A preliminary socio-economic, technical and environmental feasibility study for Waste for Life in the Western Province of Sri Lanka

Toni Alyce Smythe

Supervisors: Professor Caroline Baillie & Randika Jayasinghe

November 2011

This thesis is presented in partial fulfilment of the requirements of the Bachelor of Engineering (Environmental) at The University of Western Australia
Abstract

Informal waste collectors or ‘waste pickers’ gather recyclable waste from households, roadsides or dumpsites, to sell as a source of income. In Sri Lanka the informal waste sector plays an important role in municipal solid waste management and creates a significant number of jobs. Due to the low prices paid by middlemen (waste buyers) informal waste collectors make low profits, but in many cases this represents the person’s full income. Waste for Life (WfL) is a not-for-profit organisation which aims to develop and apply poverty-reducing solutions to waste problems. WfL has developed a low-cost hotpress to convert waste plastic and fibre to higher-value composite products, allowing informal waste collectors to improve their livelihoods and working conditions.

This study presents the results of a preliminary feasibility study conducted for a potential WfL initiative in the Western Province of Sri Lanka. Feasibility studies are structured ways to assess the technical, social, financial and environmental viability of a project, used to make an informed decision about whether the project should be implemented. Feasibility studies are used by various not-for-profit organisations and government bodies, including AusAID, UNICEF, and Oxfam, to assess development projects.

To assess the socio-economic feasibility of the WfL project a Stakeholder Analysis, Health and Safety Risk Assessment, and identification and critical assessment of some potential sources of funding were performed. Technical feasibility was evaluated through an identification and critical assessment of potential sources of waste plastic and fibre. Finally the air pollution, energy use, and water use and pollution of the WfL process was compared to current practices of plastic recycling in Sri Lanka to assess the environmental feasibility of the project.

Qualitative and quantitative data was obtained from conventional ‘hard’ sources (journal articles, published reports, and theses), as well as through personal communication with academics and experts in Sri Lanka. A short questionnaire for plastic recyclers and supermarkets was also designed to provide local data, and collected on the ground in Colombo District by a student at the University of Sri Jayawardenapura. Results of the study indicate that a WfL project in the Western Province is technically, socio-economically, and environmentally feasible at this stage of the planning.
Acknowledgements

I would firstly like to thank my supervisors, Caroline Baillie and Randika Jayasinghe, for their support and guidance throughout the project. I would also like to acknowledge the valuable first-hand knowledge and experience each contributed. As one of the founders of Waste for Life and a materials engineer, Caroline provided unique insight into Waste for Life and natural fibre composites. Randika was an invaluable source of knowledge regarding waste management and various other aspects of life in Sri Lanka.

Thank you to Eric Feinblatt for further advice and insight into Waste for Life, and to Darko Matovic at Queen’s University and Angus Tavner at the University of Western Australia for their expert advice regarding technical and safety aspects of the hotpress.

Special thanks to Chathuranga Deshapriya, undergraduate student in the Department of Forestry and Environmental Science at the University of Sri Jayawardenapura, for generously donating his time to collect results of the questionnaire. I would also like to acknowledge those participated in the project by answering the questionnaires.

I would like to thank Dr. W.R.G. Witharama, Principal Research Officer, at the Sugar Research Institute at Udawalawe, Sri Lanka for providing expert knowledge of the sugar manufacturing industry in the country.

Finally, thank you to Frank Jayasinghe, Project Appraiser for the Gemidiriya organisation, for valuable advice on various topics, and for acting as a go-between with other experts in Sri Lanka.
Table of Contents

Abstract ........................................................................................................................................... ii
Acknowledgements .......................................................................................................................... iii
Table of Contents ............................................................................................................................... iv
List of Tables................................................................................................................................... vi
Abbreviations .................................................................................................................................... vii
1. Introduction ................................................................................................................................... 1
   1.1 Project Aims ................................................................................................................................. 2
2. Literature Review ........................................................................................................................... 3
   2.1 Sri Lanka: Geographical, Social, and Economic Context ............................................................... 3
      2.1.1 The Western Province ............................................................................................................. 3
   2.2 The Solid Waste Problem in Sri Lanka ....................................................................................... 4
      2.2.1 Plastic Waste in Sri Lanka ....................................................................................................... 5
      2.2.2 Plastic Recycling in Sri Lanka ................................................................................................. 5
      2.2.3 The Informal Waste Sector in Sri Lanka ............................................................................... 7
   2.3 Waste for Life ............................................................................................................................. 7
      2.3.1 The Waste for Life Hotpress .................................................................................................. 7
      2.3.2 Natural Fibre Composites ....................................................................................................... 7
   2.4 Microfinance ............................................................................................................................... 9
   2.5 Feasibility Assessment ................................................................................................................ 10
   2.6 Stakeholder Analysis .................................................................................................................. 11
3. Approach and Methodology ........................................................................................................ 12
   3.1 Socio-economic Feasibility ......................................................................................................... 12
      3.1.1 Stakeholder Analysis ............................................................................................................... 12
      3.1.2 Health and Safety Risk Assessment ....................................................................................... 12
      3.1.3 Identification and Critical Assessment of Some Potential Sources of Funding ............... 13
   3.2 Technical Feasibility ................................................................................................................... 13
      3.2.1 Identification and Critical Assessment of Potential Sources of Waste Plastic and Fibre... 13
   3.3 Environmental Feasibility .......................................................................................................... 13
   3.3.1 Stakeholder Analysis ............................................................................................................... 13
List of Tables

Table 1. Common types of plastic used in Sri Lanka (Bandara et al., 2010). ........................................... 5

Table 2. Potential impacts upon the interests of stakeholders of WfL Sri Lanka. ................................. 23

Table 3. Stakeholder matrix showing the relative influence and importance of stakeholders of WfL Sri Lanka. .................................................................................................................................................................... 24

Table 4. Summary of recommended stakeholder participation in WfL Sri Lanka. .............................. 26

Table 5. Risk assessment matrix adapted from Hardy (2010); red represents high priority risks, orange, moderate priority risks and yellow, low priority risks. ....................................................................................................................... 28

Table 6. Summary of results of the health and safety risk assessment for WfL Sri Lanka. .................... 33

Table 7. Potential sources of natural fibre for WfL Sri Lanka. ............................................................... 43
## Abbreviations

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Full Form</th>
</tr>
</thead>
<tbody>
<tr>
<td>CBO</td>
<td>Community-Based Organisation</td>
</tr>
<tr>
<td>CEA</td>
<td>Central Environmental Authority</td>
</tr>
<tr>
<td>DS</td>
<td>Divisional Secretary</td>
</tr>
<tr>
<td>HDPE</td>
<td>High Density Polyethylene</td>
</tr>
<tr>
<td>LDPE</td>
<td>Low Density Polyethylene</td>
</tr>
<tr>
<td>LKR</td>
<td>Sri Lankan Rupees</td>
</tr>
<tr>
<td>MFI</td>
<td>Microfinance Institution</td>
</tr>
<tr>
<td>MC</td>
<td>Municipal Council</td>
</tr>
<tr>
<td>UC</td>
<td>Urban Council</td>
</tr>
<tr>
<td>LA</td>
<td>Local Authority</td>
</tr>
<tr>
<td>MSW</td>
<td>Municipal Solid Waste</td>
</tr>
<tr>
<td>NFC</td>
<td>Natural Fibre Composite</td>
</tr>
<tr>
<td>NGO</td>
<td>Non-Governmental Organisation</td>
</tr>
<tr>
<td>PET</td>
<td>Polyethylene Terephthalate</td>
</tr>
<tr>
<td>PP</td>
<td>Polypropylene</td>
</tr>
<tr>
<td>PPE</td>
<td>Personal Protective Equipment</td>
</tr>
<tr>
<td>PS</td>
<td>Polystyrene</td>
</tr>
<tr>
<td>PVC</td>
<td>Polyvinyl Chloride</td>
</tr>
<tr>
<td>RPR</td>
<td>Residue to Product Ratio</td>
</tr>
<tr>
<td>SEEDS</td>
<td>Sarvodaya Economic Enterprise Development Services</td>
</tr>
<tr>
<td>UNDP</td>
<td>United Nations Development Programme</td>
</tr>
<tr>
<td>UWA</td>
<td>The University of Western Australia</td>
</tr>
<tr>
<td>WfL</td>
<td>Waste for Life</td>
</tr>
<tr>
<td>WMA</td>
<td>Waste Management Authority</td>
</tr>
<tr>
<td>WPC</td>
<td>Wood Plastic Composite</td>
</tr>
</tbody>
</table>
1. Introduction

Solid waste management is a key issue in urban environments to ensure the safety and health of their inhabitants, and allow sustainable economic growth (Visvanathan and Trankler, 2003). The industrialisation of ‘developing’ countries in Asia has triggered rapid economic growth and urbanisation, placing serious pressure on waste disposal infrastructure (International Solid Waste Association, 2002); there is a positive correlation between economic development and municipal solid waste generation (Amin, 2006). The people who suffer most from improper solid waste management are the urban poor (Kungskulniti, 1990, Lohani, 1984); authorities tend to allocate their limited funding for waste management to higher income areas where citizens pay more taxes and have greater political power (Zurbrugg, 2003). Wealthier residents are also able to pay to avoid exposure to waste problems, shifting them elsewhere (Zurbrugg, 2003).

The problems in solid waste management faced by low-income countries in Asia have given rise to practices very different from those of ‘developed’ countries, in particular the involvement of voluntary groups, non-governmental organisations (NGOs), community-based organisations (CBOs), and the informal sector (Visvanathan and Trankler, 2003). Informal waste collection is a rapidly-growing sector in labour-abundant and resource-poor nations, in which waste is turned into a resource as a means of gaining an income (Amin, 2006). The informal recovery of materials from waste can provide a source of income for a significant proportion of the population in cities of developing countries in Asia; up to 2% of the population in these cities survives by collecting waste (Medina, 2000). Informal waste collectors (also called ‘scavengers’ or ‘waste pickers’) therefore collectively recover large amounts of materials for reuse and recycling; in low income countries, most of the recycling which takes place occurs through the informal sector (Amin, 2006).

The materials collected by informal workers are sold to small-scale waste buyers at a low prices (usually a fraction of their worth to the recycling industry) and as a result waste buyers, who on-sell the materials to recycling companies, receive most of the profits whilst the collectors receive very low incomes (Medina, 2000). Informal waste collectors also face various hazards through their work, such as unsanitary conditions, disease, and discrimination or even harassment from the wider community (Medina, 2000). The activities of informal waste collectors however may represent significant environmental benefit through the diversion of waste from landfill and as savings in energy and water, and pollution generated, when compared to the production of virgin materials (Medina, 2000).

Waste for Life (WfL) is a multi-disciplinary, international network of professionals and students which aims to develop and apply poverty-reducing solutions to waste problems (Baillie et al., 2010). In Maseru, Lesotho, and Buenos Aires, Argentina, WfL has worked with co-operatives to develop and implement low-cost compression moulds or hotpresses to transform waste plastic and fibre into higher-value natural
fibre composites (NFCs) (Baillie et al., 2010). This allows informal waste collectors to diversify; by producing and selling products directly to the community, they can circumvent the middlemen and improve their livelihoods and working conditions. WfL intends to implement a similar project in Sri Lanka, where less than half of all waste generated is collected by local government bodies (UNEP, 2001). However before the project can be implemented WfL must first assess the feasibility of the project. Various not-for-profit organisations use feasibility assessments for this purpose; these are structured ways to assess a project’s technical, social, financial and environmental viability (Jordaan et al., 2004), used to make an informed decision about whether the project should be implemented (Karagiannidis et al., 2009).

1.1 Project Aims

This study aims to assess the preliminary socio-economic, technical and environmental feasibility of a Waste for Life project in the Western Province of Sri Lanka.
2. Literature Review

2.1 Sri Lanka: Geographical, Social, and Economic Context

Sri Lanka is an island nation located just south-east of India in the Indian Ocean, with an area of 65,610 km² (UNDP, 2009). The country is densely populated; with a population of approximately 21 million (BSCAA, 2011) the population density is approximately 320 persons per square kilometre. Sri Lanka’s population is highly diverse; the ethnicity of the country comprises Sinhalese (74%), Tamil (18%), Muslim (7%), Burghers and others (1%) (UNDP, 2009).

Sri Lanka is governed by an Executive President (an elected position) and a parliamentary system (UNDP, 2009). For administrative purposes the country is divided into nine provinces, which consist of 25 districts (UNDP, 2009). Within these districts local government administrative units, called Local Authorities (LAs), are (in order of decreasing size) Municipal Councils (MCs), Urban Councils (UCs) and Pradeshiya Sabhas (van Zon and Siriwardena, 2000). High public expenditure in the sectors of health and education has resulted in a similar life expectancy to developed countries, and high literacy rates and gender equality (UNDP, 2009).

Whilst Sri Lanka’s economic growth has generally been strong since the 1990s, long-term ethnic conflict in the country and the devastation of the 2004 tsunami has undermined development and poverty reduction (UNDP, 2009). Sri Lanka was the second most impacted country by the 2004 Indian Ocean tsunami, and this event destroyed the livelihoods of thousands of people who depended upon the coastal resources of Sri Lanka and increased poverty in coastal areas (UNDP, 2009). In 2006/07 it was estimated that 15.2% of the population was below the poverty line (excluding the Northern Province) (Department of Census and Statistics, 2009). However this figure does not take into account the poverty of Internally Displaced Persons caused by the tsunami and armed conflict (UNDP, 2009).

2.1.1 The Western Province

The Western Province of Sri Lanka consists of the three districts of Colombo, Kalutara and Gampaha, which collectively make up just 5.4% of Sri Lanka’s area (Department of Health Services, n.d., CIA World Factbook, 2011), but are home to 28% of the country’s population (Mannapperuma and Basnayake, 2007). This province contains both the country’s commercial capital of Colombo city and the official capital, Sri Jayewardenepura-Kotte. Whilst the poverty ratio of the Western Province is relatively low, due to its large population the poverty head count is high (Vishwanath and Yoshida, 2007). Poverty in Sri Lanka is also characterised by significant spatial variation; within provinces and districts pockets of extreme poverty may exist, as is the case in Colombo city (Vishwanath and Yoshida, 2007).
2.2 The Solid Waste Problem in Sri Lanka

The LAs – MCs, PCs, and Pradeshiya Sabhas - are responsible for waste collection and disposal in their territories, usually via a Public Health Inspector appointed by the Ministry of Health (van Zon and Siriwardena, 2000). The public health departments of LAs however are also responsible for areas such as health and sanitation, so solid waste management is somewhat neglected (Bandara, 2008). Whilst the total municipal solid waste (MSW) generation in Sri Lanka is estimated to be around 6400 tonnes per day, the collection rate of LAs is only about 2500 tonnes per day (UNEP, 2001); less than half of all waste generated is collected by the authorities.

As a result, illegal dumping is common practice in Sri Lanka with approximately 20% of households dumping waste on the roadside (Bandara, 2008). According to the Environmental Foundation (2007, pg 1) this practice is not limited to households: “private householders as well as companies and industries, schools and hospitals, all dump their wastes largely wherever they can conveniently do so”. Littering is rife and occurs on the streets, in public places, and in residential areas (Environmental Foundation, 2007). This presents a significant health risk in the provision of container habitats for rats and mosquitoes which are vectors for disease (van Zon and Siriwardena, 2000). Open burning of waste is also widely practiced; this can release harmful atmospheric pollution including toxic and even carcinogenic particles, particularly when plastics are burnt at low temperatures (van Zon and Siriwardena, 2000).

Most of the waste which is collected by LAs is placed in open dumps, sites of low-lying, degraded land where all types of waste (industrial, hospital and slaughterhouse waste as well as MSW) are disposed of with no separation, resulting in the release of landfill gases and leachate, and reducing flood retention capacity of suburban areas (Bandara, 2008). Septage (septic tank sludge) is also often disposed of at these open dumps, with no environmental or health precautions (Environmental Foundation, 2007), posing a significant health risk to those who frequent the dumps. Dump sites are generally small (1-2 hectares), so workers managing the sites regularly burn waste in an effort to extend the life of the dump (Environmental Foundation, 2007).

Solid waste management poses a significant problem to LAs, due to the poor collection capabilities of most LAs (Environmental Foundation, 2007), and the conflict of increasing land scarcity with the need for dumping grounds (Bandara, 2008). Improper solid waste disposal is a major cause of environmental degradation in Sri Lanka and has significant health impacts for the community (Bandara, 2008). Poor waste disposal also causes social impacts including odour, the presence of pests and a decline in property values (Bandara and Hettiaratchi, 2010). The problem will only become more pressing as an increase in urban MSW generation of 25% is predicted by 2025 (World Bank, 1999).

Poor waste disposal practices have been found to be “a primary cause for degradation of the quality of water resources in Sri Lanka” and this problem is most severe in the Western Province of Sri Lanka.
According to a paper jointly produced with the Waste Management Authority (WMA) of the Western Province, the collection rate by LAs is comparatively high at 60-70%, however the total MSW generation of the area is extremely high; it contributes 60% of the total solid waste generation in Sri Lanka due to factors such as the abundance of vehicles and industry within the area (Mannapperuma and Basnayake, 2007). The use of low-lying areas and wetlands for waste disposal has significantly reduced the flood retention capacity of suburban areas in Colombo city and current practices threaten ecologically sensitive areas in and around the suburbs (Bandara, 2008).

### 2.2.1 Plastic Waste in Sri Lanka

Plastics are widely used in Sri Lanka due to their low cost and availability; in 2010 total annual plastic consumption in the country was estimated at 100,000 tonnes (Jayasekara, 2010). There are between 20 and 25 types in use (Lakmali and Dissanayake, 2008); the most commonly used types are shown below (Table 1).

**Table 1. Common types of plastic used in Sri Lanka (Bandara et al., 2010).**

<table>
<thead>
<tr>
<th>Type</th>
<th>Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>Polyethylene: high-density polyethylene (HDPE) and low-density polyethylene (LDPE)</td>
<td>Widely used for packaging, plastic bags and insulation</td>
</tr>
<tr>
<td>Polythene terephthalate (PET)</td>
<td>Used in recyclable containers such as plastic bottles</td>
</tr>
<tr>
<td>Polypropylene (PP)</td>
<td>Used for packaging as relatively heavy films and woven sheets or bags</td>
</tr>
<tr>
<td>Polystyrene (PS)</td>
<td>Used for protective packaging and insulation</td>
</tr>
<tr>
<td>Polyvinyl chloride (PVC)</td>
<td>Primarily used for building materials such as pipes and flooring</td>
</tr>
</tbody>
</table>

The widespread use of plastics and their persistent nature make plastic materials one of the major challenges in solid waste management (Environmental Foundation, 2007). The improper disposal of plastics poses a particularly serious health threat due to the long-lasting container habitats they provide, and the emission of toxic gases and particles caused by burning plastics at low temperatures (van Zon and Siriwardena, 2000). Plastics also take up significant amounts of the available space at dumpsites (Jayasekara, 2010).

### 2.2.2 Plastic Recycling in Sri Lanka

The main types of plastics in use in Sri Lanka (discussed above) all fall into the class of thermoplastics, which soften on heating and harden again when cooled; this property makes them suitable for mechanical recycling (Jayasekara, 2010). Most plastic recycling enterprises in Sri Lanka are small-scale operations, generally processing approximately 75-100 tonnes of plastic per month (Jayasekara, 2010). The most commonly used raw materials are PP, HDPE, LDPE, PET, and PS, with polycarbonate and PVC also being recycled (Gunarathna, 2010). After these materials are collected and sorted the recycling of plastics...
generally occurs through the following four processing steps: size reduction, washing, extrusion, and pelletising (Jayasekara, 2010). Size reduction involves breaking down plastic waste into smaller pieces which can be fed into an extruder; this is usually achieved by manual cutting (using tools such as scissors, shears, or saws), mechanical shredding, or agglomeration (Jayasekara, 2010). A mechanical shredder comprises an electric motor driving a series of rotating blades, through which the plastics move before passing through a grid for size grading (Jayasekara, 2010). Agglomeration is the process of heating and rapidly cooling soft plastics (such as films) to solidify the material before it is crushed into smaller pieces; this ‘pre-plasticising’ produces coarse and irregular plastic grain, called ‘crumbs’ (Jayasekara, 2010).

Washing is considered to be the most important step in the conventional recycling of plastic in Sri Lanka, as the quality of products made entirely from waste plastic is highly dependent upon the purity of the input materials (Jayasekara, 2010). Washing is usually conducted by hand; a solution of alkaline detergent (such as laundry powder) or caustic soda in water is used to remove contaminants from the plastic flakes (Jayasekara, 2010). The plastic is then rinsed and dried, either by the sun or using heated air (Jayasekara, 2010). At this point the flakes are melted down and extruded; the plastic is passed through a fine grill to remove any remaining foreign particles and then through a die, a plate with numerous small holes (Jayasekara, 2010). This creates long strings of plastic which are pelletised by being quickly sprayed with water and cut up by rotating blades (Jayasekara, 2010). The resulting small pellets are sold to a manufacturer to be used similarly to virgin plastics in the creation of new products (Jayasekara, 2010).

### 2.2.2.1 Environmental Impacts of Plastic Recycling in Sri Lanka

It is well documented that recycling of plastics can result in significant environmental benefits, particularly the conservation of fossil fuels, water, and energy used in the production of virgin plastics (Jayasekara, 2010, Medina, 2005). For example, approximately 110 GJ of energy is used to produce one tonne of virgin LDPE, compared to an estimated 27-35 GJ to produce one tonne of recycled LDPE bags; this represents an energy saving of up to 75% (Singer, 1994, in Jayasekara, 2010). This kind of substitution can also significantly reduce air pollution; on average nitrogen oxides (NOₓ), sulphur dioxide (SO₂) and carbon dioxide (CO₂) emissions are reduced by 70% when products are made using recycled material (Singer, 1994, in Jayasekara, 2010). In Sri Lanka plastic recycling also plays an important role in diverting these materials from burning and indiscriminate dumping.

Plastic recycling can be associated with some environmental costs however, such the discharge of wastewater and effluents, and the release of toxic fumes (Nesiah, 1994, in Jayasekara, 2010). In Sri Lanka in particular plastic recycling is an environmentally hazardous industry, due to the high usage of water for washing, rinsing, and cooling waste plastic and the discharge of polluted water to the environment (Jayasekara, 2010).
2.2.3 The Informal Waste Sector in Sri Lanka

Informal waste collectors in Sri Lanka gather recyclable and reusable waste from households (door-to-door waste collectors) or directly from roadsides and dumpsites (waste pickers), and sell these materials to waste buyers who in turn sell them to recycling companies. The informal waste sector creates a significant number of jobs in the country, in collection, buying and selling, sorting, transport, and recycling. Informal waste collectors in Sri Lanka make low profits, but in many cases this represents the person’s full income (van Zon and Siriwardena, 2000).

2.3 Waste for Life

WfL is a international network of engineers, scientists, academics, architects, designers, and cooperatives working to develop poverty-reducing solutions to environmental problems (Waste for Life, 2011). The goals of WfL are to:

a) promote self-sufficiency and economic security in vulnerable communities which rely on waste as a source of income; and
b) reduce the environmental impact of plastic waste (Waste for Life, 2011).

Engineers play a key role in WfL through the design of low-cost technologies to convert waste plastic and fibre with to NFCs, improving the livelihoods of some of the poorest members of society (Baillie et al., 2010). WfL has already implemented two successful projects in Maseru, Lesotho, and Buenos Aires, Argentina, in which co-operatives use low-cost compression moulds or hotpresses to produce NFCs from locally available waste (Baillie et al., 2010). These products have included insulating roof tiles (Baillie et al., 2010), wallets, and waste bins (Waste for Life, 2011).

2.3.1 The Waste for Life Hotpress

The hotpresses designed by WfL for its previous projects are each based upon the first model developed by the organisation, the ‘Kingston hotpress’, designed at Queen’s University in Kingston by Darko Matovich (Baillie et al., 2011). This machine was designed to maintain pressures of up to 6 MPa (requiring a total force approximately 2 MN) and temperatures of up to 200°C (Baillie et al., 2011). The hotpress cost less than $3000 and utilised standard 220 V circuits for heating, as opposed to industrial presses with similar abilities, which are typically between $50,000 and $100,000 and require industrial electrical circuitry to power electric motors of 5–10 kW (Baillie et al., 2011). The total mass of the Kingston hotpress is approximately 350 kg (Baillie et al., 2011).

2.3.2 Natural Fibre Composites

NFCs aim to combine the excellent mechanical and physical properties of fibre with the appearance, bonding and physical properties of polymers (van Rijswijk et al., 2001). These materials can have advantages over conventional materials, due to their low cost, low weight, increased bio-degradability and
the abundance of natural fibres (Torres and Cubillas, 2005, in Thamae and Baillie, 2008). Thamae and Baillie (2008) conducted Life Cycle Assessments (LCAs) to compare the environmental impacts of NFC car door panels (made with wood fiber and poly-propylene) with conventional glass fiber reinforced panels; this study showed that in this case the use of a NFC material reduced the environmental impacts of the panels.

The properties of NFCs depend heavily upon the particular fibre and matrix used, as well as the manufacturing process (Ticoalu et al., 2010). The proportion of fibre to matrix also influence the properties of the resulting composite, as will any treatments applied to the fibres (Ticoalu et al., 2010). Treatments are applied in order to enhance the adhesion between the fibre and the matrix, and thereby improve the interface of natural fibre composites (Ticoalu et al., 2010). In general, composites can grouped into two categories, based on the type of fibre used: short-fibre and long-fibre composites (Chou and Kelly, 1980).

Short-fibre NFCs are composites reinforced with discontinuous fibres, with small length relative to their diameter (Chou and Kelly, 1980). Whilst these types of NFCs tend to be relatively weak in the longitudinal direction, they are very tough materials (C. Baillie, 2011, pers. comm., 10 August). One common short fibre used in commercial NFCs is sawdust; these are typically referred to as Wood Plastic Composites (WPCs). The use of long fibres in NFCs can result in very good mechanical properties, particularly when fibres are layered at an angle or woven (Hull and Clyne, 1996). However these types of fibres are generally more valuable and costly than other fibres due to their suitability for other uses (C. Baillie, 2011, pers. comm., 10 August).

WfL has developed several unique NFCs for previous WfL projects: in Canada, HDPE bale wrap was reinforced with flax and hemp, in Lesotho, corn, wheat and agave were combined with LDPE plastic bags, and in Buenos Aires NFCs were created using paper, card or fabric, and plastic film (Baillie et al., 2011). These fibres were sourced from dedicated crops (agave, hemp, or flax), agricultural byproducts (corn stalk or wheat straw), or post-consumer sources (cardboard, office paper, and newspaper) (Baillie et al., 2011). Out of the fibres used for previous WfL projects, only office paper and newsprint may be used without any pre-processing (remaining as whole layers); they may also be simply shredded (Baillie et al., 2011).

2.3.2.1 Processing of Natural Fibre Composites

The NFCs of previous WfL projects have been produced by various methods (see Figure 1); however the following processing stages are common to all: (i) selection of fibre material, (b) fibre material preparation, (c) primary fibre/plastics bonding, and (d) creation of final products. The method employed for fibre material preparation depends upon the fibre material selected and the capabilities of the available processing facilities. Primary fibre/plastics bonding or pre-impregnation is achieved by hot-pressing the
materials into thin layers. These thin ‘pre-preg’ laminates are then be shredded, or shredded, extruded and pelletised, before a second press moulding to form the final product (Baillie et al., 2011).

Processing of the fibre has significant impact upon the final product, as changes to the length distribution and alignment of the fibres may significantly affect the strength and stiffness of the product (Chou and Kelly, 1980). This may result in higher NFC product strength when compared with shredding, mixing and pressing, which has the potential for agglomeration and fibre breakage (Baillie et al., 2011). Laminates may also be made in a single pressing, provided that the viscosity of the polymer is sufficiently low to allow it to permeate the fibre layers (Baillie et al., 2011). These production methods present significant advantages in processing through reducing the number of steps and equipment required, and potentially improving the strength of the product (Baillie et al., 2011).

### 2.4 Microfinance

To support the organisation’s project in Buenos Aires, Argentina, WfL sourced funding from a microfinance organisation (micro-credit) (Baillie et al., 2010). Microfinance is the provision of a variety of small-scale financial services, including credit, savings, and insurance, to people who cannot access funds through formal financial institutions (Colombage, 2004). Usually these schemes are characterised by easy access for impoverished people, group-based lending, little or no collateral requirements and
reasonable” interest rates (Colombage, 2004, pg 2). According to Rhyne (2009) there are approximately 133 million microfinance borrowers and 3,316 microfinance institutions (MFIs) worldwide. Microfinance is widely regarded as having significant potential for poverty alleviation and development, with MFIs thought to encourage entrepreneurship and economic development “at the grassroots level” (Hudak, 2010, pg 10).

However there are various criticisms associated with microfinance, which is vulnerable to poor implementation. In India, a nation-wide bank reform to provide microfinance through state owned banks from 1969 to 1990 failed due to corruption, economic inefficiency, and high default rates and transaction costs requiring heavy subsidization (Srivastava, 2010). Most importantly much of the ‘cheap credit’ supplied by this program found its way to the politically-connected rich, rather than the poor (Armendariz de Aghion and Morduch, 2007, Gaiha and Nandhi, 2008, in Srivastava, 2010). A key criticism of microfinance is that microcredit can lead to ‘microdebt’ and leave borrowers in more difficult financial situations than before the loan (Srivastava, 2010). Contrary to expectations microfinance can be extremely expensive for borrowers; the global average interest rate for microfinance is approximately 35% (Kneiding and Rosenberg, 2008). It is argued that high rates of interest are required to cover operational costs, loan defaults, and to raise capital for future expansion (Fernando, 2006). Microfinance can be a highly effective tool for poverty alleviation, however it is not a fool-proof solution to poverty (Srivastava, 2010).

2.5 Feasibility Assessment

Prior to the implementation of a WfL project in Sri Lanka it was considered crucial to assess its feasibility. Feasibility assessments or studies are used by various NGOs and government bodies, such as AusAID, USAID, UNICEF, Oxfam and DFID to assess development projects or programs prior to their implementation (AusAID, 2005, Development Services, 2006, Liberian Hydrological Service, n.d., Enterprise Opportunities, 2006, Gaunt et al., 2000). Feasibility assessments can be defined as structured ways to assess the technical, social, financial and environmental viability of a project (Jordaan et al., 2004), used to make an informed decision about whether the project should be implemented (Karagiannidis et al., 2009). However there does not appear to be a well-defined structure for feasibility assessment; rather the structure is specific to each project or implementing agency (AusAID, 2005, Development Services, 2006, Liberian Hydrological Service, n.d., Enterprise Opportunities, 2006, Gaunt et al., 2000). Feasibility studies conducted by AusAID focus on evaluating the manageability, technical and institutional feasibility, effect on poverty, social and cultural impact, and environmental impact of a project (among other factors) (AusAID, 2005).
2.6 Stakeholder Analysis

“Community development projects should be driven by the present needs and problems of the community targeted, not by an abstract or universal conception of basic human need” (Manzo, 2000, pg 288). This statement reflects the evolution of the needs-based approach to community development as discussed by Manzo’s (2000) critique of NGOs in India. Whilst it is generally assumed by organizations implementing technological or economic developments that they are improving the lives of individuals in a community (Reviere et al., 1996), the results of the project must be considered ‘improvement’ not only by the implementing agencies but first and foremost by the intended beneficiaries.

One framework in which this may begin to be assessed is Stakeholder Analysis. Stakeholder Analysis is defined as “the identification of a project's key stakeholders, an assessment of their interests, and the ways in which these interests affect project riskiness and viability” (DFID, 1995a). This process draws on both institutional appraisal and social analysis and combines the information provided by these approaches into a cohesive framework (DFID, 1995a). The ultimate goal of Stakeholder Analysis is to develop a “strategic view” of the social and institutional context, the relationships between stakeholders, and their concerns (Golder and Gawler, 2005). Stakeholder Analysis can also be used to plan for stakeholder participation; however the process should be repeated at intervals throughout a project’s life to ensure its continued relevance (DFID, 1995a).
3. Approach and Methodology

The study comprises mostly qualitative, text-based analysis, with some secondary analysis of available quantitative data. Given that the main aim of the WfL project is to improve the livelihoods of economically and socially vulnerable people, the assessment of social and economic feasibility are combined in this study and this section is the major component.

3.1 Socio-economic Feasibility

To assess the socio-economic feasibility of WfL Sri Lanka, a Stakeholder Analysis, Health and Safety Risk Assessment, and identification and critical assessment of some potential sources of funding were performed.

3.1.1 Stakeholder Analysis

The methodology adopted for Stakeholder Analysis was based upon DFID (1995a) and is as follows:

1. Identification of all potential stakeholders;
2. Identification of stakeholders’ interests in regards to project and assessment of the likely impact of project on their interests;
3. Identification of influence and importance of stakeholders;
4. Identification of assumptions made about the role of stakeholders in the project; and
5. Identification of appropriate types of stakeholder participation (inform, consult, partner and control) and stages in the project (identification, planning, implementation, and monitoring and evaluation).

As part of Step 1 (identification of potential stakeholders) profiling of each stakeholder was conducted; this allowed the identification of stakeholder’s interests (in Step 2). A ‘stakeholder matrix’ was used to identify the influence and importance of each stakeholder (Step 3).

3.1.2 Health and Safety Risk Assessment

In order to ensure that WfL Sri Lanka does not pose undue risk to the intended beneficiaries, a Risk Assessment was performed to identify and evaluate potential health and safety risks associated with working with using the hotpress and producing NFCs. A simplified procedure was adapted from Hardy (2010) and UK governmental body Health and Safety Executive (2006) with the following steps:

1. Identification of potential hazards and risks;
2. Assessment of risks on the basis of likelihood and severity; and
3. Identification of mitigation measures.
3.1.3 Identification and Critical Assessment of Some Potential Sources of Funding

Some possible sources of funding for WfL in the Western Province were identified and assessed on the basis of their appropriateness to WfL values and aims. This was conducted in the following steps:

1. Review of funding for previous WfL projects; and
2. Critical assessment of some potential sources of funding for WfL Sri Lanka.

3.2 Technical Feasibility

To assess the technical feasibility of WfL Sri Lanka, an identification and critical assessment of potential sources of waste plastic and fibre was conducted.

3.2.1 Identification and Critical Assessment of Potential Sources of Waste Plastic and Fibre

Potential sources of waste plastic and fibre for a WfL project in the Western Province were identified and assessed, based upon the following considerations:

1. The materials should be currently underutilized and of little commercial worth;
2. Ideally the materials should be available year-round (i.e. supply should be continuous rather than seasonal) in sufficient quantities to sustain the project;
3. Due to the limited capital available for the project, the source of the materials should be relatively close to the manufacturing location; and
4. For ease of production the materials should require as few as possible additional processing steps.

To assess the availability of agricultural fibres, data from the Sri Lankan Department of Census and Statistics (where available) was used to estimate the generation in the potential source area. It was assumed that the generation of the agricultural product within the source area was proportional to either: a) the extent of land devoted to the crop, or b) the number of operations within the area. Then the generation of each product within the source area was calculated using this figure and the national generation value. The generation of the fibre (byproduct) was then calculated using Residue to Product Ratios (RPRs) calculated in previous studies.

3.3 Environmental Feasibility

Whilst recycling can have significant environmental benefits, the industry is also associated with some environmental costs. Furthermore the implementation of a WfL project in the Western Province could involve a CBO which is already practicing some kind of plastic recycling. As a result, a comparison of conventional plastic recycling in the Western Province with the WfL process was conducted to assess the environmental feasibility of WfL Sri Lanka.
3.3.1 Comparison of Conventional Plastic Recycling with Waste for Life Process

The environmental impacts of the WfL NFC production process was compared to current plastic recycling practices in the Western Province, in terms of:

1. Air pollution;
2. Energy use; and
3. Water use and pollution.

3.4 Sources

Due to the early stage of planning for a WfL project in the Western Province, the study was primarily based upon existing data; this was considered to be the most responsible approach as it avoided overspending of time and money (and disruption to the community a WfL project is intended to benefit) with potentially little advantage for WfL if the project proved unfeasible. Information was sourced from peer-reviewed scholarly articles, reports by government bodies and NGOs, theses and unpublished studies conducted by students at the University of Sri Jayawardenapura, and case studies of previous WfL projects (secondary sources). This was supplemented with primary sources of information such as data from the Sri Lankan Department of Census and Statistics, and contact with experts in the Western Province and WfL engineers.

To address some key information gaps two short questionnaires for supermarkets and recyclers in the Western Province was also designed and responses collected by an undergraduate at the University of Sri Jayawardenapura (see Appendix 1 –Questionnaire for Plastic Recyclers and Appendix 3 –Questionnaire for Supermarkets). These questionnaires were given to ten supermarkets in Colombo District and seven recyclers in Colombo and Gampaha districts.
4. Results

4.1 Socio-economic Feasibility

4.1.1 Stakeholder Analysis

4.1.1.1 Identification of Potential Stakeholders in the Project

Waste Pickers
Also referred to as ‘scavengers’ or ‘rag-pickers’, waste pickers collect materials from roadsides and garbage dumps to sell to waste buyers (Jayaratne, 1996, van Zon and Siriwardena, 2000). According to the Environmental Foundation (2007) dumpsite scavenging is widespread in Sri Lanka. Their discussions with “professional” waste pickers resulted in an estimated income from these activities as LKR 400-700 per day (Environmental Foundation, 2007, pg 4). This seems high given that the income of an unskilled worker in Sri Lanka is around LKR 450 per day (Environmental Foundation, 2007) however the use of the descriptor ‘professional’ may indicate that this is an estimate from the most skilled and able of waste pickers, representing the very upper end of their income range. According to Medina (2000) globally informal waste collectors are paid very low incomes which can generally be attributed to the low prices paid by waste buyers. Working conditions for waste pickers in Sri Lanka are very poor; waste is collected from garbage bins and dumpsites with bare hands, resulting in exposure to toxic chemicals and injuries from concealed sharp objects such as needles (Jayasekara, 2010). The workers are also exposed to toxic fumes from burning garbage and polluted, stagnant water surrounding garbage bins and dumpsites (Jayasekara, 2010).

Door-to-Door Waste Collectors
Door-to-door waste collectors are essentially self-employed (R. Jayasinghe, 2011, pers. comm., 7 June), and buy waste materials such as paper, cardboard, black plastics, glass and metal from households to sell to waste buyers (van Zon and Siriwardena, 2000). Neighbourhoods can be visited once or twice a week and collection and transport of the waste is usually done using a bicycle or hand-cart (van Zon and Siriwardena, 2000). The profit made by door-to-door collectors in the Western Province ranges between LKR 2-10 per item (in the case of bags and glass bottles) or per kg (for other types of waste) (R. Jayasinghe, 2011, pers. comm., 3 October). In the Ja-Ela area, which lies within the Gampaha District, the collectors’ average daily income is approximately LKR 100-300 (van Zon and Siriwardena, 2000). One factor in the low incomes of these types of waste collectors is the amount of money paid to households to buy the sorted waste (van Zon and Siriwardena, 2000).
Community-Based Organisations
According to many experts, the involvement of the community through CBOs is crucial to ensure the effectiveness of grass-roots solid waste management projects (Abeysundra and Babel, 2006). A number of CBOs engaged in waste collection and recycling projects currently exist in Sri Lanka. According to the Environmental Foundation (2007) the success of these projects has been contingent upon their direct linkage to improving the livelihoods of the poor. It is expected that a WfL project in Sri Lanka would involve a CBO; however at this early stage of the project it is difficult to identify specific local CBOs which may be interested and able to be involved in the project.

Waste Buyers
Waste buyers or middlemen buy and sort reusable and recyclable waste, such as paper, cardboard, metal, plastics and glass, storing them until they can be sold for reuse or to recycling companies in Sri Lanka or overseas (van Zon and Siriwardena, 2000). Waste buyers can make LKR 2-5 profit per item (in the case of bags and glass bottles) or per kg (for other types of waste) (R. Jayasinghe, 2011, pers. comm., 3 October); one waste buyer in the Western Province gave an estimate of income at LKR 10,000 per month (approximately LKR 350 per day) (van Zon and Siriwardena, 2000).

Plastic Recycling Companies
Whilst the exact number of plastic recycling companies operating in Sri Lanka is unknown, there are 95 plastic waste collectors and recyclers currently registered with the Central Environmental Authority (CEA) (Gunarathna, 2010). Most plastic recyclers are located in or near the commercial capital of Colombo city and are small-scale operations, generally recycling 75 – 1000 tonnes of plastic per month, using relatively simple machinery (Jayasekara, 2010). According to a survey conducted by Gunarathna (2010) almost all plastic waste recyclers currently operating in Sri Lanka (98%) obtain their materials through waste pickers which operate in rubbish dumps or the street. Whilst this practice represents a source of income for waste pickers, it also perpetuates their poor working conditions and disconnectedness from the recycling process. Conditions within small-scale recycling facilities may also be little better than those of informal waste collectors; sorters and other workers are exposed to toxic chemicals and fumes, and contaminated washing effluent (Jayasekara, 2010).

Households
The attitudes and actions of households can have a significant impact upon the recovery of useful products from MSW, as recovery is improved greatly if waste is separated ‘at source’ (Bandara, 2008). In general, waste management in Sri Lanka is thought of as a problem for practical and health reasons rather than as an environmental issue (van Zon and Siriwardena, 2000). Van Zon & Siriwardena (2000) observed that, in households in the Ja-Ela UC in the Western Province, recyclable and reusable waste materials were seen as having value, but were usually disposed of if they were not collected. Similarly a survey conducted in the Western Province by Gunarathna (2010) suggests that households will supply door-to-door collectors
with plastic waste if they are available, however the coverage of door-to-door collectors is very low, particularly in MCs. Within MCs there is a relatively high percentage of households covered by formal MSW collection (Gunarathna, 2010); this may at least partially explain the lack of door-to-door collection in these areas.

Households in Pradeshiya Sabhas were found to be much more likely to separate their waste than UCs and MCs, however few households in Pradeshiya Sabhas dispose of their plastic waste through waste collectors or collection centres (5%); most burn their plastic waste. Households within UCs showed a moderate separation level, and were the most likely to support recycling by disposing of plastic waste through door-to-door waste collectors or collection centres (14% of households); this is reflected in the relatively high availability of waste collectors in UCs. The income levels of households also has a significant effect upon their behaviour with regards to plastic waste disposal; as income levels increase there is a dramatic increase in MSW collection, which is accompanied by a corresponding decrease in disposal through burning. Low-income households were the least likely to provide plastic waste for waste collectors or collection centres (Gunarathna, 2010).

**Commercial Establishments**

There is little in the existing literature describing the means by which commercial establishments currently dispose of their waste; however they too are affected by the low level of LA waste collection services (see section 2.2). The results of the questionnaire given to ten supermarkets in Colombo District (see Appendix 4 –Responses to Questionnaire for Supermarkets) show that supermarkets dispose of plastic waste through LAs or waste buyers, or a combination of both. No supermarket reported dumping their waste but the Environmental Foundation (2007) suggests that this would also occur. Almost half (four) of the supermarkets which responded to the questionnaire were willing to provide plastic waste free of charge to WfL. Most of the supermarkets which were not willing to provide waste to WfL (five of the six unwilling) were those which disposed of their plastic waste through waste buyers, or waste buyers and LA services. Two of these cited the profit from selling waste as their reason for unwillingness to provide plastic waste to a WfL project, one referred to a company policy not to provide waste for free whilst another simply stated the company could not provide waste for free. Another supermarket reported that it would be too difficult to separate plastic waste from cardboard waste. From this brief survey it was expected that many commercial establishments may be willing to partner with WfL to provide waste for a project; however this would be more likely if the establishment was not already selling their waste to waste buyers.

**Local Authorities**

The LAs are local, elected government bodies and are responsible for waste collection and disposal in their territories (van Zon and Siriwardena, 2000). Under the Local Government Acts it is stated that LAs are responsible for the collection and disposal of domestic and industrial solid waste, and that once collected waste is the property of the LA, which then has the ‘full powers’ to sell or dispose of it
(Environmental Foundation, 2007). The Acts also require LAs to take “appropriate measures and precautions to ensure that refuse is not disposed of in ways that will cause a public nuisance” (Environmental Foundation, 2007, pg 6), a responsibility which appears to be widely unfulfilled.

Each LA has a Public Health Inspector appointed and employed by the Ministry of Health to oversee local health issues (van Zon and Siriwardena, 2000); however broad scope of the inspectors’ duties mean that solid waste management is somewhat neglected (Bandara, 2008). Many LAs also have an Environmental Development Assistant employed by the CEA; the duties of this role originally included a wide range of tasks however much of the work of Environmental Development Assistants now seems to be restricted to organising environmental education in schools (van Zon and Siriwardena, 2000).

**Local Authority Waste Collectors**

LA-employed (formal) waste collectors or ‘town cleaners’ collect waste from bags or bins, or more commonly sweep or shovel roadside waste into a handcart, tractor trailer or garbage truck (van Zon and Siriwardena, 2000). These workers earn very little, in the range of LKR 150 to 200 per day (R. Jayasinghe, 2011, pers. comm., 3 October). Some formal waste collectors separate and keep recyclables (including cardboard, glass bottles, metal cans and scrap metal) to sell to waste buyers (van Zon and Siriwardena, 2000). In Colombo these activities are encouraged (Environmental Foundation, 2007), and it was estimated that waste collectors employed by Colombo MC spend approximately 20% of their time collecting and separating recyclables for sale (Jayaratne, 1996). One estimate of the additional income which formal workers gain from these activities (from the Ja-Ela area) is LKR 85-100 per day (van Zon and Siriwardena, 2000).

**Private Waste Collection Companies**

Most LAs directly employ the town cleaners; however in Colombo MC and other LAs some or all of the waste collection services have been outsourced to private firms (van Zon and Siriwardena, 2000, Environmental Foundation, 2007). Colombo MC engages Burns Environmental & Technologies and Abans Environmental Services to collect and transport a significant amount of waste collection in the city (Visvanathan and Trankler, 2003). In Ja-Ela UC it has been reported by locals that private companies provide a better waste-collection service than public employees (van Zon and Siriwardena, 2000).

**Provincial Government Bodies**

The provincial body relevant to solid waste management in the Western Province is the Waste Management Authority.

**Waste Management Authority**

The WMA was established by the Western Provincial Council in 2004; this agency was intended to facilitate LAs in managing their waste without damaging the environment (Mannapperuma and
Basnayake, 2007). The WMA has produced several strategies aimed at improving and streamlining waste management in the 48 LAs of the Western Province, including the “Municipal Solid Waste Management Rules” (WMA, 2008); unlike some publications produced by national government bodies (see below) these documents appear to address the practical problems of MSW management by the LAs. The WMA also provides technical and financial support to LAs in the establishment of new waste processing facilities and to community-based projects such as recyclable waste collecting points (Sampath Piyasa) (Mannapperuma and Basnayake, 2007).

National Government Bodies
The national bodies relevant to solid waste management in Sri Lanka are the Central Environmental Authority, the Ministry of Forestry and Environment, and the Ministry of Health.

Ministry of Environment
In 1999 and again in 2002 the Ministry of Environment released the National Strategy for Solid Waste Management based upon the principle of integrated waste management, from generation to disposal (Vidanaarachchi et al., 2006, Bandara and Hettiaratchi, 2010). However these publications have been criticised as too vague and general, and excluding any consideration of the activities of the informal waste sector (van Zon and Siriwardena, 2000, Vidanaarachchi et al., 2006). The other measures taken by the Ministry of Environment to improve MSW management seem to be restricted to education and awareness campaigns, and the production of documents such as instructions for building and operating a compost barrel (van Zon and Siriwardena, 2000).

Central Environmental Authority
The CEA is one of the implementing agencies of the Ministry of Environment (Ministry of Environment, n.d.). The National Environmental Act provides the framework for environmental protection from improper waste disposal, prohibiting the disposal of waste in such a way as to cause pollution except with a license obtained from the CEA (Environmental Foundation, 2007). According to van Zon & Siriwardena (2000) however, regarding solid waste disposal and particularly disposal of hazardous waste “the relevant sections of the National Environmental Act have not been implemented” and CEA activities to improve waste management are in the most part limited to education, as well as the production of documents such as the ‘Technical Guidelines on Solid Waste Management in Sri Lanka’ (CEA, 2005). As a result, environmental regulations and laws are not being enforced and legislative measures to protect the environment from improper waste disposal are ineffective (van Zon and Siriwardena, 2000).

The major initiative implemented by the CEA is the National Post Consumer Plastic Waste Management Project, the operation of which dates from May 2007. It was initially funded by imposing a 1% tax on all imports of plastic (raw materials and finished products) which was increased further to 10% in 2009. This project aimed to develop a plastic recycling network and a regional plastics waste collection system, and
also to conduct an awareness campaign. In 2008 its major accomplishments were the production of a plastic collector and recycler database, a proposal for research to be conducted with the University of Sri Jayewardenepura (‘Research on Current Status on Plastic & Polythene Industry in Sri Lanka’), a plastic waste collection and crushing center at the Manikfarm refugee camp, and a pilot plant for the conversion of waste plastic into fuel at Yatiyanthota (CEA, 2008). The CEA maintains however that ultimately it is the LAs who are responsible for solid waste management and disposal (van Zon and Siriwardena, 2000).

**Ministry of Health**

The aim of the Ministry of Health is the social and economic development of Sri Lanka through the achievement of the highest possible standards of health (Ministry of Health, n.d.). This body has had an extensive publicity campaign aimed at making people aware of the connection between waste, mosquitoes and disease; however this may have recommended burying or burning waste to address the problem of waste-related disease vectors (van Zon and Siriwardena, 2000).

**Educational Institutions**

The work of WfL provides educational institutions such as universities opportunities for cutting-edge, socially relevant research; already countless students have been involved in projects focused on WfL, in Canada, Argentina, the USA and Australia (Baillie et al., 2010). According to van Rijswijk et al. (2001, pg 34) NFCs are a “hot item” on an international scale. It is also argued that when research conducted by educational institutions is socially relevant and involves new technology such as NFCs, educational institutions can expect government support, international recognition, and the opportunity for cooperative research and student exchange (van Rijswijk et al., 2001). The University of Sri Jayawardenapura and The University of Moratuwa in Sri Lanka, and The University of Western Australia (UWA) are expected to be highly involved in a WfL project in Sri Lanka. Already a postgraduate student from The University of Sri Jayawardenapura (Randika Jayasinghe) is working with WfL, studying towards her PhD at UWA as part of an AusAID Leadership Awards Scholarship. Other universities associated with WfL, in Canada and the USA, may also contribute to the project.

**Waste for Life**

Waste for Life (WfL) is a multi-disciplinary, international network of professionals and students which aims to develop and apply poverty-reducing solutions to waste problems (Baillie et al., 2010). In traditional community development terms, WfL is the ‘implementing agency’ of the project in Sri Lanka. However as in its previous projects WfL intends to take on a more participatory role whereby any products, processes and systems are co-created with the intended beneficiaries, partner NGOs and universities. Whilst the organisation’s previous experiences in Lesotho and Argentina give WfL a unique understanding and experience of how informal waste groups can transition to produce NFCs, this will need to be informed by and adapted to the Sri Lankan context by utilising local knowledge.
Other Non-Governmental Organisations

A WFL project in the Western Province may involve Sri Lankan NGOs as partner organisations or for the exchange of knowledge and experience. Various NGOs with a focus on waste management and poverty alleviation exist in Sri Lanka and within the Western Province; some key organisations are the National Forum of People’s Organization, Seth Sevana, Sevanatha, and The Arthacharya Foundation.

**National Forum of People’s Organizations**

The National Forum of People’s Organizations, based in Nugegoda (Wiser Earth, 2005), provides technical support, training, and information to facilitate community development in Sri Lanka, through various programs which include environmental and income-generating projects (Kumarasiri and Muthukuda, 1994). This organisation has initiated several waste management projects, encompassing source separation of waste by households, paper recycling, and small-scale composting and biogas production (Visvanathan and Norbu, 2006). In Piliyandala, a suburb of Colombo city, the organisation conducted a pilot program for source separation of waste in 500 low to middle income households (Visvanathan and Trankler, 2004). Each household paid LKR 30 per month for the separated waste to be collected (to cover labour costs) (Visvanathan and Trankler, 2004).

**Seth Sevana**

Seth Sevana operates a project based in the Moratuwa area, in which source separation of waste was practiced by 1280 households (Visvanathan and Trankler, 2004), 18 km south of Colombo city. These activities generated materials for its plastic recycling plant, a small- to medium-scale facility processing HDPE, LDPE and PP into pellets or granules (Visvanathan and Trankler, 2004); this facility processes approximately 750 to 1000 kg of waste plastic per day (Changshe Norbu Consultancy, 2009).

**Sevanatha**

Sevanatha has initiated a community-based solid waste management project in Badowita, a low-income housing settlement of approximately 1141 households in the Dehiwala-Mount Lavinia MC area, around 10 km south of Colombo city (Sevanatha, 2002). This project involved community-based waste collection and recycling, in partnership with the Dehiwala-Mount Lavinia MC, local CBOs, private waste recycling companies (Ceylon Glass Corporation and National Paper Corporation of Sri Lanka) which provided training, and the Sri Lanka Land Reclamation and Development Corporation, which provided the land for the recycling centre (Sevanatha, 2002).

**The Arthacharya Foundation**

The Arthacharya Foundation (Arthacharya) is based in the Galle District of the Southern Province of Sri Lanka. Arthacharya has implemented several community-based waste collection and recycling programs and established the Galle Recycling Plant in 1992. The recycling plant obtains waste plastic from households through a source separation program, in which separate collection bins, one each for plastics,
bottles, glass, and paper, are provided to the households registered with the 45 CBOs which operate the plant. Plastics are recycled at the plant to produce fine particles and pellets while other recyclable materials such as glass, paper and plastics are sold to other. The production capacity of the Galle Recycling Plant is 10 tonnes per month, however the supply of recyclable plastic from CBOs and other sources is less than 5 tonnes per month (AIT, n.d.).

Based on the success of the Galle plant, Arthacharya embarked on a similar project in Negombo (a town in Gampaha District, lying approximately 37 km north of Colombo city) through the CEA’s Integrated Resource Management Project (van Zon and Siriwardena, 2000). It was concluded however that different conditions in Negombo contributed to “drastically reducing” the project’s effectiveness (van Zon and Siriwardena, 2000, pg 2).
4.1.1.2 Assessment of Potential Impacts on Stakeholders’ Interests

The interests of each stakeholder were identified based upon the profiling above (section 4.1.1.1). The relative priority of stakeholders’ interests and potential impact of the project on these interests were predicted based upon WfL’s vision for the project and case studies of past WfL projects.

Table 2. Potential impacts upon the interests of stakeholders of WfL Sri Lanka.

<table>
<thead>
<tr>
<th>Stakeholder</th>
<th>Interests</th>
<th>Potential project impact</th>
<th>Relative priority of interests</th>
</tr>
</thead>
<tbody>
<tr>
<td>Waste pickers</td>
<td>Income</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Working conditions</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Door-to-door waste collectors</td>
<td>Income</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Working conditions</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Waste buyers</td>
<td>Profits</td>
<td>-</td>
<td>5</td>
</tr>
<tr>
<td>Plastic recycling companies</td>
<td>Profits</td>
<td>-</td>
<td>5</td>
</tr>
<tr>
<td>CBOs</td>
<td>Income</td>
<td>+</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Status in community</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Households</td>
<td>Cleanliness of neighbourhood</td>
<td>+</td>
<td>2</td>
</tr>
<tr>
<td>Commercial establishments</td>
<td>Profits</td>
<td>+</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Public image</td>
<td></td>
<td></td>
</tr>
<tr>
<td>LAs</td>
<td>Cleanliness of streets</td>
<td>+</td>
<td>4</td>
</tr>
<tr>
<td>LA waste collectors</td>
<td>Side-income from recyclables</td>
<td>-</td>
<td>2</td>
</tr>
<tr>
<td>Private waste collection companies</td>
<td>Profits</td>
<td></td>
<td>5</td>
</tr>
<tr>
<td>WMA</td>
<td>Less waste going to landfill and dumped</td>
<td>+</td>
<td>4</td>
</tr>
<tr>
<td>Ministry of Environment</td>
<td>Decrease in pollution caused by poor waste disposal</td>
<td>+</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Public image</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CEA</td>
<td>Decrease in pollution caused by poor waste disposal</td>
<td>+</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Public image</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ministry of Health</td>
<td>Decrease in disease caused by plastic waste</td>
<td>+</td>
<td>4</td>
</tr>
<tr>
<td>Educational institutions</td>
<td>Public image</td>
<td>+</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Institutional learning</td>
<td></td>
<td></td>
</tr>
<tr>
<td>WfL</td>
<td>Institutional learning</td>
<td>+</td>
<td>3</td>
</tr>
<tr>
<td>Other NGOs</td>
<td>Institutional learning through example or collaboration</td>
<td>+</td>
<td>3</td>
</tr>
</tbody>
</table>
4.1.1.3 Identification of Stakeholders’ Influence and Importance

A stakeholder matrix was used to identify each stakeholder’s relative influence (to what extent they may affect the project) and importance (the degree to which they are affected by the project).

Table 3. Stakeholder matrix showing the relative influence and importance of stakeholders of WfL Sri Lanka.

<table>
<thead>
<tr>
<th>Least affected</th>
<th>Most affected</th>
</tr>
</thead>
<tbody>
<tr>
<td>CBOs</td>
<td>Other NGOs</td>
</tr>
<tr>
<td>Middlemen</td>
<td>Commercial establishments</td>
</tr>
<tr>
<td>LA waste collectors</td>
<td>WfL</td>
</tr>
<tr>
<td>Waste pickers</td>
<td>National government bodies</td>
</tr>
<tr>
<td>Door-to-door waste collectors</td>
<td>Provincial government bodies</td>
</tr>
<tr>
<td>Middlemen</td>
<td>LAs</td>
</tr>
<tr>
<td>Plastic recycling companies</td>
<td></td>
</tr>
<tr>
<td>Private waste collection</td>
<td></td>
</tr>
<tr>
<td>companies</td>
<td></td>
</tr>
</tbody>
</table>

4.1.1.4 Identification of Assumptions Made About the Role of Stakeholders

Due to the early stage of the project in Sri Lanka, various assumptions have been made about the role of stakeholders in the project (which may change as the project becomes more well-defined). It was assumed that the project would initially involve only existing CBOs (as was the case with cooperatives in Buenos Aires and Lesotho) as they are already organised and may be ready to progress from collecting and sorting waste or the production of plastic pellets to the manufacture of NFC products. It is expected that to organise and involve waste pickers and door-to-door waste collectors in the project initially would be too difficult and beyond the scope of the project; as such these stakeholders would not be affected by the project. However it is hoped that in the long term waste pickers and door-to-door waste collectors may become involved in WfL Sri Lanka through inclusion in the CBO working with WfL. Households and commercial establishments were assumed to be providing waste plastic for the project (see section 4.2.1).

LA waste collectors were assumed to be negatively affected by the project given that it may result in a decreased amount of recyclable waste available for them to collect and sell as a side-income. However it is not anticipated that the amounts used by a WfL project would have a great affect upon the local availability of recyclable waste, and ideally the project would target areas which are not already covered
by formal waste collection, and utilise those types of waste which are not currently recycled, for example plastic bags (see section 4.2.1). Similarly the potential impact upon middlemen and plastic recycling companies (if there is any) was assumed to be slightly negative as a ‘worst-case’ scenario, however depending on how and from where waste plastics are sourced these stakeholders may not be affected at all.

The project was assumed to have no effect on private waste collection companies; whilst any increase in waste collection via informal activities could result in a decrease in the potential ‘market’ for their services, the generally low coverage of waste collection services in the Western Province (see section 2.2) means that the effect would not be felt by this stakeholder. It was also assumed in this analysis that WfL would work with NGOs, national and provincial government agencies and LAs in Sri Lanka, and (provided the project is a success) this would reflect well upon these bodies and assist them (albeit slightly) to achieve their goals. It was considered a very reasonable assumption that educational institutions would continue to be involved in WfL as the organisation progressed with the project in Sri Lanka, in a similar way to previous involvement in other WfL projects.

### 4.1.1.5 Identification of Appropriate Stakeholder Participation

A key outcome of Stakeholder Analysis for a potential WfL project in Sri Lanka is an outline of stakeholder participation in the project. DFID (1995a) recommends this for key stakeholders, defined as those to whom are ascribed a high importance or influence (or both). Stakeholders with high influence and importance to the project are considered potential partners in the planning and implementation stages (DFID, 1995a). According to DFID (1995b), for primary stakeholders (those ultimately affected by the project, whose importance is high but whose influence may be low) participation in the project is essential; the strongest form of participation is partnership which would be the aim for WfL as is consistent with the needs-based approach to development (as discussed in section 2.6). Stakeholders with high influence but low importance may be ‘managed’ by consultation or keeping them informed (DFID, 1995a).

In Step 3, stakeholders of a WfL project in Sri Lanka which were identified as being of high influence and importance were WfL and educational institutions, whilst stakeholders with low influence but high importance (primary stakeholders) were CBOs and NGOs. National government bodies, provincial government bodies, and LAs were identified as stakeholders with high influence but low importance. As is consistent with the values of WfL a stronger emphasis was placed on consultation and partnership with stakeholders rather than informing or controlling. It is anticipated that most of the key stakeholders will take on either consultation or partnership roles throughout the project, which the exception of national government bodies, provincial government bodies, and LAs. These stakeholders will be simply kept informed at the identification stage (which involves identifying and clarifying the problems the project
aims to address), and during monitoring and evaluation. These roles can be seen in the summary matrix of recommended stakeholder participation (see Table 4 below).

Table 4. Summary of recommended stakeholder participation in WfL Sri Lanka.

<table>
<thead>
<tr>
<th>Stage</th>
<th>Type of participation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Inform</td>
</tr>
<tr>
<td>Identification</td>
<td>National government bodies, provincial government bodies, LAs</td>
</tr>
<tr>
<td>Planning</td>
<td>National government bodies, provincial government bodies, LAs</td>
</tr>
<tr>
<td>Implementation</td>
<td>National government bodies, provincial government bodies, LAs</td>
</tr>
<tr>
<td>Monitoring and evaluation</td>
<td>National government bodies, provincial government bodies, LAs</td>
</tr>
</tbody>
</table>

4.1.2 Health and Safety Risk Assessment

4.1.2.1 Identification of Potential Hazards and Risks

A summary table showing each risk and its primary causes can be seen in section 4.1.2.3 (Table 6).

Burns to the Skin

Due to the high temperatures which may be reached by the hot plates during operation, a risk of burns to the skin (in particular the hands and forearms) is associated with use of the hotpress. In the case of the UWA hotpress, the plates take about an hour to heat to 170°C, and as a result the materials are assembled between thin metal sheets which are then inserted into the small opening between the pre-heated hot plates (A. Tavner, 2011, pers. comm., 21 September). The hot plates also take some time to cool (C. Baillie, 2011, pers. comm., 27 July) so this risk is present even when the hotpress has been switched off. The poor insulation of the plates means that the whole press (which is almost entirely constructed of metal) can also
reach high temperatures and thus pose a burning hazard (A. Tavner, 2011, pers. comm., 21 September). In particular the faces of the press core which lie adjacent to the hot plates (in the UWA press separated by only a thin insulating layer of wood) reach extremely high temperatures (A. Tavner, 2011, pers. comm., 21 September).

**Crushing of Limbs or Fingers**
The hotpress is comprised of various moving parts such as the hot plates and the jack which drives the movement of the hot plates. These moving parts are potential hazards, associated with a risk of injury if limbs or fingers are caught within them. Crushing of limbs could also be caused by the press assembly falling from its holders, four steel rods with a diameter of 2.5 cm (D. Matovic, 2011, pers. comm., 1 September). The press is suspended on these holders approximately 20 cm above the ground; whilst this is not a great distance, due to the large weight of the press (350 kg) this could cause serious injury if it landed on a foot of an operator standing beside the equipment (D. Matovic, 2011, pers. comm., 1 September).

**Electrical Shocks**
The experiences of WfL in Buenos Aires have shown that electric shocks are another potential risk in the operation of the hotpress, particularly when electrical components are poorly installed or maintained (C. Baillie, 2011, pers. comm., 27 July). The press is almost entirely constructed of metal and as such would be highly conductive. In particular, the area where the electric cables enter and leave the press lids to heat the hot plates have been prone to short circuiting (D. Matovic, 2011, pers. comm., 1 September).

**Fire**
There are various possible sources of ignition in recycling operations, including poorly installed or maintained mechanical equipment which can overheat (Health and Safety Executive, 2009). Due to the few moving parts in the WfL hotpress (and their slow motion) this source is restricted to the overheating or burning of debris in the hot plates, which would most likely be caused by the presence of foreign materials (A. Tavner, 2011, pers. comm., 21 September). Poorly installed or maintained electrical equipment can also cause sparks or excessive heat which might trigger a fire (Health and Safety Executive, 2009); the short circuiting which occurred in the hotpress in Buenos Aires produced visible sparks (D. Matovic, 2011, pers. comm., 1 September). Smoking and other open flames are further possible sources.

**Infection, Disease, and Exposure to Hazardous Substances**
Waste materials, and in particular plastics, may be contaminated with potentially hazardous substances such as chemical residues and pesticides (Health and Safety Executive, 1998). Unwashed waste (particularly that provided by households) can also be expected to house bacteria which could cause
disease or infection. Furthermore hazardous fumes can be produced when plastic materials are overheated (Health and Safety Executive, 1998).

**Slips and Trips**
Slips and trips (falls from the same level) are a risk in the premises of a WfL project, particularly if the floor is wet or cluttered, or lighting is poor.

4.1.2.2 **Assessment of Risks on the Basis of Likelihood and Severity**
A risk assessment matrix, which assigns a risk assessment value based on the likelihood and severity of risks, was adapted from Hardy (2010) and simplified to suit WfL’s needs (see Table 5). Those risks with an assessment value of 1 to 3 were considered high priority; risks rated between 4 and 6 were considered moderate priority, and risks assessed at values of 7 to 9 constituted low priority risks. A summary table showing risk assessment values of each risk can be seen in section 4.1.2.3 (Table 6).

Table 5. Risk assessment matrix adapted from Hardy (2010); red represents high priority risks, orange, moderate priority risks and yellow, low priority risks.

<table>
<thead>
<tr>
<th>Likelihood</th>
<th>Severity</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>High</td>
</tr>
<tr>
<td>High</td>
<td>1</td>
</tr>
<tr>
<td>Moderate</td>
<td>2</td>
</tr>
<tr>
<td>Low</td>
<td>4</td>
</tr>
</tbody>
</table>

**Burns to the Skin**
According to the designer of the Kingston press, the hot plates are “no more dangerous than a stove or a laundry iron, or an oven” (D. Matovic, 2011, pers. comm., 1 September). This appears to be true of the plates, to which access is restricted due to the manual work required to increase the width of the opening between the plates (in the operation of the UWA hotpress the plates are generally only opened to a width of 100mm) (A. Tavner, 2011, pers. comm., 21 September). However the extent to which the entire press is heated (and the exposed state of many of these heated parts) means that the risk of burns to the skin was considered to be high. Due to the high temperatures reached by these parts, severity of burns to the skin from the hotpress was considered to be moderate.

**Crushing of Limbs or Fingers**
The hot plates and the jack which drives the press are the parts most potentially dangerous in terms of trapping limbs in moving parts due to their closing action and the high pressures they operate under;
however the movement of these parts is extremely slow and can be compared to the speed of a hydraulic jack lifting a car (D. Matovic, 2011, pers. comm., 1 September). The location of the jack on the underside of the press would also tend to impede crushing of limbs or fingers within it, and as discussed above access to the area between the plates is restricted. The press assembly has also been designed so that it is unlikely to fall from its holders; even if this did occur it is also not very likely that it would fall on an operator’s foot and cause injury (D. Matovic, 2011, pers. comm., 1 September). As a result whilst this risk was considered to be of high severity, the likelihood was considered to be low.

**Electrical Shocks**

The risk of electrical shocks from the hotpress due to poorly installed or maintained electrical components was considered to be of moderate likelihood in the context of a developing country such as Sri Lanka. Injuries from electrical shocks depend upon the length and severity of the shock but can include burns to the skin, burns to internal tissues, and damage to the heart (which can cause the heart to stop) (Comcare, n.d.). The severity of an electrical shock is primarily dependent upon the current which passes through the body (OSHA, n.d.). Under dry conditions the human body has a resistance of approximately 100,000 Ω (OSHA, n.d.); given the voltage of the Kingston hotpress (220 V) and using Ohm’s law this will result in a current of approximately 2.2 mA. A shock at this order of magnitude is described as a “slight tingling sensation” (OSHA, n.d.). However in less than ideal conditions, for example when the body is wet, the resistance can drop as low as 1000 Ω (OSHA, n.d.); in this case the shock from the hotpress would be approximately 220 mA. At this level the shock would likely cause death (OSHA, n.d.). As a result the severity of this risk was considered to be high.

**Fire**

The likelihood of fire is dependent upon the presence of a source of ignition; due to the number of potential sources of ignition in the premises of a WfL project this risk was considered to be of moderate likelihood. Provided with a source of ignition, fire has the potential to be extremely dangerous when there are large stockpiles of plastic present, as was shown when the Reciclando Suenños cooperative warehouse in Buenos Aires burnt down in 2007 whilst WfL was conducting scoping for its project in the city (Baillie et al., 2010). Plastic fires spread quickly, burn at very high temperatures and are difficult to extinguish (Health and Safety Executive, 1998). Fumes from these fires can also be toxic (Health and Safety Executive, 2009); burning plastic emits an acrid, black smoke in which poisonous gases such as carbon monoxide may be present (Health and Safety Executive, 1998). As a result the severity of this risk was considered to be high.

**Infection, Disease, and Exposure to Hazardous Substances**

Given that the cleanliness of the waste which will be handled in the project is currently still unknown, it is difficult to accurately judge the likelihood and severity of the risk of infection, disease, and exposure to hazardous substances. As plastic waste materials will most likely be sourced from households or
commercial establishments, it can be expected to be relatively free of hazardous substances but contaminated with bacteria. There is a chance that fibres used in the project may have come into contact with chemicals (for example pesticides and herbicides in the case of agricultural fibre). As a conservative estimate the likelihood and severity of this risk were each considered to be moderate.

**Slips and Trips**
No information could be found regarding the frequency and impacts of slips and trips in Sri Lankan workplaces; however slips and trips are a relatively common work-related injury in Australia, accounting for approximately 13% of injuries (WorkSafe, 2011). As a result the likelihood of slips and trips was considered to be moderate. The severity of this risk was considered to be low.

### 4.1.2.3 Identification of Mitigation Measures

The redesign of the hotpress (to suit materials available and operating conditions in Sri Lanka) provides an opportunity to mitigate some of the health and safety risk associated with using the hotpress. Modifications to the design of the press are expected to be the most robust mitigation measures as they would be least easily undermined (unlike for example the use of personal protective equipment). Therefore those risks assessed as high-priority should be mitigated where possible in this manner. However it is important to note that for all risks present, mitigation measures should not be overly cumbersome or interfere with the operation of the press; the operators of the press may abandon or remove safety devices if it will improve their ease of working or productivity (A. Tavner, 2011, pers. comm., 21 September). The proper training of hotpress operators and the provision of good lighting for visibility are general mitigation measures which may help to address many of the risks discussed here. A summary table showing mitigation measures for each risk can be seen below (Table 6).

**Burns to the Skin**
According to the UK government body Health and Safety Executive (1999), accidental contact with machinery heated to above 80°C should be prevented by guards or insulation; if it is necessary for hot parts to be exposed warning signs should be displayed. Improving the insulation of the hot plates would greatly decrease the extent to which the rest of the press is heated, whilst the addition of guards (particularly on the faces of the press core) could effectively prevent contact with those parts of the press which are most exposed and likely to become hot (A. Tavner, 2011, pers. comm., 21 September). As has been found with the UWA hotpress these measures may be difficult to implement once the hotpress has been constructed, but can be achieved with relative ease if applied during the design phase (A. Tavner, 2011, pers. comm., 21 September). Personal protective equipment (PPE) can also help to mitigate the risk of burns to the skin: in particular, long cuff mitts such as those common in welding (D. Matovic, 2011, pers. comm., 1 September); these are being successfully used by first-year engineering students operating the UWA press (A. Tavner, 2011, pers. comm., 21 September).
**Crushing of Limbs or Fingers**

Installing guards and an emergency stop could effectively mitigate the risk of crushing of limbs in the hotpress, which can be combined with PPE such as robust mitts (D. Matovic, 2011, pers. comm., 1 September). Guards should cover moving parts such as the jack whilst an emergency stop should be installed within easy reach of the main operating positions. Whilst the likelihood of the press falling from its stand was expected to be very low, PPE such as steel-capped work boots is a good general safety practice in machine or production workshops, and would mitigate the risk crushing of feet from falling objects (D. Matovic, 2011, pers. comm., 1 September).

**Electrical Shocks**

In order to mitigate the risk of electrical shocks it is essential that the entire hotpress is well grounded; this means that any direct contact between the press body and live wires would immediately burn the fuses (D. Matovic, 2011, pers. comm., 1 September). Electrical shocks can also be mitigated to some extent by ensuring workers are wearing insulating (rubber-soled) shoes; however this measure is much less robust as the footwear of a worker could easily be overlooked.

**Fire**

It is expected that, similarly to the use of the UWA hotpress, plastics and fibre will be assembled before use by hand on metal sheets, which would mean that foreign materials (which might overheat or burn when in contact with the hot plates) would be able to be removed in this stage. The metal pin holding the upper section of the press core can also be easily removed to fully open the hot plates and allow visual inspection and cleaning, which should be conducted approximately once a week (A. Tavner, 2011, pers. comm., 21 September). Smoking and other open flames should be banned on the premises and basic security precautions should also be taken to prevent fires caused by people not associated with the project: in particular, storage areas containing flammable materials should be secured after operating hours.

**Infection, Disease and Exposure to Hazardous Substances**

The risk of infection, disease, and exposure to hazardous substances to workers may be mitigated by the use personal protective equipment such as gloves and face masks. All minor wounds should be treated with antiseptic and covered, and toilet and hand-washing facilities should be made available to encourage good personal hygiene practices. The operating temperatures of the hotpress and other heated processing machinery which may be in use (such as an extruder) should be checked regularly to ensure they are not overheating and thus producing hazardous fumes. Heated surfaces which come in contact with plastics should be kept clean (through the visual inspection discussed above), and good ventilation should be provided.
Slips and Trips
The risk of slips and trips may be mitigated by ensuring the floor is clear of obstacles such as electrical cables, and spills of liquid are cleaned up promptly. Allowing adequate room for the storage of waste materials and products would assist in keeping the floor clear of obstacles.
## Table 6. Summary of results of the health and safety risk assessment for WfL Sri Lanka.

<table>
<thead>
<tr>
<th>Risk</th>
<th>Cause</th>
<th>Likelihood</th>
<th>Severity</th>
<th>Risk Assessment Level</th>
<th>Priority</th>
<th>Mitigation measures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Burns to skin</td>
<td>High temperatures reached by hotpress</td>
<td>High</td>
<td>Moderate</td>
<td>3</td>
<td>High</td>
<td>Guards; improved insulation; personal protective equipment (gloves); warning signs.</td>
</tr>
<tr>
<td>Crushing of limbs or fingers</td>
<td>Exposed mechanical action of jack and other parts of hotpress</td>
<td>Low</td>
<td>High</td>
<td>4</td>
<td>Moderate</td>
<td>Guards; emergency stop; personal protective equipment (gloves, steel-capped boots).</td>
</tr>
<tr>
<td>Electrical shocks</td>
<td>Poorly installed and/or maintained electrical equipment</td>
<td>Moderate</td>
<td>High</td>
<td>2</td>
<td>High</td>
<td>Properly grounding press.</td>
</tr>
<tr>
<td>Fire</td>
<td>Flammable stockpiles of plastic and fibre combined a source of ignition</td>
<td>Moderate</td>
<td>High</td>
<td>2</td>
<td>High</td>
<td>Maintaining clean heated surfaces, ban on smoking and open flames in the area; ensuring flammable materials are sited sufficiently far from hotpress and other electrical systems; securing premises.</td>
</tr>
<tr>
<td>Infection, disease, and exposure to hazardous substances</td>
<td>Contact between workers and contaminated waste materials, overheating of plastics</td>
<td>Moderate</td>
<td>Moderate</td>
<td>5</td>
<td>Moderate</td>
<td>Personal protective equipment (gloves, face masks); treating and covering wounds; toilet and washing facilities; regular checks of equipment operating temperatures, maintaining clean heated surfaces; adequately ventilated work space.</td>
</tr>
<tr>
<td>Slips and trips</td>
<td>Untidy or dirty workspace</td>
<td>Moderate</td>
<td>Low</td>
<td>8</td>
<td>Low</td>
<td>Ensuring floor is clear of obstacles; cleaning up spills of liquid promptly.</td>
</tr>
</tbody>
</table>
4.1.3 Identification and Critical Assessment of Some Potential Sources of Funding

4.1.3.1 Review of Funding for Previous Waste for Life Projects

Funding for previous WfL projects have been sourced from a micro-credit organisation and an international aid program (Baillie et al., 2010). Funding for WfL Lesotho was obtained via the Small Grants Fund of the Global Environment Facility (Baillie et al., 2010). This program awarded USD$50,000 to the Cooperative College, to make and maintain the hotpress and provide training to the community group (Maseru Aloe) who use the press to produce NFCs (C. Baillie, 2011, pers. comm., 14 September). However the situation in Lesotho is currently being investigated as some of these funds have gone astray, presumably as a consequence of inexperienced persons managing the funds on the ground (C. Baillie, 2011, pers. comm., 14 September). Whilst securing a grant for a WfL project in Sri Lanka would avoid the potential pitfalls of microfinance (discussed in section 2.4), the experience of WfL in Lesotho demonstrates the risks of putting inexperienced people in charge of large amounts of ‘gifted’ money, in particular poor financial management and corruption.

Funding for the second WfL project, in Buenos Aires, was sourced very differently to Lesotho; in this case through a microfinance organisation, The Working World (Baillie et al., 2010). In order to ensure finance for the project (and avoid competition with the many other community-based organisations in Buenos Aires which were attempting to secure funding at the time) The Working World acts as a conduit for funding from WfL rather than providing the funds itself; WfL raised the funds (USD$4000) which were donated to The Working World on the proviso that the money was loaned to the cooperative producing NFCs (C. Baillie, 2011, pers. comm., 14 September). The Working World thus takes on the responsibility of managing the loan, and the funds will be available to lend for another WfL project when the loan is paid back by the cooperative in Buenos Aires (C. Baillie, 2011, pers. comm., 14 September).

Given the success of WfL’s previous arrangement with The Working World, it is expected that a similar situation would be beneficial for a WfL project in Sri Lanka; however the practices of the microfinance organisation involved must be consistent with WfL’s values and project aims. The Working World for example was chosen for WfL Buenos Aires as it is a not-for-profit organisation and provided the loan with zero interest (C. Baillie, 2011, pers. comm., 14 September). Whilst in Sri Lanka average loan interest rates are much lower than the global average, at 17% (Kneiding and Rosenberg, 2008) these may still be too high for the poorest of Sri Lankan society.

The Working World was also previously involved with cooperatives in the area (Baillie et al., 2010) and worked with the cooperatives, providing support and training (C. Baillie, 2011, pers. comm., 14 September). Furthermore if the project failed, The Working World was willing to forgive the loan and simply reclaim the press (C. Baillie, 2011, pers. comm., 14 September). To try to identify microfinance institutions with which a similar arrangement may be possible, government and not-for-profit
microfinance institutions (and microfinance offered through NGOs) were identified as key groups likely to contain suitable potential sources of funding for WfL Sri Lanka.

4.1.3.2 Critical Assessment of Some Potential Sources of Funding for Waste for Life Sri Lanka

Grants

The Global Environment Facility

The Global Environment Facility, a funding body which is structured as a trust fund, operates in partnership with the United Nations Development Programme (UNDP), the United Nations Environment Programme, and the World Bank, its implementing agencies (GEF Small Grants Programme, 2006a). The Small Grants Fund, funded by the Global Environment Facility and implemented by UNDP, was launched in 1992 and supports projects run by NGOs and community groups in developing countries. As was the case with WfL Lesotho, grants are given directly to the community group or NGO; these average approximately USD $20,000 with a maximum grant of USD $50,000. The grants are awarded through ‘decentralised decision-making’ based on the strategic direction of the country’s National Steering Committee (a voluntary group) (Global Environment Facility, 2010).

According to Jayamana (2008) the Small Grants Programme could be the largest provider of grant funding to Sri Lankan NGOs with an environmental focus. A WfL project Sri Lanka may be eligible for grants from this program under the Persistent Organic Pollutants focus area (which includes waste recycling) (GEF Small Grants Programme, 2006b). The Global Environmental Facility has been criticised as having been designed to service “a set of global institutions that themselves exist at least partly to serve certain globalised political and business interests”; in particular due to its ties to The World Bank, which tends to imposes ‘top-down’ solutions to environmental problems and disregard the livelihoods of affected communities (Young and Boehmer-Christiansen, 1998, pg 17). However securing a grant from this organisation would have little influence on how WfL works or the implementation of its project in Sri Lanka, and as such this program remains a viable opportunity for securing funding.

Microfinance

The Central Bank of Sri Lanka (CBSL) is the supervisory and regulatory body which governs regulated microfinance institutions in Sri Lanka (Gomez, 2009). Due to a CBSL mandate in shortly after the tsunami in December of 2004, commercial banks must allocate 5% of their portfolio to microfinance. However microfinance in Sri Lanka is generally provided by non-regulated institutions, such as government bodies, NGOs, societies and cooperatives (Gomez, 2009), and these institutions may be the most suited to managing the finances of a WfL project. There are a vast number of small-scale, local unregulated microfinance institutions operating in Sri Lanka (Gomez, 2009). These smaller-outreach
organisations have been criticised for being “administratively weak and financially dependent on donors for sustainability” and average loan sizes are fairly low (below USD 200, or approximately LKR 22,000 for 94% of MFIs) (Gomez, 2009) however this remains an option for further investigation at a later stage of planning for a WfL project.

**Jana Suwaya People Development Foundation**

The Jana Suwaya People Development Foundation (Jana Suwaya) is an NGO established in 1994 in Hambantota, a rural district on the South East coast of Sri Lanka, by a local Member of Parliament. Jana Suwaya aimed to improve the economic and social standards of the community of Hambantota, particularly through improvements to infrastructure in the region. According to the organisation the success of its projects can be attributed to the active participation and leadership of the local community. More recently the organisation has diversified to microfinance and expanded to a national level, with loan schemes already implemented in Anuradhapura, Kurunegala and Kalutara districts. Of particular interest to WfL is Jana Suwaya’s zero-interest loans, initially provided to women of the fishing community in Hambantota. Jana Suwaya is funded by national and international donors, with 100% of all donations contributing to the loan scheme (rather than to administration costs); first loans are LKR 5000. (Jana Suwaya - UK Branch, n.d.).

As part of plans to further expand the organisation and develop their zero-interest microfinance scheme, Jana Suwaya may be interested in partnering with WfL (in a donation-loan scheme similar to the role of The Working World) in the Western Province. The values of Jana Suwaya also appear to be consistent with WfL, particularly the organisation’s focus on community participation, zero-interest loans, and the ethical management of donations. However due to the political position of the organisation’s founder and sometimes chairman (United National Party, 2007) it is recommended that Jana Suwaya be investigated further to ensure its political neutrality and long-term sustainability.

**Sarvodaya Economic Enterprise Development Services Pvt Ltd**

Sarvodaya Economic Enterprise Development Services Pvt Ltd (SEEDS) is the “economic arm” of Sarvodaya, the largest and oldest indigenous NGO in Sri Lanka (SEEDS, 2008). Whilst SEEDS is a private MFI (Gomez, 2009), according to the organisation its primary aim is poverty alleviation (SEEDS, 2008). SEEDS has approximately 1.8 million active microfinance clients, and has been described as “probably the most professional and transparent MFI in Sri Lanka” (Gomez, 2009, pg 28). The organisation has offices in both Colombo and Gampaha (SEEDS, 2008), and its average loan is approximately LKR 24,600 (Gomez, 2009) however as of 2007 the organisation’s interest rate on loans was 20% (Herath, 2007).
SANASA (Federation of Thrift and Credit Cooperative Societies in Sri Lanka)
SANASA is the Sinhala acronym for the Federation of Thrift and Credit Co-Operative Societies in Sri Lanka, a microfinance cooperative network comprising 8424 societies and covering all provinces in Sri Lanka (SANASA, 2007). Thrift and Credit Cooperative Societies are the oldest microfinance providers in Sri Lanka (GTZ ProMiS, 2010). In the 1970s many of these societies were grouped into a federation under the SANASA banner; however some remain independent of this movement (GTZ ProMiS, 2010). Both SANASA and independent Thrift and Credit Cooperative Societies are registered with and supervised by the Department of Co-operative Development (GTZ ProMiS, 2010). According to the organisation, their members of SANASA societies number 805,000 but each society functions autonomously within its designated area (SANASA, 2007).

Samurdhi Bank Societies
Samurdhi Bank Societies, government institutions regulated by the Samurdhi Authority of Sri Lanka, were established in 1996 as part of a governmental poverty alleviation initiative (SAMN, n.d.). Loans are available to low income-earners at interest rates of between 7 and 12%. Based on data current at the end of 2009, available from the Samurdhi Authority of Sri Lanka (2010), it was calculated that the average loan is approximately LKR 13,000. Samurdhi Bank Societies also provide planning and technical support for income generation projects (Samurdhi Authority of Sri Lanka, 2011). There are approximately 1000 branches of the Samurdhi Bank Societies network (Samurdhi Authority of Sri Lanka, 2010) with approximately 2.95 million active microfinance clients (Gomez, 2009). For group loans each member must open an individual account and deposit LKR 500, but the group may apply for loans up to 10 times of the total value of deposits (Samurdhi Authority of Sri Lanka, 2011).

4.2 Technical Feasibility

4.2.1 Identification and Critical Assessment of Potential Sources of Waste Plastic and Fibre

4.2.1.1 Source Area
The proximity of sources of fibre and plastic to the production site was considered to be extremely important for ease of collection and budgetary considerations; transport costs (on a per km basis) in Sri Lanka are relatively high by international standards, particularly around Colombo (Kamburugamuwa, 2010). The mountainous inner region poses a significant barrier to collecting materials from the central and eastern districts, however sourcing fibre from districts to the north and south, and adjacent to the Western Province to the east, was considered to be a viable option since the distances involved are very low. As a result the following districts were considered as the potential source area for materials for a WfL project in the Western Province: Puttalam and Kurunegala (which make up the North Western Province),
Kegalle and Ratnapura (the Sabaragamuwa Province), Galle and Matara (in the Southern Province), and of course Colombo, Gampaha and Kalutara (the Western Province).

**Figure 2.** The potential source area considered for waste materials for WfL Sri Lanka (yellow and green); the districts of the Western Province are shown in yellow.

### 4.2.1.1 Potential Sources of Waste Plastic

Sourcing waste plastic for a WfL project in the Western Province may be a challenge for the project; six of the seven plastic recyclers surveyed in Colombo and Gampaha districts cited a lack of plastic waste materials as a problem associated with the recycling industry. Of the seven recyclers which responded to the questionnaire (see Appendix 2 – Responses to Questionnaire for Plastic Recyclers), three recycled only HDPE and LDPE plastics whilst a further three recycled one of these types, or both amongst other types of plastic. It is expected that PET is also commonly used by recyclers in the Western Province, as in most countries there is a well-developed market for recycled PET (C. Baillie, 2011, pers. comm., 31 August). However the use of PET would pose a challenge for a WfL project as this plastic tends to crystallise during heating (annealing) and become very brittle unless additives are used (Scheirs, 2003).

PVC and PS which are also recycled in Sri Lanka are generally avoided by WfL due to their tendency to emit toxic fumes when overheated (C. Baillie, 2011, pers. comm., 31 August). Among other fumes and vapours, PVC and PS can produce carbon monoxide gas (Georgia Gulf Chemicals and Vinlys, 2005, Denka Singapore, 2003), which is toxic when inhaled (ChemADVISOR, 2008). PVC can also emit hydrochloric acid fumes; this is most likely to occur during thermal degradation caused by overheating, but these fumes may be produced even during normal plastic processing conditions and can accumulate if the building is inadequately ventilated (Georgia Gulf Chemicals and Vinlys, 2005). The inhalation of
these fumes can cause various symptoms including chest pains, headaches, and palpitations (ScienceLab, 2010).

**Waste Plastic Products**

Previous studies of composites made using the WfL hotpress have utilised LDPE and HDPE plastics (Thamae and Baillie, 2009). These types of plastic commonly compose thin films or bags; whilst rigid plastics can be used in the hotpress, they must first undergo grinding, a process in which a specialised machine breaks rigid plastic into small pieces (C. Baillie, 2011, pers. comm., 31 August). Whilst grinding machines are typically very large, the inclusion of an existing group which own and operate this kind of machinery (but sell ground or pelletised plastic) may provide an opportunity to utilise rigid plastics, as well as adding value to the operations of the existing group through extending their recycling process to product manufacturing (C. Baillie, 2011, pers. comm., 31 August). However the potential for using rigid plastics is dependent upon further assessment, in more depth and on a local scale in Sri Lanka, to identify such groups which may be willing to be involved in the WfL project.

Whilst the results of the questionnaire indicate that HDPE and LDPE plastics are already widely used in existing recycling facilities in the Western Province, plastic in the form of films is typically difficult to collect, store and clean, the thus the demand for HDPE and LDPE *films* in the current recycling market can be expected to be very low (C. Baillie, 2011, pers. comm., 31 August). Plastic films also allow for greater ease of production in the WfL hotpress as they may be simply layered with fibre, without grinding or chopping (C. Baillie, 2011, pers. comm., 31 August). As a result this study focused on assessing the availability of a selection of thin flexible plastic products (made from HDPE, LDPE or PP) common in Sri Lanka.

**Flexible Food Packaging**

Most items sold in supermarkets in the Western Province are packaged in plastic materials, including the following products: milk powder, biscuits, nuts, confectionary, dried noodles, flour, spices, grains, sugar, tea leaves and coffee (Bandara et al., 2010). These kinds of packets are commonly made from HDPE film (R. Jayasinghe, 2011, pers. comm., 24 August) and as they contain dry food goods are expected be relatively easy to clean. The packaging of spices, biscuits and milk powder in particular are some of the most frequently used types of packaging in households in the Western Province (Bandara et al., 2010). These products may have some potential for use in a WfL project however further information is required regarding the generation of this kind of waste, its level of contamination and its current use in conventional plastic recycling.

**Plastic Bags**

One of the primary applications of LDPE goods produced in Sri Lanka is plastic bags (JICA & PRI, 2000 in Jayasekara, 2010). These products are extremely widespread in Sri Lanka, with a survey of households
in the Western Province showing that plastic bags are accumulated in 100% of households at all LA levels (Gunaratna, 2010). This is supported by a survey conducted by Bandara et al. (2010), which showed that plastic bags are the most commonly used packaging material by households of all income levels. One major factor in this abundance is that supermarkets in Sri Lanka provide plastic shopping bags free of charge (Bandara et al., 2010). Plastic bags are often reused in households, but their low quality combined with the very large quantities of plastic bags in the waste stream means that this practice has little effect on the quantities available (van Zon & Siriwardena 2000). In the Western Province, approximately 1270 tonnes of plastic bags enters the MSW stream annually (Steele et al., 2005 in Jayasekara, 2010).

According to a report prepared for the CEA, thin plastic shopping bags (called ‘Sili-sili bags’) are the most problematic plastic products in Sri Lanka (Lakmali and Dissanayake, 2008). The Sili-sili bags’ thinness and low weight means that they are difficult to reuse and recycle by conventional means, and thus they are not collected by the majority of informal waste workers (Lakmali and Dissanayake, 2008). In 2006 a ban was introduced on the production and sale of any plastic product below 20 microns in thickness; whilst this may have increased the usage of raw materials for production this measure has also increased the durability of the bags (Lakmali and Dissanayake, 2008). Due to their abundance and the difficulty in recycling this product by conventional means plastic bags have significant potential for use in a WfL project.

Supermarket Wrapping

Supermarkets in the Western Province, such as Cargills, Keels, and Arpico, may generate large amounts of plastic waste in the form of primary (for bulk food goods), secondary (for multiple products) and tertiary (pallet) wrappings; these can be either LDPE or HDPE films (R. Jayasinghe, 2011, pers. comm., 24 August). The results of the questionnaire carried out in ten supermarkets in Colombo District (see Appendix 4 –Responses to Questionnaire for Supermarkets) show that the amount of this type of waste generated by supermarkets can vary significantly, but may be up to 30 kg per week. The average amount of plastic wrap waste generated by the surveyed supermarkets was 10 kg per week. These wraps may be an excellent source of plastic for a WfL project as it is expected that this waste would be very clean, homogenous, and generated continuously. The results of the questionnaire also indicate that they are generated in large amounts.

Other Plastic Films

Other products made from plastic film may be available in significant amounts on a local scale. Textbooks are provided free of charge by the Sri Lankan government to schoolchildren, but are required to be covered in thin plastic film (usually HDPE) each year before they may be taken to school (R. Jayasinghe, 2011, pers. comm., 24 August). Plastic book covers are one of the most widely used forms of plastic packaging in the Western Province, occurring in 20% of households (Bandara et al., 2010). Thin HDPE tablecloths are also extremely popular in Sri Lanka and may have a useful life of only six months or so (R.
Jayasinghe, 2011, pers. comm., 24 August). Each may have potential for use in a WfL project but further investigation into these products is required.

**Collection of Waste Plastic**

There are various possible methods for collection of plastics waste for recycling, including collection from households, collection from a central point (such as a collection centre), purchase from informal waste collectors or middlemen, or collection from commercial establishments (Jayasekara, 2010). Of the seven recyclers which responded to the questionnaire, none collected waste from households or a central point. One reported that it purchased waste from “external collectors” although it was not specified whether these collectors were waste pickers, door-to-door collectors, or LA-employed workers. Two recyclers purchased plastic from middlemen. A further two collected waste from commercial establishments whilst three (including one which also purchased from middlemen) specified that they had their own “collection network”.

Purchasing plastic waste from informal waste collectors or middlemen was not considered a viable collection method for a WfL project. This practice, whilst providing an income for informal waste collectors, would perpetuate their poor working conditions and disconnectedness from the recycling process. Ideally, in the long term waste pickers and door-to-door collectors would become a part of the project, from the collection of plastic and fibre (in safer and less difficult conditions), to the operation of the hotpress and final modifications to produce the NFCs.

Whilst collection from a central point may be a convenient and cheap, these ‘bring back’ schemes depend upon members of households and businesses travelling to this point to deposit their plastics. The MSW stream does however comprise a significant amount of plastic wastes; according to the Ministry of Environment’s Database of Solid Waste (2005) plastics make up 5.9% of the municipal waste collected in Sri Lanka. In the district of Colombo a similar proportion (5.8% or 73,047.30 tonnes) of MSW collected is plastics, however in Gampaha district this value rises to 8.6% (26,788.25 tonnes) (Ministry of Environment, 2005). These figures do not take into account the significant amounts of plastics which are currently collected by informal waste collectors, illegally dumped, or burned. The results of the questionnaire also suggest that in the Western Province collection from households is underexploited by plastic recyclers (and therefore household waste is generally collected only by informal workers or LAs, if at all).

One disadvantage of plastics sourced from the MSW stream is the high risk of contamination, which may significantly affect the quality of the final product (Jayasekara, 2010). Many plastic recycling facilities in Sri Lanka (approximately 63%) wash their plastics (Gunarathna, 2010). This is unsurprising given that much of the plastic material they obtain is in an unclean condition (Gunarathna, 2010) however this practice has a significant negative impact upon the environment in Sri Lanka (as discussed in section
4.3.1.3. A large proportion of waste plastic obtained by plastic recyclers in Sri Lanka is also in unsorted condition (Gunarathna, 2010), which necessitates extra processing through sorting. Collecting plastic waste before it enters the municipal waste stream (i.e. from households which have ‘pre-sorted’ their waste) would mean that waste would be relatively clean and require little sorting (Jayasekara, 2010).

The willingness of households to supply door-to-door collectors with plastic waste combined with the low coverage of door-to-door collectors (discussed in section 4.1.1.1) means that there exists an opportunity for collection from households without competing with door-to-door collectors. A source separation scheme similar to that organised by Arthacharya for its Galle recycling plant (see section 4.1.1.1) may eliminate the necessity of extensive sorting and washing of household waste before producing NFCs. Furthermore the involvement of the community in waste collection through source separation can not only improve the quality of waste collected but also the social standing of the collectors (Kent, 2010).

Whilst the sale of excess recyclables collected with useable plastics from households would support the middlemen of the waste sector, the practice would increase the total amount of waste being recycled (maximising the environment benefits) and increase the profitability of the project. The social and environmental benefits of household collection may be maximised by targeting low-income households within Pradeshiya Sabhas, which are currently the least involved in plastic recycling and most commonly dispose of plastics through burning. As discussed in section 4.1.1.1, there is a greater ‘gap’ in informal plastic waste collection from households in MCs, however these households are least likely to separate their waste and a relatively high percentage are covered by LA waste collection services.

Household collection alone however may not be able to provide sufficient quantities of plastic waste for the project, as was found with the Galle Recycling Plant (see section 4.1.1.1). In order to ensure a continuous supply of plastic in sufficient quantities, household collection may be best combined with collection from one or more commercial facilities, through an arrangement with a shop, restaurant, factory or hotel. It is also hoped that as the community becomes aware of the WfL project, some businesses or households not covered by the collection scheme may also voluntarily deposit suitable plastic wastes at the site of production.

4.2.1.2 Potential Sources of Natural Fibre

In Sri Lanka there are many existing sources of natural fibre; these may be roughly grouped into agricultural byproducts, post-consumer sources, and dedicated fibre sources. Short fibres currently produced in Sri Lanka include sawdust, rice husk, rice straw, and chopped paper. Long fibres include coir, sugar cane bagasse, and fabric off-cuts.
Table 7. Potential sources of natural fibre for WfL Sri Lanka.

<table>
<thead>
<tr>
<th>Agricultural byproducts</th>
<th>Post-consumer sources</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coconut husk</td>
<td>Paper</td>
</tr>
<tr>
<td>Rice husk</td>
<td>Textile waste</td>
</tr>
<tr>
<td>Rice straw</td>
<td></td>
</tr>
<tr>
<td>Sawdust</td>
<td></td>
</tr>
<tr>
<td>Sugar cane bagasse</td>
<td></td>
</tr>
<tr>
<td>Banana stems</td>
<td></td>
</tr>
</tbody>
</table>

**Dedicated Fibre Sources**

The excellent soil conditions and abundance of water in Gampaha has meant that historically the economy of the area has been dominated by agriculture (Hoekstra, 2010). In recent years there has been increasing urbanisation, and many of the paddy fields in and around the city have been abandoned due to rising costs and lack of labour (Hoekstra, 2010); according to the 2004 census there was 202 hectares of fallow fields (7.2% of the total area of GMC), whilst the extent of cultivated fields was just 39 hectares (1.4% of total area) (RUAF and International Water Management Institute, n.d.). The Sri Lankan government, in a bid to ensure food security for the country, has banned the sale of this agricultural land for construction (Hoekstra, 2010).

As part of the national ‘Grow More Food Campaign’ (Api Wavamu Rata Nagamu) incentives are being given to farmers to revitalise the paddy fields or convert them to the cultivation of fruit, vegetables, and commercial crops (Hoekstra, 2010). The Western Province Department of Agriculture has also been involved in promoting the establishment of home gardens and ‘Family Business Gardens’ in Gampaha, as a way to provide food and generate income for its citizens (Hoekstra, 2010). The availability of abandoned land for cultivation and the commitment of the government to supporting urban agriculture may present an opportunity for the production of a dedicated fibre crop for a WfL project. To maximise the environmental and social benefits of the project however the use of an agricultural byproduct which is currently wasted is a much preferable option for sourcing fibre; however a dedicated fibre crop remains an option for the future if a specific type of fibre is desired, and if economically feasible.

**Agricultural Byproducts**

It is anticipated that most of the agricultural byproducts discussed in this section will require drying in an oven to remove any residual moisture before use in NFCs (C. Baillie, 2011, pers. comm., 25 October). For a summary table showing the estimated generation of agricultural byproducts in the source area (the districts of Colombo, Gampaha, Puttalam, Kurunegala, Kegalle, Ratnapura, Kalutara, Galle, and Matara) see Appendix 5 –Estimated Generation of Agricultural Byproducts in the Source Area.
Coir

Coir is a byproduct of coconut production; coconuts comprise the husk, which can be further separated into fibre (coir) and coir dust, the shell and the nut (Perera et al., 2005). Coir is a strong, durable, and light fibre, which is relatively water-proof and resistant to microbial degradation and damage by saltwater (Ray, 2005, van Rijswijk et al., 2001). The husk is removed manually from the coconut fruit on a spike and after retting (in which the husk is generally soaked in brackish ponds or lagoons for up to six months), the fibre is decorticated and extracted from the husk by beating, and then washed (van Rijswijk et al., 2001, van Dam, 2002). For commercial purposes, coir is processed mechanically (Industrial Development Board of Sri Lanka, 2007) which can be conducted after only five days of soaking the husk in water tanks (van Dam, 2002).

Availability

Coconut is grown extensively in Sri Lanka, particularly within the districts of Colombo, Gampaha, Kurunegala and Puttalam, a region called the ‘coconut triangle’; these four districts collectively make up approximately 58% of the total extent of land under coconut in Sri Lanka (Department of Census and Statistics, 2008). In one coconut, the weight of the husk is approximately 350g and the weight of the coir is approximately 140 g (the remaining 210g comprises coir dust), and the average weight of the nut (product) is 340g (Sepalage, 1986, in Perera et al., 2005). As such the Residue to Product Ratio (RPR) of husk and coir can be considered as 1.03 and 0.41 respectively. Coconut production in 2009 was reported to be 939,080 tonnes (Department of Census and Statistics, 2002). Based on the extent of land devoted to the crop it was assumed that 75.9% of coconut production takes place within the potential source area; this represents an annual coir production of approximately 292,000 tonnes. Coconuts are produced throughout the year, but due to the seasonal pattern of rainfall, more fruits are produced in some months than others (Chan and Elevitch, 2006); in Sri Lanka, coconut production peaks in the May/June period (Coconut Research Institute of Sri Lanka, n.d.).

Significant amounts of coconut husk are consumed in the fibre industry; raw baled fibre and coir products, such as twine, geo-textiles, brushes, and horticultural pots, are exported extensively from the Western and North-Western Provinces (Industrial Development Board of Sri Lanka, 2007). Coconut husk is also used as a fuel for domestic cooking, and exported in the form of chips (Industrial Development Board of Sri Lanka, 2007). The demand for coconut husk and coir for other applications, particularly export purposes, suggests that this fibre would be more highly valued than other agricultural byproducts; one community-based income generating project, run by members of a local NGO in Kurunegala, purchased coconut husks at LK 3 each to produce chips (Sri Lanka Centre for Development Facilitation, 2011). Fresh coconut however is a significant part of the Sri Lankan diet, with the per capita consumption of fresh coconut at approximately 90 nuts per year (Peiris, n.d.). As fresh coconut in Sri Lanka is usually sold with the husk on (R. Jayasinghe, 2011, pers. comm., 24 August) households may be a potential source of
coconut husk for coir. There may also be some cases of waste husk generated by coconut mills producing food goods (for example desiccated coconut) which is not currently utilised (R. Jayasinghe, 2011, pers. comm., 24 August).

Implications for Waste for Life

Whilst coir is a high-quality, long fibre and produced year-round, the demand for coir in other applications (particularly for export products) may mean it has a relatively high commercial value and thus would be somewhat difficult to obtain for a WfL project. Processing of the husk is also time-consuming and labour-intensive unless suitable machinery can be obtained. Whilst coir remains a potential source of fibre for a WfL project, its use may depend upon the collection of husk from households, or an agreement with a smaller coconut mill which is not currently capitalising on its waste husk. The value of a NFC product from coconut husk would also need to be relatively high to make up for the difficulty of fibre extraction.

Rice Husk

Rice or paddy husk is the hard protective outer layer of the rice grain, which comprises the husk, bran, germ and inner edible portion (Lantin, 1999). In traditional rice mills in Sri Lanka, de-husking and polishing (the removal of the bran) (Lantin, 1999) usually occur together in steel hullers, whilst in more modern operations a separate specialized machine called a ‘rubber roll sheller’ is used for de-husking of the raw grains (Liyanapathirana, 2006). In previous studies of NFCs, rice husk has been milled or ground before use in NFCs (Yang et al., 2004, Yang et al., 2007, Nourbakhsh et al., 2011, Yang et al., 2006); this may be due to the poor chemical and physical adhesion properties of rice husks, which grinding can address (Ndazi et al., 2007).

Availability

Rice is produced in two growing seasons in Sri Lanka: Maha (October to January) and Yala (April to August) (RUAF and International Water Management Institute, n.d.). Rice mills however store the rice produced in each season and thus operate year-round (R. Jayasinghe, 2011, pers. comm., 24 August). Spatially too the availability of rice husk is dependent upon the distribution of mills rather than rice paddies; a considerable transfer of rice occurs between districts (Perera et al., 2005). As a result it was not considered appropriate to estimate the generation of rice husk in the WfL source area using the percentage of land devoted to the crop in the area.

In Sri Lanka there are approximately 7000 rice mills which process over 2 mega-tonnes of rice annually (Perera et al., 2005). Due to the widespread cultivation of rice and the large number of mills across the country it can be expected that there are numerous rice mills within the nine source districts of the potential WfL project. According to the Department of Census and Statistics in Sri Lanka (2010), the total production of rice in 2009 was 2,325,000 tonnes. Various varieties of rice are cultivated in Sri Lanka due to changes in factors such as climate, rainfall and soil type. Each of these have different RPR values,
however an average value for the most commonly grown varieties is 0.20 (Perera et al., 2005); this gives a total national rice husk production of 465,000 tonnes in 2009.

In the Central and Eastern districts, rice is generally parboiled before milling, for which the rice husk is used as a fuel for steam generation (Perera et al., 2005). Small amounts are also used for other applications such as brick manufacturing (Senanayake et al., 1999, in Perera et al., 2005). Surplus rice husk is generally considered waste and is often available free of charge or, in some cases, larger mills may pay contractors to remove the husk regularly (Perera et al., 2005). Some smaller mills are known to engage in illegal dumping of rice husk into streams or onto vacant land or roadsides (F. Jayasinghe, 2011, pers. comm., 5 September).

*Implications for Waste for Life*

Rice husk has the potential to be an excellent source of fibre for a WfL project: it is produced year-round in large amounts and there is little demand for other applications, which means it is of no worth to producers. The only apparent disadvantages to the use of rice husk in a WfL project are its small size and lightness, which suggest that this fibre would be somewhat difficult to store and protect against fire, and the necessity of grinding the husk (which should be verified by further studies).

*Rice Straw*

Rice straw is the stalk material which remains after the grains of rice have been removed (Ricegrowers’ Association of Australia, n.d.). This is produced by threshing of the harvested paddy (rice with attached stalk), a process in which the grains are separated from the straw by rubbing, impact or stripping (Doyle et al., 1986). In Sri Lanka harvesting is generally carried out by hand with sickles after which buffaloes (through treading), four-wheeled tractors or mechanical threshers are used for threshing (Adhikarinayake, 2005). Like rice husk, rice straw is generally milled or ground into particles before the production of NFCs (Pan et al., 2011); one possible reason for this may be the extra processing and energy requirements of extracting true fibres from the stalk (C. Baillie, 2011, pers. comm., 7 September). Milling of plant byproducts such as rice straw also ensures a more even distribution of fibre properties within the NFC (C. Baillie, 2011, pers. comm., 7 September).

*Availability*

The total generation of rice or paddy straw in Sri Lanka is extremely high; according to the Department of Census and Statistics (2010), annual production in 2005 was over two million tonnes. Rice is grown in almost all areas of Sri Lanka, and Kurunegala is one of the major rice-producing districts (Liyanapathirana, 2006). Based on the extent of land devoted to growing rice it was assumed that 31.5% of rice produced in Sri Lanka is from within the source area for the project. Using the RPR of rice straw given by Perera (2005), 1.76, approximately 1,112,000 tonnes of straw is produced in the source area each
year. However the availability of rice straw is highly seasonal; harvesting is conducted at the close of each growing season, in February (Maha) and August (Yala) (Perera et al., 2005).

Currently much of the straw is simply burnt or ploughed into the field (Perera et al., 2005, National Cleaner Production Center, 2010). There is some small demand for rice straw in the paper making industry and for animal feed, and other activities including as a raw material for biogas production systems (Perera et al., 2005). However due to the large amounts which are generated, these uses have little effect upon the availability of rice straw (Perera et al., 2005).

Implications for Waste for Life
Whilst large amounts of rice straw may be expected to be available in the potential source districts (in particular Kurunegala) and there is relatively little demand for other applications, the seasonal nature of rice straw production may pose a significant barrier to its use in a WfL project due to the large storage areas which would be required to sustain a year-round operation and the fire hazard this would present. Rice straw would also require milling before it may be suitable to use in NFCs. Therefore this fibre was not considered a strong potential source for a WfL project.

Sawdust
Previous testing using the Kingston hotpress has shown that due to its high moisture content, sawdust must be either drying in an oven or extruding into pellets before pressing into NFCs; however this may be true of other agricultural byproducts (C. Baillie, 2011, pers. comm., 27 July). To produce sawdust composites with HDPE and PP, Najafi et al (2006) dried sawdust in an oven at approximately 100°C for 24 hrs. Sawdust is commonly used in commercially-produced NFCs and thus the properties of sawdust NFCs are relatively well known.

Availability
There are more than 4000 saw mills in Sri Lanka (Perera et al., 2005). The main sawmilling area in Sri Lanka is the city of Moratuwa, in Colombo District (R. Jayasinghe, 2011, pers. comm., 24 August); there are approximately 400 saw mills in this area (Nizam, 2010). Based on data from Gunatilake and Gunaratne (2002) a minimum of 968 mills were identified in the potential source area for a WfL project. It was assumed that the generation of sawn wood within the source area was proportional to the number of mills (i.e. the average output from mills located within the source area was the same as the national average); therefore approximately 24.2 % of sawn wood produced in Sri Lanka is generated in the source area. Using the predicted RPR of sawdust, 0.35, and the predicted national generation of sawn wood for 2010 of 606,000 tonnes (Perera et al., 2005), the generation of sawdust within the source area is 51,328 tonnes. Saw mills in Sri Lanka generally operate year-round (R. Jayasinghe, 2011, pers. comm., 19 October).
Sawdust poses a significant disposal problem for the sawmills; most is dumped in large heaps around the mills and is freely available (Perera et al., 2005). In Moratuwa, pollution from the timber industry is a major problem as the sawdust produced is generally dumped indiscriminately into rivers and the ocean (Nizam, 2010). A small amount of sawdust is consumed for heat generation in the manufacturing industry and for domestic purposes (Perera et al., 2005).

**Implications for Waste for Life**

Sawdust has significant potential for use in a WfL project; whilst the generation of sawdust in the source area is low relative to the generation of other fibres, the low use of this byproduct in other applications and its status as a nuisance waste suggests that it is of no commercial value and would be very readily available. Furthermore this ‘fibre’ is produced year-round and very little extra processing would be involved, particularly if sawdust is dried rather before use in NFCs rather than extruding the sawdust/plastic mixture before pressing (which would necessitate an additional piece of equipment).

**Sugar Cane Bagasse**

Sugar cane bagasse is the fibrous material remaining after sugar cane is crushed for the production of sugar (Perera, 2010). For use in NFCs it is necessary to first clean the bagasse to remove organic debris and sugar residue (Monteiro et al., 1998), however this may be achieved simply through washing in water (Acharya et al., 2008). The fibres may then be dried and cut into uniform pieces to ensure consistent properties within the composite (Acharya et al., 2008). Sugar can bagasse has a moisture content of 50% (National Cleaner Production Center, 2010); this is approximately equal to that of sawdust and thus the use of this fibre in a WfL project is also expected to necessitate thorough drying in an oven before pressing.

**Availability**

There are three main sugar manufacturing plants in Sri Lanka: Sevanagala Sugar Industries Ltd in the Ratnapura District (within the source area), Pelawatta Sugar Industries Ltd in the Monaragala District of the Uva Province, and Kantale Sugar Industries Ltd in the Trincomalee District of the Eastern Province (W.R.G. Witharama, 2011, pers. comm., 19 July). The processing capacity of the factory in Sevanagala is 1250 tonnes of sugar cane per day (W.R.G. Witharama, 2011, pers. comm., 22 August). Whilst the sugar mills generally operate year-round, during Yala season (April to September) the mills do not operate at full capacity; crushing at full capacity occurs on only approximately 200 days of the year (R. Jayasinghe, 2011, pers. comm., 18 September). Therefore the actual annual capacity of the Sevanagala mill can be estimated as 250,000 tonnes of sugar cane per year (W.R.G. Witharama, 2011, pers. comm., 22 August). According to Perera et al. (2005) the RPR of sugar cane bagasse is 0.29; thus the bagasse production of Sevanagala is approximately 72,500 tonnes per year. As this mill is the only major sugar plant in the source area, this figure was considered an estimate of the total generation of sugar cane bagasse within the source area.
Most sugar factories use the bagasse they produce for an energy source, burning it to generate steam and electricity; this is done even at very low efficiencies due to the fire hazard posed by storing dry bagasse (Koopmans and Koppejan, 1998). According to the estimations of Perera et al. (2005) 100% of bagasse is used and therefore nothing remains for other applications. The amount of bagasse produced by a sugar mill however is generally more than sufficient to satisfy its energy requirements (Prabhakar Reddy and Subbaiah Choudary, 2006); surplus bagasse generated in Sri Lanka is used to produce alcohol, feed animals and make compost (W.R.G. Witharama, 2011, pers. comm., 19 July).

Implications for Waste for Life

Whilst a significant amount of sugar cane bagasse, a long fibre, is produced within the source area, its high usage in other applications means that it is not a strong potential source of fibre for a WfL project. In particular its use in energy generation suggests that this fibre is of some worth to its producers and as such would not be as readily available as other fibres. Furthermore bagasse requires not only drying but washing and chopping before use in NFCs, and as it is not produced at a consistent rate all year round the fibre is expected to require a larger storage area than other fibres, posing an increased risk of fire.

Post-Consumer Sources

Paper

The most common types of paper waste in Sri Lanka are office paper, newspaper, and paper packaging (R. Jayasinghe, 2011, pers. comm., 19 October). In the Ja-Ela Divisional Secretary (DS) division of the Gampaha district, packaging materials make up greater than half of the paper constituent of MSW (by both weight and volume) (van Zon and Siriwardena, 2000). Paper packaging is extremely common in Sri Lanka; most of the products sold through small grocery shops, which low-income earners generally shop in, use paper and paper bags for packaging food (R. Jayasinghe, 2011, pers. comm., 19 October). For NFCs produced with paper materials pre-pregs may be simply layered and press-moulded without any shredding (Baillie et al., 2011; C. Baillie, 2011, pers. comm., 14 March).

Availability

According to the Ministry of Environment’s Database of Solid Waste (2005) paper products comprise 6.47% of the MSW collected in Sri Lanka; this is the greatest contributor to MSW after short-term biodegradable waste. The MSW collected within Gampaha MC in particular has a very high paper component at 18% (Department of Census and Statistics, 2001). Paper recycling is already practiced in Sri Lanka, through informal waste collectors and middlemen, at large and small scales as well as in home based industry (Bandara, 2008). However the extent of paper recycling in Sri Lank may be constrained by a lack of collection; paper recycling is most successful in areas which are well-covered by door-to-door waste collectors, such as suburban areas of Colombo (Bandara, 2008).
**Implications for Waste for Life**

The lack of available data regarding the generation and availability of paper in the Western Province and in Sri Lanka in general means that it is difficult to make conclusions regarding its potential as a source of fibre for a WfL project. However the limited information which is currently available however does not eliminate paper as a potential source. Whilst it may be beneficial for WfL to carry out its own research in the area to better understand the availability and use of waste paper in the Western Province, the existence of other sources with strong potential for use in the project may mean that this is not a high priority for further study at this stage.

**Textile Waste**

Garment manufacturing is a major industry in Sri Lanka; garments comprise 45% of exports from the country (Asian Development Bank, 2008). Most textiles in Sri Lanka are composite materials made from cotton and synthetic plastics (Environmental Foundation, 2007). Like paper products, textiles may be incorporated into NFCs by simply layering and press-moulding the pre-pregs (C. Baillie, 2011, pers. comm., 14 March); apart from washing if dirty textiles would require little extra processing. When impregnated with plastic the long, woven fibres of textiles can result in very strong and flexible NFCs (C. Baillie, 2011, pers. comm., 10 August).

**Availability**

There are 12 major industrial areas in Sri Lanka, most of which are Export Processing Zones (EPZs) (Board of Investment, n.d.); companies operating these zones export over 90% of their production (Abeywardene et al., 1994). Other large industrial areas are classified as Export Processing Parks (EPPs) or Industrial Parks (IPs) (Board of Investment, n.d.). Most of the major industrial areas are situated in Western Province, particularly in Gampaha District (Board of Investment, n.d.). Biyagama and Katunayake EPZs in Gampaha are the largest industrial areas in Sri Lanka (Sivananthiran, n.d.). The waste produced by both these industrial areas is dominated by textiles; according to data supplied to Aparakkakankanamage (2005) by the Board of Investment of the Government of Sri Lanka, the waste generated at Katunayake and Biyagama EPZs comprises 60% and 52.3% fabric respectively.

Waste pickers frequent EPZ dump sites to collect waste (R. Jayasinghe, 2011, pers. comm., 24 August). One study reports that at Katunayake EPZ, textiles comprise a major component of materials collected by waste pickers; generally waste pickers gather between 10 and 100 kg of fabric pieces per day, which they sell for just LKR 2 per kg (Geocycle, 2009). Thus whilst large quantities of textiles may be collected, they represent only a moderate source of income for the waste pickers at LKR 20-200 per day. Plastics and polythene on the other hand are collected in moderate amounts (1-50 and 1-20 kg per day respectively) but fetch a much higher price of LKR 35 per kg (Geocycle, 2009), making them the highest paying types of waste (earning waste pickers LKR 35-700 and 35-1750 per day respectively).
Implications for Waste for Life

Textile waste has a strong potential for use in a WfL project, due to its likely high generation at EPZs and the excellent mechanical properties of NFCs made with fabric. Given that textile waste is already collected by waste pickers at EPZs however it must be ensured that using this type of fibre for a WfL project will have no negative impact upon these informal workers. As a result of the large difference in price per unit weight, waste picker groups at EPZs may be interested in and benefit from being involved in a WfL project where textiles are collected from EPZs (and plastic and polythene sourced from other avenues).

4.3 Environmental Feasibility

4.3.1 Comparison of Conventional Plastic Recycling with Waste for Life Process

4.3.1.1 Air Pollution

The use of PVC and PS as raw materials in recycling in Sri Lanka is relatively common; 55% of recyclers currently operating use PS and 24% use PVC among other materials (Gunarathna, 2010). Recycling these materials can cause the release of HCl fumes and CO gas (as discussed in section 4.2.1.1); this may be particularly likely if the equipment used in the facility is old, faulty or unsuitable to recycling PVC and PS and thus overheats the plastics. HCl has an acute toxic effect on all forms of life, and also contributes to the processes which cause photochemical smog and acid rain (DSEPWC n.d.). CO is a precursor to greenhouse gases as it increases the concentration of methane (a greenhouse gas) and ozone in the atmosphere, and eventually oxidises to produce carbon dioxide (CO$_2$) (Environment Australia, 2001), the key contributor to global climate change (Beer et al., 2006). When overheated PVC and PS can also directly emit CO$_2$ (Georgia Gulf Chemicals and Vinyls, 2005, Denka Singapore, 2003).

Whilst plastics may emit harmful fumes even at low temperatures, the exclusion of PS and PVC from the WfL manufacturing process avoids the production of HCl, CO and CO$_2$ gas from these sources. The incorporation of natural fibres into WfL’s products can also act as a ‘sink’ for atmospheric carbon dioxide due to the stored carbon within the fibres (Pervaiz and Sain, 2003). In particular if the project made use of a fibre which is currently burnt, such as rice husk (see section 4.2.1.2), this would prevent the release of combustion fumes and greenhouse gases (including carbon dioxide) which would otherwise occur.

4.3.1.2 Energy Use

Whilst the energy use of plastic recyclers in the Western Province could not be estimated, current practices in Sri Lanka generally involve a relatively high number of processing steps (four), suggesting a high energy use. Furthermore the end product of most of these operations is not in a usable form; according to a survey by Gunarathna (2010) only 27% of plastic recyclers in the Western Province progress to manufacturing after pelletizing. The results of the questionnaire given to plastic recyclers in
Colombo and Gampaha districts (see Appendix 2 – Responses to Questionnaire for Plastic Recyclers) suggest that the proportion of recyclers which progress to *useful products* is even smaller; only one of the seven recyclers (14%) made useful products (plastic bags) whilst two others manufactured intermediate products (plastic film). Therefore the plastics produced by most current recycling operations in the Western Province require further processing and energy input before they are fully recycled to useful products.

The rate of energy use (power drawn) by the UWA hotpress has been estimated as 8 kW whilst the press is heating. However once the plates are hot the controls switch the heating element off and on as required to maintain an approximately constant temperature (A. Tavner, 2011, pers. comm., 21 September). The energy footprint of the press may be greatly reduced by improving the insulation of the hot plates (A. Tavner, 2011, pers. comm., 21 September); this would also help in preventing burns to those working with the press (see section 4.1.2.3). As an aspiration the rate of energy use of a press may be something in the range of 4 kW (E. Feinblatt, 2011, pers. comm., 12 September).

As the hotpress would be custom-made for Sri Lankan WfL project, its capacity (maximum temperature and pressure) could also be adjusted to suit the requirements of the materials used (C. Baillie, 2011, pers. comm., 31 August). If for example the plastic waste sourced for the project was characterised by a low melting point and viscosity, lower temperature and pressure would be required for the polymer to permeate the fibre layer, reducing the energy usage of the press. Whilst the Kingston hotpress was designed to reach a maximum temperature of the 200°C (Baillie et al., 2011), the hotpress at UWA has a maximum temperature of 190°C (with temperature adjustable below this point) (C. Baillie, 2011, pers. comm., 14 September).

### 4.3.1.3 Water Use and Pollution

Jayasekara (2010) observed that large amounts of water are used for washing, rinsing and cooling of plastics in the recycling industry in the Western Province; this is generally pipe-born or sourced from wells, or occasionally taken from natural streams. This is supported by Gunarathna (2010) who found that 72% of plastic recyclers in the Western Province sourced water from a private well whilst 14% used river water and 11% used water from a tap. The resulting wastewater is discharged, without treatment and generally without reuse, in batches into unsealed pits in the ground behind the facility, nearby surface water bodies, or stormwater drainage pipes which eventually discharge to surface water bodies (Jayasekara, 2010). According to Gunarathna (2010) the majority of recyclers (78%) discharge to the nearest water body.

Sampling conducted by Jayasekara (2010) of six plastic recycling centres in the Western Province has shown that this wastewater is generally of poor quality, with low dissolved oxygen (DO) concentrations, high levels of total dissolved solids (TDS), total suspended solids (TSS), chemical oxygen demand
(COD), and oil and grease, and extremely high concentrations of coliforms (total coliform and faecal coliform). Some facilities also showed extreme pH values, or high levels of heavy metals such as iron, lead, cadmium, and zinc (Jayasekara, 2010). The pollution of wastewater is highly dependent upon the methods used for washing the waste plastics, which is controlled by the source of the plastics as it affects their level of contamination (Jayasekara, 2010).

Previous WfL projects and testing has demonstrated that it is generally unnecessary to prepare waste plastic used in the organisation’s production method through intensive cleaning (Baillie et al., 2011), saving water and preventing pollution of soil, groundwater, and surface water through discharge of washing water. A WfL project also has potential for prevention of water pollution if the fibre source used would otherwise be dumped in waterways, for example sawdust (see section 4.2.1.2).
5. **Discussion**

Due to the early stage of planning for a potential WfL project in the Western Province this study was necessarily very broad, and as a result no one aspect of the project was able to be investigated in very great depth. The early stage of the project, combined with budgetary and time constraints, also meant that very little data could be collected for the study. As such the major limitation of the study was the reliance on existing data, and the lack of detailed, current data from the Western Province. It is expected that more quantitative data, if it were available, would have greatly improved the assessment of technical and in particular environmental feasibility. Some factors (such as the availability of waste materials) are also expected to vary considerably on a local scale.

Stakeholder Analysis and Risk Assessment are processes based upon individual judgments, and therefore the results of the study may have been influenced somewhat by the personal bias of the author (and the fact that one of the supervisors for the study was a member of WfL). However the objectivity of the study was ensured by the unwillingness of the author and of WfL to allow an unfeasible project to be implemented, which could harm both the intended beneficiaries and WfL.

Regardless of the limitations associated with the study, the conclusions made may be used as an early estimation of the project’s viability, as well as providing a solid starting point for future planning and investigation.
6. **Conclusions**

Overall the results of this study indicate that a WfL project in the Western Province of Sri Lanka can be considered highly feasible at this stage of planning, warranting further, more in-depth studies incorporating data collection on the ground.

6.1 **Socio-economic Feasibility**

The results of the Stakeholder Analysis indicate that, whilst a WfL project in the Western Province will not affect individual waste pickers, it will benefit the majority of stakeholders and in particular the other high-priority stakeholders. CBOs and NGOs involved in the project are expected to have the least influence of all stakeholders but be the most affected by the project. The most significant health and safety risks posed to people working with the waste and hotpress (those assessed as high priority) are burns to the skin, electrical shocks, and fire; however these risks may be mitigated relatively easily. The project is expected to be able to obtain funding consistent with WfL’s values and aims from the Global Environment Facility Small Grants Programme, Jana Suwaya People Development Foundation, or Samurdhi Bank Societies.

6.2 **Technical Feasibility**

A WfL project in the Western Province should be able to source sufficient amounts of suitable waste materials to sustain the project. Household collection from Pradeshiya Sabhas (with a source-separation scheme) combined with collection from one or more commercial facilities is expected to be most successful collection method for plastic waste. Plastic bags are considered to have the strongest potential as a waste plastic in the WfL project due to their abundance and the difficulty in recycling these products. Primary, secondary and tertiary wrapping from supermarkets are also expected be excellent sources due to the large amounts generated, and their likely cleanliness and homogeneity. Of the eight types of fibre examined, rice husk and sawdust have the greatest potential for use in the project, due to the large amounts generated year-round in the source area, low demand in other applications (and therefore low commercial value), and suitability for use in NFCs with little extra processing. Textile waste from EPZs also has significant potential as a source of fibre.

6.3 **Environmental Feasibility**

Whilst a direct quantitative comparison could not be achieved within this study, a WfL project is expected to have some environmental advantages over current practices of plastic recycling in the Western Province, through decreased energy use, water use and pollution, and air pollution. The project may also provide an alternative use for fibres which are currently causing significant environmental problems through improper disposal, namely burning or dumping. WfL would also most likely use types of plastics which are not currently recycled by conventional means, such as thin HDPE or LDPE films.
7. **Recommendations**

It is recommended that the results of this study be verified by further studies involving data collection conducted on behalf of Waste for Life on the ground in Western Province. In particular, quantitative data may be able to provide a more accurate assessment of technical and economic feasibility. This may be undertaken as part of a more detailed feasibility study at a later stage in the planning for the project.

7.1 **Socio-economic Feasibility**

It is recommended that as part of further planning for a WfL project in the Western Province consideration and prevention of any potential negative impacts upon Local Authority waste collectors should be a high priority. In the current stage of the project (identification) it is recommended that WfL should partner with educational institutions whilst consulting CBOs and NGOs which have the potential to be involved in the project. Stakeholder participation for other key stakeholders (national and provincial government bodies, and LAs) should consist of simply keeping them informed. It is also recommended that Stakeholder Analysis be repeated once more specific stakeholders can be identified and profiled in greater depth (ideally through personal communication with stakeholders). In particular more detailed profiling of specific CBOs should be conducted to gain an understanding of their organizational structure and ensure this is consistent with the values of WfL; for example whether a CBO has a ‘boss’ or whether it operates as a cooperative, where each member is considered equal.

To ensure the health and safety of the people who will be working in the project it is recommended that mitigating the risk of burns to the skin, electrical shocks, and fire be a high priority in further planning for the project. Burns to the skin should be mitigated primarily through modifications to the press and also the use of PPE, and it should be ensured that the press is properly grounded to prevent electrical shocks. To mitigate the risk of fire it is recommended that smoking and open flames are banned on the site of the project, flammable materials are sited as far as possible from electrical devices, and the premises are secured after hours. It is recommended that a more comprehensive assessment of potential sources of funding be carried out for WfL Sri Lanka, in particular further investigation on the ground into local, small-scale, unregulated microfinance providers in the Western Province which may be able to provide zero- or very low-interest loans.

7.2 **Technical Feasibility**

Whilst this study identified several sources of waste plastic and fibre with strong potential for use in a WfL project in the Western Province, the selection of materials should be an iterative process which occurs concurrently with the design of the NFC product. This process should occur with and be primarily driven by the needs of the intended beneficiaries. Thus it is recommended that more in-depth and focused studies of technical feasibility be carried out once the specific groups which will be involved have been
identified and consulted; these should include research to determine the local availability of specific fibres and plastics and to characterise the properties of NFCs produced from potential fibres and plastics.

7.3 Environmental Feasibility

It is recommended that further studies involving quantitative data collection be conducted to assess the environmental feasibility of the project with greater accuracy. This may be achieved through more direct, quantitative comparison of the WfL NFC production process with current plastic recycling practices in the Western Province, or through other methods such as Life Cycle Analysis.
References


INDUSTRIAL DEVELOPMENT BOARD OF SRI LANKA 2007. Developing the Coir Sector in North-Western Province: Value Chain Development for more Competitiveness and Decent Work. Industrial Development Board of Sri Lanka & Industrial Services Bureau.


Search-Results&utm_medium=RSS&utm_campaign=WiserEarth&utm_term= [Accessed 30 October 2011].


Appendix 1 – Questionnaire for Plastic Recyclers

1. Details
   
   a. Name
   
   b. Address
   
   c. Number of workers

2. Types of plastic waste recycled (eg. LDPE, PP)

3. Amount of plastic waste recycled

4. Method of collection of plastic waste

5. Products (eg. pellets)

6. Problems associated with the industry
### Appendix 2 – Responses to Questionnaire for Plastic Recyclers

<table>
<thead>
<tr>
<th>Name of company or operator</th>
<th>Location</th>
<th>Number of workers</th>
<th>Plastics recycled</th>
<th>Amount recycled (tonnes/month)</th>
<th>Method of collection</th>
<th>Products</th>
<th>Problems associated with the industry</th>
</tr>
</thead>
<tbody>
<tr>
<td>C.D. Pack</td>
<td>Ragama</td>
<td>120</td>
<td>HDPE, LDPE</td>
<td>90</td>
<td>Collection from commercial establishments</td>
<td>Plastic film</td>
<td>Lack of waste</td>
</tr>
<tr>
<td>ECO SansPlastics</td>
<td>Boralasgamuwa</td>
<td>20</td>
<td>PET</td>
<td>30 - 40</td>
<td>Have their own collection network</td>
<td>Pellets</td>
<td></td>
</tr>
<tr>
<td>Hiden Packaging</td>
<td>Polgasowita</td>
<td>12</td>
<td>HDPE, LDPE, PS</td>
<td>16</td>
<td>Purchase from middlemen</td>
<td>Pellets</td>
<td>Lack of waste</td>
</tr>
<tr>
<td>Poly Packaging Industries</td>
<td>Colombo</td>
<td>5</td>
<td>LDPE</td>
<td>20</td>
<td>Purchase from waste collectors</td>
<td>Plastic bags</td>
<td>Lack of waste</td>
</tr>
<tr>
<td>Sanasuma Recycling Centre</td>
<td>Horana</td>
<td>5</td>
<td>HDPE, LDPE</td>
<td>15</td>
<td>Have their own collection network &amp; purchase from middlemen</td>
<td>Pellets, plastic film</td>
<td>Lack of waste, difficulty of drying plastic after washing</td>
</tr>
<tr>
<td>Sha Plastic</td>
<td>Ragama</td>
<td>5</td>
<td>HDPE, PP</td>
<td>20</td>
<td>Have their own collection network</td>
<td>Pellets</td>
<td>Lack of waste, lack of machinery</td>
</tr>
<tr>
<td>[Name withheld]</td>
<td>Moratuwa</td>
<td>4</td>
<td>HDPE, LDPE</td>
<td>7 - 8</td>
<td>Collection from commercial establishments</td>
<td>Pellets</td>
<td>Lack of waste, lack of capital to expand business</td>
</tr>
</tbody>
</table>
Appendix 3 – Questionnaire for Supermarkets

1. Details
   a. Name
   b. Location/branch

2. Types of plastic wrappings used (eg. secondary, tertiary)

3. Estimate of weight of plastic wrapping waste generated per week

4. Current disposal practices of wrappings

5. Willingness to supply wrapping waste to a community based recycling project free of charge
## Appendix 4 – Responses to Questionnaire for Supermarkets

<table>
<thead>
<tr>
<th>Supermarket</th>
<th>Location</th>
<th>Types of wrapping used</th>
<th>Approximate generation (kg/wk)</th>
<th>Current disposal practices</th>
<th>Willingness to provide wrap to WfL free of charge</th>
<th>Reason if unwilling</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arpico</td>
<td>Nugegoda</td>
<td>Primary, tertiary</td>
<td>&lt; 1</td>
<td>Collection by MC</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Piliyandala</td>
<td>Primary, secondary, tertiary</td>
<td>1</td>
<td>Collection by UC</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>Arpico Super Center</td>
<td>Borealsegamuwa</td>
<td>Primary, secondary</td>
<td>10</td>
<td>Sold together with cardboard</td>
<td>No</td>
<td>Difficult to separate plastic and cardboard</td>
</tr>
<tr>
<td>Cargills</td>
<td>Kohuwala</td>
<td>Primary, secondary, tertiary</td>
<td>12</td>
<td>Sold</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Borealsegamuwa</td>
<td>Primary, secondary, tertiary</td>
<td>15</td>
<td>Collected by MC (primary) or sold (secondary and tertiary)</td>
<td>No</td>
<td>Company policy is not to provide waste for free</td>
</tr>
<tr>
<td>Laughs</td>
<td>Borealsegamuwa</td>
<td>Primary, tertiary</td>
<td>10</td>
<td>Sold to an external buyer</td>
<td>No</td>
<td>Profit from sale of waste</td>
</tr>
<tr>
<td></td>
<td>Kohuwala</td>
<td>Primary, secondary, tertiary</td>
<td>30</td>
<td>Collection by MC</td>
<td>No</td>
<td>Not specified</td>
</tr>
<tr>
<td>Sathosa</td>
<td>Kohuwala</td>
<td>Primary, secondary, tertiary</td>
<td>4</td>
<td>Collected by MC (primary and secondary) or sold (tertiary)</td>
<td>Yes, except tertiary wrap</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Piliyandala</td>
<td>Primary, secondary, tertiary</td>
<td>&gt; 8</td>
<td>Sold</td>
<td>No</td>
<td>Profit from sale of waste</td>
</tr>
<tr>
<td>Super K</td>
<td>Piliyandala</td>
<td>Primary, secondary</td>
<td>10</td>
<td>Sold</td>
<td>No</td>
<td>Cannot provide waste for free</td>
</tr>
</tbody>
</table>
## Appendix 5 – Estimated Generation of Agricultural Byproducts in the Source Area

<table>
<thead>
<tr>
<th>Product</th>
<th>Byproduct</th>
<th>RPR(^1)</th>
<th>Year</th>
<th>National product generation(^2) (tonnes)</th>
<th>National byproduct generation (tonnes)</th>
<th>Product generation in source area (% of national generation)(^3)</th>
<th>Product generation in source area (tonnes)</th>
<th>Byproduct generation in source area (tonnes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coconut</td>
<td>Coir</td>
<td>0.41</td>
<td>2009</td>
<td>939,080</td>
<td>385,023</td>
<td>75.9</td>
<td>712,762</td>
<td>292,232</td>
</tr>
<tr>
<td></td>
<td>Husk</td>
<td>1.03</td>
<td></td>
<td></td>
<td>967,252</td>
<td></td>
<td></td>
<td>734,145</td>
</tr>
<tr>
<td>Rice</td>
<td>Husk</td>
<td>0.2</td>
<td>2005</td>
<td>2,006,388</td>
<td>401,278</td>
<td>31.5</td>
<td>632,012</td>
<td>Not applicable</td>
</tr>
<tr>
<td></td>
<td>Straw</td>
<td>1.76</td>
<td></td>
<td></td>
<td>3,531,242</td>
<td></td>
<td></td>
<td>1,112,341</td>
</tr>
<tr>
<td>Sawn wood</td>
<td>Sawdust</td>
<td>0.35</td>
<td>2010</td>
<td>606,000 (projected)</td>
<td>212,100</td>
<td>24.2</td>
<td>146,652</td>
<td>51,328</td>
</tr>
<tr>
<td>Sugar cane</td>
<td>Bagasse</td>
<td>0.29</td>
<td>2005</td>
<td>991,550</td>
<td>287,550</td>
<td>25.2</td>
<td>250,000</td>
<td>72,500</td>
</tr>
</tbody>
</table>

Note 1: Coconut RPR values calculated from Sepalage (1986); rice, sawn wood, and sugar cane RPR values from Perera (2005).

Note 2: Coconut production from the Department of Census and Statistics (2002); sugar cane production from the Department of Census and Statistics (2005); sawn wood production from Perera (2005); rice production from the Department of Census and Statistics (2010).

Note 3: Generation of coconut and rice in the source area was assumed to be proportional to the extent of the crop in the source area, calculated from the Department of Census and Statistics (2002); generation of sawn wood in the source area was assumed to be proportional to the number of sawmills within the source area, calculated from Gunatilake and Gunaratne (2002) and Perera et al. (2005). Generation of sugar cane in source area calculated based on product generation of Sevanagala Sugar Industries (W.R.G. Witharama, 2011, pers. comm., 22 August).