricity sales of £200,000
- Overhead costs (insurance, maintenance, etc.) of electricity sales are 20-30%
  - Assumed 30% (conservative) annual overhead charges = £60,000
  - **Implies net annual income = £140,000**
- A conservative estimate of 3,000 tCO_2 avoided annually per turbine

[127] @ 100.7284 IN₹/GB£ (www.msn.com/en-gb/money/currencyconverter, accessed 13th November 2015).

A6.4 Net carbon dioxide sequestered/avoided from one-off investment of turbine operating margins into one ha TDEF restoration

If a one-off investment of £16,255 (11.6% of £140,000) is made from net annual income from a 2.1 MW wind turbine is made in restoration of one hectare area of TDEF, assuming a lag phase of a year for the start of sequestration, cumulative annual carbon dioxide sequestered/avoided over the first five years of investment are (for details see Table below):

- In each of years 2 to 5 = 24,995.6 tCO_2 $year^{-1}$.
- Cumulatively over a five-year horizon = 102,982.4 tCO_2.

Operational year	Annual tCO_2 from turbine	Annual tCO_2 from one hectare TDEF	Total annual tCO_2 avoided	Cumulative total
1	3,000 tCO_2 $year^{-1}$	0	3,000 tCO_2 $year^{-1}$	3,000 tCO_2
2	3,000 tCO_2 $year^{-1}$	21,995.6 tCO_2 $year^{-1}$	24,995.6 tCO_2 $year^{-1}$	27,995.6 tCO_2
3	3,000 tCO_2 $year^{-1}$	21,995.6 tCO_2 $year^{-1}$	24,995.6 tCO_2 $year^{-1}$	52,991.2 tCO_2
4	3,000 tCO_2 $year^{-1}$	21,995.6 tCO_2 $year^{-1}$	24,995.6 tCO_2 $year^{-1}$	77,986.8 tCO_2
5	3,000 tCO_2 $year^{-1}$	21,995.6 tCO_2 $year^{-1}$	24,995.6 tCO_2 $year^{-1}$	102,982.4 tCO_2

A6.5 Net carbon dioxide sequestered/avoided from one-off investment of £100,000 turbine operating margins into TDEF restoration

If a one-off investment of £100,000 is made in TDEF restoration (land purchase and reforestation activities @ £16,255 per hectare) this would purchase an additional 6.15 hectares TDEF, sequestering 135,272.94 tCO_2 $year^{-1}$ (@ 21,995.6 tCO2 ha^{-1} $year^{-1}$; Annex 5). Assuming a lag phase of a year for the start of sequestration, cumulative annual carbon dioxide sequestered/avoided over the first five years of investment (for details see Table below):

- In each of years 2 to 5 = 138,272.94 tCO_2 $year^{-1}$.
- Cumulatively over a five-year horizon = 556,091.76 tCO_2.

Operational year	Annual tCO_2 from turbine	Annual tCO_2 from additive hectares of TDEF	Total annual tCO_2 avoided	Cumulative total
1	3,000 tCO_2	0	3,000 tCO_2	3,000 tCO_2
2	3,000 tCO_2	135,272.94 tCO_2	138,272.94 tCO_2 $year^{-1}$	141,272.94 tCO_2
3	3,000 tCO_2	135,272.94 tCO_2	138,272.94 tCO_2 $year^{-1}$	279,545.88 tCO_2
4	3,000 tCO_2	135,272.94 tCO_2	138,272.94 tCO_2 $Year^{-1}$	417,818.82 tCO_2
5	3,000 tCO_2	135,272.94 tCO_2	138,272.94 tCO_2 $Year^{-1}$	556,091.76 tCO_2

A6.6 Net carbon dioxide sequestered/avoided from reinvestment in TDEF of £100,000 per turbine per operating year

If £100,000 (71% of operating margins from annual renewable energy sales) is reinvested in 6.15 hectares of TDEF restoration **for each operational year**, again assuming a lag phase of a year for the start of sequestration, cumulative annual carbon dioxide sequestered/avoided over the first five years of investment are (for details see Table below):

- Between years 2 to 5, rising from 138,272.94 to 544,091.76 tCO_2 $year^{-1}$.
- Over a five-year horizon, cumulative emissions avoided = 1,367,729.40 tCO_2.

Operational year	Annual tCO_2 from turbine	Annual tCO_2 from additive hectares of TDEF	Total annual tCO_2 avoided	Cumulative total
1	3,000 tCO_2	0	3,000 tCO_2	3,000 tCO_2
2	3,000 tCO_2	135,272.94 tCO_2	138,272.94 tCO_2 $year^{-1}$	141,272.94 tCO_2
3	3,000 tCO_2	270,545.88 tCO_2	273,545.88 tCO_2 $year^{-1}$	414,818.82 tCO_2
4	3,000 tCO_2	405,818.82 tCO_2	408,818.82 tCO_2 $year^{-1}$	823,637.64 tCO_2
5	3,000 tCO_2	541,091.76 tCO_2	544,091.76 tCO_2 $year^{-1}$	1,367,729.40 tCO_2

Extending the above assumptions over scheme life (20 x 3,000 tCO_2 $year^{-1}$ turbine generation over depreciation period + 100 year carbon sequestration in each of the 20 x 6.15 block of TDEF [total 123 hectares] until it reaches climax community), this yields:

- Lifetime carbon sequestration/avoidance of 270,605,880 tCO_2, of which:
  - CO_2 sequestration through TDEF restoration = 270,545,880 tCO_2 (99.978%)
  - CO_2 avoidance from the turbine = 60,000 tCO_2 (0.0.22%)

A6.7 Price per tonne of carbon dioxide sequestered/avoided from annual £100,000 reinvestment of turbine operating margins into TDEF restoration

Up-front costs for turbine installation/commission (land acquisition, capital, planning, installation, connection, etc.) are approximately £750k per MW, with linear depreciating over 20 years (source: Wendy Stephenson, TCW). Therefore, for a 2.1 MW wind turbine:

- Installation costs = £1,575,000.
- Annual linear depreciation over 20 years = £78,750 $year^{-1}$.
- (Operational costs are included in calculation of net annual income in Box A6.3).

Dividing installation cost for a 2.1 MW wind turbine (£1,575,000) by gross carbon sequestration/avoidance over scheme life for annual reinvestment of £100,000 in TDEF restoration (270,605,880 tCO_2) yields:

- Cost per unit tCO_2 sequestered/avoided = £0.0058 £ per tCO_2 (0.58p per tCO_2)

The overwhelming contribution of TDEF restoration to the above value concurs with the findings of the 'Stern Review' that reforestation is one of the most economically efficient means to tackle climate change.

The cost-effective figures above compare with a return of £26.25 per tCO_2 avoided over the 20 year depreciation life of the wind turbine alone.

A6.8 Additional benefits from other ecosystem services

These carbon sequestration/avoidance benefits are in addition to co-benefits arising from the broader spectrum of ecosystem service outcomes from both TCW Group renewable energy generation (Section 2; Annex 3) and TDEF eco-restoration (Section 3; Annex 4), quantification of which would indicate their additional contributions to gross benefits.

End of Annex 6

Annex 7: Overview of ecosystem service valuation, with methods and illustrative examples

Valuation of ecosystem services is important if they are to be weighted in decision-making. Whilst quantification and valuation have not formed part of this brief initial study, this section outlines the kinds of methods that could be applied in future (with an illustrative example allied to carbon sequestration in restored forest). Valuation of natural assets and services has its critics, at least in the media, and this is addressed below.

A7.1 The case for and against valuation of ecosystem service benefits

A common argument against valuation ecosystems and their services is that valuation attempts to solve sustainability problems by playing the market system at its own game, inevitably falling foul of the desire of a world driven to make profit and the accumulation of wealth as an end-game in itself as capitalism constitutes a barrier to sustainability[128]. Conversely, others argue that capitalism is a pervasive ideology that we not only have to work with, but that can work for sustainable development if the values of nature are progressively integrated into it as the most basic and foundational, yet currently massively externalised, form of capital[129] [130].

Commonly, critics of taking an economic approach to ecosystems and their services make a combination of any of three flawed assumptions[131]:

- That an economic approach to ecosystems and their services is about putting a 'price on nature' to be traded in the economy. The reality is that it is not about valuing nature itself, but instead about recognising the multiple values that flow to people from ecosystems, providing an important input to better informed decision-making.
- Confusion between valuation and accountancy. Whilst accountancy is narrowly framed by cash values and arithmetic judgements, a proper understanding of valuation is, as reflected by the qualitative differences in ecosystem service categories defined by the Millennium Ecosystem Assessment[132], necessarily pluralistic in approach, recognising often incommensurable value systems. Though these different types of value are often subsequently normalised in decision-making frameworks, commonly into a monetary value, this is primarily to indicate their relative magnitudes rather than absolute financial quantum, better enabling them to be recognised and weighed in inevitably political decision-making processes.
- That we do not already value nature. In fact, we routinely value ecosystems and their services in decision-making today. By large majority, the default value applied is zero. For some services, such as the presence of selected species and habitats in nature reserves, or maintaining river quality above a statutory minimum level, the value is theoretically infinite though, in practice, this is negotiable where 'overriding public interest' leads to derogations or pro-development decisions.

Neither the zero-value nor infinite-value scenario is helpful in factoring the value of ecosystems and their services into decision-making processes. Processes for valuing all of the diverse types of

---

128 Klein, N. (2014). *This Changes Everything: Capitalism vs the Climate*. Simon and Schuster, London.
129 Hawken, P. (1993). *The Ecology of Commerce*. HarperCollins.
130 Porritt J. (2005). *Capitalism as if the World Matters*. Earthscan: London.
131 Everard, M. (in preparation). *The Ecosystems Revolution*.
132 Millennium Ecosystem Assessment. (2005). *Ecosystems & Human Well-being: Synthesis*. Island Press: Washington DC.

ecosystem service are far from perfect. Many valuation techniques, for example using travel cost methods to indicate social importance of a place or habitat, merely represent magnitudes of significance though the value itself is incommensurable and non-substitutable with money. However, valuation – by however questionable a means often linked to surrogate rather than real markets – can at least illustrate to policy- and decision-makers the relative weighting of a breadth of values to society, potentially informing more integrated decision-making.

As some form of valuation is necessary to weigh the services of ecosystems, both market and non-market, in decision-making, valuation is therefore seen as essential if anything other than a zero value is to be assumed if indeed anything other than immediate market values are to be completely overlooked.

A7.2 Valuation of ecosystem services

As outlined above, monetary values ascribed to various ecosystem services are often merely representative of the magnitude of societal benefit or disbenefit, often articulating societal significance based on a value system that is incommensurable with money.

Three important principles are identified in how valuation is to be most usefully approached:

- Valuation does not automatically imply monetisation, and often monetisation is not necessary or even helpful when only a subset of services can be confidently monetised. For some decision-making purposes, a purely semi-quantitative form of valuation may be sufficient (as described below);

- It is essential to retain a systemic overview, rather than to base decisions on only a subset of services whilst overlooking others that will inevitably have implications for overlooked beneficiaries and potentially for ecosystem functioning and resilience. Only when a systemic overview has been taken can one safely focus on what emerges as the most significant services for further study if necessary; and

- Absolute valuation of ecosystems and their services has little or no objective meaning, given the uncertainties and stacked assumptions involved in their assessment and also that most services can't be simply substituted for money (for example if access to healthy air or water runs out). However, meaningful information can be deduced from determining marginal impacts on ecosystem services between a 'baseline' or 'counterfactual' condition (i.e. prior to restoration works) and post-intervention condition (actual or projected). For this reason, the 'baseline' value is often taken to be zero (except where marginal values were based on an uplift of existing value), pre-intervention status acting as a datum from which relative benefits and dis-benefits are calculated.

To support a pragmatic approach to valuation of ecosystem services, the Department for Environment, Food and Rural Affairs (Defra) identified a three-tier approach[133]:

- Semi-quantitative assessment, advocating a consensual 'likelihood of impact' weighting score which is reproduced in Box A7.1;
- Value transfer, transferring values ascribed in other linked studies with appropriate assumptions and modifications; and
- Bespoke valuation, which tends to be very expensive and time-consuming.

Box A7.1. Defra 2007 'likelihood of impact' weighting system

Score	Assessment of effect
++	Potential significant positive effect
+	Potential positive effect
O	Negligible effect
-	Potential negative effect
--	Potential significant negative effect
?	Gaps in evidence / contention

It is important to ensure that the method chosen is proportionate with the issues being addressed. For example, The Economics of Ecosystems and Biodiversity (TEEB) advocates a three-stage process of: (1) recognising; (2) capturing; and (3) demonstrating value of ecosystems, which may be quantitative or qualitative according to the scale and contention of the issue being addressed[134].

A7.3 Economic valuation tools

The neoclassical economic concept of value relates to benefits to people[135]. Ecosystem services too are anthropocentric as they relate to benefits flowing from ecosystems to society. However, many of the benefits that flow to people from ecosystems – such as future resilience, nutrient cycling, habitat for wildlife, soil formation and erosion regulation – have no associated market values and so have tended to be overlooked and consequently eroded in pursuit of narrower, more tangible and market-based rewards (for example as seen in the loss of soil, biodiversity and efficient water recycling in landscapes used for intensive farming).

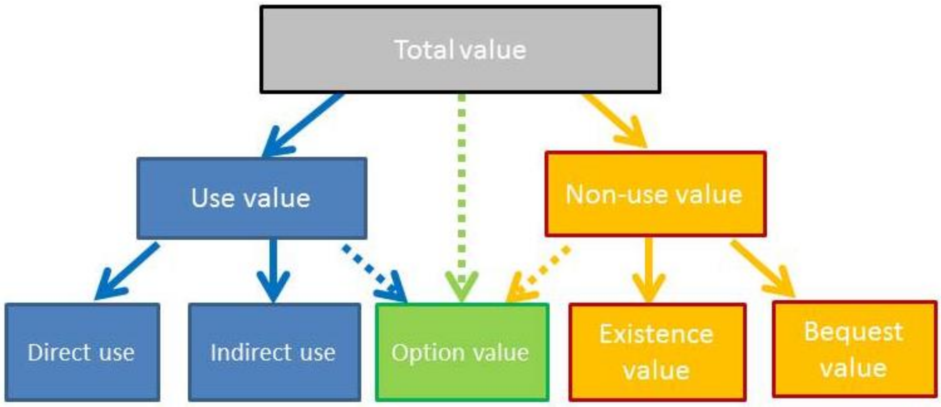
---

[133] Defra. (2007). *An introductory guide to valuing ecosystem services*. Department for Environment, Food and Rural Affairs, London. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/69192/pb12852-eco-valuing-071205.pdf. (accessed 10th July 2015).

[134] TEEB. (2010). *The economics of ecosystems and biodiversity: mainstreaming the economics of nature: a synthesis*. The Economics of Ecosystems and Biodiversity. (http://www.teebweb.org, accessed 06th November 2015.)

[135] Freeman, A.M. (1993). *The Measurement of Environmental and Resource Values: Theory and Methods*. (Washington, DC, Resources for the Future).

The widely accepted concept of Total Economic Value (TEV) addresses a broader range of benefits, include multiple dimensions of use and non-use values[136], as outlined in the Figure below.



Some services, such as soil formation and nutrient cycling, as indeed many supporting services and several regulatory services, are not directly consumed but are part of the production systems contributing to more directly consumed and marketed services (such as food production). However, their exclusion from markets, in terms for example of the price paid for farmed food products, has led to their serial erosion with adverse implications for continuing human wellbeing. So, although neoclassical economists typically argue that to value them separately is to 'double-count', the reality is that they are not already included in values ascribed to marketed goods and so must be valued in some way.

Various methods are available to assign values to non-marketed services. For example, economic value can be measured by the amount of money an individual is willing to pay for a good or service or the amount of money an individual is willing to accept as a compensation for forgoing the good or service. Willingness to pay (WTP) and willingness to accept (WTA) are measures that can be revealed in interview or by questionnaire. These 'stated preference' values can be useful to assign value where no other methods are available, but tend to be unreliable; 'revealed preferences', such as what people actually spend to visit a wildlife or spiritually important site rather than what they say, tend to be more reliable. Hence travel cost assessment integrating cumulative spend by all visitors can give an indication of the economic value of a place or habitat, albeit that spiritual and existence values tend in reality to be incommensurable with monetary values. However, the weighting by economic value at least indicates scale of importance (large/small, positive/negative), which in turn can then inform more integrated decision-making (noting that decision-making itself is always political weighing up multiple factors rather than defined by monetisation or other forms of valuation alone).

A7.4 Examples of how economic methods may be applied to ecosystem service benefits

The *Ecosystem services assessment: How to do one in practice* guide[137], produced for Defra but published by the IES due to prohibitions on departmental publications introduced under the UK's coalition government of 2010-2015, provides examples of where different economic methods have been used to value a range of services in a series of ecosystem service case studies.

[136] http://www.eoearth.org/view/article/156666/ (accessed 10th November 2015).
[137] https://www.the-ies.org/resources/ecosystem-services-assessment.

Examples of how different valuation methods are applied to qualitatively different services are provided below. Only one value, the regulatory service of climate regulation, is calculated within this study for illustrative purposes.

- Provisioning services:
    - Fresh water: valued in terms of cost savings on treatment of abstracted water resulting from river quality protection
    - Food: net marginal market change associated with lost arable production replaced by rare breeds grazing outputs
    - Biochemicals, natural medicines, pharmaceuticals: loss of natural biochemicals through inundation of mountainous habitat by reservoir filling
- Regulatory services
    - Air quality regulation: impact of tree growth on problematic air quality determinands linked to estimates of health impact of urban air pollution
    - Climate regulation (assessed as carbon sequestration): traded price of carbon multiplied by averaged sequestration of carbon through habitat eco-restoration over defined project life. A worked example of TDEF eco-restoration is provided in Box A7.2.

Box A7.2: A worked illustrative example of value associate with TDEF eco-restoration
For tropical dry evergreen forest (TDEF) eco-restoration in this case study, the estimated annualised carbon sequestration rate of 21,995.6 tCO_2 ha^{-1} $year^{-1}$ (see Annex 5) can be multiplied by a consensual financial value reflecting the 'social cost of carbon' (representative of damage resulting from climate change). Various authors suggest that current politically accepted social cost of carbon figures are too low to take account of tipping points in climate change[138] [139]. However, using the accepted Shadow Price of Carbon of \$US39/tCO_2e (Annex 5), this equates to annualised benefit of \$US857,789, or \$US85,778,900 total value-add over a century.

    - Water regulation: improved river flow buffering multiplied by the value of vulnerable property protected downstream
- Cultural services:
    - Recreation and tourism: change in visitor numbers to site linked with travel cost
    - Spiritual and religious value: additional travel and time costs of finding alternative temples and sites for traditional cremation ceremonies
    - Social relations: estimates of time expenditure by volunteers on catchment restoration scheme
    - Educational resources: averted cost of school coach trips to access similar resources

[138] Thomas S.L., Cai, Y., Judd, K.L. and Lenton, T.M. (2015). Stochastic integrated assessment of climate tipping points indicates the need for strict climate policy. *Nature Climate Change*, 5, pp.441–444.
[139] Allen, M., Frame, D., Frieler, K., Hare, W., Huntingford, C., Jones, C., Knutti, R., Lowe, J., Meinshausen, M., Meinshausen, N. and Raper, S. (2009). The exit strategy. *Nature Reports Climate Change* [online], doi:10.1038/climate.2009.38.

- Supporting services:
    - Nutrient cycling: Value transfer from nitrogen and phosphorus cycling studies on a similar site
    - Provision of habitat: costs averted from bespoke management works for priority species or general requirements for wildlife enhancement

Other than climate regulation, these methods are not elaborated any further here as they are outside the scope of this brief initial study. However, the above descriptions provide indicative methods that may be applied for more comprehensive valuation required in follow-on research. Inevitably, there will be greater uncertainties associated with some values lacking clear or surrogate market prices, and the illustrated calculation for climate regulation too will need to be verified and updated.

A7.5 Further economic considerations

Assessment of overall economic value over project or scheme life generally requires some form of comparison of net value over a defined project life cycle, compared with initial costs. In neoclassical economics, 'net present value' is typically derived using an agreed annual discount rate applied as compound on future benefits accruing in future years. The UK government's 'Green Book' (HM Treasury[140]) provides a reference for methods to assess lifetime benefits and costs.

However, this method of net benefit assessment, particularly discounting the value of future benefits, is a highly contested topic. Not only is a discount rate highly political, determining in effect the extent to which benefits to people in the present take precedence over people in the future[141], but also potentially overlooking positive feedback such as the likelihood of compounding climate change (and hence the greater benefits of controlling it now versus higher costs later) and the increasing value of scarce and functional habitat in securing human wellbeing over time.

Deeper consideration of the economics of ecosystems and climate change is beyond the scope of this initial study, but can be expanded during future research if required.

End of Annex 7

[140] HM Treasury. (undated). *The Green Book: Appraisal and Evaluation in Central Government: Treasury Guidance*. https://www.gov.uk/government/publications/the-green-book-appraisal-and-evaluation-in-central-governent.
[141] Ackerman, F. (2009). *Can We Afford the Future? The Economics of a Warming World*. Zed Books, London.

The Converging World:
The social and environmental impact of convergence

UWE research output UWE-JPT#01

Research supported by the John Pontin Trust

A Bristol 2015 European Green Capital legacy project