Virtuous Circles: Values, Systems and Sustainability

Andy Jones, Michel Pimbert and Janice Jiggins

Reclaiming Diversity & Citizenship

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Values, Systems and Sustainability

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Table of Contents

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Foreword and in memory of Andy Jones

I warmly welcome this book's contribution to the debate on how food systems can be redesigned and re-localised to sustain diverse local ecologies, economies and human well being. The authors rightly emphasise the need for a systemic and fundamental transformation of industrial food and farming in the face of peak oil, climate change, biodiversity loss, the water crisis, food poisonings, and the impoverishment of farmers and rural communities.

But rather than look at food and agriculture in isolation, the authors of this book consider ways of re-integrating food and energy production with water and waste management in a diversity of local contexts in rural and urban areas, - and at different scales. They offer a vision of how policies and technologies can be combined to make the shift from linear, centralized and globalised ways of providing basic needs to more circular systems based on principles of agroecology, ecoliteracy, eco-design and local control. In effect, this timely and richly illustrated book shows how the very means of life (food, energy, water, shelter, income generating activities…) can be transformed for ecological sustainability and local democratic control by communities of citizens.

Sadly, this book was just about completed when its lead author, Andy Jones, met with a sudden death on 17th November 2010. Between 2008 and 2010 Andy was a much respected researcher associated with IIED's Agroecology and Food Sovereignty Team. He brought fresh ideas, enthusiasm and positive energy into IIED's work on *Designing Resilient Food Systems With, By and For People*. Before IIED Andy worked on several major policy research initiatives and publications on food, agriculture and land use, - including "Stopping the Great Food Swap. Relocalising Europe's Food Supply" published by The Greens at the European Parliament. All of us who had the pleasure of working with Andy knew how much he was a tireless, energetic, and passionate human being who was committed to bringing about more sustainable and socially just food systems. His friends and colleagues will miss him. But his vision and contributions will live on to inspire many other people who are looking for ways out of the dead end of corporate controlled, industrial food systems.

Dr. Caroline Lucas, MP
Green Party of England & Wales

About the Authors

Andy Jones has a PhD in the Environmental Impacts of Alternative Supply chains and worked as a research associate with the Agroecology and Food Sovereignty Team at the International Institute for Environment and Development (IIED) between 2008 and 2010. He is the author of *Eating Oil: Food Supply in a changing climate* as well as several publications that explore the links between energy, food security and affordability.

Janice Jiggins is a Visiting Fellow at IIED. She is a social scientist who has worked for leading international development agencies in Africa and South Asia for more than thirty years, in the fields of farming systems research, participatory technology development, and gender issues. She studies and writes on agricultural and food systems development and sustainable resource management in Europe, sub-saharan Africa, India, and internationally. More recently, Dr. Jiggins was a co-author of the International Assessment of Agricultural Knowledge, Science and Technology for Development.

Michel Pimbert is Principal Researcher and Team Leader for Agoecology and Food Sovereignty at IIED. He is also the Deputy Chair of the Commission on Environment, Economic and Social Policy (CEESP) of The World Conservation Union (IUCN). Dr. Pimbert's work centres on food sovereignty and citizenship, sustainable agriculture and livelihoods, the political ecology of natural resource and biodiversity management, as well as participatory action research and deliberative democratic processes.

Executive Summary

In recent years, simultaneous crises in energy costs, the price and availability of food, water supplies, biodiversity loss, the financial system and climate change have all had a major impact on lives and livelihoods across the globe. Energy prices have increased sharply in most countries during the last few years and the price of a barrel of oil reached $147 during the summer of 2008. The latest surge in food prices has been the most marked of the past century in its magnitude, duration and the number of foodstuffs affected – some food products increased in price by between 50 and 200%. For many households there has not only been a large increase in the cost of food, but also of electricity, fuel, water and other basic needs. These sharp price rises have driven more people into poverty and meant that an additional 100 million people can no longer afford to eat adequately; for the first time since 1970, the number of undernourished people in the world is over one billion.

Indications are that this situation is unlikely to improve. The International Energy Agency (IEA) predicts that global energy demand will increase by 40% by 2030, while at the same time oil and gas production will decline significantly and prices increase sharply. If this demand for energy is met by fossil fuels then average global temperatures could increase by up to 6°C this century—an increase that will have dramatic impacts worldwide. The impacts of climate change on agricultural output and water supplies in particular will exacerbate the situation, and the end result will be a world spiralling ever more rapidly into a vicious cycle of food shortages, climate chaos, famine and disaster.

This book paints a vivid picture of an alternative future: sustainable and fair systems for the provision of food, energy, fibre and textiles, housing and water that are environmentally benign and involve positive interventions in natural cycles. While their environmental impacts are negligible, non-existent or positive, their socio-economic benefits are multiple and significant. The book is an output of a project known as Designing Resilience (Box 1), and documents the initial findings from the first phase of Designing Resilience within the Latin America and Caribbean region.

Craig Mayhew and Robert Simmon, NASA GSFC

Box 1. Designing Resilience

The Designing Resilience project is part of ‘*Designing Resilient Food Systems with, by and for People*’—a collaborative research and communication programme co-ordinated by the International Institute for Environment and Development (IIED) in Africa, China, the Andean region of Latin America and the Caribbean, and parts of Europe. Several concepts and values form the foundations of the Designing Resilience project. These include ecoliteracy, circular systems, food sovereignty, limits, eco-communities, agroecology and permaculture, the carbohydrate economy, the proximity principle, co-operative structures and sustainability. The research approach is based on systems analysis, which encourages a comprehensive, cross-disciplinary and holistic approach. We have chosen this over sectoral analysis—looking at food, water or energy in isolation—which can overlook the root causes and links between problems as well as sustainable solutions. We call our approach ‘joining the dots’ because integrated approaches avoid the problems of looking at systems in a piecemeal, fragmented way. We advocate an approach in which all options for a given need are assessed from a lifecycle perspective: production systems and supply chains are modelled and resource inputs as well as outputs, in the form of pollution and waste are quantified.

Linear thinking and vicious circles

There are two basic reasons underlying the food, energy, water and climatic crises:

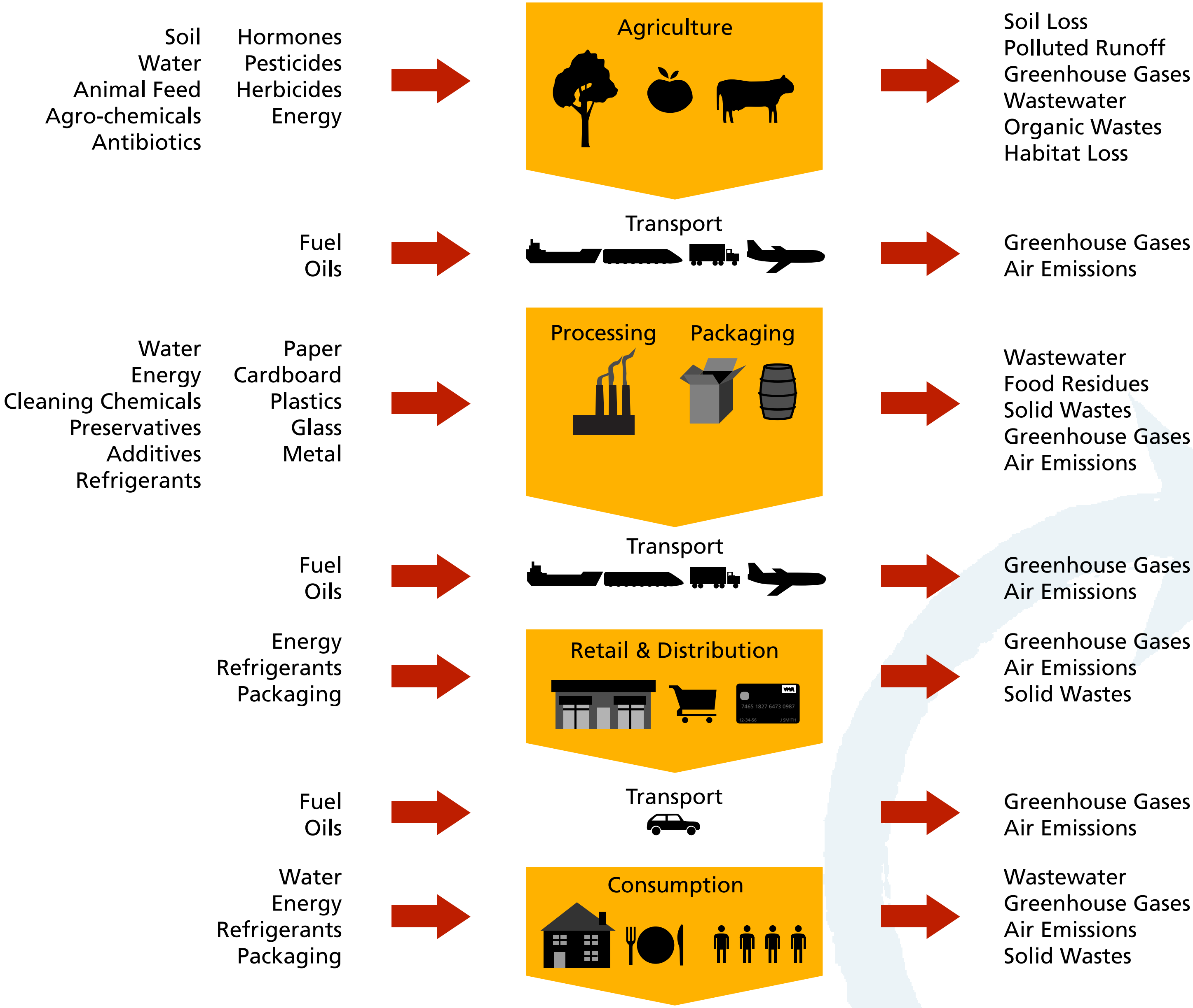
1) The systems that have evolved to supply us with our basic needs are totally dependent on fossil fuels; the inevitable consequence of this is large amounts of greenhouse gas emissions, as well as solid waste and water and air pollution. It is especially unsustainable given that the era of cheap energy, crude oil and natural gas in particular, is about to end.

2) Our current way of providing basic needs – be they food, water, waste management or energy - involves industrialised systems that are linear, centralised and globalised (Figure 1). In the linear approach, it is assumed that at one end of a system there is an unlimited supply of energy and raw materials (which there isn’t), while at the other the environment has an infinite capacity to absorb pollution and waste (which it hasn’t). The inevitable result is resource shortages on the one hand and solid waste, climate change and air pollution problems on the other.

Unsustainable energy and climate change

Our addiction to fossil fuels means that virtually everything we eat, purchase or do is dependent on crude oil, natural gas and their derivatives. A linear approach to the supply of electricity, in which the combustion of finite resources results directly in carbon dioxide and other polluting emissions, has large and widespread consequences. Globally, the electric power sector is by far the most important source of global anthropogenic CO_2 emissions. Increasing demand for fossil fuels, particularly in OECD and transition countries such as China, Brazil and India, is contributing to higher energy costs. More importantly, prices are increasing due to supply constraints and the peaking of oil production. ‘Peak oil’—the point at which half of the total oil

Figure 1: The Linear Approach to Food



known to exist has been consumed, and beyond which extraction goes into irreversible decline—means that every time demand grows the price of oil (and gas) will rise, and will do so ever more steeply as supply constraints increase.

Unsustainable food production

The causes of the food crisis appear to be complex and multi-faceted. These include poor harvests due to unusual weather events; the use of agricultural land to produce biofuels instead of food; market speculation and profit-taking by agribusiness corporations; and rising energy costs pushing up the price of fertilisers, pesticides and the fuel used to power farm machinery and to distribute food. Some commentators see the food crisis as a sign of structural meltdown in the food system, the direct result of industrial agriculture, unsustainable food chains and three decades of neoliberal globalisation. Industrialised farming consumes 50 times the energy input of traditional agriculture; in the most extreme cases, energy consumption by agriculture has increased 100 fold or more. It has been estimated that 95% of all food products in European countries require the use of oil. The manufacture of synthetic fertilisers is also energy-intensive—fertiliser use typically accounts for around one-third of agricultural energy consumption. As energy costs have increased in recent years so have fertiliser prices.

Another key problem is the emergence and increasing market share of multinational corporations. In OECD countries multinational food retailers typically account for 70-80% of food sales. Supermarket expansion in the South has been even more rapid than in the North, with similar consequences. These include a shift to: more industrialised farming systems; larger farms and a decrease in the number of small family farms; food being transported much longer distances; increasing food

imports; more processed and packaged foodstuffs; and increased consumption of fats, sugars and salt resulting in higher levels of diet-related ill-health. As the power of multinational food companies grows, their decisions affect more people and the negative environmental and socio-economic impacts become more widespread and prevalent.

Unsustainable water and waste systems

More than 2.6 billion people worldwide lack access to adequate sanitation services and 1.1 billion must still defecate in the open. In high income countries people turn on a tap to access unlimited supplies of fresh water and go to the toilet where they can flush and forget. Neither of these approaches is sustainable. The 'modern' sanitation systems being introduced in many countries in the South are inadequate because they are based on a linear, industrial world-view in which sewage is disposed, 'somewhere' rather than recycled. The system involves uni-directional flows of food and nutrients from farms in the countryside to the city, which are then converted to sewage and dumped, treated or untreated, into rivers or directly into the sea. The lost nutrients are never returned to the land, and instead, combined with soluble synthetic fertilisers running off agricultural land, result in eutrophication and the formation of toxic algal blooms in freshwater and marine environments.

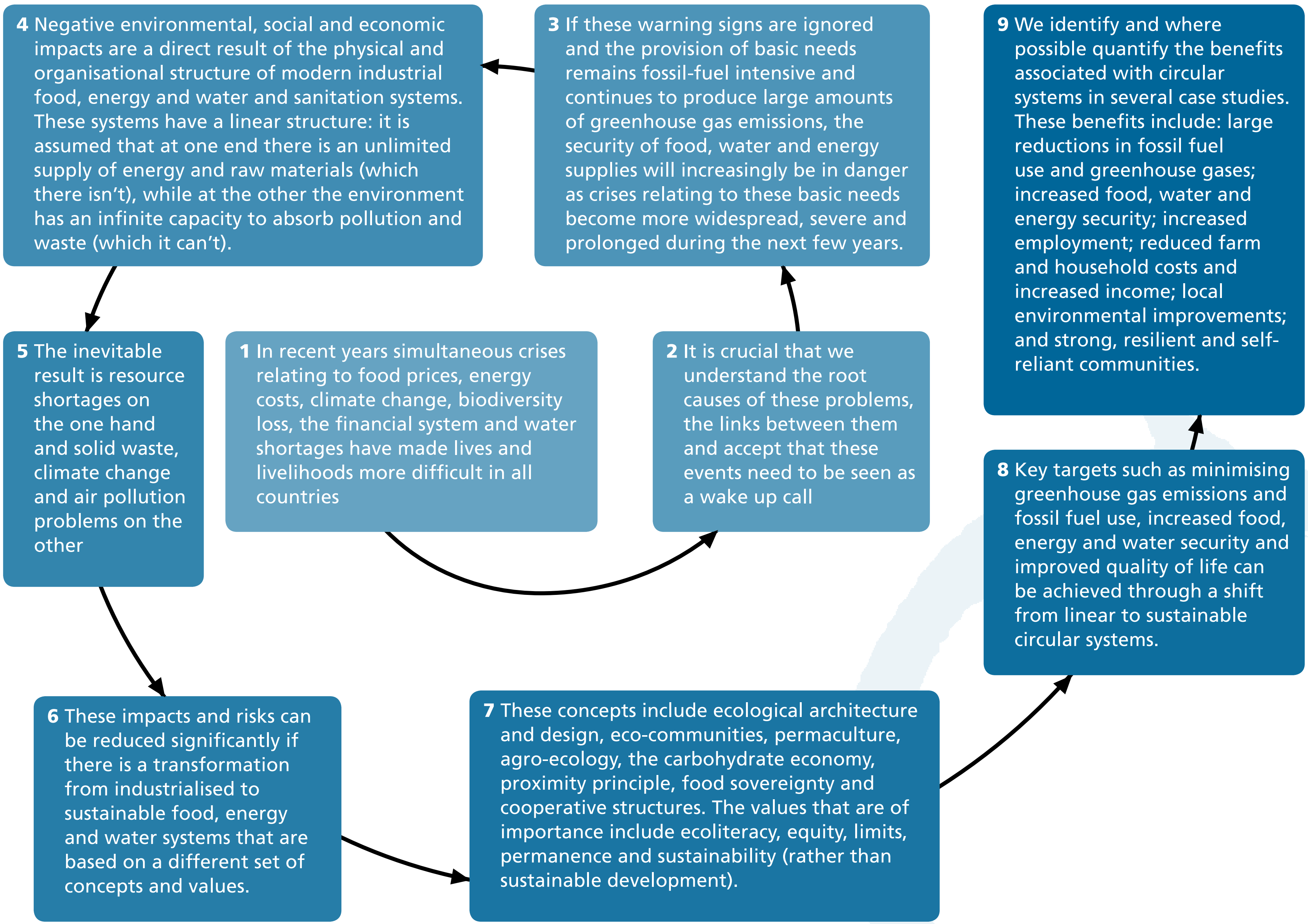
Joining the dots: highlighting the links between these problems

If we take a closer look behind many of these problems, we can see how interlinked they are and how much our reliance on fossil fuels is fuelling the vicious cycles of unsustainability:

- The shift to biofuels, based on industrially produced crops, is a naive attempt at energy security in a peak oil era—often, replacing fossil fuels with biofuels does not reduce greenhouse gas emissions, uses more energy than it produces and requires vast amounts of land that should be used to grow food.
- Along with the increasing competition for land between different uses, other constraints are also becoming more critical. These include water supplies and other finite resources, such as phosphorus and soil, which has become increasingly eroded and degraded.
- The water shortages and extreme weather events that have resulted in lower crop yields and crop losses are probably due to climate change; the primary cause of climate change is fossil fuel use.
- Agriculture is a major contributor to climate change due to emissions of methane from livestock, nitrous oxide from synthetic fertilisers, the release of carbon from soils when ploughed, as well as carbon emissions from fuel use on farms and during the manufacture of inputs such as fertiliser. Worldwide, agriculture and land use changes related to agricultural activity alone are responsible for about a third of the world's greenhouse gas emissions.
- Globalised food chains are another major contributor to climate change given the amount of transportation involved.
- In its turn, climate change reduces farm output and the availability of food.
- The production of energy from fossil fuel or industrial biofuels consumes large quantities of water. This is water that could in many cases be used for food production or for drinking….and so it goes on.

All of these factors combine to pose an increasing threat to livelihoods and the provision of basic needs (Figure 2).

Figure 2: Vicious Cycles: The Hypothesis



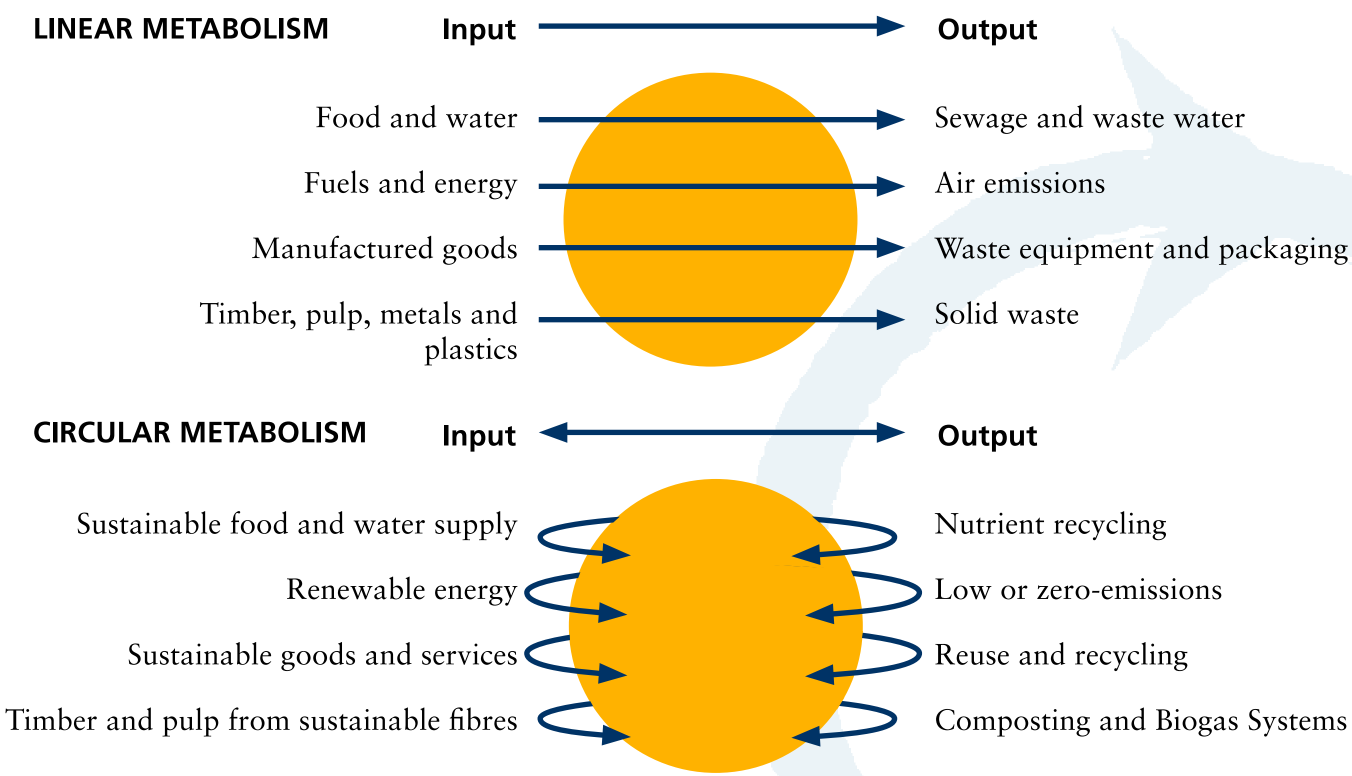
From vicious cycles to virtuous circles

The imperative now is for change. Whether the primary reason for this is increasing energy and fuel costs; the security of food, water and energy supplies; or the need for large cuts in greenhouse gas emissions—or all of these— a fundamentally different approach is required and it will need to begin very soon. So far, national and international policy and decision makers have ignored calls for a fundamental rethink and many questions remain unaddressed. For example can the current systems of food production, processing, packaging, distribution and retail achieve the required cuts in greenhouse gas emissions or will alternative systems need to be developed? How will food, energy and transport systems be powered following the fossil fuel era? Can renewables meet energy requirements in the current food system? Are supermarket systems compatible with the goals of sustainability or is it now time to contemplate a post-supermarket era?

An alternative to the current linear paradigm is to develop productive systems that minimise external inputs, pollution and waste (as well as risk, dependency and costs) by adopting a circular metabolism. There are two principles here, both reflecting the natural world. The first is that natural systems are based on cycles, for example water, nitrogen and carbon. Secondly, there is very little waste in natural systems. The 'waste' from one species is food for another, or is converted into a useful form by natural processes and cycles (Figure 3).

Figure 3.

Settlements with a linear and a circular metabolism



Source: adapted from Girardet, H (1996) *The Gaia Atlas of Cities: New Directions for Sustainable Urban Living*. Gaia Books Ltd., London

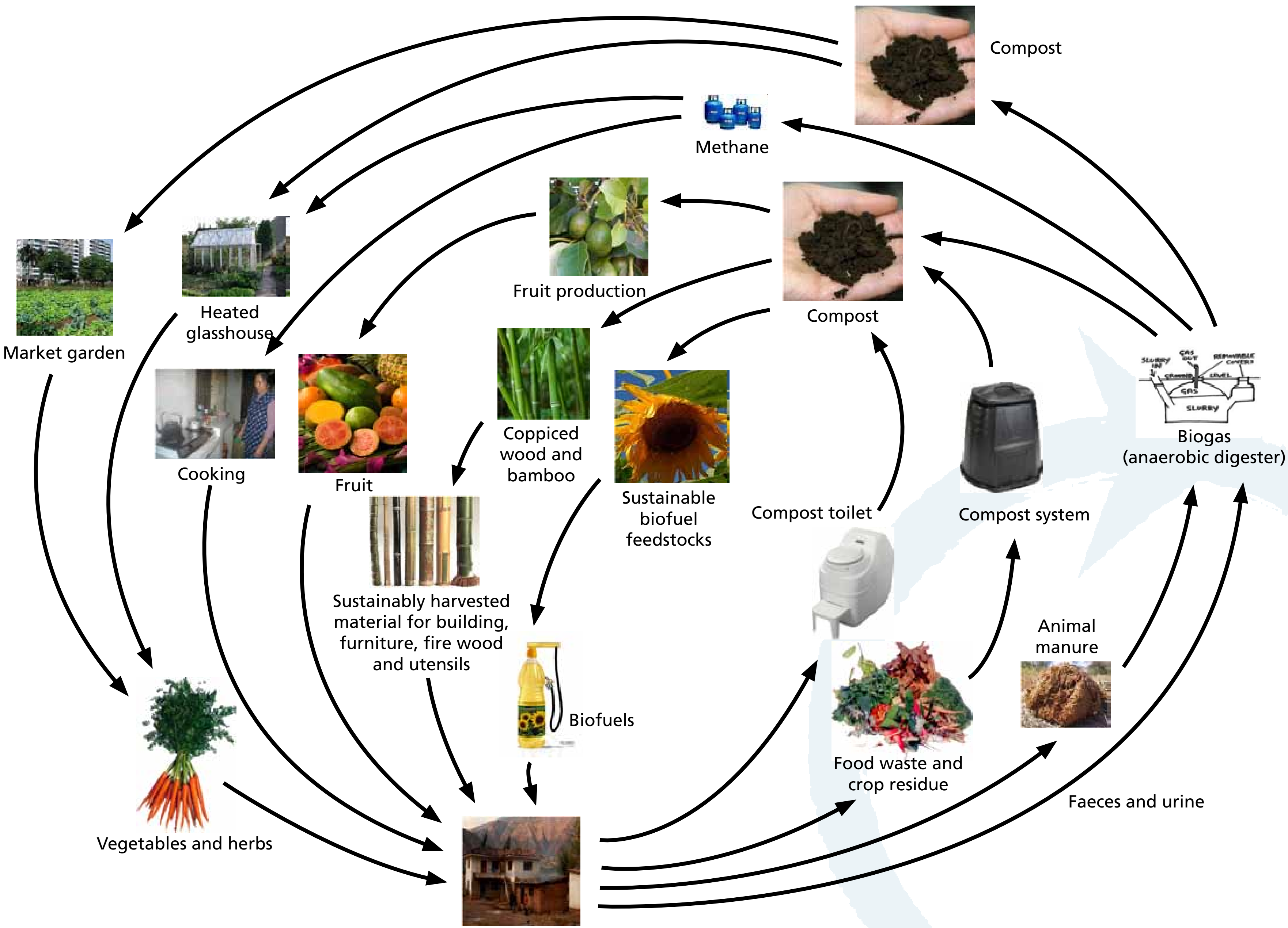
If these principles are applied to human needs we can create systems and settlements that provide food, energy and water; that do not consume large quantities of fossil fuels and other finite resources; and that also maximise the possibilities for recycling and reuse. In the process, greenhouse gas emissions, air pollution, water pollution and solid waste are minimised.

The example in Figure 4 is of a composting and biogas system that can provide food, household and farm energy needs, fertiliser for crops and trees and construction materials. It also avoids many problems associated with current approaches to waste management, sanitation and food and energy supplies.

The aim of the initial stages of the Designing Resilience project has been to identify the key characteristics of these localised, closed loop, low external input systems. These systems vary enormously in terms of their structure, how they function and their geographic and physical scale, as they are adapted to local conditions, capacities and culture. However, we have identified common themes that contribute to resilient, sustainable and integrated food-energy-waste-water-fibre-housing systems:

- Self reliance and the proximity principle
- Low external input, regenerative systems of food production
- Appropriate scale and technology
- Diversity, multifunctionality and complexity
- Stability, security and safety
- High levels of reuse and recycling so that a large proportion of resources and 'wastes' remain in the system or locality
- Vibrant local organisations to sustain them

Figure 4. A composting and biogas system to provide food; household and farm energy needs; fertiliser for crops and trees; and construction materials



Self reliance and the proximity principle

Circular systems for food, energy, water and fabrics can be optimised when they are localised. Local and regional sourcing of food from allotments, community food projects or through home delivery box schemes or independent retailers is environmentally efficient. The products that cannot be supplied by local producers are sourced within the district or province or through fair trade initiatives, using ships rather than air transport.

Low external input, regenerative systems of food production

Highly sustainable agricultural systems aim to make the best use of environmental goods and services whilst not damaging these assets. The key principles for sustainability are:

- Integrating biological and ecological processes such as nutrient cycling, nitrogen fixation, soil regeneration, competition, predation and parasitism into food production processes.
- Minimising inputs which have to be brought in from outside the system or locality. These include synthetic pesticides and fertilisers, animal feed and energy (electricity and fossil fuels).
- Applying the principles of agro-ecology and permaculture to all scales of food production: from growing a few plants in containers in a small city garden to relatively large farm holdings. Manure and other biodegradable material (crop residue, paper and card) from the farm and the local community are composted or passed through a biogas system to provide nutrients, trace elements, minerals and energy.
- Making productive use of the knowledge and skills of farmers, so improving their self-reliance and substituting human capital for costly external inputs.

T.M. Thiyagarajan. The System of Rice Intensification.

- Making productive use of people's collective capacities to work together to solve common agricultural and natural resource problems, such as for pest, watershed, irrigation, forest and credit management.

- Applying the principles of food sovereignty—the right of peoples to define their own food, agriculture, livestock and fisheries systems—in contrast to having food largely subject to international market forces.

Appropriate scale and technology

In the contemporary food system, the main driver of change during the last 50 years has been increased economic efficiency through economies of scale. This has led to the application of industrial practices and a culture of 'bigger is better' that permeates every link in the food chain. In circular systems, as farm and energy inputs are sourced and food products distributed locally, a reduced geographic scale is accompanied by the production of a wider range of foodstuffs in urban, peri-urban and rural areas in gardens, allotments, on farms and in market gardens. Food is processed on the farm or in small local processing units and there is a significant shift away from large-scale, centralised electricity generation to decentralised small-scale renewable energy systems.

Diversity, multifunctionality and complexity

In sustainable food and energy supply chains, specialisation and centralisation are replaced by diverse localised food and energy production. Diverse food production systems, based on permaculture and agro-ecological approaches, minimise pests, maximise economic benefits and minimise risks, as well as ensuring a diverse food supply throughout the year. This will require a shift away from monocultures in which large areas are devoted to the production of a small number of (or perhaps a single) crops or livestock. In the case of energy, diverse, local renewable supplies mean that households, farms and communities can avoid the costs and risks associated with the purchase of imported electricity and fossil fuel supplies.

Stability, security and safety

Security applies to household and farm income as well as employment. It also relates to systems that can ensure food, energy and water security. Economic security for farmers is improved through direct links between themselves and the consumer – locally through direct marketing or internationally through fair trade initiatives. This security allows food producers to diversify and expand their product range which contributes, both directly and indirectly, to local employment and regeneration. This provides a viable and sustainable alternative to dealing with the multiple retailers, exporters and middlemen. Food and energy security are also improved and dependency – on oil, food imports, farm inputs, the whim of supermarket buyers and fluctuating prices on international commodity markets – is minimised.

Reuse and recycling

The predominant systems for the supply of goods and services, because of their linear structure, result in vast amounts of solid waste. Only a very small fraction of this waste is recycled, reused or composted: this applies to OECD countries and countries in the South. In circular systems the aim is to develop zero-waste by reducing external resource inputs, and re-using and recycling materials (organic matter, sewage, animal manure, metals, glass and plastics) that are currently treated as waste. When this is not possible, as is often the case with plastic material, they are replaced by alternative materials. Biogas systems, composting and wormeries can all convert waste into useful energy and nutrients that can be reused in the system.

Local organisations to sustain circular systems

Local organisations have always been important in facilitating collective action and co-ordinated management of food systems and their environments at different spatial scales. Local organisations— individually and collectively—play a key role in:

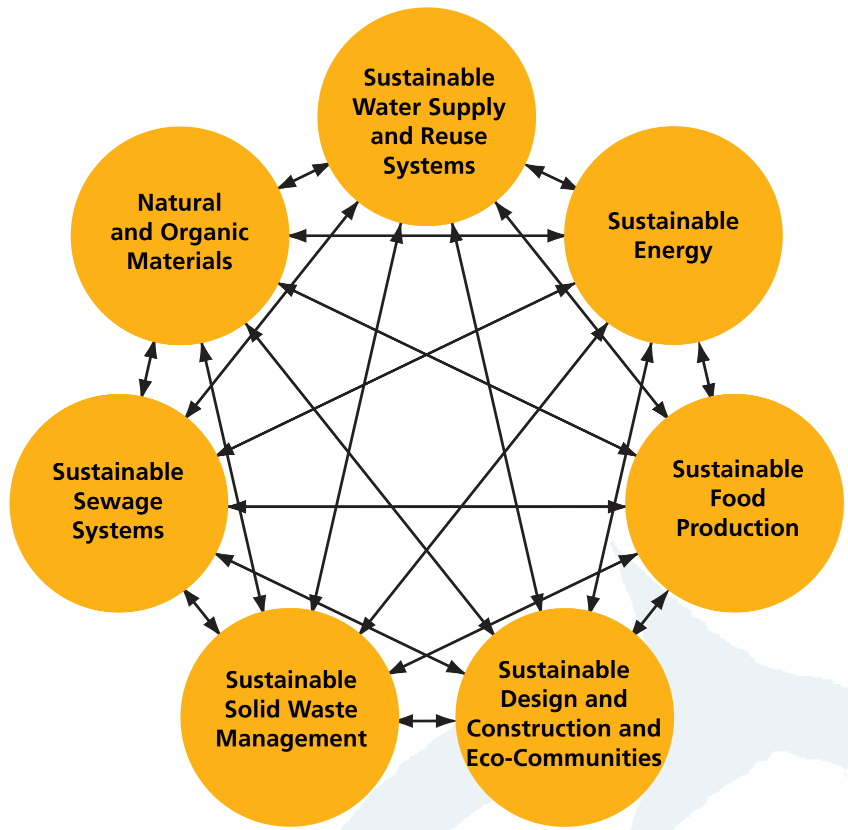
- sustaining the ecological basis of circular systems that combine food and energy production with water and waste management in rural and urban areas;
- co-ordinating human skills, knowledge and labour to generate both use values and exchange values in the economy of these multifunctional circular systems; and
- the local governance of circular systems, including decisions about people's access to food, energy, water, clean air and other resources.

Joining the dots: integrating circular energy, food and water systems

Most sustainable food, water, energy and waste systems have been implemented in isolation. However, greater synergy can be obtained when ecological agriculture, renewable energy systems and sustainable water and waste management systems are all integrated. This can contribute to food, water and energy security and also to financial security and poverty reduction. The aim of Designing Resilience is to highlight the synergy involved when all of these factors are considered from the outset and these systems are integrated and developed simultaneously.

There have been many positive developments in the implementation of sustainable circular systems in recent years. In the main report we highlight the social, economic and environmental benefits of circular systems in several case studies from the Andes, Asia, Cuba and Ecuador. These benefits can be significant and include large reductions in fossil fuel consumption and greenhouse gas emissions and increased food, water and energy security (Table 1). Other benefits that we have identified include:

- Increased local employment that is meaningful, secure and rewarding.
- Increased income from additional output and reduced input purchases
- Energy, food and water security: supplies that are reliable, safe and low cost (or free) once systems have been established.
- Improvements in the local environment – less waste, water and air pollution, vermin and disease.
- Reducing or avoiding the risks, dependency and costs associated with high-external inputs/supplies – for food, fossil fuels (for energy, transport and machinery), fertiliser (and other farm inputs) and other materials.



- Contributing to the creation of strong, resilient and self-reliant communities, including local and direct links between households and productive systems, which means that supply chains are clearly visible and distancing effects avoided
- Co-operative, fair and equitable systems based on participatory approaches to decision making and planning.

top: Biogas digester, Nepal. bottom: Biogas digester, Vietnam. www.snvworld.org

Table 1. The main household benefits of a biogas plant in the SNV Biogas Support Programme in Nepal

Benefits to household	Details
Reduction of workload (especially for women)	1,100 hours per year (3 hours per day)
Improvement of sanitation and health	No indoor pollution. Introduction of toilets as part of the biogas plant (for 72% of all plants). Improved dung management
Reduced firewood use	2,000kg per year
Reduced kerosene use	32 litres per year
Reduction of greenhouse gas emissions	4,900kg per year (as per 2005 Clean Development Mechanism rules)
Increase of agricultural production resulting from improved soil structure and fertility	Availability of agricultural residue (1,000kg per year) and dried manure (500 kg per year) originally used for cooking
Savings of chemical fertiliser per year	39kg nitrogen 19kg phosphates 39kg potash

Source: Nes, W. *et al* (2009) Building Viable Domestic Biogas Programmes. SNV; October 2009. At www.snvworld.org/en/Documents/SNV_Building_viable_domestic_biogas_programmes_2009.pdf

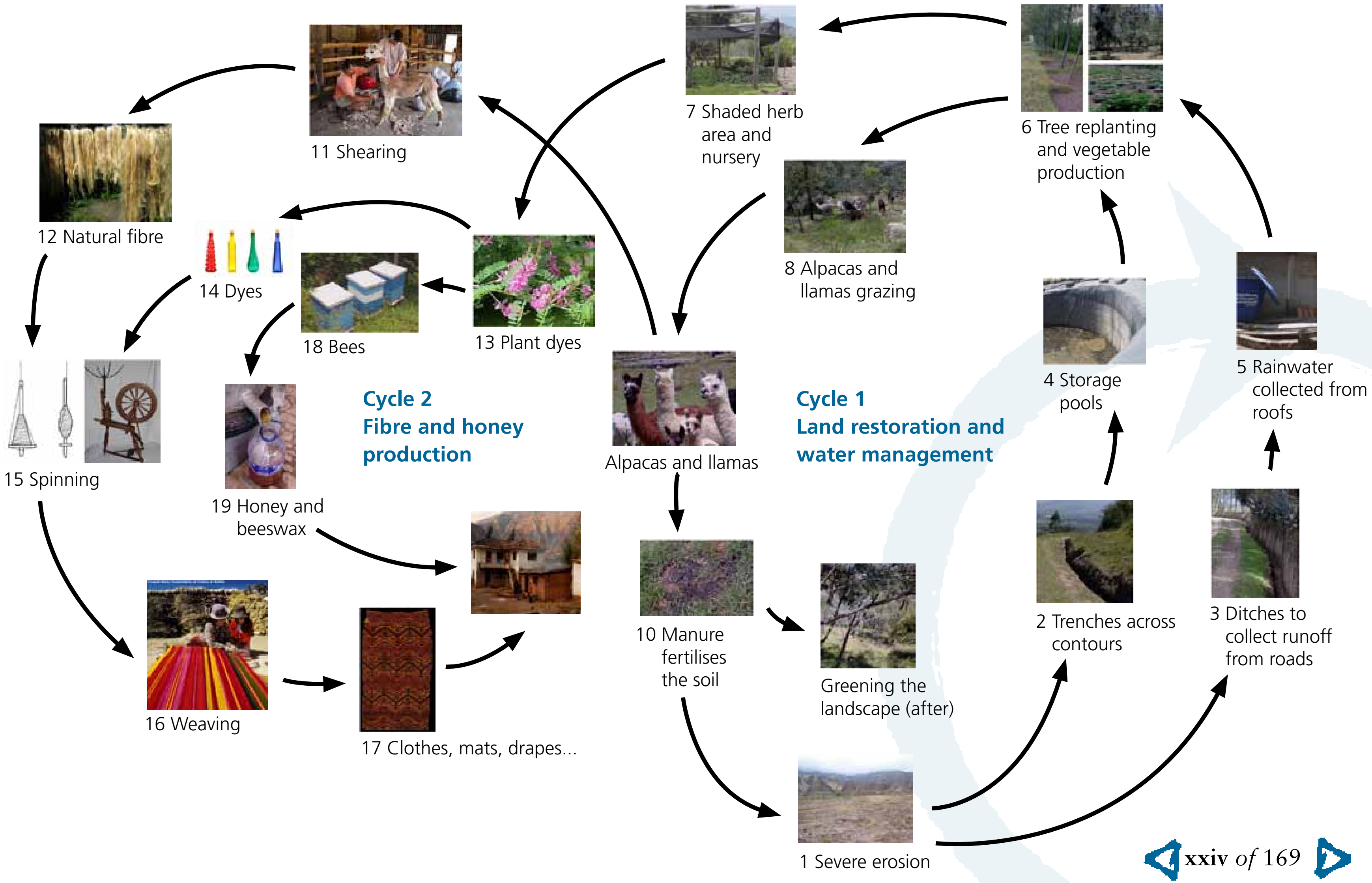
There are an increasing number of such practical examples of successful initiatives, some of which involve integrated approaches (Figure 5). However, they remain isolated examples and in most countries food and energy supply is based either on industrial models or unsustainable use of local natural resources. The challenge now is to replicate sustainable projects on a much wider scale.

Figure 5. Sustainable water systems, greening the landscape and the production and processing of natural fibres and honey in Ecuador

Notes: Severe erosion caused by over-grazing and the clearance of vegetation to produce charcoal makes livelihoods and food production increasingly difficult. These photographs are from projects on the Ilalo mountain area near Quito in Ecuador. To harvest rainwater, trenches are dug across contours in the landscape (2) as well as ditches to collect runoff from roads (3). These are linked in a network of trenches and storage pools (4). This, together with rainwater collected from roofs (5) provides water to irrigate the trees, plants and grasses that have been reintroduced (6).

Alpaca and llama are now able to graze (8) and there is sufficient water for herb, flower and vegetable beds (7). The animal manure (10) together with green manures, mulch, compost and biogas fertilizer improves soil structure, fertility and water-retention. Alpaca and llama hair comes in many colours, but can also be dyed using natural plant dyes (13). The fibres are spun (15) and woven (16) into clothes and other fabrics (17). Bees (18) can also be introduced to produce honey and beeswax (19) and to pollinate plants and fruit trees.

In many places rainwater collection, storage and use can be totally based on gravity - where water flows into a series of pools then to areas requiring irrigation. If this is not possible, solar, wind or hand pumps are used. Water can be channelled to where it is required, connected to drip irrigation and sprinkler systems and piped under roads and paths. Settlement tanks are used to reduce blockages and trap valuable nutrients. These are cleared as required and the sediment used as compost on nearby beds.



Recommendations

The current crisis can and should be seen as an opportunity to discuss, design and develop truly sustainable systems to meet the need for food, water and energy. However, this will require a paradigm shift and an acceptance that values, objectives, policies and economies in the North and the South will have to change dramatically and soon. Reversals in policies, legislation and market rules are needed to make the following shifts to sustainability:

- From mining the soil to managing nutrient cycles.
- From managing water use to managing hydrological cycles.
- From proprietary technologies and patents on biodiversity to legal frameworks that recognise farmers' rights and guarantee equitable access to diverse seeds and livestock breeds.
- From investment policies that favour land grabs and displacement of local communities to policies that support equitable access, use and local control over land and territories in both urban and rural contexts.
- From investments in research and development that favour energy and resource intensive systems to support for decentralised and integrated food, energy, water and waste management systems based on principles of agroecology, ecoliteracy, ecodesign, biomimicry, socio-ecological resilience, equity and democratic control.
- From global, uniform standards for food and safety to a diversity of locally evolved food standards that meet food and safety requirements (from seed to plate).
- From support for centralised and capital-intensive energy systems to policies and legislations that promote innovations and internal markets for decentralised, distributed micro-generation of renewable energies (solar, wind, biogas….).

As part of this paradigm shift we suggest the following practical recommendations for individuals, communities, non-governmental organisations (NGOs) and policy makers at the local, national and international level:

- Adopt as a key policy objective the identification and rapid development of sustainable food, energy and water systems based on circular economy models. This process should be based on clear targets including minimising GHG emissions and fossil fuel use and increasing food and energy security and sovereignty at the local level.

http://www.feasta.org/events/foodconf/food_conference.htm

- Reformulate agricultural, energy, trade and development policies specifically to promote sustainable food, energy and water systems. This will include designing institutional frameworks and regulatory processes that support and sustain circular systems capable of self-renewal and high production.

- Introduce stricter measures to internalise the external environmental and social costs of food, energy and transport systems, and use the resulting revenues to support sustainable initiatives. Large corporations involved in the food, agriculture, energy, water and waste management sectors should be the main—but not exclusive—targets of these measures. This policy would act as a driver of change in terms of a shift to sustainability and the transition to a low carbon economy.

- Introduce fiscal measures such as tax incentives to encourage the shift to sustainable systems. Relatively small taxes on financial exchange market speculations (e.g. Tobin tax and similar proposals) —and on other global money transactions— should be introduced through a multilateral agreement. This decision alone will generate immediate and substantial funding for the design and spread of circular systems that regenerate local ecologies and economies for the public good.

- Design and implement a major eco-literacy programme to raise awareness of the hidden environmental and social problems caused by our current linear systems, and the alternative options for supplying food, energy and water that minimise risks and negative impacts.

- Introduce local research, demonstration and training centres which focus on sustainable food, energy and water systems. These centres will provide advice and training and demonstrate best practice in order to develop a new skills and knowledge base. They should be designed so as to strengthen local knowledge systems, organisations and institutions, thereby enhancing capacities for local innovation and their horizontal spread to more people and places.

- Build on farmers and other citizens' proposals for transformation (such as the food sovereignty movement) as part of a larger paradigm shift towards food and energy sovereignty.

Virtuous Circles:
Values, Systems and Sustainability

**...and remove the filters that conceal
the social and environmental impact of current policy and practice**

1. Introduction

1.1. Designing Resilience

This book paints a vivid picture of sustainable and fair systems for the provision of food, energy, fibre and textiles and water that are environmentally benign and involve positive interventions in natural cycles. While their environmental impacts are negligible, non-existent or positive, their socio-economic benefits are multiple and significant.

The book is an output of a project known as Designing Resilience. The Designing Resilience project is part of *"Designing Resilient Food Systems With, By and For People"* — a collaborative research and communication programme co-ordinated by the International Institute for Environment and Development (IIED). A broad platform of co-inquiring partners furthers the objectives of this programme in Africa, China, the Andean region of Latin America and the Caribbean and parts of Europe. The co-inquiry process is designed to strengthen the capacity, knowledge and innovations of local organisations of farmers, indigenous peoples, pastoralists, food workers and other citizens to bring about positive change in meeting human needs.

Comparative policy and field work in a range of different settings allow IIED and its partners to simultaneously focus on both the technological and institutional transformations needed to promote resilient food, energy and water systems for the 21st century. This is done through two complementary research streams:

1. An assessment of the options available to meet basic needs: with a focus on the structure and geography of production systems and supply chains.

2. Policy research, focusing on the following questions: how, and under what conditions, can new institutions for resilient food and farming systems be designed and mainstreamed? What "rules of the game" and institutional arrangements might confer transition toward resilience in conditions of heightened risk and irreducible uncertainty?

We describe the main themes and document the initial findings from the first phase of Designing Resilience within the Latin America and Caribbean (LAC) region (Box 1).

The options for sustainable livelihoods in both rural and urban settings are assessed, with the aim of identifying, describing and disseminating information as widely as possible on food, water, textile and fibre, energy and sanitation systems that have minimal environmental impact while improving the quality of life of all those involved.

Although this aim may appear to be uncomplicated and clear-cut, there is major disagreement on how it can be achieved. In fact the debate on what constitutes sustainable products, systems and supply chains is polarised and a consensus is extremely unlikely. The two schools of thought within this polarised debate can be illustrated by the case of agriculture and food chains, where there are loosely two visions of the future of food and farming. The first is basically a continuation and acceleration of current trends: a shift to larger, more specialised, corporately-controlled farms; foreign direct investments in land that displace local people or push them into contract farming and 'joint ventures' schemes for the export of agricultural commodities; food supply chains that are more energy and carbon intensive; increasing use of genetic engineering; further supermarket expansion; and financial speculation on food commodities. The second scenario involves food sovereignty and more localised food systems together with a large increase in fair trade (for products that cannot be sourced locally). Agroecology replaces industrial farming and the aim throughout the food chains is to minimise environmental impact, maximise the use of renewable energy, enhance human well being and food justice. Food production is based on diverse, biodiversity-rich, small-scale and farmer-owned or co-operatively run farms, market gardens, urban agriculture, and

Box 1. Geographic focus

The initial focus has been on Latin America and the Caribbean (LAC), with most of the case studies drawn from this region. However, examples of good practice in other regions are included. Although the analysis centres on LAC and other regions in the South, we also assess food, energy, water and sanitation systems in the North and trends here in recent decades. The reason for considering these issues in Europe and other OECD countries is four-fold:

Food and energy policies and systems in the North have an enormous impact on farmers and communities in the South. This has a long history that covers colonisation and, more recently, rapid globalisation.[1] This includes the appropriation of resources, dumping of subsidised food in the South and food exports from the South to the North via increasingly concentrated multinational food trading and retail sectors. The shift to transport biofuels in the North has also had an impact on countries that rely on food exports from the North, a situation that could worsen if industrial biofuel production in the South expands as many have predicted (Houtart, 2010).

The industrialised linear approach to food, energy and water supplies that predominates in the North is being adopted in the South. The processes involved include foreign direct investments in agriculture, energy, water and sanitation systems. For example, multinational supermarket chains and food processors and traders are expanding rapidly in the South. This is having major impacts on agriculture—particularly for smallholders and traditional fresh produce markets (see Box 8 for an example).

If this shift continues to take place in the South, the consequences in terms of climate change and food, energy and water security will be severe.

The systems that we describe, although developed from LAC countries, could also be applied in all other countries – including OECD countries. In fact it is the latter that should be taking the lead. A new development path is required for both the North and the South.

1 See, for example: Chapman (2008); Shiva (2004, 2008); Robins (2006) and GRAIN (2008a).

local food processing and distribution facilities—so that more of the food dollar is retained by the farmer and within the local economy.[1]

These two schools of thought also reflect two ways of managing our systems to meet basic needs: linear versus circular approaches. In Section 2 we consider how our current way of providing food, water, sanitation and waste disposal or energy involves industrialised systems that are linear, centralised and globalised.

In the linear approach, it is assumed that at one end of a system there is an unlimited supply of energy and raw materials (which there isn't), while at the other the environment has an infinite capacity to absorb pollution and waste (which it hasn't). The inevitable result is resource shortages on the one hand and solid waste, climate change and air pollution problems on the other. Despite their unsustainability, linear systems have become ingrained in the North and are being introduced in the South at an extremely rapid rate. In Section 3 we contrast linear with circular approaches and outline how the sustainable circular systems that we describe have the potential to improve local food, energy and water security and therefore contribute to more sustainable and

1 For further information on both options see Lang and Heasman (2003) and McMichael and Schneider (2011); on the first scenario see for example Chi *et al.* (2010), Cotula, 2011, and The Gates Foundation (2008, 2011) and on the second approach see Jones (2001), Pimbert (2009a) and Tudge (2011) for example

resilient households and communities. In Section 4 we highlight the social, economic and environmental benefits of circular systems in several case studies from the Andes, Asia, and the Caribbean. The aim is to describe, assess and disseminate information on sustainable and successful approaches that already exist to meet our needs sustainably. This shows what is possible, quantifies the beneficial outcomes and demonstrates that similar projects could be introduced in other places. In the final section, Section 5, we conclude that the options to reduce negative social, environmental and economic impact are extremely limited unless production systems and supply chains are restructured to become circular and less dependent on external resources.

The overall aim of the project is to provide a framework for positive change by supplying relevant and easily accessible information to decision makers at all levels, from households up to the international level. The programme focuses equally on the technological and institutional dimensions of change towards sustainability and the ultimate goal is to contribute to a paradigm shift in how decision makers approach these issues.

We consider what food, energy and water systems could look like in the coming decades if we make the right decisions now, and what the consequences will be if we do not. In order to differentiate between these two scenarios and the options available we ask the questions that have mostly been avoided, but that will need to be addressed if we are to make the shift to genuinely sustainable systems. For example, how will food and transport systems be powered following the fossil fuel era? Can renewable energy meet current energy requirements for food production, processing, packaging, distribution and retail? How do we make significant cuts in greenhouse gas emissions in food and energy systems? How do we ensure food, water and energy security and improve livelihoods, particularly for smallholders and the urban poor in the South (and increasingly in the North)? What technological and institutional transformations are needed for sustainability?

1.2. Values, concepts and principles

Several concepts and values form the foundations of the Designing Resilience project. These include agroecology, eco-literacy, circular systems, food sovereignty, limits, eco-communities, permaculture, the carbohydrate economy, the proximity principle, co-operative structures and sustainability (summarised in Annex 2). These approaches and concepts have emerged in response to environmental and social challenges. They are sometimes considered separately; however, when brought together they can provide a platform for change, by providing important insights that allow us to:

1. Gain a better understanding of environmental and social problems and their root causes.

2. Begin to develop descriptions and a conceptual model of new and sustainable structures in relation to organisations, communities, production systems and supply chains.

3. Describe pathways for the transition from (1) to (2).

Together, these concepts and values form the basis of a new, post-industrial world view. They also provide a description of the planning and design tools, technologies and possible social and community structures that underpin the paradigm shift required if we are to make the transition to sustainability.

Very few of these have been accepted and used by policy makers (apart from some of the analysis techniques). Nevertheless, they have been developed and tested, often on a small scale at grassroots level and with no institutional support. This applies to both the theory and the practice of sustainable products, services and communities. Understanding the approach we take in Designing Resilience also means understanding the clear distinction between the concepts of (1) sustainability *versus* sustainable development and (2) linear *versus* circular systems. We discuss each in turn below.

Sustainability *versus* sustainable development

The distinction between *sustainability* and *sustainable development* lies at the heart of our approach. Sustainable development has been defined in so many ways, often with conflicting aims, that it has to a certain extent been devalued. This has also resulted in uncertainty over what constitutes a sustainable product, system, community or livelihood.

In many instances the discussion surrounding sustainable development does not question the existence or continuation of current systems, infrastructure and supply chains or the dominant principles, values and strategies that led to their introduction. Sustainable development is thus mainly seen as an ever increasing *"commodification of nature and social relations"* (Rist, 1997). Viewed in this way, sustainable development can be seen as taking what we have at present and attempting to reduce negative environmental and social impacts gradually over time. Improvements, if any, are too small and too slow and real successes too few and far between. The failure of the sustainable development approach during recent decades is becoming apparent. Whatever the indicator used, whether it be a reduction in greenhouse gas emissions, water pollution, biodiversity loss, poverty or malnutrition, it is clear that sustainable development is not only a contested and nebulous concept, but that it has also failed to deliver. This is accepted at the local and the international level: see for example the address of Simon Upton, Chairman of the OECD Round Table on Sustainable Development, to the Inaugural Holcim Forum, Zurich 16th September (Upton, 2004). The problem is partly because an operational meaning is still elusive—as long the concept remains abstract, the shift to sustainable policy and practice will not take place (Levine, 2002).

Sustainability, on the other hand, is a dynamic process that enhances resilience to shocks and stresses—one that is flexible and allows for systems and communities to adapt, as long as specific goals are met, for example minimising greenhouse gas emissions when meeting a particular human need.

Having sustainability as the goal, rather than sustainable development, focuses the mind away from the idea that our only option is to gradually reduce the negative environmental, social and economic impacts of current systems over several decades and transforming them into something that is slightly more sustainable.

As Paul Dolan explains, it is now essential that

> *"…leaders shift from a perspective of incremental change to a perspective of transformation. The key is to paint a Vivid Picture. The point of the picture is not to accommodate the present; it's to accelerate the arrival of a particular version of the future. We must stand in the future and look back at the way we came."* (Dolan, 2003)

In this book sustainability is the guiding principle, rather than sustainable development, and we argue that it will be achieved only by adopting a new set of values, principles and concepts which will lead to new structures for the supply of food, energy, water and other material needs. It can be achieved only through a new world view (based on the concepts described in Annex 2), and new structures for productive systems (based on the circular systems described in Section 3).

We also introduce another concept—that of *permanence*. Food, water and energy systems that are designed for permanence not only meet sustainability goals at a particular point in time, but are structured and function in such a way as to continue in perpetuity. They may evolve and adapt to changing circumstances, but the basic sustainability goals are still met.

Linear *versus* circular systems

The aim of Designing Resilience is to outline and assess all options available to meet basic needs. We make an important distinction between a continuation of current trends and a paradigm shift in relation to the structure of production systems, supply chains and waste management systems. In terms of current arrangements our needs are met either by:

1. industrialised, globalised, corporately controlled systems that are dependent on the use of fossil fuels; or

2. non-industrial systems that can also be unsustainable when they result in the depletion or degradation of local natural resources and are unable to ensure food, energy and water security; or

3. systems that are based on a circular metabolism, use renewable energy, and reuse and recycle materials, nutrients and resources.

Section 2 summarises the first two approaches for food, water and energy supplies and sanitation systems; both can be described as having a linear structure. In linear systems renewable and non-renewable resources are used up and then disposed of with little or no mechanism for reuse, replanting or recycling. Industrialised systems are unsustainable because they are totally dependent on fossil fuels and other finite resources - which results in large amounts of air pollution and other waste and pollution that enters water courses or is buried in landfill sites. This linear throughput also results in large quantities of greenhouse gases (GHG). Non-industrial systems can also be linear if they involve the unsustainable harvesting and use of natural resources.

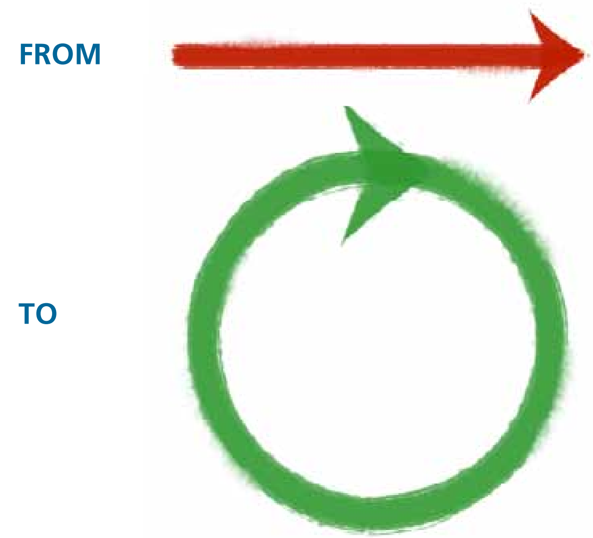
In the North, and increasingly in the South, particularly in cities, these problems are often hidden from the consumer, who can light and heat or cool a room at the flick of a switch, or find a wealth of food products at an out-of-town supermarket. Only by "unravelling" supply chains and shedding light on the processes involved—particularly the situation for smallholders, farm workers and communities in the South, and increasingly in the North—is change likely.

The alternative to linear systems is circular systems (Figure 1). This "circular" model is founded on the values of autonomy, resilience, knowledge-sharing and fairness and ecological, social and economic sustainability.

Production systems and supply chains are restructured to achieve a circular metabolism: so that external inputs are minimised; materials and nutrients are reused and recycled; and local production of food, renewable energy and other material needs is maximised. In Section 3 we describe some of the possibilities within the circular systems approach: for supplies of food, water, energy and other materials and services.

Figure 1. The shift required from linear to circular systems

In relation to the current situation, negative impacts could be minimised and positive outcomes facilitated by a shift:



In our assessment of linear *versus* circular systems we include both environmental and socio-economic factors. Our approach is based on systems analysis (Box 2). Throughout this research exercise we encourage a cross-disciplinary and holistic approach because we feel that in a sectoral analysis—looking at food, water or energy in isolation—the root causes and links between problems can be overlooked as well as sustainable solutions. We call this approach "joining the dots" because integrated approaches avoid the problems of looking at systems in a piecemeal, fragmented way.

When current food, energy, water, biodiversity and financial crises, as well as potential problems in the future are assessed together, the challenges can appear overwhelming. However, a holistic cross-sectoral assessment is essential because a sense of urgency is required: business as usual is no longer viable or acceptable. Overall our message is a positive one—sustainable alternatives are available and are feasible as are pathways to sustainability; however, this journey cannot be delayed.

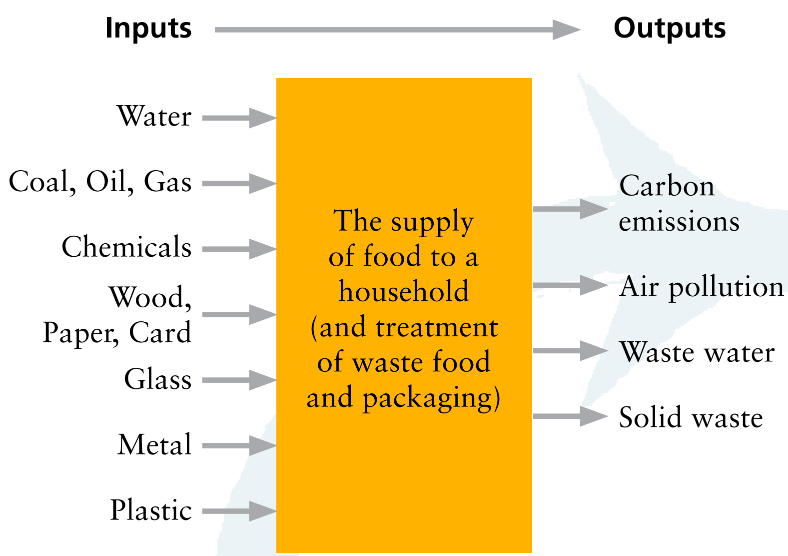
Figure 2 summarises the four main components of the project. Of these, this book focuses on: (1) values and (2) systems. In this diagram organisations and institutions are placed at the centre and shown as having direct input into (and receiving feedback from) all other components. This is intended to highlight the importance of institutions. Currently institutions mostly perpetuate a business-as-usual approach in the dominant development model, but they could play a pivotal role in developing truly sustainable systems. Institutions, organisations and rules can either act as a barrier to the paradigm shift that is described in this book or facilitate and play a key role in the transition to sustainable livelihoods.[2] We focus mainly on

2 For further information on the role of organisations in developing sustainable livelihoods see Section 4 in the IIED online multimedia publication – Pimbert, 2009. Towards food sovereignty: reclaiming autonomous food systems (www.iied.org/pubs/display.php?o=G02374) and Jiggins *et al.* (forthcoming).

Box 2. A systems analysis approach

In our assessment of industrialised and circular systems we include both environmental and socio-economic factors. Our approach is based on systems analysis. Where possible we quantify resource inputs to the productive process and outputs in the form of solid waste and water and air emissions when supplying a particular amount of food, energy, water etc., for example a kilogram of a food product, or one kilowatt of energy, or one litre of potable water.

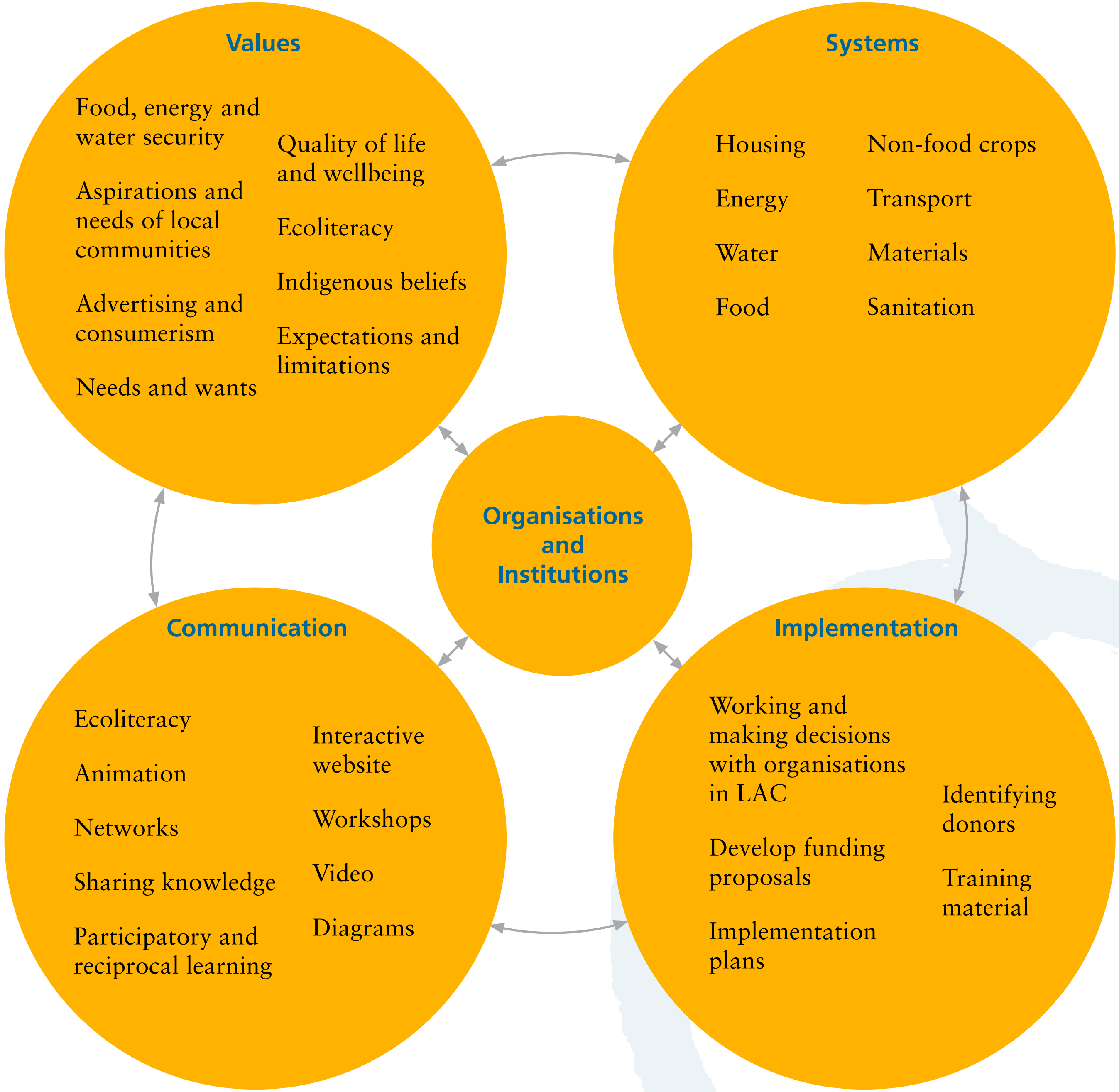
Food Supply from a Systems Analysis perspective



Further information on the tools that are used to assess the socio-economic and environmental impact of products and services is provided in Section 5.1 on measuring sustainability.

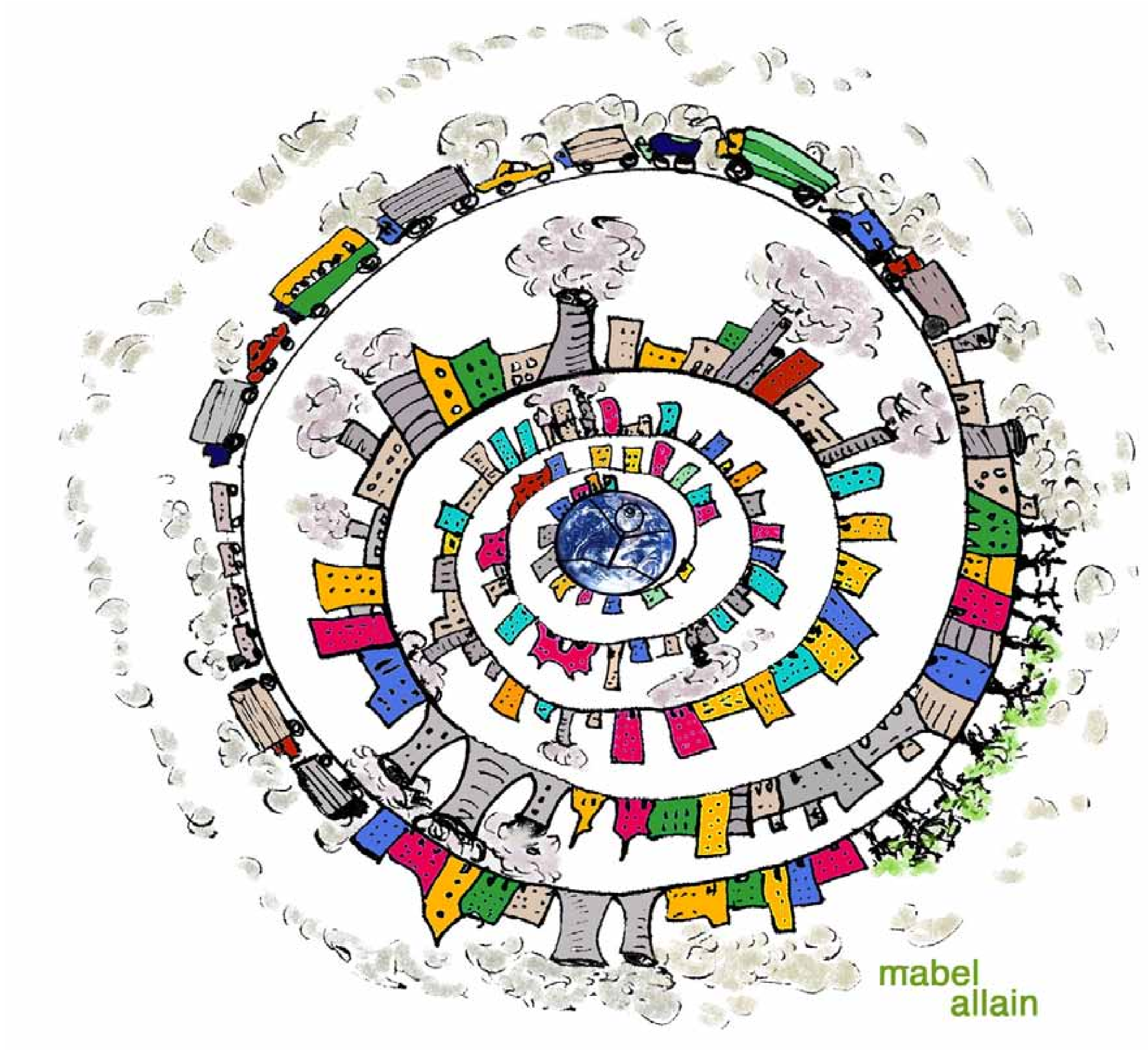
Figure 2.

The main components of the Designing Resilience project



the physical, geographic and functional aspects of circular systems. Organisational structures and institutional aspects of this transition are discussed in detail in other papers (especially Jiggins *et al.*, forthcoming, and Pimbert, 2009 a).

2. Joining the Dots (I)
Why Linear Thinking Creates Vicious Circles



2.1. Spiralling into environmental, social and economic crises

Several events have merged during the last few years to produce what has been described as 'a perfect storm': crises in the price and availability of food; water shortages; deforestation and biodiversity loss (Box 3); energy costs; the financial system; and a changing, less predictable climate with more extreme weather events.

We discuss several of these issues in this section—especially linear and industrialised approaches to energy supplies, food production, water and waste systems—all of which point to inherently unsustainable approaches. We consider some of the root causes of each of these problems and the links between them.

Box 3. Biodiversity

In 2010 the third edition of Global Biodiversity Outlook (GBO3) was published (GBO3, 2010). The report was the culmination of an exhaustive four year research, analysis and review process involving: 110 National Reports; the Biodiversity Indicators Partnership; the Biodiversity Futures Study; 500 scientific papers; and an open review process.

In April 2002, the Parties to the Convention on Biological Diversity, or CBD, agreed the following target: "to achieve, by 2010, a significant reduction in the current rate of biodiversity loss at the global, regional and national level as a contribution to poverty alleviation and to the benefit of all life on Earth." This pledge was subsequently endorsed by the World Summit on Sustainable Development in Johannesburg later in 2002, and by the UN general assembly. It was also incorporated as a new target within the Millennium Development Goals, as part of the goal to ensure environmental sustainability. So even though the CBD has near-universal participation, it is important to note that the 2010 Biodiversity Target was signed up to by all member countries of the UN, not just the Parties to that Convention.

The 2010 review found Amazon loss slowing in Brazil and overall the proportion of land and oceans designated as protected areas has continued to grow steadily, with more than 120,000 terrestrial protected areas occupying nearly one-eighth (12.2%) of the total land surface of the Earth. Marine protected areas, although covering a much smaller area, have grown significantly in recent years, concentrated almost entirely in coastal waters.

However, the Living Planet Index (LPI) suggests that globally, the abundance of vertebrate species has fallen by nearly one-third on average between 1970 and 2006, and continues to fall, with a sharp decline for tropical species. The status of coral species has declined sharply and amphibians are the group facing the highest extinction risk. For domesticated livestock it was found that over 30% of all breeds of cattle, pig and chicken are extinct or at risk of becoming extinct.

An important indicator of biodiversity is what is happening to the extent of habitats around the world. GBO3 notes that many are in serious decline: notably freshwater wetlands, coastal ecosystems such as salt marshes, coral reefs and seagrass beds; and Arctic sea ice, an important habitat for a wide range of species, has been reducing in extent and thickness in recent years. Ecosystems around the world, especially forests and rivers, are becoming increasingly

Box 3. Biodiversity

fragmented, threatening the viability of many species. The decline of mangrove forests, richly varied ecosystems of great value to fisheries and for protection of coastal communities, continues. Nearly one quarter (24%) of the world's land area was undergoing degradation, as measured by a decline in primary productivity, over the period 1980-2003. Degrading areas included around 30% of all forests, 20% of cultivated areas and 10% of grasslands.

GBO3 also considers projections in the coming decades based on the outcome of current trends for biodiversity, and its implications for human societies. Three of its main conclusions are as follows. First, projections of the impact of global change on biodiversity show continuing and often accelerating species extinctions, loss of natural habitat, and changes in the distribution and abundance of species, species groups and biomes over the 21st century. Second, there is a high risk of dramatic biodiversity loss and accompanying broad range of ecosystem services if the Earth's systems are pushed beyond certain tipping points (see Box 5, Tipping points). Finally, the study concludes that biodiversity loss and ecosystem changes could be prevented, significantly reduced or even reversed if strong action is applied urgently, comprehensively and appropriately, at international, national and local levels.

The disappointment is clear in the message from the Executive Secretary:

> *"The news is not good. We continue to lose biodiversity at a rate never before seen in history — extinction rates may be up to 1,000 times higher than the historical background rate. The assessment of the state of the world's biodiversity in 2010, as contained in GBO-3 based on the latest indicators, over 110 national reports submitted to the Convention Secretariat, and scenarios for the 21st Century should serve as a wake-up call for humanity. Business as usual is no longer an option if we are to avoid irreversible damage to the life-support systems of our planet. The Convention's new Strategic Plan, to be adopted at the 2010 Nagoya Biodiversity Summit must tackle the underlying causes of biodiversity loss. And the linked challenges of biodiversity loss and climate change must be addressed with equal priority and close cooperation. Joint action is needed to implement the Conventions on Biodiversity, Climate Change and to Combat Desertification — the three conventions born of the 1992 Rio Conference. The Rio+20 Summit offers an opportunity to adopt a work plan to achieve this."*
> Ahmed Djoghlaf, Executive Secretary, Convention on Biological Diversity (see www.cbd.int/secretariat).

2 For a fuller view of the current state of biodiversity see the website of the Biodiversity Indicators Partnership, www.twentyten.net.

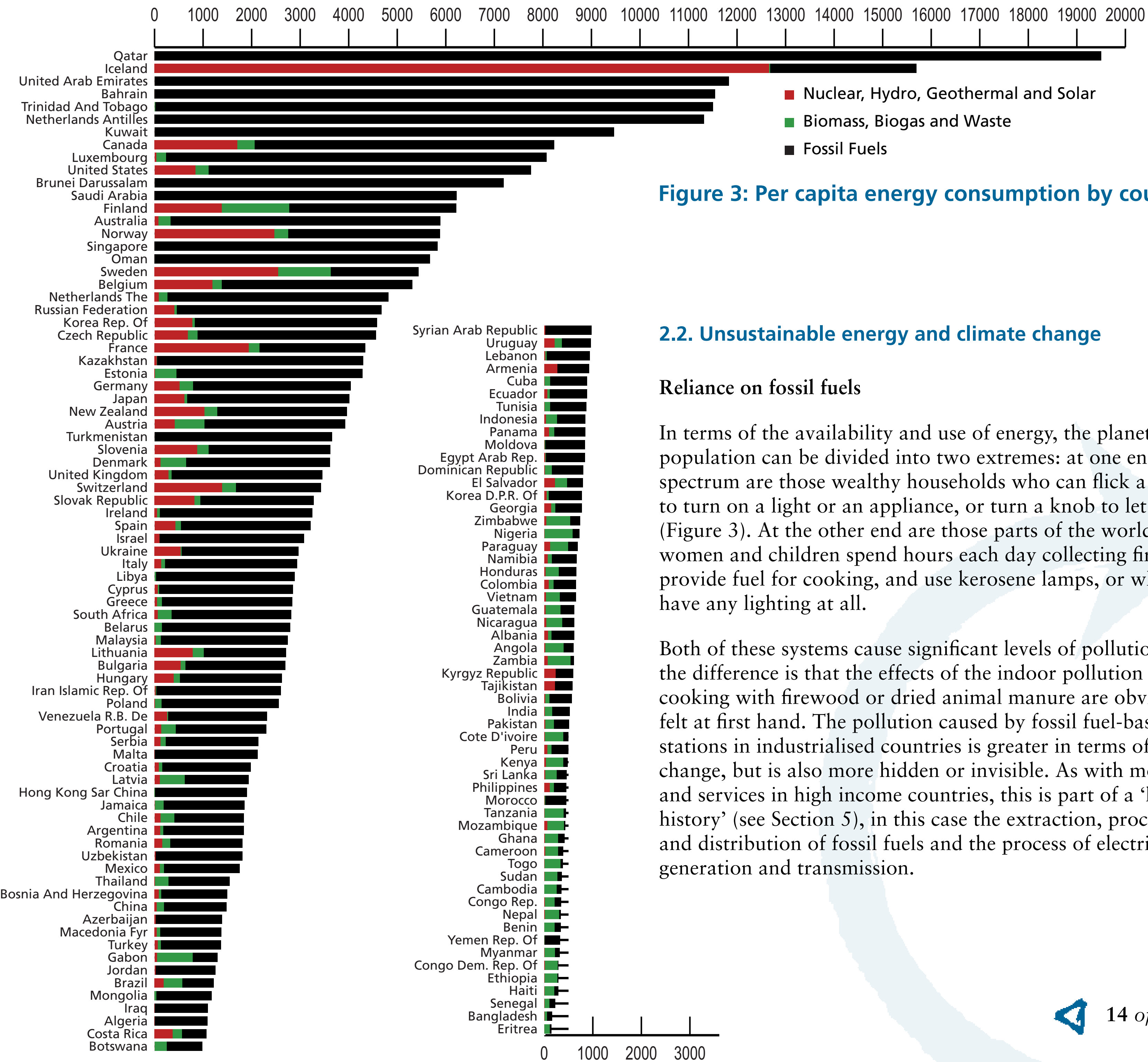


Figure 3: Per capita energy consumption by country

2.2. Unsustainable energy and climate change

Reliance on fossil fuels

In terms of the availability and use of energy, the planet's population can be divided into two extremes: at one end of the spectrum are those wealthy households who can flick a switch to turn on a light or an appliance, or turn a knob to let gas flow (Figure 3). At the other end are those parts of the world where women and children spend hours each day collecting firewood to provide fuel for cooking, and use kerosene lamps, or who do not have any lighting at all.

Both of these systems cause significant levels of pollution, but the difference is that the effects of the indoor pollution caused by cooking with firewood or dried animal manure are obvious and felt at first hand. The pollution caused by fossil fuel-based power stations in industrialised countries is greater in terms of climate change, but is also more hidden or invisible. As with most goods and services in high income countries, this is part of a 'hidden history' (see Section 5), in this case the extraction, processing and distribution of fossil fuels and the process of electricity generation and transmission.

Both systems are also unsustainable and under threat. The use of firewood can lead to deforestation, soil erosion and flooding. Electricity produced in large power stations that rely on fossil fuels and supplied through a centralised grid is extremely inefficient, expensive and polluting. Often around one-third of the energy content of the fuels is lost during electricity generation and transmission. These large power stations can operate only by using fossil fuels (or nuclear power, see below), thus the countries that do not have domestic oil, coal or natural gas reserves are dependent on increasingly expensive imports. Often the huge capital costs are either covered by loans—thus increasing developing country debt—or foreign direct investment—which means that energy supplies are controlled by foreign corporations.

The resulting environmental impacts of this linear approach to the supply of electricity, in which the combustion of finite resources results directly in carbon dioxide and other pollutant emissions, are large and widespread. In many countries power stations account for at least a quarter of fossil fuel use and greenhouse gas emissions, as well as being a significant source of other air pollutants—most notably carcinogenic particulates and gases that are precursors to acid rain. This pollution is experienced locally, where levels often exceed World Health Organisation (WHO) guidelines, regional impacts include acid rain, and globally, electricity generation and the use of fossil fuels in homes and industry is one of the main sources of greenhouse gases.

Our addiction to fossil fuels means that virtually everything we eat, purchase or do is dependent on crude oil, natural gas and their derivatives. Crude oil is used for transport fuels and as a feedstock in the manufacture of pesticides and plastics: *"Plastics, made from oil, dominate our consumption existence. The device you are reading this on is made out of oil. The keyboard you type on. The water bottle you drink out of. The trainers you wear. Your CDs and DVDs. Your toothbrush. The packaging you unwrap and the bin you put it into. Thirty-two litres of oil go into the production of a single tyre. That's four tyres a car, eight hundred million cars on the planet and rising; the new middle classes of China and India want theirs too."* (Dwyer, 2010)

Let's take a peek at peak oil (and gas)

> *"World oil reserves are being depleted three times as fast as they are being discovered. Oil is being produced from past discoveries, but they are not being replaced. The disparity between increasing production and declining discoveries can only have one outcome: a practical supply limit will be reached and future supply to meet conventional oil demand will not be available."* US Office of Petroleum Reserves, quoted in Lucas *et al.*, (2006)

During the last few years the evidence for peak oil—the theory that the global peak and decline of oil production is either imminent or has already been reached—has been mounting:

- **Declining energy return on investment (no new easy oil)**: The ratio of the energy used to extract oil and the energy content of that oil is an important indicator of a peak in our oil reserves.3

3 EROEI (energy return on energy invested) or EROI (energy return on investment), is the ratio of the amount of usable energy acquired from a particular energy resource to the amount of energy expended to obtain that energy resource. When the EROEI of a resource is equal to or lower than 1, there is no net energy gain and that energy source becomes an "energy sink", and can no longer be used as a primary source of energy. Researchers have highlighted an important fact, that *"economies are fuelled by energy produced in excess of the amount required to drive the energy production process. Therefore any successful society's energy resources must be both abundant and exploitable with a high ratio of energy return on energy invested (EROI)."* (Gagnon *et al.*, 2009). These researchers estimate that the global EROI at the wellhead was roughly 26:1 in 1992, increased to 35:1 in 1999, and then decreased by almost half to 18:1 in 2006. They conclude that these *"trends imply that global supplies of petroleum available to do*

When oil production first began in the mid-nineteenth century, the largest 'easy' oil fields recovered 50 to 100 barrels of oil for every barrel used for extraction, transportation and refining. Currently, it has been estimated that between one and five barrels of oil are recovered for each barrel used in the recovery process (the ratio is approximately 3:1 in the US and 10:1 in Saudi Arabia (Wikipedia, n.d.). The shift to unconventional oil will reduce the energy return on investment even further; the extraction of the oil from tar sands requires heat and thus the burning of vast amounts of natural gas—effectively one barrel of gas to extract two of crude. Overall, the extraction of oil from tar sands requires three times more energy than that required for conventional oil (see below).

- **Exponential increase in consumption**: While it has taken one and a half centuries to consume half of the 2-2.5 trillion barrels of conventional oil supplies generally regarded as the total available, it is likely that, given the huge increases of demand, the other half will be largely consumed within the next 30-40 years.

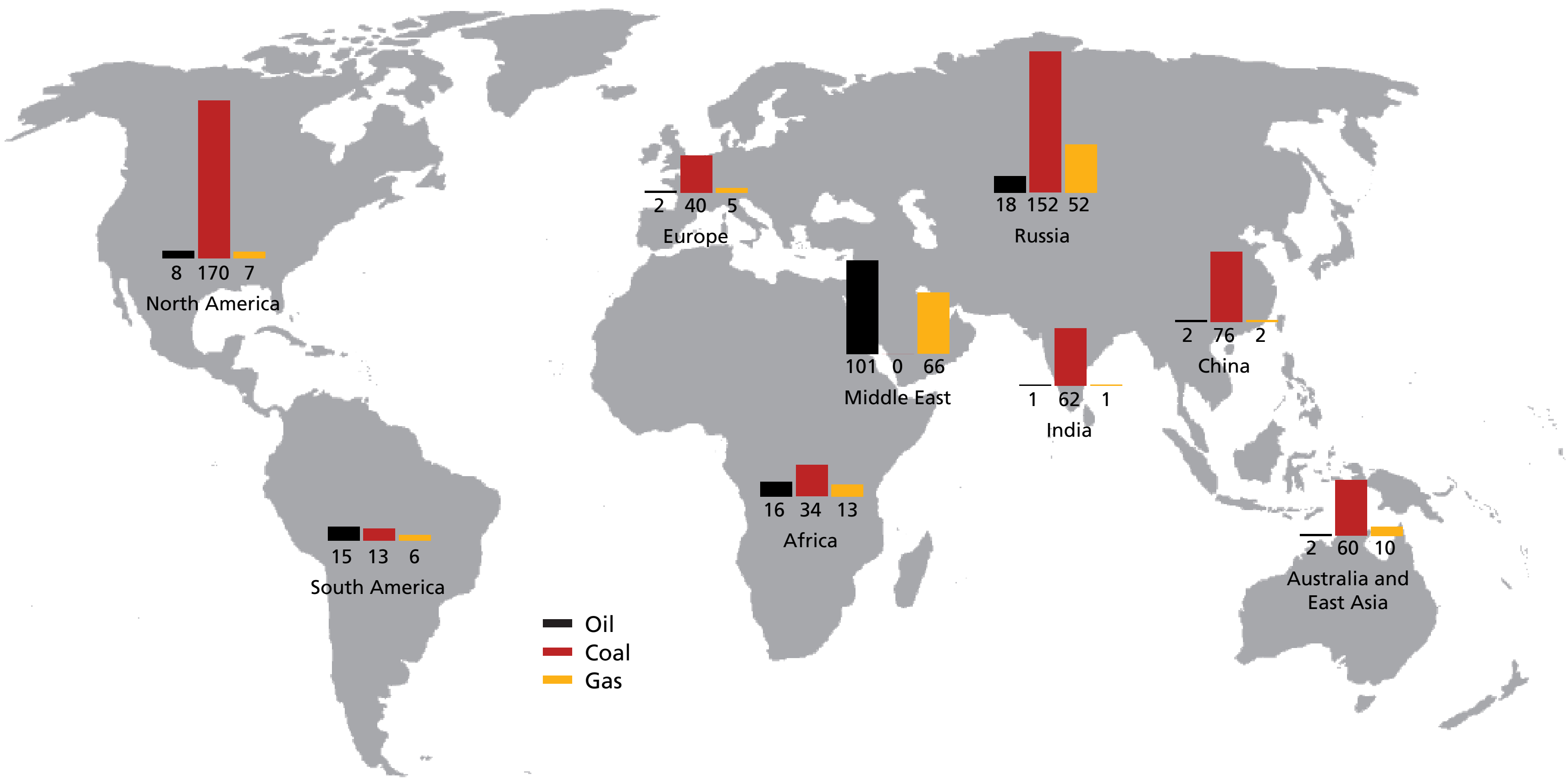
- **Peaks in major producing countries:** Some 98% of global crude oil comes from 45 nations and 95% of proven reserves are in just 20 countries (Figure 4); 33 of the 48 significant oil-producing nations are already experiencing declining production (Heinberg, 2006) including 7 of the 11 *Organization of the Petroleum Exporting Countries* (OPEC) nations.

- **Decline in discovery of new giant oilfields:** The recent rate of discovery of "giant" oilfields, of more than 500 million barrels, is on a dramatic downward curve: in 2000 there were 16 discoveries, in 2001 nine, in 2002 just two, and in 2003 none. It takes around six years from the discovery of an oilfield for the first oil to come to market. The world's biggest oilfields, the giants of Saudi Arabia and Kuwait, were discovered in the 1930s and 1940s. Perhaps most ominously, the last time more oil was discovered in a year than was used was a quarter of a century ago.

- **Shrinking supply and growing demand**: World oil and gas production has been declining at an average rate of 4-6% a year, while demand was growing at 2-3% a year up until the financial crisis.

economic work are considerably less than estimates of gross reserves and that EROI is declining over time and with increased annual drilling levels."

Figure 4: Location of the world's main fossil fuel reserves (gigatonnes of oil equivalent)



The consequences of our increasingly desperate search for more oil

Deep sea drilling

Another indicator of the depletion of "easy" oil is the increase in offshore oil exploration and the shift from shallow sea to deep sea drilling. Oil companies are drilling further out into the sea and deeper under the ocean floor at depths greater than 1,000 feet. Deep water oil is much more expensive to extract than drilling on land: the only reason to do so is to tap into one of the last remaining pockets of oil and natural gas in the world. Global proven reserves of oil at the beginning of 2009 were 1.18 to 1.34 trillion barrels. About 10% of this is in deep water. However 40% of offshore reserves are over 1.5 kilometres below sea level.

On April 20, 2010, the Deepwater Horizon platform, 52 miles off-shore of New Orleans, (owned by Transocean and leased to BP) exploded, killing 11 people. In May 2010 the resulting spill was described as the worst environmental disaster in US history, eclipsing the Exxon Valdez oil spill. There did not appear to be a

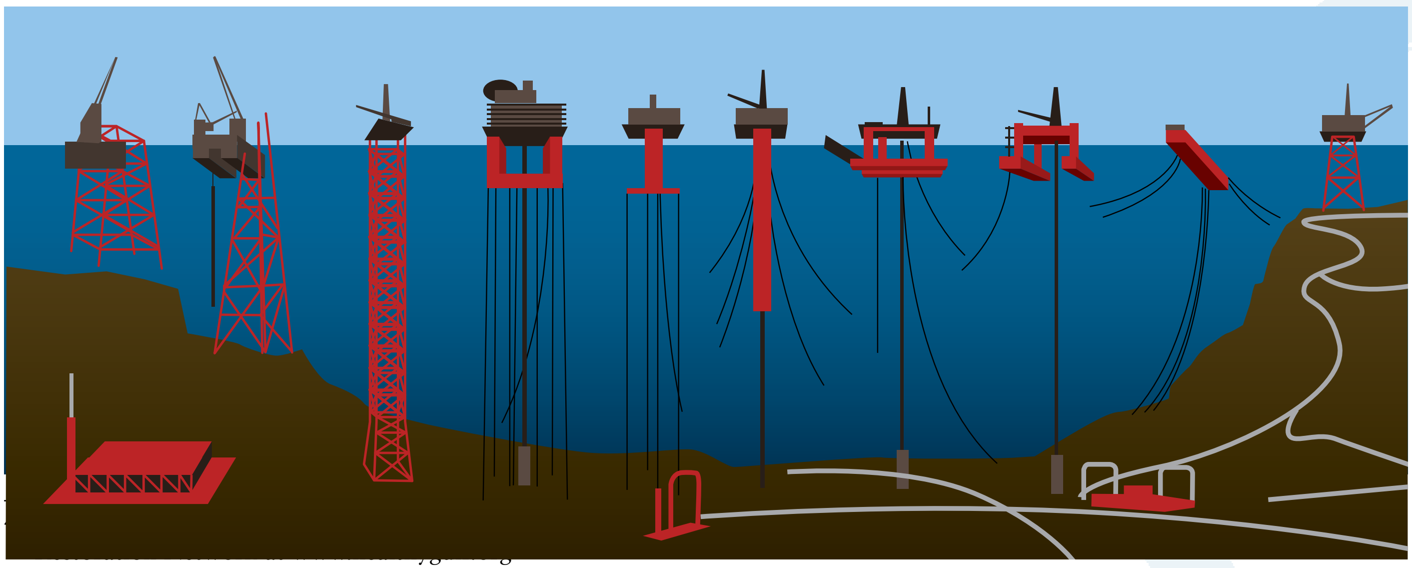
contingency plan in place in the event of a leak. After five weeks of post-disaster experimentation, and the failure to plug the hole with golf balls, one commentator described deep sea drilling as having similar risks to a high wire act without a safety net (Viles, 2010).[4] In August 2010, efforts to seal the ruptured oil well finally appeared to have been successful, 15 weeks after the explosion. However, by that time nearly five million barrels of oil had been released into the Gulf of Mexico.

Although the Deepwater Horizon blowout received considerable media attention, it is important to recognise the frequency and scale of accidents that result in crude oil being released into oceans and on land. There were at least four other large spills within four months of the Deepwater Horizon incident and since the grounding of the Torrey Canyon supertanker in 1967 there have been over 80 oil-related disasters, an average of almost two per year, each releasing between 34 and 1.5 million tonnes of crude into the environment. It has been estimated that over the last 100 years at least 6.1 to 7.6 million tonnes (7.2 to 8.9 billion litres) of crude oil has leaked into rivers, seas and land (Vidal, 2010; NOAA, 1992; Wikipedia, n.d. b).

Worldwide there are currently over 1,000 offshore rigs: 759 mobile offshore drilling units (MODU), 79% of which are in operation, and 296 platform rigs (Figure 5). Over 100 new mobile drilling units were produced just in the four years to 2010 (ODS-Petrodata, 2010).

The world's deepest oil platform is the floating Independence Hub which is a semi-submersible platform in the Gulf of Mexico in a water depth of 2,414 metres (7,920 feet). The Petronius Platform, also in the Gulf of Mexico, stands 610 metres (2,000 feet) above the ocean floor and is one of the world's tallest structures. The Hibernia platform is the world's largest offshore platform in terms of weight at 1.2 million tonnes. It lies in the Atlantic Ocean off the coast of Newfoundland and is 111 metres

Figure 5. Types of offshore oil and gas structures



1, 2) conventional fixed platforms; 3) compliant tower; 4, 5) vertically moored tension leg and mini-tension leg platform; 6) Spar ; 7,8) Semi-submersibles ; 9) Floating production, storage, and offloading facility; 10) sub-sea completion and tie-back to host facility.

Adapted from: Office of Ocean Exploration and Research (2008)

(364 feet) high with a storage capacity for 1.3 million barrels of crude oil. The platform has serrated outer edges which it is hoped will withstand the impact of an iceberg.

Transportation of crude also frequently results in environmental pollution in the form of oil spills from tankers and leaks in the pipelines, often in ecologically sensitive areas.

The exploitation of "unconventional" oil sources

As supplies of "easy oil" decline, the exploitation of "unconventional" oil sources is likely to increase. Unconventional oil exists in huge quantities in several big deposits, notably Canada's tar sands and Venezuela's Orinoco oil belt (Box 4). However, tar sands have to be mined, not drilled, and it is energy intensive to pump and refine heavy oil, which means that these sources of oil are virtually worthless in terms of net energy gain. The environmental costs also include the use of large quantities of water in the extraction process and the resulting water pollution, plus the huge amounts of natural gas required to extract deeper reserves and to process the crude oil. Similarly, strip-mining for coal and mining shale gas are more energy intensive and ecologically damaging than conventional sources.

The implications: from Petropolis to petrocollapse

Peak oil and natural gas has received relatively little attention. However, it will have a massive impact if it is not addressed soon, with especially devastating consequences for the poorest and most vulnerable in both the North and South. The implications of peak oil and gas are vast and will affect every aspect of our lives. The prospect can be overwhelming. Regardless of the actual date of peak oil, the disruptions that will be caused by the permanent end of cheap oil are so huge and will affect so many sectors of agriculture and industry, as well as

Box 4. Canada's tar sands

"Canada is developing the world's second largest reserve of oil. It's actually a filthy mixture of bitumen, sand, heavy metals and toxic organic chemicals. The tar sands, most of which occur in Alberta, are being extracted by the biggest opencast mining operation on earth. An area the size of England, of pristine forests and marshes, will be dug up. To extract oil, it needs to be heated and washed. Three barrels of water are used to process one barrel of oil. The contaminated water is held in vast tailing ponds, some of which are so toxic that the tar companies employ people to scoop dead birds off the surface. Most are unlined. They leak organic poisons, arsenic and mercury into the rivers. The First Nations people living downstream have developed a range of exotic cancers and auto-immune diseases. Refining tar sands requires two to three times as much energy as refining crude oil. The companies exploiting them burn enough natural gas to heat six million homes. Alberta's tar sands operation is the world's biggest single industrial source of carbon emissions. By 2020, if the current growth continues, it will produce more greenhouse gases than Ireland or Denmark" (Monbiot, 2009).

Heavy hauler mining trucks are used to move tar sand in Canada. These machines can carry up to 400 tonnes of sand and have tyres that are 15 feet high.

Even bigger mining shovels are used. These cost $20m each and stand seven storeys high. They can dig out 100 tonnes with one shovelful. Four shovel loads fill one truck.

having such far reaching economic implications, that efforts to mitigate the effects must begin immediately.

Once oil production has peaked, much of the remaining volumes (between 1 and 1.35 trillion barrels, i.e. about as much as has been extracted so far), will be of lower quality and more expensive, ecologically damaging and energy intensive to extract (Fortson, 2008).[5] In short, peak oil means that every time demand grows, the price of oil (and gas, whose price is linked to it) will rise, and will do so ever more steeply as supply constraints increase.

Energy prices have increased significantly in most countries over the last few years and the price of a barrel of oil reached US $147 during the summer of 2008: the average price during that year was US $100 a barrel. During the 20 years to 2005, the price was constantly below $40 a barrel, and for most of these two decades the price was around $20 a barrel. Even the International Energy Agency has predicted that prices will increase to over $200 a barrel over the next few years, with only a modest increase in economic activity.

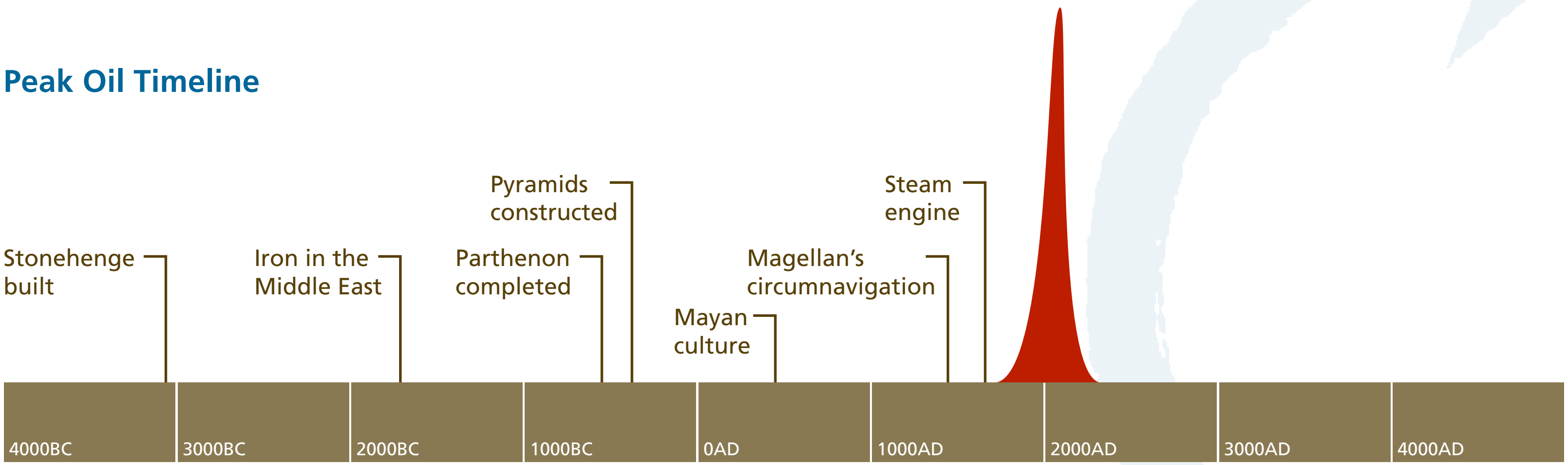
When economic activity fell sharply following the 2007 financial crisis, the price of oil also fell. This implies that economies in the OECD, and increasingly transition countries, are dependent on oil as well as other fossil fuels and finite commodities. Thus when oil supplies decline (post peak oil), economies will struggle to function and the supply of and access to goods and services will be in jeopardy—particularly in low income households and countries whose systems rely heavily on fossil fuels, e.g. energy-intensive systems to supply food, energy, clothing and housing.

The financial costs are also high in terms of the infrastructure required: in each country billions of Euros are spent on the construction, operation and maintenance of power stations and electricity supply grids.

As the expansion of renewable energy has been so slow, it is possible that over the next few decades as reserves of conventional crude oil and natural gas are depleted, our insatiable appetite for energy will lead to the use of unconventional oil, shale gas, and back to coal once again

5 Estimates of proven reserves vary significantly—by over 13%. See for example Energy Information Administration (2009) and Read (2000).

Peak Oil Timeline



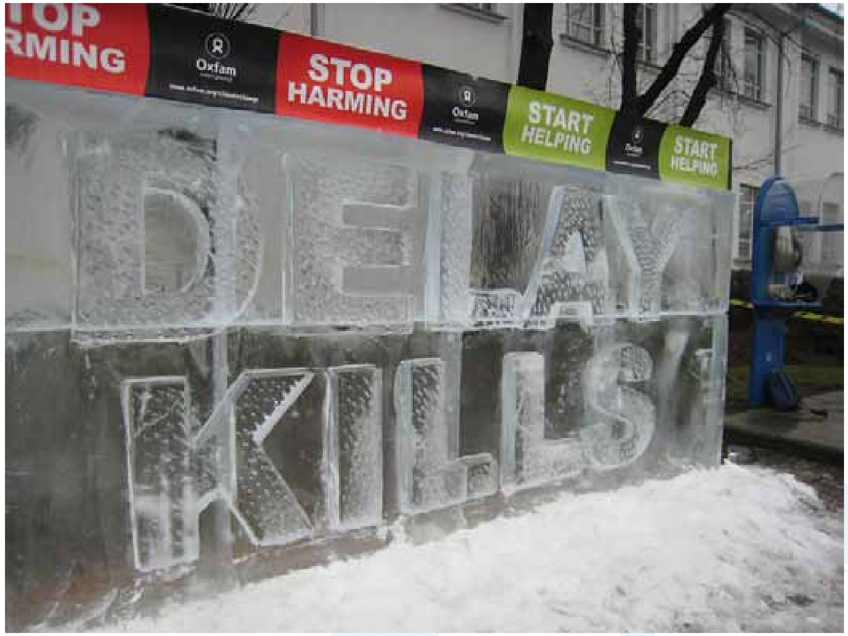
(McRae, 2006). If this prediction is correct, the consequence in terms of climate change will be catastrophic. The extraction and processing of oil from tar sands produces three times more carbon dioxide emissions than conventional oil. This does not include the climate impacts of the land use changes associated with strip-mining tar sands. In Canada alone it is predicted that 141,000 square kilometres of boreal forest is being cleared and the peat bog removed. Toxic waste water, or tailings, is sent to giant ponds where the heavy metals take up to 20 years to settle. These artificial lakes are so large they can be seen from space. The vast tar sands of Alberta in Canada hold oil reserves six times the size of Saudi Arabia's (Edemariam, 2007).

If *per capita* energy consumption is not reduced and there is not a wide scale and rapid shift to renewables then the risks are many and varied. The problems associated with fossil fuel dependency for household energy and food supplies will become more apparent—the fact that low fossil-fuel electricity, coking and food systems are so few and far between will exacerbate the situation. An acceleration of unsustainable biomass use and deforestation is one possible outcome; malnutrition and starvation are others.

Cuba has already experienced petrocollapse: imports of oil and gas, as well as farming inputs based on these feedstocks, decreased rapidly and sharply following the removal of Soviet aid. Over the decade following this crisis Cuba responded by developing new forms of food production based on low external-input agroecological approaches, urban agriculture and local distribution (see Cuba case study in Section 4). How will other countries respond to such a crisis when the impacts of peak oil unfold?

A shift away from oil to renewable energy and from systems that are energy intensive to those that minimise fossil fuel use will not only make it easier to weather the peak oil storm, it will also help tackle another major challenge facing human kind—climate change. If there is a shift to the use of coal in power stations when natural gas and crude oil supplies become more expensive, the consequences for climate change will be disastrous.

Peak oil and climate change: two sides of the same coin



"Delay kills" - Oxfam's ice sculpture at the UN Climate Talks in Poznan, 2009.

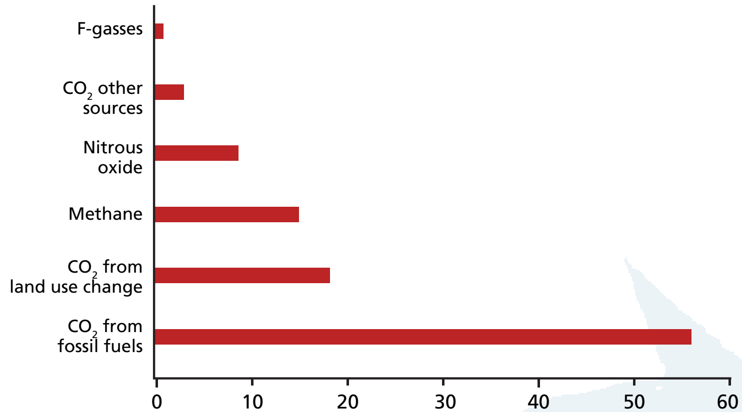
> *"The last 10 days have seen torrential rain falling in parts of West Africa, with cities like Ouagadougou in Burkina Faso devastated by floods. Many people have lost their homes, while dams and bridges have been broken, and electricity supplies cut off. These extreme events give some sense of the dangers ahead for our warming planet"* Camilla Toulmin, IIED Director, IIED Newsletter September 2009 (www.iied.org).

Climate change is perhaps the greatest challenge that humankind has faced.[6] Scientists have developed sophisticated computer models that predict that temperatures could increase by several degrees during this century, resulting in extreme weather events that lead to drought and water shortages, flooding, crop failure, famine and disease.

Despite strenuous and expensive efforts to convince the public that climate change is a myth, it is now widely accepted that human-induced climate change is taking place and has to be addressed by making significant cuts in greenhouse gas emissions—particularly carbon dioxide (CO_2)—resulting from the use of fossil fuels. The Chief Scientific Advisor to the UK Government, Sir David King, has said that climate change is a bigger threat than international terrorism (King, 2004).[7] Even the chairman of Shell has warned that we face a disaster if governments fail to introduce new regulations that reduce incentives to consume fossil fuels.

Fossil fuels are the main source of greenhouse gases (Figure 6), which are emitted during their use as transport fuels, in power stations, for heating, refrigeration and cooking in homes, and in industry to provide heat and power. However, to reach the point of consumption (combustion), these fuels also require large quantities of energy to mine, refine and transport them. These processes also result in greenhouse gas emissions, as well as other forms of pollution and, in many instances, have significant ecological impacts.

Figure 6. Global warming potential of all anthropogenic greenhouse gases.



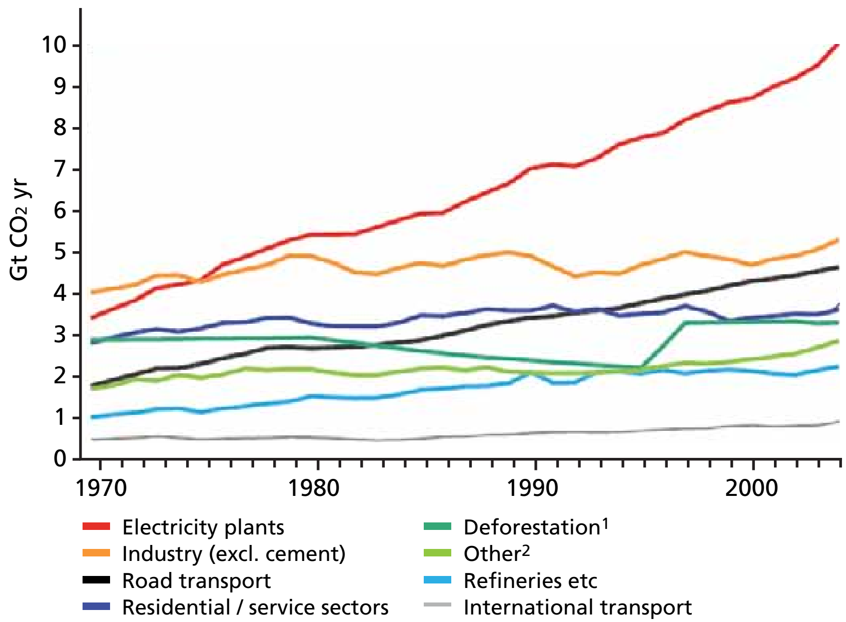
Source: Sigma Xi (2009)

Globally, the electricity generation sector is by far the most important source of global anthropogenic CO_2 emissions (Figure 7). Electricity generation is also the sector from which emissions are increasing at their fastest rate: between 1970 and 2004 CO_2 emissions from refineries, road transport and international transport doubled, while emissions from power stations almost trebled (Rogner *et al.*, 2007).

6 It is not possible to predict at this stage whether it is the full impact of climate change or peak oil that will be experienced first (or if they will occur at the same time). What is clear is that both are imminent and will have enormous and widespread consequences.

7 David King expressed these concerns in the US journal *Science* in 2004. In this article he appeared to criticise the Bush administration for abandoning the Kyoto Treaty. At that time in the US there was no consensus as to the existence and therefore causes of climate change. Businesses with a vested interest in maintaining the *status quo* supported media campaigns that questioned the science of global warming and claimed that mitigation policies would result in job losses. American lobbyists have even targeted David King and cast doubt on his claims.

Figure 7. Sources of global CO_2 emissions, 1970–2004 (only direct emissions by sector)



Notes: 1) Including fuelwood at 10% net contribution. For large-scale biomass burning, averaged data for 1997–2002 are based on the Global Fire Emissions Database satellite data (van der Werf *et al*., 2009). Including decomposition and peat fires (Hooijer *et al*., 2010). Excluding fossil fuel fires.

2) Other includes domestic surface transport, non-energetic use of fuels, cement production and venting/flaring of gas from oil production.

3) Including aviation and marine transport.

Source: Rogner *et al*. (2007)

Climate change is already having an impact on water supplies and agriculture. If current trends continue it has been predicted that agricultural productivity could decline in many countries, including those in Africa, South and South-East Asia and South America, Australia and the US by between 15 and 50% by 2080 (Cline, 2007; GRAIN, 2009a, IPPC, 2011). According to the World Health Organisation, climate change is killing 150,000 people a year through increased heatwaves, floods, storms, droughts and the spread of water- and insect-borne diseases.

Wake Up!!!

Or many more houses are going to be here

To avoid the worst-case scenarios, in 1990 the Intergovernmental Panel on Climate Change called for a reduction in emissions of 60-80% by 2050. However, in January 2005, the International Taskforce on Climate Change reported that we might have only 10-15 years to avert catastrophic climate change. There is now agreement that it is vital that global temperatures do not rise by more than 2°C above pre-industrial levels (see, for example European Commission, 2007). However, current trends mean that this temperature increase could be breached within a few decades. Allowing more than a 2°C rise could mark a "point of no return" and involve substantial agricultural losses, widespread adverse health effects and water shortages. The risk of abrupt, accelerated or runaway climate change also increases, for example, the loss of the West Antarctic and Greenland ice sheets and the Gulf Stream which warms North-West Europe (Box 5).

In 2007 the International Energy Agency (IEA) predicted that global energy demand could increase by 50% by 2030 (IEA, 2007). In 2009 the IEA forecast was revised downward to a 40% increase by 2030 because of the financial crisis. However, the IEA states that a continuation of *"current trends in energy use puts the world on track for a rise in temperature of up to 6°C and poses serious threats to global energy security."* This temperature increase would take us beyond several tipping points (Box 5). *"The time has come to make the hard choices needed to combat climate change and enhance global energy security"*, says the latest IEA *World Energy Outlook press release (IEA, 2009b).*

Box 5. Tipping points

Climate scientists maintain that it would be a mistake to think that climate change will be a slow and steady process, almost imperceptible, that follows a fairly predictable, perhaps even manageable path. The theory of tipping points implies that climate change won't be a smooth transition to a warmer world; instead, step changes should be expected as climate tipping points are passed (WWF, 2009).

A tipping point is defined as the point where a small increase in temperature or other change in the climate could trigger a disproportionately larger change. They are, in effect, points of no return. The Intergovernmental Panel on Climate Change has said the critical threshold is a global average temperature increase of 2-3°C, which many climate scientists expect to be reached in the coming decades. Nine ways in which the Earth could be tipped into a potentially dangerous state that could last for many centuries have been identified by climate scientists investigating how quickly global warming could run out of control during the next century (Lenton *et al.*, 2008). Most and probably all of the nine scenarios are likely to be irreversible on a human timescale once they pass a certain threshold of change, and the widespread effects of the transition to the new state will be felt for generations to come.

The effects of the changes are likely to be varied, from a dramatic rise in sea levels that flood coastal regions to widespread crop failures and famine (Connor, 2008). Some of the tipping points may be close at hand, such as the point at which the disappearance of the summer sea ice in the Arctic becomes inevitable, whereas others, such as the tipping point for the destruction of northern boreal forests, may take several more decades to be reached.

The nine are:

Box 5. Tipping points

- Arctic sea ice: some scientists believe that the tipping point for the total loss of summer sea ice is imminent.
- Greenland ice sheet: total melting could take 300 years or more but the tipping point that could see irreversible change might occur within 50 years. The melting of the entire Greenland ice sheet would produce enough water to raise world sea levels by more than six metres. An average global temperature rise of 6°C would push Greenland into irreversible melting (Adam, 2009).
- West Antarctic ice sheet: scientists believe it could unexpectedly collapse if it slips into the sea at its warming edges.
- Gulf Stream: few scientists believe it could be switched off completely this century but its collapse is a possibility.
- El Niño: the southern Pacific current may be affected by warmer seas, resulting in far-reaching climate change.
- Indian monsoon: relies on temperature difference between land and sea, which could be tipped off balance by pollutants that cause localised cooling.
- West African monsoon: in the past it has changed, causing the greening of the Sahara, but in the future it could cause droughts.
- Amazon rainforest: a warmer world and further deforestation may cause a collapse in the levels of rainfall supporting this ecosystem. A temperature increase slightly in excess of 2°C will likely trigger the slow but inevitable death of most of the Amazon rainforest. That would destroy a vital carbon sink and a giant water tap for regional agriculture, hydropower, and drinking.
- Boreal forests: cold-adapted trees of Siberia and Canada are dying as temperatures rise.
- Desertification of South West North America (California and neighbouring states): In the South Western US the tipping point has probably already been passed. It is now predicted that levels of aridity last seen in the 1930s Dust Bowl will have become the norm by mid-century (WWF, 2009).

The impacts of climate change will be global and a response will be required from all nations. This demands a different perspective in which individuals, businesses and governments accept responsibility for greenhouse gas emissions—including those emissions occurring outside their borders that are associated with the products they import. Industrialised countries will face increasing pressure to take the lead in reducing greenhouse gas emissions. This is because from a historical perspective OECD countries have been responsible for the vast majority of carbon emissions. If developing countries are to achieve low-carbon economies they will want to see action from the wealthy nations. This could include the transfer of appropriate technology and the introduction of climate change policies such as “contraction and convergence”, national carbon budgets and possibly a personal carbon allowance. However, OECD countries are not taking the lead and rapidly developing countries such as China, Russia, Brazil and India are adopting the same unsustainable economic policies, technologies and systems of production and distribution, thus exacerbating the problem.

The alternatives

Nuclear power: a false promise?

Several commentators have stated recently that in order to combat climate change, the shift away from oil, natural gas and coal will require an increase in nuclear power. However, the promise that nuclear power would provide plentiful supplies of clean and cheap energy has proved unfounded. Firstly, nuclear power production is dangerous: there have been several major accidents over the last few decades, together with many '"minor" incidents in which lower levels of radioactive material have been released into the environment. Human, mechanical or computer error, or terrorism, could cause another disaster on the scale of Chernobyl.

Secondly, another crucial and often overlooked aspect of nuclear power is that uranium, as with fossil fuels, is a finite resource. There are only decades rather than centuries of proven reserves of ore available, even at the current rate of use, and there are only a few countries with significant uranium reserves, even fewer than the number of countries that have significant fossil fuel resources. This concentration could result in geo-political conflicts in the future—the desire to control uranium supplies, together with other finite resources such as minerals, land, water and fossil fuels—leading to a new wave of resource wars.[8]

> *"To produce enough nuclear power to equal the power we currently get from fossil fuels, you would have to build 10,000 of the largest possible nuclear power plants. That's a huge, probably nonviable initiative, and at that burn rate, our known reserves of uranium would last only for 10 or 20 years.... The ultimate solution to our energy problem would be to master the power of controlled thermonuclear fusion, which we've been talking about doing for more than half a century. The solution has been 25 years away for the past 50 years, and it is still 25 years away"* (Goodstein, 2004).

Thirdly, the financial costs of nuclear power are also high in terms of constructing, operating and decommissioning nuclear power plants and treating and storing nuclear waste. These high costs require large amounts of government support. In the UK for example British Energy, the main operator of nuclear power plants, made a £349 million loss in just nine months in 2004—it only exists today because of a £5 billion government bailout (*The Independent*, 2005). When the electricity supply industry was privatised in the UK, the government was not able to sell the nuclear power stations. As a result, the taxpayer was left to pick up the tab for the cost of decommissioning and disposing of the waste, and the bill is £72bn and rising (ISISa, 2010).

Perhaps of most importance is that a programme of new nuclear plants would mean that less funding is available for renewable schemes and would delay their implementation. **In 2004, world governments provided US $20 billion per year in subsidies for renewable energies, compared to $250 billion for other energy sources** (Sigma Xi, 2009).

The real third way: decentralised renewable energy systems

The concept of a relatively small number of large nuclear, coal and gas power stations supplying electricity through the national grid is outdated and highly inefficient. Decentralised renewable energy

8 The Iraq war was just the first of this century's "resource wars", in which powerful countries use force to secure valuable commodities, according to the UK government's former chief scientific adviser. Sir David King predicts that with populations growing, natural resources dwindling, and seas rising due to climate change, the squeeze on the planet will lead to more conflict. This strategy could also be used to control supplies of other resources, such as minerals, water and fertile land, Sir David pointed out, adding: "Unless we get to grips with this problem globally, we potentially are going to lead ourselves into a situation where large, powerful nations will secure resources for their own people at the expense of others." Randerson (2009); see also Tabb (2007).

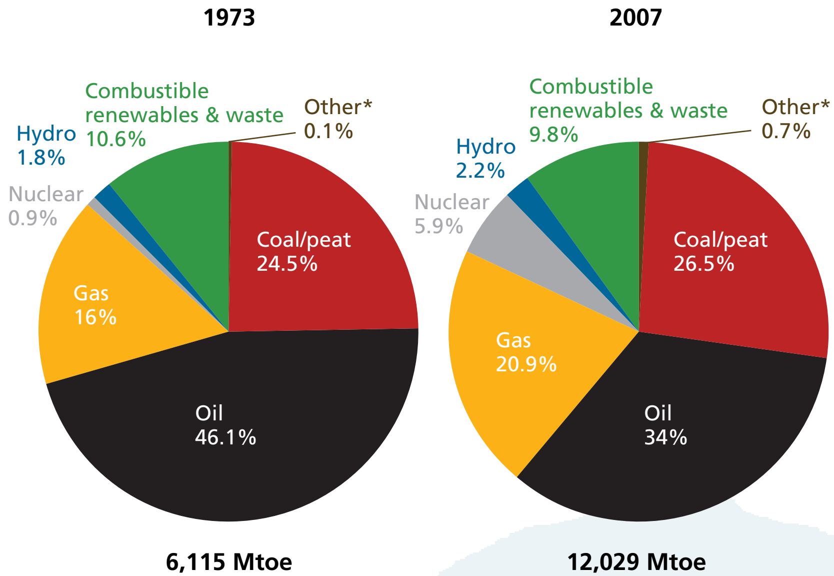
systems are the only safe and sustainable option to ensure energy security and climate stability. The energy required for heating, lighting and power in homes, on farms, market gardens and in small-scale industries, together with fuel for farm machinery, local distribution and international shipping trade can be provided from local and regional renewable sources. Importantly, these systems also offer diversity in terms of both supply and scale and can be adapted to local conditions and requirements.

This approach has already proved successful in many rural areas in developing countries where a centralised grid system is deemed impractical or unprofitable. Numerous options are available, such as biogas, biomass, wind power, geothermal, tidal, small-scale hydro and solar thermal systems. Sustainable biofuel production is also possible if planned carefully and feedstocks are produced on marginal land (see Sections 3 and 4 for many examples). Coppicing systems and sustainable harvesting of woodland (combined with tree planting on a vast scale) to produce wood fuel and timber are other options.

However, fossil fuels still dominate energy supplies. Between 1973 and 2007, global energy consumption almost doubled and the extent to which energy supplies depended on oil, coal and gas did not change significantly, down by around 5% from 86.6% to 81.4% (Figure 8). There was an increase in nuclear (5%) and gas (5%) but the share of combustible renewables and hydro remained virtually the same. No mention is made of the percentage of combustible renewables that are renewed and used on a sustainable basis, which in the case of firewood would require more trees to be planted than are used for cooking and heating. It is alarming to see that solar, wind and geothermal, which are placed in a category described as "other", supplied only 0.7% of energy in 2007.

Figure 8. Total world primary energy supply by fuel type

1973 and 2007 Fuel Shares of TPES



*Other includes geothermal, solar, wind, heat, etc.

Source: IEA (2009)

Note: Mtoe: million tonnes of oil equivalent per year

2.3. Unsustainable food production

> *"The surge in food prices in the last years, following a century of decline, has been the most marked of the past century in its magnitude, duration and the number of commodity groups whose prices have increased. The ensuing crisis has resulted in a 50–200% increase in selected commodity prices, driven 110 million people into poverty and added 44 million more to the undernourished. Elevated food prices have had dramatic impacts on the lives and livelihoods, including increased infant and child mortality, of those already undernourished or living in poverty and spending 70–80% of their daily income on food"* (Nellemann et al., 2009).

In the last few years, the rising cost of food all over the world has had a major impact on food availability and affordability and the ability of families to meet their nutritional needs. These sharp price rises have driven more people into poverty and have meant that an additional 100 million people can no longer afford to eat adequately; for the first time since 1970, the number of undernourished people in the world is over one billion. Of the one billion hungry, half are small farmers, a quarter are landless labourers working on plantations and the rest are urban poor who have migrated from rural areas because they can no longer find a living there. Over 24,000 people are dying of hunger each day, half of them children. Meanwhile, the World Food Programme faces a budget shortfall of US $4.1 billion (ISIS, 2010b).

Between mid-2007 and mid-2008, the price of wheat increased by 130%. Rice doubled in price in Asia in the first three months of 2008 alone, and hit record highs on the Chicago futures market in the first quarter of 2008: three times its price at the start of 2007. There were fears that millions across Asia would struggle to afford their staple food (Phoonphongphiphat, 2008). For most of 2007-08 the spiralling cost of cooking oil, fruit and vegetables, as well as of dairy and meat products, led to a fall in the consumption of these items. From Haiti to Cameroon to Bangladesh, people took to the streets in anger at being unable to afford the food they needed (GRAIN, 2008b).

Food prices had been rising since 2003 and by mid-2008, the food commodity price index peaked at 230% of its 2002 value, with most of the increase due to the grain prices. Corn and wheat both reached 350% and rice 530% respectively of their 2002 values (ISIS, 2010b). Although prices have fallen since the peak in July 2008, they are still well above those in 2004 for many key commodities. The underlying supply and demand tensions are little changed from those that existed when these prices were close to all-time highs (FAO HLPE 2011b).

During the height of the crisis many food exporting countries reduced or banned exports in order to ensure domestic supply. For wheat, export bans or restrictions in Kazakhstan, Russia, Ukraine and Argentina meant that a third of global exports were closed off. The situation with rice was even worse: China, Indonesia, Vietnam, Egypt, India and Cambodia banned or severely restricted exports, leaving just a few sources of export supply. Countries like Bangladesh and the Philippines that had come to rely on imports couldn't buy the rice they needed because the prices were so high.

Russia reintroduced an export ban on cereals in August 2010 following a summer of extremely high temperatures, drought and widespread fires covering 816,000 hectares in central areas. This resulted in the loss of at least a third of the grain crop which was expected to be as low as 60 million tonnes in 2010 compared to 97.1 million tonnes in 2009. Twenty-nine crop-producing regions declared a state of emergency with crop losses in 18 regions estimated at US $1.2 billion and farmer bankruptcy a serious concern (Khrennikov and Kolesnikova, 2010). Over half of the potato crop was also lost, which could lead to a 67% increase in wholesale prices, and 2010 sugar beet output was forecast to be 20% lower than the previous year.

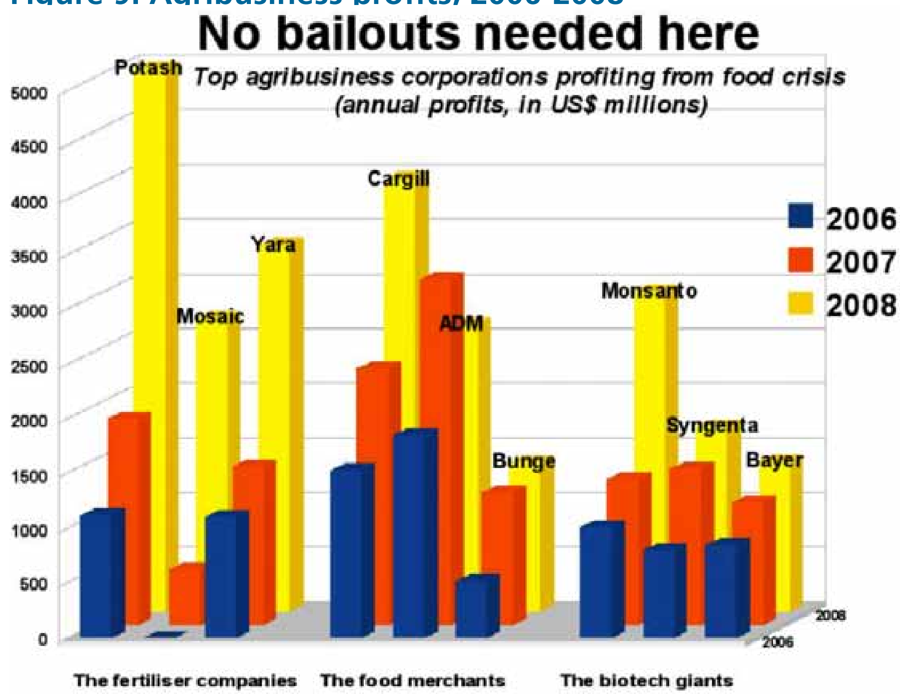
In the same month early estimates of the impact of heavy flooding in Pakistan indicated that 700,000 hectares of standing crops—mainly rice, maize, cotton and sugarcane—had been damaged or lost to the floods, along with households' food stocks, seriously disrupting food availability for rural families until the next harvest. If the flood waters moved further south into Sindh Province, which is the second largest rice producing region, further damage to rice crops could have resulted. Pakistan normally has an exportable surplus of rice, representing about one-third of domestic production, and in 2010 was expected to export 3.8 million tonnes of rice.

The impact on other countries of climate related crop losses such as these in Pakistan and Russia can be significant as they are large grain exporters; in 2009 Russia was the third largest wheat exporter. In China, flooding in 2010—the worst in more than a decade—could result in rice output falling by 5 to 7% and rising prices—thwarting government efforts to keep inflation under 3% (Pearson and Javier 2010).

So as people's livelihoods are devastated and food supplies become even more insecure in some parts of Asia because of too much rain, in other Asian countries and in Europe and Africa, drought and extreme temperatures are resulting in exactly the same outcome. The 2007/08 food crisis could be repeated in 2011 and in the near future (FAO HLPE, 2011b).

Before we consider the underlying reasons for these food crises it is important to highlight one of the outcomes—one that sheds light on the systemic problems in the modern food system and one that many will find disturbing. During the 2008 food crisis, at a time in which the number of hungry people in the world rose to one billion for the first time since 1970, corporate food companies profited. Figure 9 shows the increase in profits in 2008, in some cases a very sharp increase, of some of the large agribusiness corporations. These are the companies that supply agricultural inputs such as **seed, fertiliser and pesticide,** and the merchants that export food. As explained in the section below ("Concentrated power: invasion of the multinational retailers"), the companies at the other end of the food chain, the multinational food retailers, have also become extremely profitable and powerful as they have gained control of food supplies in the North and more recently in the South. In most cases, the revenues of the multinational food retailers did not fall during the food crisis; in fact they increased. Walmart may have slipped to third in the Fortune 500 list, but still has an annual revenue of US $406 billion. It is interesting to note that the other four in the top five are all oil companies.

Figure 9. Agribusiness profits, 2006-2008



Source: GRAIN (2009b)

Neoliberal globalisation

> *"The reason why the modern food system is inherently unsustainable goes to the heart of the economic rationale that has produced industrial agriculture, long-distance food freight transport and a highly concentrated food retail sector. As a result, the potential to reduce the negative social, environmental and economic impacts in existing food supply chains is extremely limited. Indeed, if current trends in food production, trade, processing, distribution and retailing continue, the damage caused to the environment, human health and farming communities will increase. The barriers to the contemporary food system being transformed into a sustainable system are insurmountable because this system is so inflexible in relation to its structure, operation and the priorities of multinational food corporations."* (Lucas and Jones, 2003)

The causes of the food crisis appear to be complex and multi-faceted. These include poor harvests due to unusual weather events; the use of agricultural land to produce biofuels instead of food; market speculation and profit-taking by agribusiness corporations; and rising energy costs pushing up the price of fertilisers, pesticides and the fuel used to power farm machinery and to distribute food.

Although policy makers have claimed that the food crisis could not have been foreseen, several reports had warned of the inherent dangers of a food system that is totally dependent on fossil fuels, as well as the impact on food prices when productive land is used to supply transport biofuels rather than food (Lucas *et al*., 2006).

Some commentators have argued that the food crisis was not due to food shortages, but a sign of structural meltdown in the food system, the direct result of three decades of neoliberal globalisation:

> *"In fact, once you look behind the cold curtain of statistics, you realise that something is fundamentally wrong with our food system. We have allowed food to be transformed from something that nourishes people and provides them with secure livelihoods into a commodity for speculation and bargaining"* (GRAIN, 2008b).

There have been many calls for a fundamental rethink of food and farming policy:[9]

> *"The FAO (Food and Agricultural Organization), CGIAR (Consultative Group on International Agriculture and Research) and other agriculture research centres are calling for more research on boosting crop yields. That's more of the same thing. No one is looking at access to food and land. It's much easier to talk about technology fixes rather than the big picture...It is now time to look long and hard at what is wrong with the global food system and to find ways to make it work better, especially for poor and marginalized communities. We need to open up our vision or the problems we face will simply continue...Governments, international corporations and other elites either marginalize or directly threaten these diverse systems and the ecologies they depend on. Thirty years of neo-liberal policies have devastated local food systems by dumping heavily subsidized foods from the rich nations on the poor"* (Michel Pimbert, quoted in Leahy, 2008)

> *"It's time to challenge this blinkered economist's version of efficient and ask, is an efficient farming system one that produces food to the lowest unit cost so that others can add 'value' and enormous profit? Or is an efficient farming*

9 Long before the food crisis of 2008, a few analysts and researchers were warning that if agriculture, trade and food policy did not change then food crises were inevitable. They also presented the results of research and analysis that showed that alternatives were available and that a paradigm shift was required. See for example Madeley (2000, 2002); Lang and Heasman (2003); Patel (2008); Pimbert,(2008), and Curtis (2005).

system one that produces safe wholesome food to the highest welfare and environmental standards; that gives the farmer a decent living; that maintains and enhances the environment; and that supports the rural economy and rural communities" Peter Lundgren, an arable farmer from Lincolnshire and Founder Member of *FARM*, cited in Lucas and Jones (2003)

The chief economist at the International Monetary Fund (IMF), John Lipsky, urged world leaders to act amid fears that the cost of food and fuel was spiralling out of the reach of many families (Cecil, 2008). However, Mr Lipsky's main concern appeared to be the threat to global economic growth and the "globalisation project". It is ironic that it is the structural adjustment policies of the IMF, combined with those of its sister organisations the World Bank and World Trade Organization, that are the root causes of the food crisis (Box 6). These policies have involved an incessant push towards a "Green Revolution" agricultural model since the 1950s and an imposition of trade liberalisation on poor countries since the 1970s. The World Bank's President, Robert Zoellick, tried to win the world over with his call for a "New Deal" to solve the hunger crisis, but there is nothing new about it: he called for more trade liberalisation, more technology and more aid (GRAIN, 2008b). Today's food crisis is the direct result of decades of these same policies, which have reduced food security, self-reliance and agricultural sustainability, and which should now be rejected.

"In this process, fertile lands have been diverted away from serving local food markets to the production of global commodities or off-season and high-value crops for Western supermarkets. Today, roughly 70% of all so-called developing countries are net importers of food and of the

Box 6. The consequences of accepting IMF, World Bank and World Trade Organization policies and programmes: lessons from the South

A few decades ago Haiti was self-sufficient in rice. But conditions on foreign loans, particularly a 1994 package from the IMF, forced it to liberalise its market. Cheap rice flooded in from the US, backed by subsidies and corruption, and local production was wiped out. In 2008 prices for rice rose by 50% and the average Haitian could not afford to eat so people took to the streets in protest. Food protests have also erupted in West Africa, from Mauritania to Burkina Faso. There, too, structural adjustment programmes and food-aid dumping have destroyed the region's own rice production, leaving people at the mercy of the international market. In Asia, the World Bank constantly assured the Philippines, even as recently as 2007, that self-sufficiency in rice was unnecessary and that the world market would take care of its needs (GRAIN, 2008b). In 2008 the government was in a desperate plight: its domestic supply of subsidised rice was nearly exhausted and it could not import all it needs because prices were too high.

In the aftermath of the catastrophic earthquake that struck Port-au-Prince in January 2010, Haitian peasant organisations urged the Haitian government and international organisations to support family farming, with policies to make the commitment a reality. The aim is to provide land and the resources necessary to allow people to earn a living wage and to provide job security and health protection in rural areas so that rural people are not forced to move to urban areas. Sustainable family farms are the key to achieving these goals; at the national level, increasing food production within Haiti for Haitians would mean that Haiti would no longer have to depend on imports and hand-outs (Bell, 2010).

Box 6. The consequences of accepting IMF, World Bank and World Trade Organization policies and programmes: lessons from the South

The earthquake was preceded by four huge storms in the 2008 hurricane season which battered Haiti for three weeks, destroying crops, rural roads and bridges. While these two disasters have had devastating consequences, the people of Haiti have suffered for decades at the hands of IMF, WTO and World Bank policies. Even in 2004, 88% of the rural population lived in poverty, 67% in extreme poverty (UNDP, 2004). As a result people flocked to the capital from rural areas to provide cheap labour for sweatshops. There is a direct relationship between the state of agriculture and the earthquake's high toll in deaths, injuries, and homelessness. The quake was so destructive because more than three million people live in a city meant for a population of 200,000 to 250,000—most were living in extremely precarious and overcrowded housing.

Dependency on imports in Haiti has not been restricted to rice: overall 57% of food supplies are imported (Bell, 2010). In order for farming families and the rural economy to thrive, the policies that caused the problems need to be reversed so that tariffs and quotas on food imports are reintroduced, farmers receive financial and technical support, and food and farming policy is reoriented away from exports to meet Haitian food needs. This will require farm diversification and a shift away from a dependency on sugar and coffee exports.

Another detailed study has found that the pressure put on African countries in the mid-1980s to embrace "free" trade, reduce government involvement in agriculture and instead rely on the private sector, has had a devastating impact in many of the continent's poorest countries (Moseley et al., 2010).

During this time, tariffs, subsidies and critical support systems for poor farmers were reduced or abolished and farmers were encouraged to produce cash crops for export rather than staples. The insistence on agricultural exports was meant to spur economic growth, but instead undercut traditional agricultural systems, eventually leading to a food crisis which left millions hungry, led to multiple food riots, and destabilised governments.

Traditional poor African farmers: "were then asked to compete with some of the most efficient agricultural systems in the world, and they simply couldn't do it. " (Moseley et al., 2010). They couldn't compete in the global food market against heavily mechanised, subsidised, and corporate agricultural systems and they were forced to migrate to cities. Rather than aid Africa's farmers, the emphasis on trade liberalisation undercut local food production for a quarter of a century, according to the study, placing increased reliance on imported rice. The emphasis on "cash crops" for export meant that many farmers were no longer focusing on the food staples they had grown for generations to feed local communities. Then in 2008 global rice prices doubled leaving millions of Africans—who spend much of their income on food—hungry.

The authors suggest that West Africa should focus less on increasing rice production—a focal point of the Green Revolution in Africa—and more on historically important crops, such as sorghum, millet, maize, cassava, and yam. In addition, some other possible solutions include increased tariff barriers on imports to allow local producers to be competitive, and introducing extension systems, better credit systems, building local mills, and employing subsidies when appropriate. Mali has maintained a cultural commitment to local rather than foreign products; furthermore its location makes imported rice expensive, and so local crops have been supported and only 20% of rice is imported.

estimated 845 million hungry people in the world, 80% are small farmers....Agricultural policy has completely lost touch with its most basic goal of feeding people." (GRAIN, 2008b)

Up until the last few years, the food price crisis took a different form. Since the 1980s, neo-liberal economics has flourished, with new impetus given to it in the 1990s by the policies of the World Trade Organization's Agreement on Agriculture (AOA) and, more recently, bilateral trade deals. The net result of these policies had been the collapse of the price that farmers receive for their produce. For the last few decades, the crisis has engulfed the majority of farmers worldwide—from Britain to Brazil and from Germany to the Gambia.

These WTO trade rules promote the interests of agribusiness, multinational food processors, the commodity traders and multinational retailers, industrial production and long distance transport, and force countries to compete to produce each other's food at the expense of domestic production. Trade liberalisation is a disaster for food security, particularly in poorer countries, as subsistence farms are increasingly put out of business or forced into export production instead. The dominance of multinational food retailers in the OECD countries and their recent entry and rapid expansion in the South also has significant negative impacts (see the section below, "Concentrated power: invasion of the multinational retailers").

Industrialised food and farming systems

In OECD countries over the past 50 years there have been significant changes to the way in which food is sourced, produced, processed, packaged, distributed and marketed; a process that is being replicated in the South. For many households, shopping for food now consists of a journey by car to a large out-of-town self-service retail outlet. Here, up to 40,000 products from all over the world will be available in various forms including fresh, canned, bottled and frozen. In these countries, food supply and shopping for food is now synonymous with convenience, extensive choice, and the year-round availability of both processed and fresh produce.

Food production, trade, processing, distribution and retailing systems have undergone significant change and as a result there are fundamental differences between the contemporary food system and its counterpart 50 or even 30 years ago. The most significant of these include:

- Increasing levels of fossil fuel dependency throughout ever more complicated food supply chains, resulting in a global food system that is probably the biggest source of greenhouse gas emissions and the main reason for the destruction of forests and other carbon sinks.

- High levels of external inputs into farms in the form of synthetic fertilisers, pesticides, animal feed, fuel and antibiotics, which increase production costs and create dependence.

- Highly industrialised and mechanised farming systems increasingly based on monocultures and often requiring unsustainable levels of irrigation.

- Increased food freight transport: both within countries due to centralised "just-in-time" distribution and between countries due to increased international trade in food, fertilisers and other farm inputs.

- A major shift to highly processed and packaged food; for example, in many European countries up to 80% of food is now pre-processed and a third of meals pre-prepared. Half of all goods consumed in Europe are now packaged in plastic.

- Increased concentration: supermarkets typically control 70-80% of food sales, and this has been accompanied by the

loss of small shops, markets and traditional wholesalers (see below). Running parallel to this trend is the concentration of the supply base into the hands of fewer, larger suppliers and traders, partly to meet supermarket preferences for bulk year-round supply of uniform produce.

The social and environmental implications of this transformation are now clear. The food system in the US uses 10,551 quadrillion joules of energy each year, comparable to the total annual energy consumption in France. Growing food accounts for only one-fifth of this—the other four-fifths are used to move, process, package, sell and store food after it leaves the farm (Murray, 2005). The consequences of "modern food" have been devastating for small family farms, independent shops and rural communities in the North as well as the South. The social costs of the modernisation of the food system are high: in the North diet-related ill-health takes the form of obesity, heart problems and strokes. In the South the lack of an adequate diet often results in hunger, malnutrition and starvation. In the sections which follow we discuss some of these implications.

Industrialised farming and energy

Industrialised farming consumes 50 times the energy input of traditional agriculture; in the most extreme cases, energy consumption by agriculture has increased 100-fold or more. It has been estimated that 95% of all of all food products in European countries require the use of oil (Skrebowski, 2004). Meat production is particularly energy, water, and land-intensive. Just to raise a single cow and deliver it to market requires the energy equivalent of six barrels of oil (National Geographic, 2004).

The manufacture of synthetic fertilisers is also energy-intensive—fertiliser use typically accounts for around one-third of agricultural energy consumption. As energy costs have increased in recent years so have fertiliser prices. The cost of synthetic fertiliser increased dramatically to reach levels in 2008 that were 5-7 times higher than prices in the previous 10 years (IRRI, 2010a). Although prices have dropped from the highs in 2008, they remain two to three times more expensive. Farmers who

Box 7. Synthetic fertiliser

Fertilisers provide the three major plant nutrients—nitrogen (N) phosphorus (P), and potassium (K)—as well as secondary nutrients and trace elements. For over half a century farmers have been encouraged to use synthetic fertilisers and have become dependent on these chemical fixes, as well as other external inputs like pesticides, machinery, antibiotics and imported feed.

Although synthetic fertilisers have only been used on a large scale since the 1950s, consumption has increased dramatically since then. World fertiliser consumption doubled between 1970 and 2000, from 70 to 138 million tonnes, and is expected to rise to 200 million tonnes by 2030. China now consumes the most fertiliser, at 40 million tonnes of N, P and K in 2004, and 32.6 million tonnes of nitrogen fertiliser in 2007 (Kalaugher, 2010). It has been estimated that about 40% of world food protein production now relies on synthetic nitrogen fertilisers.

Nitrogen fertilisers are derived from atmospheric nitrogen fixed by the Haber-Bosch process to produce ammonia, a very energy-intensive process as it involves breaking the strong bond between two nitrogen atoms and requires high pressure and temperatures around 450-500°C.

Ammonia can be applied directly to the soil or used to produce other compounds, notably ammonium nitrate, a

Box 7. Synthetic fertiliser

dry, concentrated product. It can also be used in yet another chemical reaction, the Odda Process, which requires phosphate rock and nitric acid, to produce compound fertilizers, or urea - the product of the reaction of ammonia with carbon dioxide.

Table 1 shows that the production of one kilogram of nitrogen fertiliser requires the energy equivalent of two litres of diesel; producing the same amount of phosphate fertiliser requires almost half a litre of diesel.

The energy consumed during fertiliser manufacture was equivalent to 191 billion litres of diesel in 2000, which could rise to 277 billion litres in 2030.

The price of synthetic fertiliser has increased significantly in recent years: a six- to seven-fold increase in the case of several compound fertilisers. Although prices have fallen back from their peak in 2008, they will increase again in the near future as energy prices increase. This dependency on fossil fuels is exacerbated because natural gas is used as a feedstock and because fertilisers are bulk products that are energy intensive and expensive to transport.

Another reason that prices are increasing for phosphate fertilisers is that reserves of phosphate rock are becoming depleted—some researchers have warned of "peak phosphorus"—the deposits that remain are more difficult, energy intensive and expensive to extract.

Price increases mean that many farmers can no longer afford these inputs—not just the poorest smallholders, but also medium-sized farms. The situation is made worse when yields are lower than promised by the purveyors of chemical inputs. In the worst cases this results in tragedy, with farmers who took out loans they could not repay committing suicide.

Table. Energy requirements for synthetic nitrogen, phosphate, and potash (MJ/kg)

Nutrient	Production	Packaging	Transportation	Application	Total	Litres diesel equivalent/kg
N Nitrogen	69.5	2.6	4.5	1.6	78.2	2.03
P_2O_5 Phosphate	7.7	2.6	5.7	1.5	17.5	0.45
K_2O Potassium	6.4	1.8	4.6	1.0	13.8	0.36

Source: Lucas *et al.* (2006)

have become dependent on synthetic fertiliser are struggling to meet the costs. The price of synthetic fertiliser, and other external inputs to farming, will increase further during the next few years if, as the IEA predicts, energy prices rise (Box 7).

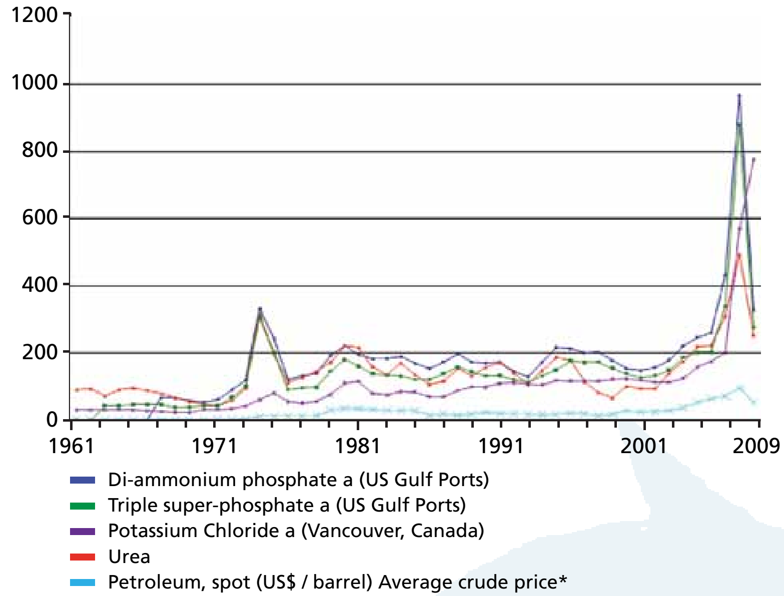
International trade in fertilisers and their raw materials

Fertiliser producers include many of the giants of the chemical and mining industries. The export of fertilisers, and the raw materials used to produce them, is a significant constituent of sea-borne bulk trade: the fourth most traded bulk commodity in world shipping.

The 10 largest nitrogen fertiliser producing countries account for about three-quarters of world production. In the case of phosphates, the 10 largest producers account for about 80% of world production with a shift in recent decades towards the processing of phosphate rock to areas with substantial deposits, such as Africa, China, the US, and the Middle East. It has been estimated that two-thirds of world phosphate rock deposits are concentrated in Morocco.

Higher energy and fuel prices will be a triple blow for the synthetic fertiliser industry and those farmers who have become dependent on this quick fix: (1) because of the large amount of energy required to extract ores and consumed during the manufacturing process (Box 6); (2) the use of natural gas as a feedstock; and (3) the fuel required to transport these bulk commodities. Figure 10 shows the close correlation between the price of fertiliser and that of crude oil.

Figure 10. International prices of fertilisers and crude oil



Source: Jones (2010)[10]

A shift from synthetic fertiliser and pesticide to agroecology

The Petroleum Period has allowed us to do many things—some good and some bad—but one result that stands out is the belief that fossil power plus science and technology can solve any

10 Based on data compiled by the International Rice Research Institute - Table 46. World prices (US$/t fob) of major fertilizer raw materials and petroleum, 1961-2009. At http://beta.irri.org/solutions/index.php?option=com_content&task=view&id=250. Sources: World Bank. Commodity trade and price trends. The Johns Hopkins University Press, Baltimore and London (various issues). 1994-2009: http://www.worldbank.org and FAO Food Outlook. Rome (various issues).

problem that we come across and can always improve our lives. The application of an industrial world view to the food system is based on a belief that a scientific, reductionist approach is superior to a natural systems and organic approach. The use of synthetic fertiliser and pesticide is a case in point. Unfortunately both have significant social and environmental impacts and neither will be a viable option for most farmers when energy costs rise further. This quick fix response has proved addictive since synthetic fertilisers have been made available and, because of low energy costs, affordable.

World fertiliser manufacture and transportation requires the energy equivalent of 191 billion litres of diesel each year and is projected to increase by 45% in 2030 which would require the energy equivalent of 277 billion litres of diesel.

This increase is simply not feasible in terms of cost, energy supplies and ecological impacts. Over-dependence on fertiliser is just one aspect of the economic and social consequences of industrial farming. Its ecological impacts are also high in relation to greenhouse gas emissions, the acidification and erosion of soil, water pollution and eutrophication, and biodiversity loss. Sooner or later, all of these environmental impacts also affect agriculture and result in reduced yields, crop losses and less food.

A very real and immediate problem is that the sustainable low-cost alternative in the form of farming systems that employ agroecological approaches—green manures, compost, livestock manure, and rotation—can take several years to improve soil fertility and increase yields in soils that have been mined through poor farming practices. This is why the shift away from dependency on external inputs to agroecological approaches has to begin now.

Alternative methods for increasing soil fertility include green manures, animal manure (as well as methods to recycle human faeces and urine), biogas filtrate, rotation and composting systems (of varying scales). All of these options are based at the local level. As oil prices increase and fertiliser price rises further, there will be a premium on closing the nutrient cycle at the local level and replacing synthetic fertiliser with agroecological farming and local organic waste (Murray, 2005). The point here is that peak oil will not only require us to minimise the distance between farm and household, but also to avoid all other energy consumption and transportation associated with food supplies, including farm inputs.

Concentrated power: invasion of the multinational retailers[11]

Supermarkets are where the vast majority of OECD, and increasingly non-OECD, consumers meet the produce of the world's farmers. However, in the countries of the South, as happened in the North, farmers often find it difficult to market their produce locally or in towns and cities because supermarket retail chains prefer to deal with large-scale producers, often overseas. Furthermore, as the market share of the large retailers increases, traditional marketing outlets, such as small independent shops, fresh produce markets and wholesale markets disappear, sometimes very rapidly.[12]

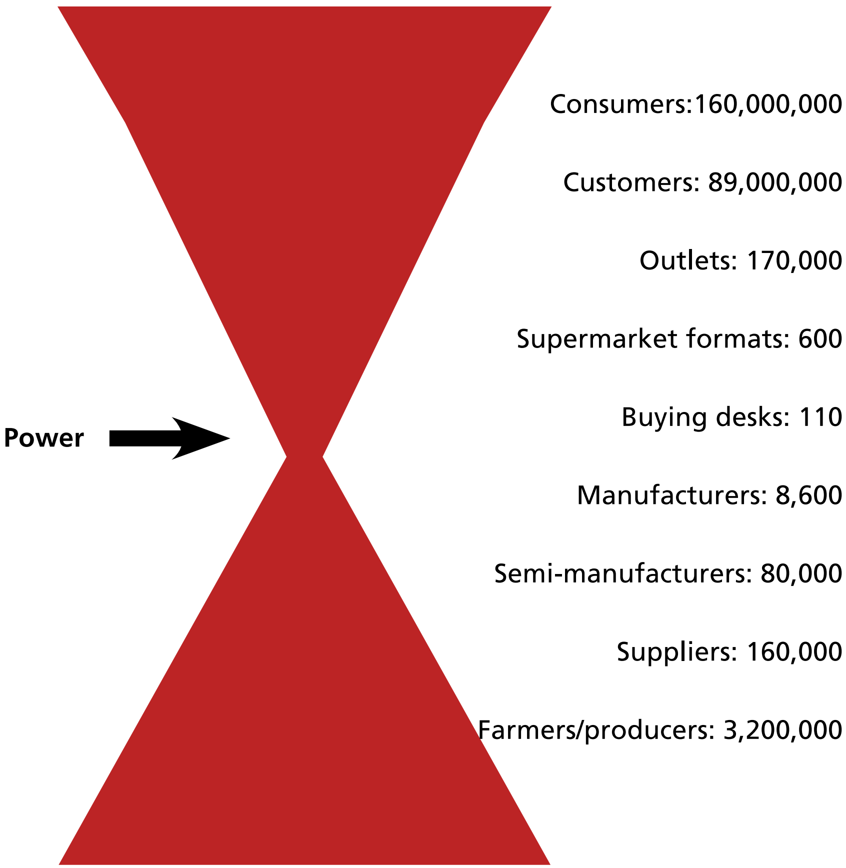
The supermarkets' role at the narrowest point of the "hourglass" or "bottleneck" between farmers and consumers (Figure 11) has led to a wave of civil society and regulatory scrutiny of this sector in recent years. This is partly driven by the farm-retail price gap and very different levels of profitability between the farming and retail industries. In the UK, the total profit of all

11 The data, information and charts in this section are based largely on extracts from: Vorley, B. (2003), *Food, Inc. - Corporate concentration from farm to consumer*. Report for the UK Food Group, London, available at www.ukfg.org.uk/docs/UKFG-Foodinc-Nov03.pdf.

12 See for example: Competition Commission (2000); FOE (2003); Raven et al. (1995); and DETR (1998).

230,000 farms is roughly equivalent to the profit of just six supermarket chains, which have around 80% of the grocery market.

Figure 11. The food system "bottleneck" in Europe



Source: Vorley (2003), Grievink (2003)

There has been a major shift in recent decades from supplier-driven to buyer-driven food chains and it is the large retailers that increasingly co-ordinate and control food supply from farm to plate. As the market share of supermarkets has increased, so has their power and their ability to dictate terms to suppliers and push down farm gate prices. Their aim is to maximise their share of the retail price of each food product and in doing so they put pressure on farmers and processors to reduce their costs and accept an increasingly lower share of the price of the product. In OECD countries this has resulted in a widening of the gap between farm and retail price, and a situation in which the largest retailers have joined the billion pound profit club while many farmers face financial crisis as farm gate prices fall below the costs of production.

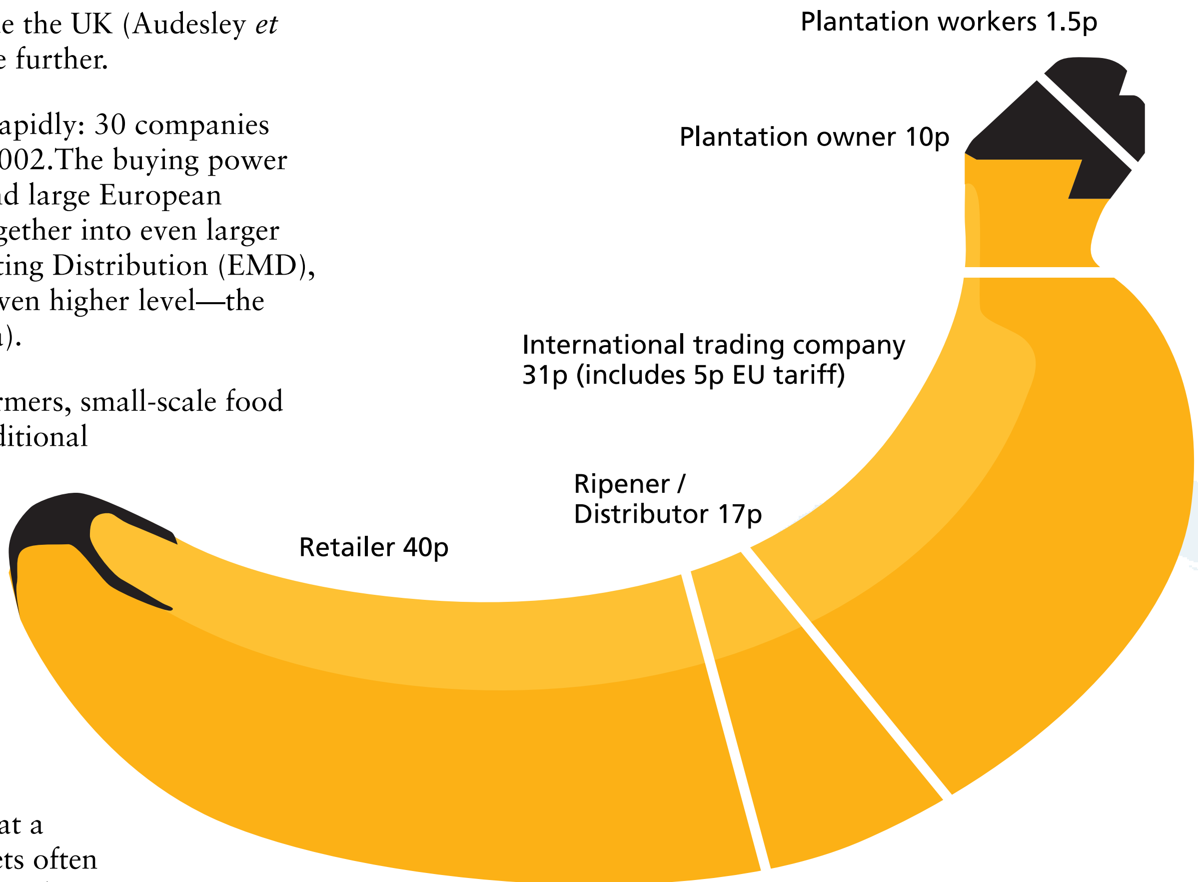
One of the consequences of these processes is that hardly any of the food produced in a district or province in Europe is consumed there. This produce, even if unprocessed, is distributed to other parts of the country or exported. The link between the land, food producers and the consumer is lost. This in turn leads to distancing effects, so that the consumer has little information on the origin of food products or awareness of the social and environmental impacts associated with food production and distribution. One example of this is the issue of virtual water, described below. Another is that of "ghost acres": the vast areas of land, often in other countries, used to cultivate animal feed and ingredients such as soy in processed foods. In terms of climate change, the globalisation of the food system means that for countries that import large quantities of food, a large fraction of the greenhouse gases associated with their food supply are emitted outside their borders. For example, 43% of the carbon dioxide emitted from the distribution of food consumed in the UK is emitted outside the UK (Smith *et al.*, 2005). A report published by WWF in 2009 found that greenhouse gas emissions associated with food supplies in the UK had been underestimated. The study discovered that when land

use change emissions (arising largely outside the UK) are taken into consideration, these account for 40% of the GHG emissions embedded in UK-consumed food and that UK food consumption is responsible for at least 30% of total GHG emissions associated with all UK consumption. When land use changes are factored in, it becomes clear that half of the GHG emissions associated with food supplies in the UK arise outside the UK (Audesley *et al*., 2009). Section 5.2 discusses this issue further.

The food retail sector has concentrated rapidly: 30 companies accounted for a third of global sales in 2002.The buying power of multinational retailers is staggering and large European retailers also pool their buying power together into even larger buyer alliances such as European Marketing Distribution (EMD), which raises buyer concentration to an even higher level—the narrowest part of Figure 11 (IGD, 2007a).

This all has profound implications for farmers, small-scale food processors, independent retailers and traditional fresh produce markets, especially in the South. In the North many of these enterprises have already disappeared. The supermarket dominance of agriculture and food chains is no longer an industrialised world phenomenon. Small-scale food producers and processors face a global supermarket sector that has enormous buying power, and which has already swept away their counterparts in the North. In the North, at a national level, the five largest supermarkets often account for 70% or more of grocery sales. This pattern is now being replicated in the South as supermarket chains are rapidly penetrating middle and lower income countries, influencing the way food is produced and the way that profits accrue along agrifood chains (see Box 8 and Figure 12).

Figure 12. Breakdown of the price of bananas: how much of £1.00 retail value of loose Ecuadorian bananas stays with each actor in the chain to cover costs and margin



Source: Banana Link. Based on June 2003 prices; quoted in Vorley (2003)

Box 8. The growth of supermarkets in the South

By 2002, supermarkets controlled 50-60% of the food retail sector in Latin America, an astounding increase considering that 10 years before their market share was only 10-20% (see Section 3.5).

In the small economies of Central America supermarket expansion has been rapid and widespread; in Guatemala, a leading supermarket chain has concluded that only 17% of the population is out of supermarket reach because of low income or geographic isolation. Supermarkets are looking for a limited number of suppliers that can provide necessary volume and quality. The expansion of new retailers with highly integrated operations and new rules of participation is pulling the market out from under the feet of thousands of small and medium rural enterprises which have played a fundamental role in job creation and rural income diversification.

One significant consequence of a shift to supermarket supply chains, and their aim of keeping the prices they pay to suppliers low (maximising their profits) through the supply chain, has been felt in China, where this approach is displacing traditional farming and distribution systems. While supermarkets were almost unknown in China prior to 1990, by the end of 2000 the retail market was worth US $412 billion, and supermarkets sales amounted to 7% of the total turnover of the whole country.

The impacts of this are summarised in a US Department of Agriculture report:

"Foreign-invested retailers, processors and chain restaurants have sourced most of their produce, meat, and other raw materials in China, but they have had difficulty obtaining reliable supplies of standardised products from China's traditional system of small household farms geared towards producing food for home consumption. To keep pace with the demand of buyers, farms will have to adjust by specialising in a particular commodity, consolidating fragmented land holdings to achieve scale economies, and forging stronger links with processors and retailers. Closer relationships between firms at different stages of production and marketing are emerging as larger commercialised farm operations grow produce and animals under contract for processors, retailers or exporters. This trend is likely to continue and may profoundly alter the way food is produced in China" (Gale et al., 2002).

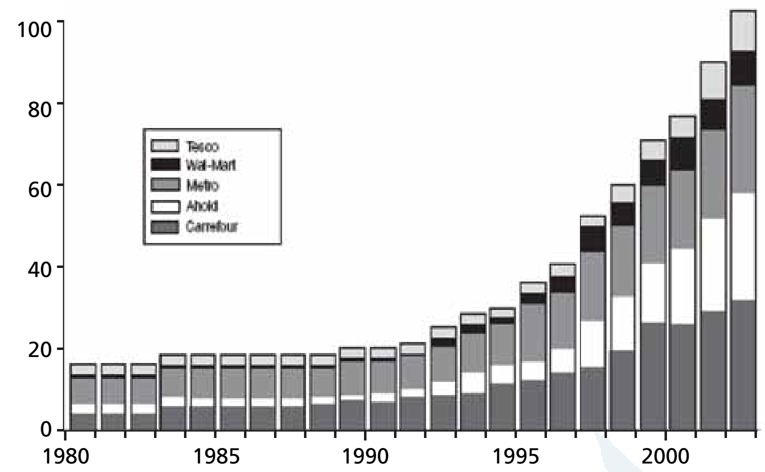
Agriculture and land use in the South has already been transformed to meet import requirements in the North. Initially this transformation was driven by plantation owners and merchant traders, then food processors and during the last two decades to supply multiple retailers in OECD countries. Production for export has promoted large-scale, specialised farming systems, often in the form of plantations that are based on high levels of external inputs that have in certain cases had major ecological, livelihood and health impacts. The introduction of Western style supermarkets in the South will result in a far more widespread and damaging impact, not only on small farms but also on small-scale processing and local markets. In many instances food supply in these countries is currently based on smallholders who produce food for their families and sell the surplus at local markets. There is very little packaging and energy use is minimal. Introduction of supermarket supply chains spreads unsustainable practices and will have a devastating impact on the environment and rural livelihoods.

Just about all population growth over the next 25 years is predicted to take place in urban centres in low to middle income countries, and global retailers are structuring their organisations to follow this demand. More than 50% of the growth in global food retail markets is expected to come from emerging markets. China and India are among the five most attractive countries for the expansion of modern food systems. The growth of supermarkets is considered to be "an entry point to economic development" as it "improves market efficiency" and thereby frees up wealth for spending on non-food items. But it also means that primary producers and processors face domestic markets that start to take on the characteristics of export markets.

This geographical expansion strategy of the multinational retailers is based on continuous growth in order to increase profits and returns to shareholders. The primary objectives are economic and little or no attention is given to the social and environmental consequences. Figure 13 demonstrates the rate at which European and US retailers have expanded beyond their borders since 1990. Carrefour, Metro, Tesco and Walmart are the largest global retailers with a combined turnover of €525 billion in 2007; Walmart alone reported sales of US $380 billion for 2007, a sum greater than the combined turnover of the next five largest retailers (IGD, 2007b).

In the context of trade liberalisation, low transport costs and supermarket sourcing policy, the inevitable outcome is that food products are supplied from wherever they can be produced at lowest cost and more foodstuffs are imported and exported. International transport increases, as does the distance that food is transported by road within countries due to the centralised distribution systems of the multiple retailers and a shift to highly processed food products. Shopping becomes a predominantly car-based activity. The massive stores do not fit into town centres and as small independent retailers are unable to compete, journeys by car are required for even basics such as bread and milk, which were once available within walking distance.

Figure 13. Global expansion of the big five global retailers, 1980-2001



Source: Vorley (2003) vertical axis - international sales (US $Billion)

In 2002, vehicles and vessels travelled a cumulative distance of 30 billion kilometres moving food products to and within the UK—this is equivalent to 234 billion tonne-kilometres. In the US it has been estimated that the average food product is transported 1,000 miles (1,670km). In Europe, the distribution of food now accounts for up to one-third of all road freight in some countries.

The food distribution system has become energy intensive, and because freight transport by sea, air and road, is completely dependent on fuels derived from crude oil, it is particularly vulnerable to high oil prices.

If all inputs to farming, food processing and packaging systems are considered, the amount of transportation in the modern food system increases sharply. See, for example, the analysis of

tomato ketchup in Section 5 which shows that there are over 50 transport stages involved in its manufacture.

Emerging threats to food security

There are several other threats to food security, apart from higher food and energy costs, in the form of desertification; soil acidification, salination and erosion; water scarcity, unreliable rainfall, depletion of groundwater and water pollution. These acute problems are often related to climate change—caused by the use of fossil fuels and deforestation—or unsustainable farming practice. These issues and the links between them are discussed further in Section 2.5.

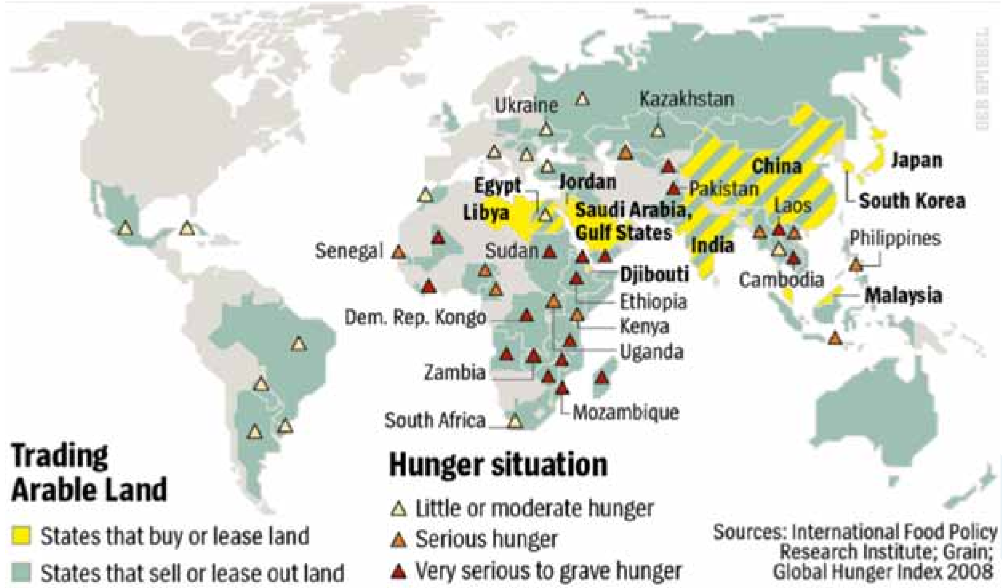
There are also threats to food security from social and economic trends such as migration to cities, farmers leaving agriculture and what has been called 'land grab', whereby corporations and national governments purchase land in other countries to produce food or biofuels solely for export.[13] There was a five-fold increase in foreign agriculture investment flows to developing countries between the 1990s and the period 2005-07, from US $600m to $3bn (Blas, 2009). GRAIN estimates that US $100 billion have already been mobilised to pay for these deals; the World Bank estimate is US $50 billion. The World Bank estimates that since 2006, 40 million hectares, equivalent to nearly half the cropland of China, has been sold, leased or is under negotiation in Africa, Asia, Latin America, of which 20 million hectares are in Africa alone (Figure 14).[14]

13 Land grab can be described as the acquisition (lease, concession or outright purchase) by corporations or states of large areas of farmland (>10,000 ha) in another country and on a long-term basis (often 30-99 years), for the production of basic staple foods and agrofuels that will then be exported.

14 See http://farmlandgrab.org. Some of these deals and the countries and businesses involved are listed at www.grain.org/m/?id=215

This process will have a significant impact on food security by reducing food supplies for local consumption and slowing or stopping the shift to agroecological farming. Recent crises are exacerbating the situation: increasing food prices means that "farming abroad" is seen as new food supply strategy by import-dependent governments and due to the financial crisis, farmland is now seen as a new source of profit by the finance industry.

Figure 14. Land grab



Source: GRAIN (2009c)

A draft report from the World Bank, *The Global Land Rush: Can it Yield Sustainable and Equitable Benefits*, leaked in August 2010 appeared to challenge the publicly held position of the World Bank on investments in agricultural lands in poor nations – or land grabbing. Although the World Bank maintains that such investments will generate jobs and infrastructure, the report states, *"investors are targeting countries with weak laws, buying arable land on the cheap, and failing to deliver on promises of*

jobs and investments, and in some cases inflict serious damage on the local resource base." (Farmlandgrab, 2010)

The report exposes the role of the Bank's private sector branch, the International Finance Corporation (IFC), in fuelling land grabs, especially in Africa. Shepard Daniel, Fellow at the Oakland Institute and co-author of the report (Mis)Investment, stated *"The report's conclusions that land deals are dangerous, lack transparency, and rarely seek to incorporate the host countries' overall investment strategies reflect our findings. The key question is how this acknowledgment will be integrated into the work of the Bank's agencies like the IFC, which have increased the ability of foreign investors to acquire land in developing country markets"* (Daniel and Mittal, 2010).

The most recent FAO report on this issue also emphasises that all available evidence shows that these new large scale investments in land are damaging food security, incomes, livelihoods and environment for local people (FAO HLPE, 2011a). According to the FAO, *"the range of interests behind large scale land investments include multinational companies engaged in a variety of investments including biofuels and extractive industries, foreign governments seeking an assured food supply, commercial farmers expanding into neighbouring countries, and financial institutions wanting to broaden their asset portfolio. Domestic investors are also important in many countries, sometimes in partnership with foreign capital….. Growing demand for food, feed, and biofuels as well as minerals and timber is driving large scale international land investments….. Ecological stress, such as water shortages and drought, combined with environmental policy, such as nature conservation, and carbon sequestration projects like REDD+, are also prompting increased international investment in land. All of these drivers are likely to increase over the next several decades, and intensify with the shifting impacts of climate change on agricultural production, putting ever greater pressure on land and water resources"* (FAO HLPE, 2011a).

The alternatives

There are now increasing calls for radical changes in agricultural policy so that small farmers around the world can gain access to land and make a living from it. Policies are required that support and protect farmers, fishers and others to produce food for their families, for the local markets and for people in cities; and strengthen and promote the use of technologies - based on the knowledge, and in the control, of those who know how to grow food. To put it another way, we need food sovereignty now: the kind that is defined and driven by small farmers, pastoralists, indigenous peoples, forest dwellers, and fisherfolk themselves (see Box 9 and Annex 3).

Box 9. Food sovereignty: what is it and how does it differ from food security?

Food sovereignty is a term coined by members of La Via Campesina (an international peasant coalition) in 1996 to refer to the right of peoples to define their own food, agriculture, livestock and fisheries systems, in contrast to having food largely subject to international market forces.

La Via Campesina's seven principles of food sovereignty include:

1. **Food: a basic human right.** Everyone must have access to safe, nutritious and culturally appropriate food in sufficient quantity and quality to sustain a healthy life with full human dignity. Each nation should declare that access to food is a constitutional right and guarantee the development of the primary sector to ensure the concrete realization of this fundamental right.

Box 9. Food sovereignty: what is it and how does it differ from food security?

2. **Agrarian reform.** A genuine agrarian reform is necessary which gives landless and farming people – especially women – ownership and control of the land they work and returns territories to indigenous peoples. The right to land must be free of discrimination on the basis of gender, religion, race, social class or ideology; the land belongs to those who work it.

3. **Protecting natural resources.** Food sovereignty entails the sustainable care and use of natural resources, especially land, water, and seeds and livestock breeds. The people who work the land must have the right to practice sustainable management of natural resources and to conserve biodiversity free of restrictive intellectual property rights. This can only be done from a sound economic basis with security of tenure, healthy soils and reduced use of agro-chemicals.

4. **Reorganising food trade.** Food is first and foremost a source of nutrition and only secondarily an item of trade. National agricultural policies must prioritize production for domestic consumption and food self-sufficiency. Food imports must not displace local production nor depress prices.

5. **Ending the globalisation of hunger.** Food sovereignty is undermined by multilateral institutions and by speculative capital. The growing control of multinational corporations over agricultural policies has been facilitated by the economic policies of multilateral organizations such as the WTO, World Bank and the IMF. Regulation and taxation of speculative capital and a strictly enforced Code of Conduct for TNCs is therefore needed.

6. **Social peace.** Everyone has the right to be free from violence. Food must not be used as a weapon. Increasing levels of poverty and marginalization in the countryside, along with the growing oppression of ethnic minorities and indigenous populations, aggravate situations of injustice and hopelessness. The ongoing displacement, forced urbanisation, repression and increasing incidence of racism of smallholder farmers cannot be tolerated.

7. **Democratic control.** Smallholder farmers must have direct input into formulating agricultural policies at all levels. The United Nations and related organisations will have to undergo a process of democratization to enable this to become a reality. Everyone has the right to honest, accurate information and open and democratic decision-making. These rights form the basis of good governance, accountability and equal participation in economic, political and social life, free from all forms of discrimination. Rural women, in particular, must be granted direct and active decision making on food and rural issues.

Food sovereignty is increasingly being promoted as an alternative framework to the narrower concept of *food security*, which mostly focuses on the technical problem of providing adequate nutrition. For instance, a food security agenda that simply provides surplus grain to hungry people would probably be strongly criticised by food sovereignty advocates as just another form of commodity dumping, facilitating corporate penetration of foreign markets, undermining local food production, and possibly leading to irreversible biotech contamination of indigenous crops with patented varieties.

Source: La Via Campesina (2003) with further detail, including policy documents on the La Via Campesina website at http://viacampesina.org

There are some encouraging signs in this direction. For example, in March 2008, the Agriculture Minister of Trinidad, Arnold Piggott, announced that the Caribbean nation plans to convert up to 8,090 hectares of state-owned land into food production and would look to Cuba for expertise in producing fruits and vegetables for local consumption.

As a response to protests and riots in Senegal the President introduced an ambitious crop expansion plan to make Senegal self-sufficient in staples. Senegal currently imports more than 80% of its rice needs: the plan is to increase rice production five-fold to 500,000 tonnes in a season.

2.4. Unsustainable water and waste systems

As with energy, there are two ends of the spectrum when it comes to water and sewage systems. In many countries, people—often women and children—have to walk for miles to reach safe, or even polluted, water supplies. More than 2.6 billion people worldwide lack access to adequate sanitation services and 1.1 billion must still practice open defecation. Seven out of ten people without adequate sanitation live in rural areas. According to a 2010 World Health Organization report, 884 million people lack access to an improved drinking water supply, 88% of the 4 billion annual cases of diarrhoeal disease are attributed to unsafe water and inadequate sanitation and hygiene, and 1.8 million people die from diarrhoeal diseases each year (WHO/UNICEF 2010). The WHO estimates that 94% of these diarrhoeal cases are preventable through modifications to the environment, including access to safe water. Simple techniques for treating water at home, such as chlorination, filters, and solar disinfection, and storing it in safe containers could save a huge number of lives each year.

At the current rate of progress, the world will miss the Millennium Development Goal (MDG) of halving the number of people without access to basic sanitation between 1990 and 2015. Even if the MDG target is met, there will still be 1.7 billion people without access to basic sanitation. If the trend remains as currently projected, an additional billion people who should have benefited from MDG progress will miss out, and by 2015 there will be 2.7 billion people without access to basic sanitation. Even though the MDG target for drinking water is likely to be met, 672 million people will still lack access to improved drinking water sources in 2015 (WHO/UNICEF, 2010).

Photo source: Peter Gleick, 2010

Open sewers carrying human wastes, animal wastes and garbage run along every major walkway in Kibera, Nairobi, Kenya, one of the world's largest urban slums; not an unusual sight in many other places.

In high income countries people turn on a tap to access unlimited supplies of fresh water and go to the toilet where they can flush and forget.

Neither of these approaches is sustainable. The "modern" sanitation systems being introduced in many countries in the South

are inadequate because they are in fact based on an outdated approach to the supply of water and treatment of grey and black water. These systems are based on a linear, industrial world view. The difference between a linear and a circular approach is explained by Herbert Girardet. The example he uses is based on the options that were available to tackle major outbreaks of typhoid and cholera due to sewage pollution of the Thames and the decision taken during 1858—the year of the "great stink":

> *"The German chemist Justus Liebig tried to persuade the London authorities to build a* sewage recycling system *for the city in the 1840s. When they decided in the 1850s to build a* sewage disposal system *instead, Liebig and others set to work on the development of artificial fertilisers, to replenish the fertility of soil feeding cities by artificial means (now that the human fertiliser was being disposed of in the sea)."* Girardet (2001)

This unsustainable system was pioneered in Rome 2000 years ago with the construction of the "*cloaca maxima*" through which much of the city's sewage was flushed into the Mediterranean. These political and economic decisions taken in Rome, and then in London, to dump sewage into rivers and eventually the sea, have undermined the sustainability of both agricultural and urban water and sanitation systems. These approaches, which continue to be introduced worldwide, are based on uni-directional flows of food and nutrients from farms in the countryside to the city. The lost nutrients are never returned to the land. London's sewage is currently transported to large treatment works such as Beckton and Crossness in 19th century sewers. Some decades ago, a proportion of it was used as fertiliser and soil conditioner, but the bulk of it was being dumped in the Thames Estuary. Now most of London's sewage is dehydrated and then burned in an incinerator, with the permanent loss of carbon as well as plant nutrients such as potash, phosphates and nitrates that should have been returned to farmland (Girardet, 2006).

In many other countries sewage is not treated before entering groundwater or streams, rivers and eventually the sea or lakes. The nutrients contained in the sewage, combined with soluble synthetic fertilisers running off agricultural land, result in eutrophication and the formation of toxic algal blooms in freshwater and marine environments. In many places vast brown sewage plumes oozing out into the sea can be seen from the air.

Worldwide, over half of humanity lives in cities, and two-thirds of the sewage from urban areas is discharged untreated into lakes, rivers and coastal waters. Every year, 5.9 trillion gallons of sewage is discharged into coastal waters, together with an estimated 41,000 to 57,000 tonnes of toxic organic chemicals and 68,000 tonnes of toxic metals into coastal waters, from 160,000 factories. In Latin America and the Caribbean, for example, treatment plants process only an estimated 14% of wastewater. In South Africa, some 63 ocean outfalls discharge approximately 800,000 cubic metres of sewage and industrial effluent into the sea every day (UNEP/UN-HABITAT, 2005).

Sewage discharge, combined with acidification of oceans as a result of global warming, and the impact of over-fishing, is resulting in increased ecological stress in all oceans. It has been estimated that oceans, as well as providing seafood, provide vital services in maintaining ecological diversity and regulating climate valued at US $23 trillion a year—only slightly less than the world's total GNP (UNEP, 2008).

Extreme cases of eutrophication caused by nutrients in sewage and farm runoff result in "dead zones", where huge growths of algae reduce oxygen in the water to levels so low that nothing can live (Figure 15). In 2006 the United Nations Environment Programme identified 200 dead zones around the world, a 34% jump in the number of such zones in just two years (Heilprin, 2006). Some are less than a square kilometre in size, while others are up to 70,000 square kilometres. Oxygen-starved areas in bays and coastal waters have been expanding since the 1960s.

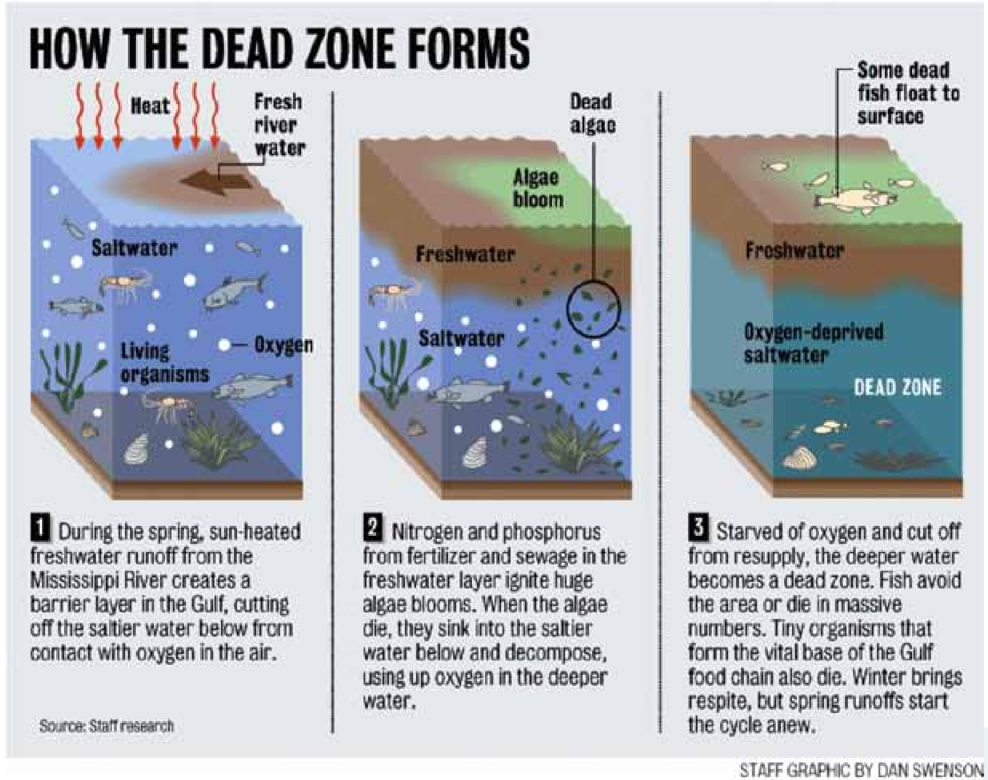
The number of known dead zone locations around the world has more than doubled since 1990.

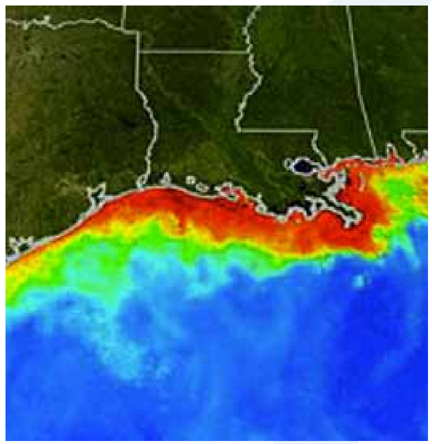
> *"While many of these sites are small coastal bays and estuaries, seabed areas in marginal seas of up to 70 000 km² are also affected. Increased flows of nitrogen from agricultural run-off and the deposition in coastal areas of airborne nitrogen compounds from fossil-fuel burning stimulate blooms of algae in these waters. The algae sink to the bottom where they are decomposed by micro-organisms that use up most of the oxygen in the system, creating an inhospitable habitat for fish, shellfish, and most other living things. In recent decades, large areas of coastal waters with harmful algal blooms, severely depleted oxygen levels, and disappearing sea grass beds have been identified and clearly linked with increased inputs from the nitrogen cascade"* (UNEP/UN-HABITAT, 2005)

An annual dead zone which forms in the Gulf of Mexico each summer measures between 2 and 8 thousand square miles (Figure 15). One study has shown that the increase in industrialised corn cultivation required to meet the goal of 15–36 billion gallons of biofuels by 2022 would increase the annual average flux of dissolved inorganic nitrogen (DIN) export by the Mississippi and Atchafalaya Rivers to the gulf by 10–34% (Donner and Kucharik, 2008). On a global scale, another study concluded that substantial reductions in fossil fuel use over the next few generations are needed if we are to avoid extensive ocean oxygen depletion lasting thousands of years, and associated adverse effects on marine life, such as more frequent mortality events (Shaffer *et al.*, 2009).

The linear approach to sanitation, in which human excreta are treated as something that has to be disposed of somewhere else, opens up the ecosystem to large and concentrated linear flows, particularly in cities with several million inhabitants. Chemical fertilisers and pesticides are used on crops, causing further

Figure 15. Dead zone in the Gulf of Mexico





Left: Dead zone off the US coast in the Gulf of Mexico

How the Dead Zone forms, source: Eggler (2007). Map source Heilprin (2006)

pollution to rivers and groundwater. The practice of feeding hormones and antibiotics to animals leads to large quantities of manure, hormones and pharmaceuticals polluting water supplies.

Ultimately, opening up the ecosystem to linear flows leads to:

– loss of soil fertility (reducing food production);

– a waste of a valuable source of fertiliser;

– destruction of marine life (declining fish populations, reducing a major source of protein for human consumption);

– loss of biodiversity on land and in water; and

– global warming and ozone depletion, when nutrients form gases that escape into the atmosphere.

All of these problems place people at risk of a multitude of health problems and increasing food insecurity.

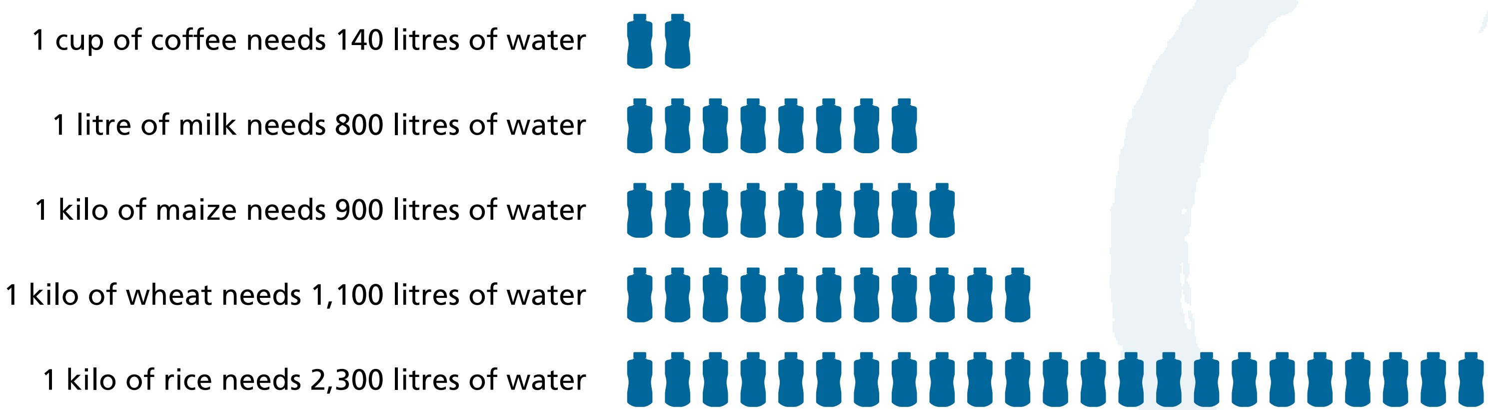
Many sustainable alternatives are available; for example, smaller scale eco-friendly sewerage technologies, such as eco-machines, with the plant nutrients contained in sewage being used in rural as well as urban and peri-urban food production.[15] The options for sustainable water supplies and sewage treatment are discussed in Section 3.

Our watery footprint

Another issue of importance in relation to water supplies is referred to as "virtual water" or our "water footprint". This is the water that has been used to produce the food and other goods we consume (Figure 16). For example, for each litre of orange juice produced, 22 litres of water are used to irrigate the groves and wash the fruit.

15 For information on eco-machines see http://toddecological.com/eco-machines/ and http://en.wikipedia.org/wiki/John_Todd_%28biologist%29. Videos that show how eco-machines function are available at www.youtube.com/watch?v=8_bxxUub9HU and http://vimeo.com/7687198

Figure 16. Water use for producing common commodities



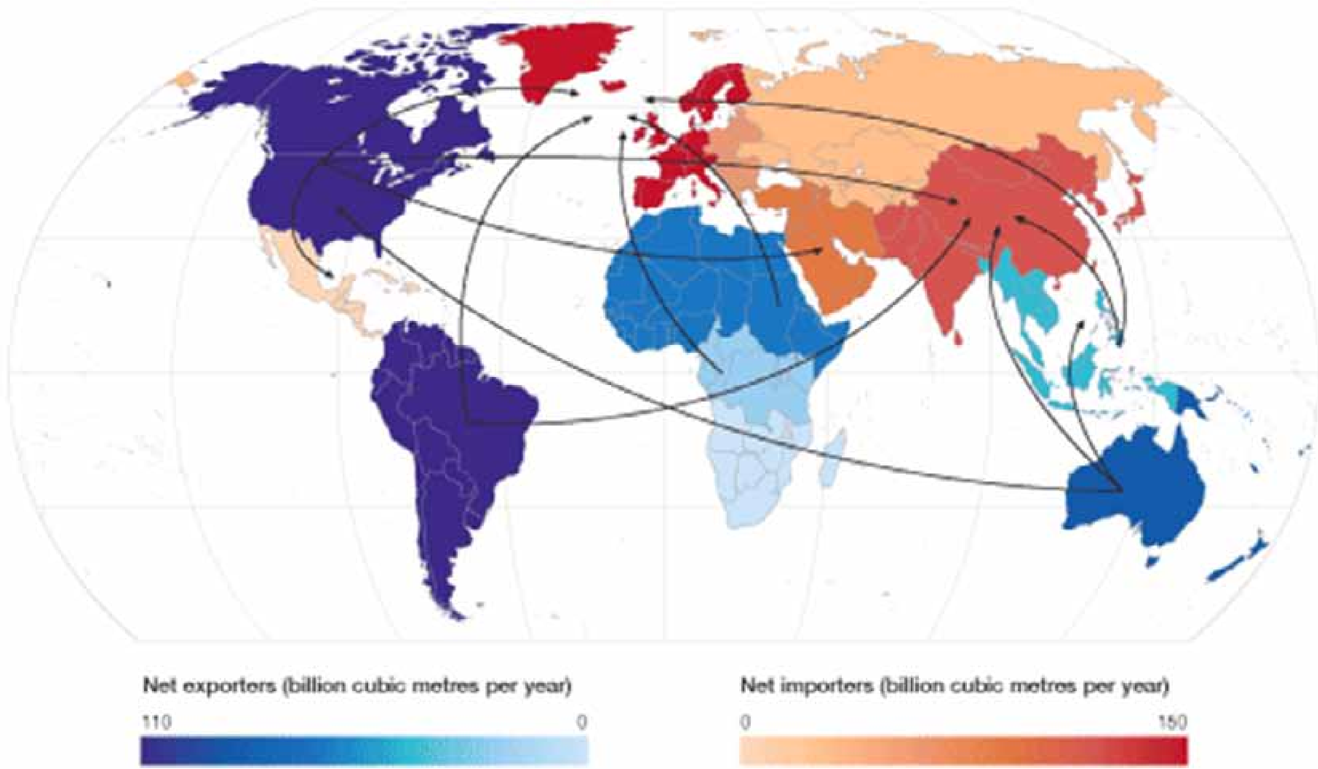
Source: UNEP (2006)

Food grown on irrigated land has a water footprint considerably larger than crops cultivated in rain fed fields. Nations with warm climates tend to use more water, as do countries which consume a lot of meat: 22,000 litres of water are used to produce just 1 kilogram of beef, compared with 1,000 litres for each kilogram of grain (Chapagain and Hoekstra, 2004).

Every time a country imports something, it also imports the virtual water embedded in its production. Importing a kilogram of grain, for instance, means importing 1,000 litres of virtual water. Such trade in virtual water is significant—it is estimated that it accounts for about 15% of the water people use. There are wide differences between countries (Figure 17): the US, Canada, Australia, Argentina and Thailand are all big virtual water exporters, while Japan, Sri Lanka, Italy and the Republic of Korea are large importers. Exporters place large demands on their own water resources; importers effectively shift part of their demand elsewhere.

Figure 17. Virtual water imports and exports around the world

Source: Chapagain and Hoekstra (2004); UN/WWAP (2006). Summarised in UNEP (2006).



2.5. Links between energy, food, climate change and water in recent and future crises

> *"Nothing reveals the thin veneer of civilisation like a threat to its food or fuel supply, or the cracks in society like a major climate-related disaster. A cocktail of all three will give cold sweats to the most hardened emergency planner. But that is what we face. Imminent, potentially irreversible, global warming; the global peak and decline of oil production; a global food chain in crisis – three linked, interacting dynamics complicated by yet another, a rich-world debt crisis."* (Simms, 2008)

As mentioned earlier, UNEP found that the key causes of the current food crisis are the combined effects of speculation in food stocks, extreme weather events, low cereal stocks, growth in biofuels competing for cropland and high oil prices.

However, if we take a closer look at the causes of food price increases and any links between them, one word comes to mind: energy. The shift to biofuels is all about energy security and peak oil. However, in many instances replacing fossil transport fuels with biofuels does not result in a reduction in either fossil fuel use or greenhouse gas emissions (Box 10). Similarly, the extreme weather events that have resulted in lower crop yields and crop losses are probably due to climate change, and the primary cause of climate change is fossil fuel use. Thirdly, high oil prices in 2008 were one of the first signs of peak oil, and the extent to which food supplies have become totally dependent on fossil fuels cannot be overestimated. So as oil prices increase the cost of food also escalates.

The links between food, energy, and land use are becoming apparent. Since virtually all the crops we currently grow for food can also be converted into fuel for transport vehicles, either in ethanol distilleries or biodiesel refineries, high oil prices inevitably open a vast new market for farm products. Those buying commodities for biofuel producers will be competing directly with food processors for supplies of wheat, corn, soybean, sugarcane, and other key crops. As Lester Brown has observed, the price of oil is setting the price for food simply because if the biofuel value of a commodity exceeds its value as food, it will be converted into fuel: "*in effect, supermarkets and service stations are now competing for the same commodities*" Lester Brown, cited in Lucas *et al*. (2006).

Brown also points out that the world appetite for automotive fuel is insatiable:

- The grain required to fill a 25 gallon SUV gas tank with ethanol (once) could feed one person for a year.
- The amount of corn used in US ethanol distilleries tripled in five years, jumping from 18 million tonnes in 2001 to an estimated 55 million tonnes from the 2006 crop.
- In South Dakota, a top-ten US corn-growing state, ethanol distilleries are already claiming over half of the corn harvest.
- The US supplies 70% of world corn exports; corn-importing countries are understandably worried about their supply.

Every link in the food chain is currently dependent on fossil fuels. The availability of cheap and reliable supplies of energy has been taken for granted, and the resulting greenhouse gas emissions largely ignored. Highly mechanised farming systems, energy intensive inputs such as fertilisers and the use of petrochemicals for plastic packaging will need to be reconsidered as energy costs rise. The geographical distances involved in food chains will need to alter drastically as we wean ourselves off fossil fuels. Until recently distance has been cheap and has allowed for specialised and large-scale farming, the products of which are distributed to distant markets through transport intensive logistical systems that cannot function without fossil fuels. This situation

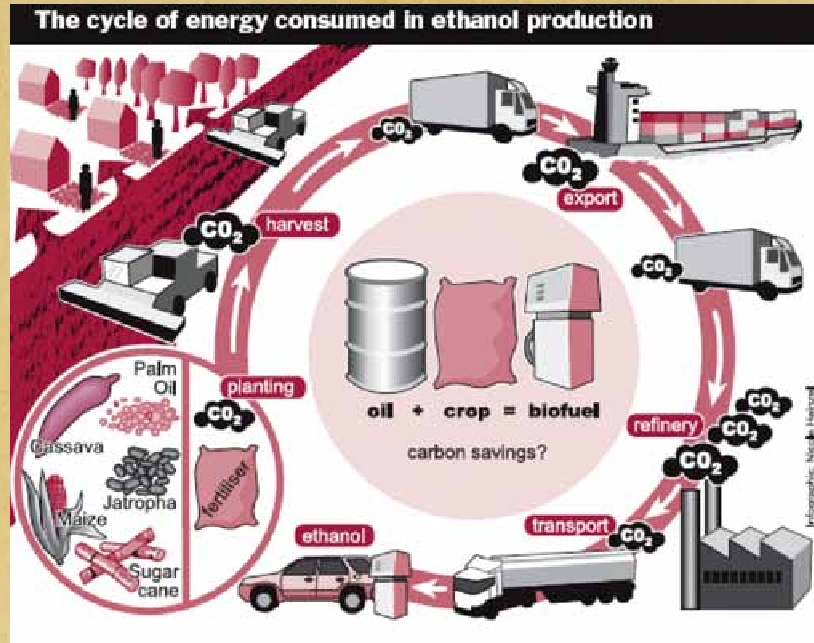
Box 10. What's wrong with industrial biofuels?

They don't save energy....or reduce GHG emissions

Biofuels can be produced from crops such as corn. A study in the US by David Pimental and Tad Patzek considered the fossil fuel energy use associated with the production of transport biofuel from crops and the total amount of energy required to cultivate, process and transport the biofuels (Pimentel and Patzek, 2005). This was then compared to the energy content of the biofuel. The results of the study are a cause for concern: using crops cultivated using industrial agricultural methods to produce biofuels requires more energy in the form of fossil fuel than was contained in the resulting biofuels.

Energy outputs from ethanol produced using corn, switch grass, and wood biomass were each less than the respective fossil energy inputs. The same was true for producing biodiesel using soybeans and sunflower; however, the energy cost for producing soybean biodiesel was only slightly negative compared with ethanol production. Other comparisons of energy outputs compared with energy inputs revealed that:

- Ethanol production using corn grain requires 29% more fossil energy than the ethanol fuel produced.
- Ethanol production using switch grass requires 50% more fossil energy than the ethanol fuel produced.
- Ethanol production using wood biomass requires 57% more fossil energy than the ethanol fuel produced.
- Biodiesel production using soybean requires 27% more fossil energy than the biodiesel fuel produced.
- Biodiesel production using sunflower requires 118% more fossil energy than the biodiesel fuel produced.



We don't have enough land to grow them

Road vehicles in the United Kingdom consume 37.6 million tonnes of petroleum products a year. The most productive oil crop which can be grown in the UK is rapeseed. The average yield is between 3 and 3.5 tonnes per hectare. One tonne of rapeseed produces 415 kg of biodiesel. So every hectare of arable land could provide 1.45 tonnes of transport fuel. To run UK cars and buses and lorries on biodiesel, in other words, would require 25.9m hectares of arable land. There are 5.7m hectares of arable land in the United Kingdom. Switching to biofuels would therefore require four and half times the UK arable area. Even if the UK were to achieve the EU's more modest target of 20% by 2020 this would consume almost all the UK's cropland (Monbiot, 2004).

Box 10. What's wrong with industrial biofuels?

Other calculations show that even on a global level a shift from crude oil to biofuels would not only threaten food security, it would in fact be unfeasible. As the table below shows, even if fairly high-yielding biofuel crops were planted all over the world, yielding 1,000 barrels of oil per year per square mile, and even if this biofuel were grown on every available scrap of arable farmland on earth, we would only replace 20% of the energy we're currently getting from crude oil (Schafer, 2006).

The Organisation for Economic Co-operation and Development (OECD) shows that Europe would need to convert more than 70% of its farmland to biofuel production to raise the proportion of biofuel used in its road transport to 10%. This limits the extent to which Europe can displace petroleum with regionally grown biofuels. Instead, imports from developing countries are already providing much of the raw materials and these are projected to increase.

The first generation of biofuels used food crops such as corn that would previously gone to human consumption. There are two options to avoid the use of arable land and crops for growing biofuels:

1. Certain biofuel feedstocks such as Jatropha can be grown on land that is too marginal to support food crops, and in urban and peri-urban areas.
2. Biodiesel and bioethanol can be refined from lignin and woody material as well as algae.

The danger is that biofuel will continue to displace commercial food crops because the profits from biofuel are often higher than those for food crops. The other danger, as has happened in countries such as Indonesia, is that the lure of biofuel crops will result in deforestation and biodiversity loss on a massive scale.

Figure 18. Can biofuels replace crude?

assumptions	constants	results	Assumptions: About 10% of the world's land area consists of arable farmland, about 5.7 million square miles. If 100% of that land was planted with biofuel crops yielding 1,000 barrels of oil per square mile, each year that would produce 5.7 billion barrels of biofuel. But world consumption of crude oil currently stands at 85 million barrels per day, which equates to 31 billion barrels per year. Source: Schafer (2006)
Biofuel Yields per Area per Year			
18			gallons per acre per year - corn
202			gallons per acre per year - jatropha
	600		acres per square mile
	55		gallons per barrel
		196	barrels per square mile per year - corn
		2,204	barrels per square mile per year - jatropha
Barrels of Oil Consumed per Year (millions)			
85			barrels per day - world consumption
22			barrels per day - USA consumption
	365		days per year
		31,025	barrels per year - world consumption
		8,030	barrels per year - USA consumption
Available Land to Grow Biofuel (thousands of square miles)			
57,393			square miles land - world (incl. Antarctica)
3,537			square miles land - USA (incl. Alaska)
10%			percent arable farmland - world
19%			percent arable farmland - USA
		5,751	square miles farmland - world
		677	square miles farmland - USA
Land Needed to Replace Crude Oil with Biofuel			
1,000			barrels per square mile per year
		540%	percent of arable farmland - world
		54%	percent of all land - world
		1187%	percent of arable farmland - USA
		227%	percent of all land - USA

could change rapidly and without warning. Large increases in international trade in the decade up to the financial crisis resulted in a 10-fold increase in shipping costs (Financial Times, 2007). If supplies of transport fuels are reduced and/or prices increase, abruptly due to geo-political conflict, or gradually because of a peak in supplies, then industrialised production systems and supply chains will be in jeopardy (Financial Times, 2007).

If food chains remain fossil fuel intensive, food security will be in danger. The ongoing food crisis and the impact that it has had on the poorest and most vulnerable, should be seen as a warning sign. In high income countries food supplies will also be at risk. For example, we caught a glimpse of just how dependent the supply of even the most basic foods have become on petroleum during the blockades at oil refineries and distribution depots in the UK in September 2000, when the protest by farmers and road hauliers against higher fuel taxes triggered a national "fuel crisis". Within days, the supermarkets began to ration sales of bread, milk and sugar. The chief executive of Sainsbury's, one of the largest retailers in the UK, wrote to the Prime Minister to warn that the petrol crisis was threatening Britain's food stocks and that stores were likely to be out of food in "days rather than weeks."

Freight transport—in the form of shipping, air transport and road freight—is almost totally dependent on crude oil: in most cases over 90% of transport fuels are derived from it. Moreover, the distribution of food and agricultural products accounts for a large fraction of international freight and within OECD countries typically makes up one-third of domestic road freight. Car ownership is increasing rapidly across the world and between 1995 and 2020 the volume of international trade is expected to triple (UNEP, 2002). In Box 10 we asked if biofuels can replace crude oil transport fuels. Based on industrialised methods and current transport fuel demand the answer is an emphatic no.

The production of energy from fossil fuel and biofuel also consumes large quantities of water (Table 2). This is water that could in many cases be used for agriculture or for drinking.

Table 2. Water consumed during energy production

Water Requirements for Energy Production (litres per megawatt hour)	
Petroleum Extraction	10-40
Oil Refining	80-150
Oil shale surface retort	170-681
NGCC* power plant, closed loop cooling	230-30,300
Coal integrated gasification combined-cycle	~900
Nuclear power plant, closed loop cooling	~950
Geothermal power plant, closed loop tower	1900-4200
Enhanced oil recovery	~7600
NGCC*, open loop cooling	28,400-75,700
Nuclear power plant, open loop cooling	94,600-227,100
Corn ethanol irrigation	2,270,000-8,670,000
Soybean biodiesel irrigation	13,900,000-27,900,000
*Natural Gas Combined Cycle	

Other links are also becoming apparent, for example the greenhouse gas emissions from food and farming systems. Agriculture is a major contributor to climate change due to emissions of methane from livestock, nitrous oxide from synthetic fertilisers, the release of carbon from soils when ploughed, as well as carbon emissions from fuel use on farms and during the manufacture of inputs such as fertiliser. Worldwide, agriculture and land use changes related to agricultural activity alone are responsible for about a third of the world's greenhouse gas emissions (Figure 19; Audsley *et al.*, 2009). When post farm gate emissions are included, it has been estimated that the food

system could account for up to half of all anthropogenic climate change impacts.[16]

Of global anthropogenic GHG emissions other than carbon dioxide, in 2005 agriculture accounted for about 60% of nitrous oxide (N2O) and about 50% of methane (CH4). Nitrous oxide emissions have grown by 50% since 1970 (11% since 1990), mainly due to the increased use of fertiliser and the aggregate growth of agriculture. Industrial process emissions of N2O have fallen during this period (Rogner *et al.*, 2007).

Thus industrialised farming systems and globalised food chains are a major contributor to climate change—and, in its turn, climate change reduces farm output and the availability of food (Box 11).

Similarly, fossil fuel use for energy and electricity supplies is a significant source of the greenhouse gases that result in climate change; and climate change is having an impact on energy consumption levels and the reliability of electricity supplies. This is because longer and more severe and prolonged periods of hot and cold weather are resulting in increases in energy consumption for cooling and heating, respectively. In most countries this energy is derived from fossil fuels – as only a very small fraction of energy is supplied from renewable energy sources, thus, in a vicious circle ever more greenhouse gases are produced. In some countries climate change is resulting in much lower levels of rainfall. In countries that rely on hydro power for electricity supplies, such as Ecuador, insufficient rainwater and low water levels in dams are resulting in rationing of electricity and blackouts.

16 GRAIN (2009d) estimate that agriculture and the food system are responsible for 44 to 57% of total global greenhouse emissions comprising: agricultural activities: 11 to 15%; land clearing and deforestation: 15 to 18%; food processing, packing and transportation: 15 to 20%; decomposition of organic waste: 3 to 4%.

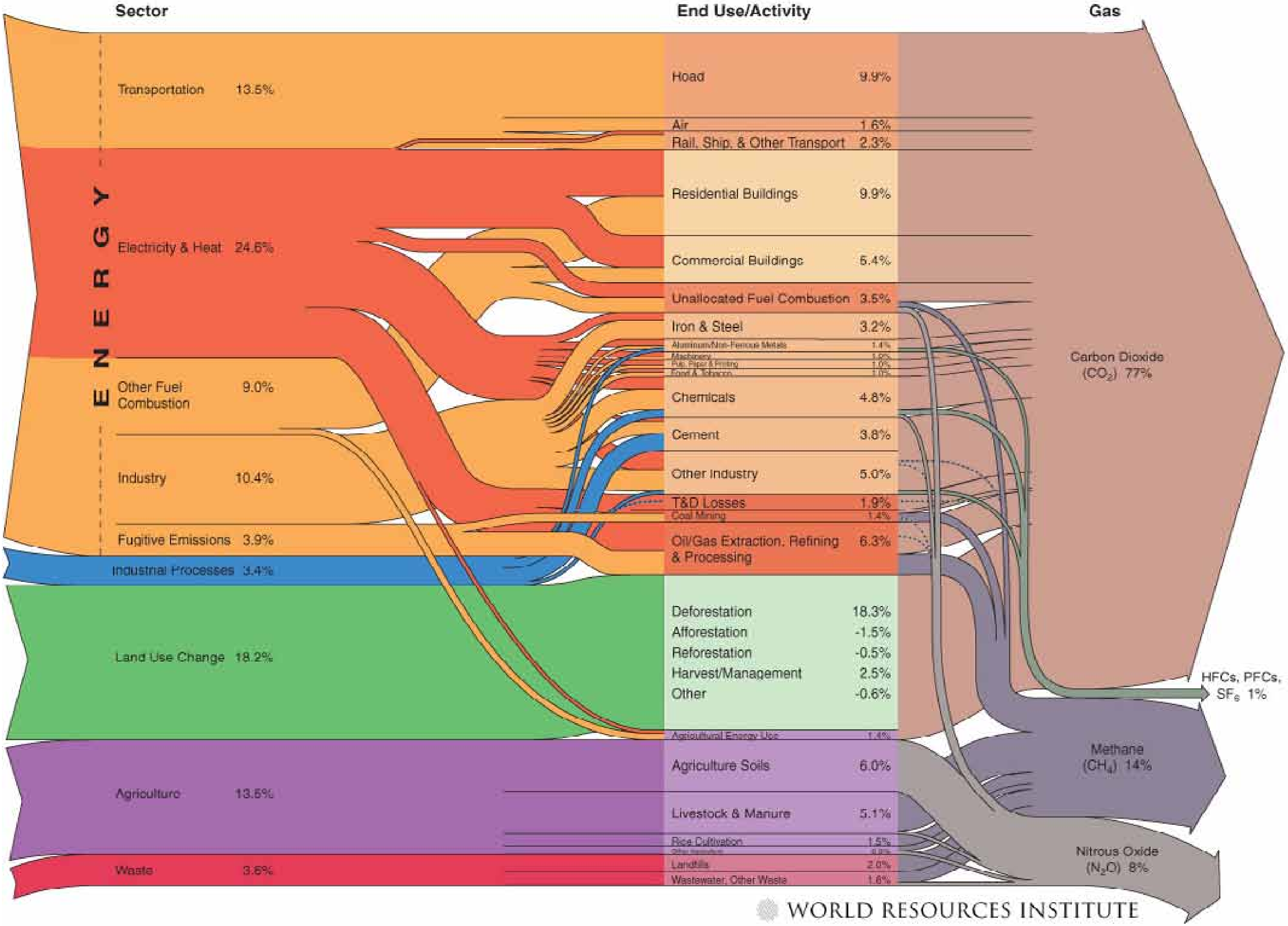
In short, continued fossil fuel dependency will lead to several interrelated vicious circles that will lead to ecological degradation, increased poverty and hunger, and an increase in health problems and deaths resulting from extreme temperatures or air pollution, as was the case in Russia in the summer of 2010.

The latest predictions for climate change are that there will be more droughts, floods, typhoons and wild fires resulting in the loss of millions of hectares of farmland by 2050. Storms caused by climate change will make an additional three million hectares of farmland in coastal areas vulnerable to inundation. Probable decline in yields by 2080 as a result of climate change are predicted to reach 16% globally, with Latin America (24%), Asia (19%) and Africa (27%) being particularly badly hit. The number of people living in highly water-stressed environments is expected to increase from 2.4 billion in 2010 to 4 billion in 2050 (Cline, 2007; GRAIN, 2009a).

So whether the primary reason for change is increasing energy and fuel costs; the security of food, water and energy supplies; or the need for large cuts in greenhouse gas emissions—or all of these—fundamental change will be required and it will need to begin very soon. So far, national and international policy and decision makers have ignored calls for fundamental change and many questions remain unaddressed.[17] For example can the current systems of food production, processing, packaging, distribution and retail achieve the required cuts in greenhouse gas emissions or will alternative systems need to be developed? How will food, energy and transport systems be powered following the fossil fuel era? Can renewable energy meet the

17 Several governments have made commitments to reduce GHG emissions during the next few decades, for example, in 2008 the UK made a commitment to reduce GHG emissions by at least 80% by 2050 (DEFRA, 2008). However, many questions remain as to how these reductions can be achieved. Sweden has been the boldest, by setting an ambitious goal to achieve a completely oil-free economy by 2020—and without building more nuclear power plants (Vidal, 2006).

Figure 19. World greenhouse gas emissions flow chart



Source: World Resources Institute, cited in Audsley *et al.* (2009).

Box 11. Climate change and food production: a stark warning from Australia

Australia's rice production fell from 1.6 million tonnes in 2000 to just 27,000 tonnes in 2007 because of drought, high temperatures and water shortages (IRRI, 2010b). Although Australia produced less than 1% of world rice, this rapid decline in production had an impact on world prices and supplies. More than 95% of rice is consumed in the countries where it is grown and over the last 30 years Australian exports had accounted for 2-4% of global exports. Countries that were heavily dependent on rice imports, such as Senegal and Haiti (each imports four-fifths of their rice), faced mounting unrest as prices increased.

> *"Ten thousand miles separate the mill's hushed rows of oversized silos and sheds — beige, grey and now empty — from the riotous streets of Port-au-Prince, Haiti, but a widening global crisis unites them. The drought's effect on rice has produced the greatest impact on the rest of the world, so far. It is one factor contributing to skyrocketing prices, and many scientists believe it is among the earliest signs that a warming planet is starting to affect food production"* Bradsher (2008)

One Australian mill, the largest rice mill in the Southern Hemisphere, once processed enough grain to satisfy the daily needs of 20 million people—but six years of drought have taken a toll, reducing Australia's rice crop by 98% (Figure 20) and leading to the closure of the mill.

Figure 20. Rice production in Australia, 1960-2008

Note: Australian rice production in thousand tonnes per year, from 1960 to 2008.

Source: Data from the annual crop reports of the Australian Bureau of Agricultural and Resource Economics (ABARE) and cited in Gleick (2009).

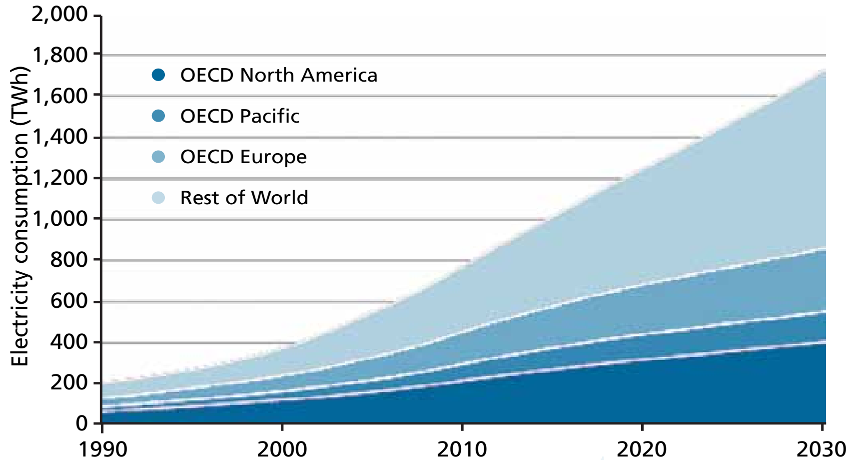
energy requirements of the current food system? Are supermarket systems compatible with the goals of sustainability or is it now time to contemplate a post-supermarket era?

The urgency of a shift away from fossil fuels is therefore not just a question of reducing greenhouse gas emissions, but also for ensuring food, water and energy security. The idea and the implications of a post-fossil fuel era will have to be addressed by us all soon. However, adopting alternatives without questioning industrialised systems, globalised supply chains and the idea of limits and reduced consumption levels, will make the situation worse—as has happened with the recent expansion of biofuels (see Box 10 and FAO HLPE, 2011b). Taking biofuels as one example, the question for policy makers, particularly in Europe and North America, is whether instead of using productive land for transport biofuels, as well as other crude oil substitutes—such as bioplastics—should policies be formulated instead that reduce the demand for freight transport? This approach would result in a reduction in greenhouse gas emissions as well as lower transport fuel consumption. If the answer is yes, then the food system is the first place to consider the options for less freight because more localised sourcing and distribution systems are a viable option.

Accepting limits

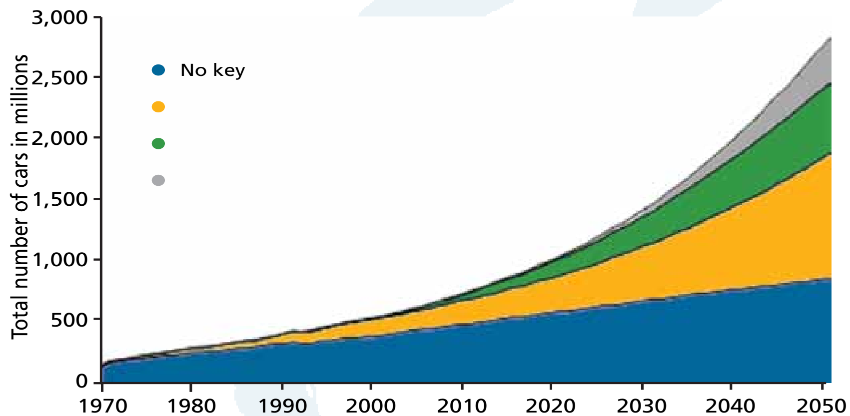
During the last fifty years, material consumption has increased to unprecedented levels. This applies to energy use, household appliances, transport vehicles, computing and communication equipment and so on. In many instances growth in consumption levels for goods and services has been exponential—as have the associated environmental impacts—a trend that is forecast to continue (Figures 21 to 24).

Figure 21. Estimated electricity consumption by ICT and CE equipment



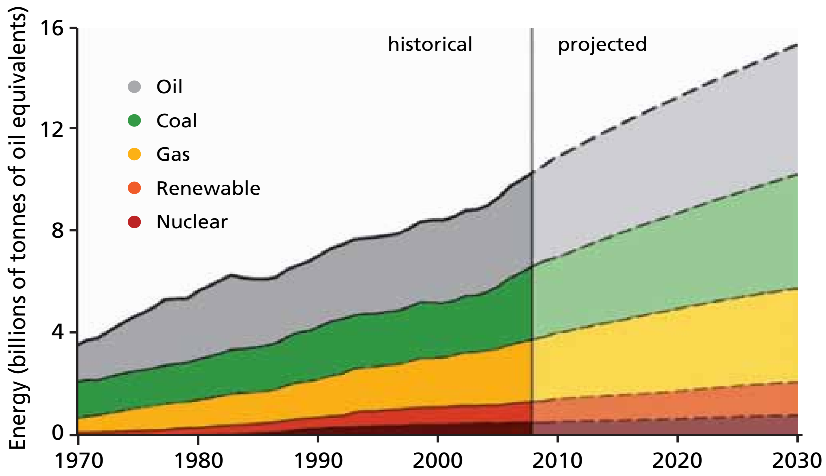
Notes: Consumer Electronics (CE) includes: TVs, set top boxes, VCR/DVDs, HiFis, MP3s, video consoles, chargers, etc. Information and Communication Technology (ICT), includes: PCs, monitors, laptops, modems, mobile phones & chargers, printers, copiers, faxes, routers, broadband etc. Source: OECD and IEA (2009)

Figure 22. Total number of cars in millions



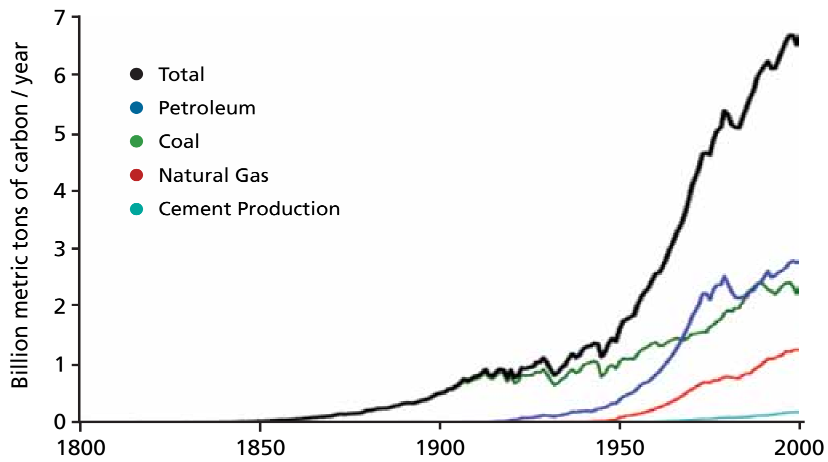
Source: Chamon *et al.* (2008)

Figure 23. Energy demand by fuel type



Source: Sigma Xi (2009)

Figure 24. Global fossil carbon emissions



Source: Marland *et al.* (2007)

During a debate in the 1970s between Barry Commoner, Paul Ehrlich and John Holdren, a formula was developed to describe the impact of human activity on the environment. The factors identified are per capita consumption levels (A) population (P) and technology (T). In this (T) is the environmental impact per unit of consumption, and refers to the systems and supply chains associated with the delivery of goods and services to the consumer. Although per capita consumption and population levels are both important (Satterthwaite, 2009), in our analysis we focus on the environmental impact per unit of consumption (T). In particular, we consider the basic human need for food, water, energy, housing and clothing and assess the various options available to meet these needs (See Section 5.1, Measuring Sustainability and the means-end analysis approach)

Although we do not include an analysis of how an absolute reduction in demand for energy and other resources can be achieved or what levels should be set, it is clear that if the ambitious targets for reductions in greenhouse gas emissions, that have been discussed in recent years are to be met then per capita consumption levels in many countries will inevitably have to be reduced significantly.

We do focus on the second aspect of (T): systems, supply chains and technologies to provide energy, water, clothing, housing, water and other material items while minimising finite resource use and greenhouse gas emissions.

This discussion leads to an important issue—that of limits. In the near future one of the key issues that will have to be accepted and then addressed is that of limits in terms of consumption levels, the availability and use of finite resources and the amount of pollution and waste that the environment can absorb.

Physical limits apply to both the resources that enter the economy and the resulting solid waste, water and air pollution. The most pressing resource issues are related to oil and gas

supplies, but many other shortages are being experienced or identified as being problems in the future, including water, phosphorus and land.

3. Joining the Dots (II) Virtuous Circles

3.1. Linear versus circular approaches

In the previous section we highlighted a common factor in the recent food, energy and water crises—these systems have a linear structure in relation to resource use, pollution and waste. In the linear approach, it is assumed that at one end of a system there is an unlimited supply of energy and raw materials (which there isn't), while at the other the environment has an infinite capacity to absorb pollution and waste (which it hasn't). The inevitable result is resource shortages on the one hand and solid waste, climate change and air pollution problems on the other (see Box 12 for an example from the food system).

Box 12. Simplified representation of the modern food chain

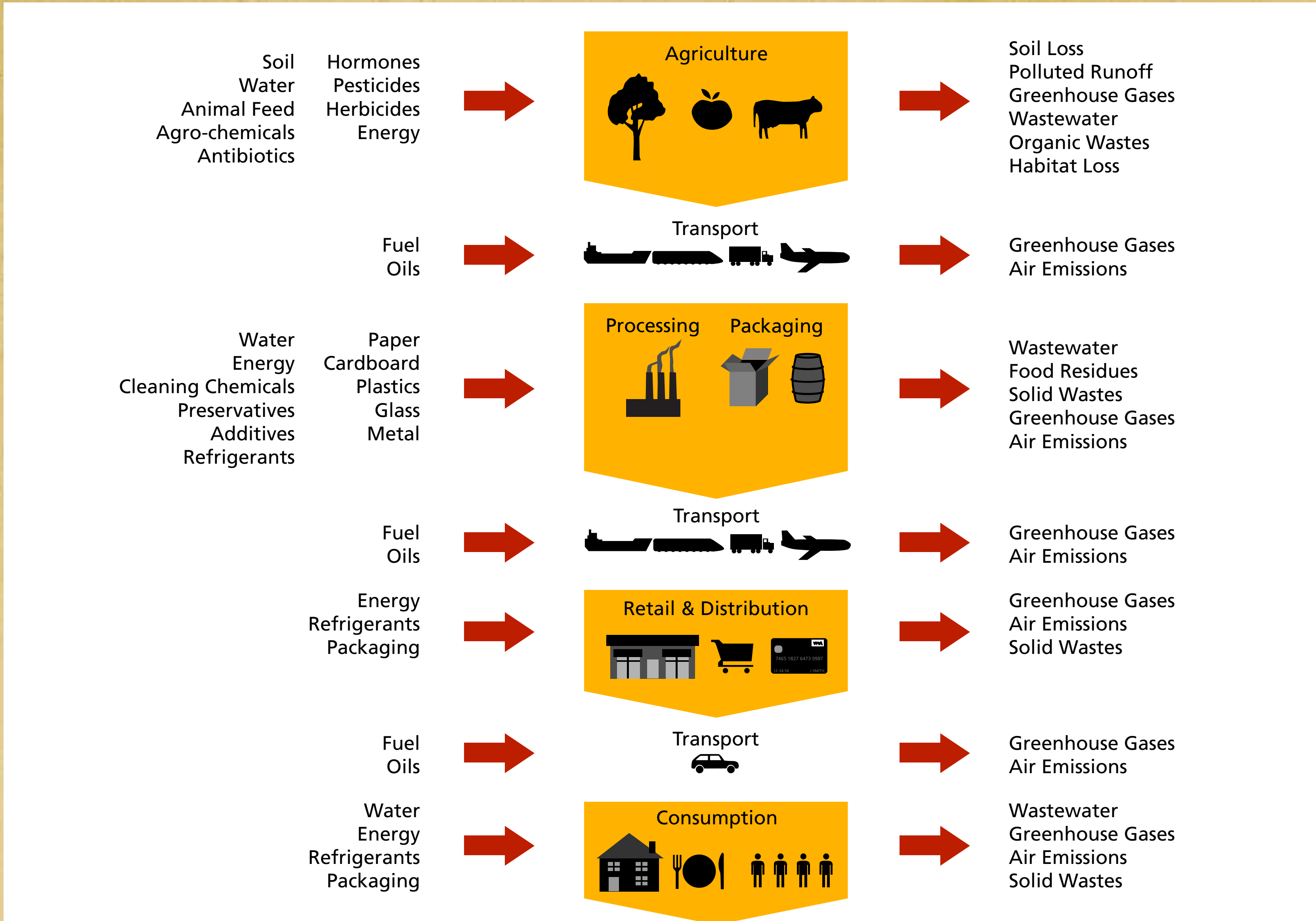
The figure below shows a simplified representation of the modern food chain in which the main stages are agriculture, processing and packaging, distribution, retail, and the preparation and consumption of meals in the home. The main inputs to each stage are energy and water. Fossil fuels are the main energy source for the manufacture of synthetic fertilisers and on the farm as well as for food processing, packaging and retail. For many products refrigeration or freezing, using electricity derived largely from coal or natural gas, is required throughout the supply chain; while foodstuffs are being transported, in shops and distribution centres and when stored in the home. Petrochemicals, also derived from fossil fuels, are used to manufacture plastic packaging, pesticides and many other inputs.

Each of the main processes is linked by transport stages. These consist of freight transport—shipping, rail, air and road freight—and shopping by car or public transport. Transportation relies on derivatives of crude oil—petrol and diesel for road vehicles, jet fuel for planes and fuel oil for shipping—and is therefore a good example of a linear process, in which the combustion of fuels (inputs) results directly in pollution (outputs) in the form of carbon dioxide as well as many other polluting gases. These emissions are dispersed rather than in a single point source, which adds to the problem.

The consequence is that the food system has become staggeringly inefficient: overall—including energy costs for farm machinery, transportation, processing and feedstocks for agricultural chemicals—the modern food system consumes between ten and fifteen calories of fossil fuel energy for every calorie of food energy (nutrition) produced.

However, with only seven stages (eight if waste management of packaging and uneaten food is included), this oversimplified diagram can be misleading. The reality is that for many food products supply chains are extremely complicated, long and global, particularly those for processed and packaged foodstuffs (see ketchup case study in Section 5.1). An expanded version of this diagram would include the separate supply chains for the production and distribution of farm inputs, such as antibiotics, fuel, fertiliser and pesticides; machinery used on farms and the vehicles used during each distribution step; and for all materials supplied to each stage, for example, wood, plastic and metal to farms and packaging and processing industries. If more stages are involved, resource use and emissions increase.

Box 12. Simplified representation of the modern food chain



3.2. Circular systems: theory and goals

An alternative to the current linear paradigm is to develop productive systems that minimise external inputs, pollution and waste (as well as risk, dependency and costs) by adopting a circular metabolism.

There are two principles here, both reflecting the natural world (Box 13). The first is that natural systems are based on cycles, for example water, nitrogen and carbon. Secondly, there is very little waste in natural systems. The "waste" from one species is food for another, or is converted into a useful form by natural processes and cycles.

Box 13. Sustainable system as an organism *versus* the dominant model

A system engaged in infinite competitive growth must inevitably swallow up the earth's resources. There is no closed cycle to hold resources within—to build up stable organised social or ecological structures. Not surprisingly, this is not sustainable, which is why we are faced with global warming and food and energy crises.

In contrast, the archetype of a sustainable system is a closed life cycle, like that of an organism. It is ready to grow and develop, to build up structures in a balanced way and perpetuate them, and that's what sustainability is all about. Closing the cycle creates a stable, autonomous structure that is self-maintaining, self-renewing and self-sufficient.

In order to do that, you need to satisfy as much as possible the "zero-entropy" or "zero-waste" ideal. A sustainable system can remain vital and stable indefinitely, and the closer it approximates to the zero entropy ideal, the better. More importantly, the zero-waste or zero-entropy model of the organism and sustainable systems does allow for growth and development, but in a balanced way, as opposed to the unbalanced, infinite growth of the dominant model. This immediately disposes of the myth that the alternative to the dominant model is to have no development or growth at all.

Balanced development and growth arises naturally in the organism, because the organism's life cycle is maintained by cycles within that are coupled together to help one another thrive and prosper. Similarly, the integrated farm is an example of a sustainable food production system. It consists of the farmer, livestock and crops. The farmer prepares the ground to sow the seeds for the crops to grow that feed the livestock and the farmer; the livestock return manure to feed the crops. Very little is wasted or exported to the environment. In fact, a high proportion of the resources are recycled and kept inside the system. The system stores energy as well as material resources such as carbon. More carbon is sequestered in the soil as the soil improves, and in the standing biomass of crops, trees, shrubs and livestock, which also increase as the soil carbon increases.

The farm can perpetuate itself like this quite successfully and sustainably, or it can grow by engaging more cycles. These other cycles, such as those involving fish, fowl, algae, earthworms, mushrooms etc., are units of devolved autonomy that essentially turn the "waste" from one cycle into a resource for another. The more life cycles are incorporated, the more energy and standing biomass are stored within the system, and the more productive the farm. It can also support more farmers or farm workers.

Box 13. Sustainable system as an organism *versus* the dominant model

Productivity and biodiversity always go together in a sustainable system, as generations of farmers have known, and more recently, academic researchers have rediscovered. It is also the most energy efficient. Why? Because the different life cycles are essentially holding the energy for the whole system by way of reciprocity, keeping as much as possible and recycling it within the system.

Industrial monoculture, in contrast, is the least energy efficient in terms of output per unit of input, and often less productive in absolute terms despite high external inputs, because it does not close the cycle, it does not have biodiversity to hold the energy within, and it ends up generating a lot of waste and entropy and depleting the soil, thereby reducing soil fertility and food quality.

Source: Ho (2007)

If these principles are applied to human needs, systems can be established to provide food, energy and water; that do not consume large quantities of fossil fuels and other resources; and that also maximise the possibilities for recycling and reuse. In the process, greenhouse gas emissions, air pollution, water pollution and solid waste are minimised (Darrell, 2008).

Sustainable circular systems:

1. Minimise fossil fuel use (crude oil, natural gas and coal).

2. Minimise greenhouse gas emissions (from the combustion of fossil fuels as well as methane from landfill sites, sewage and enteric fermentation and nitrous oxides from farming).

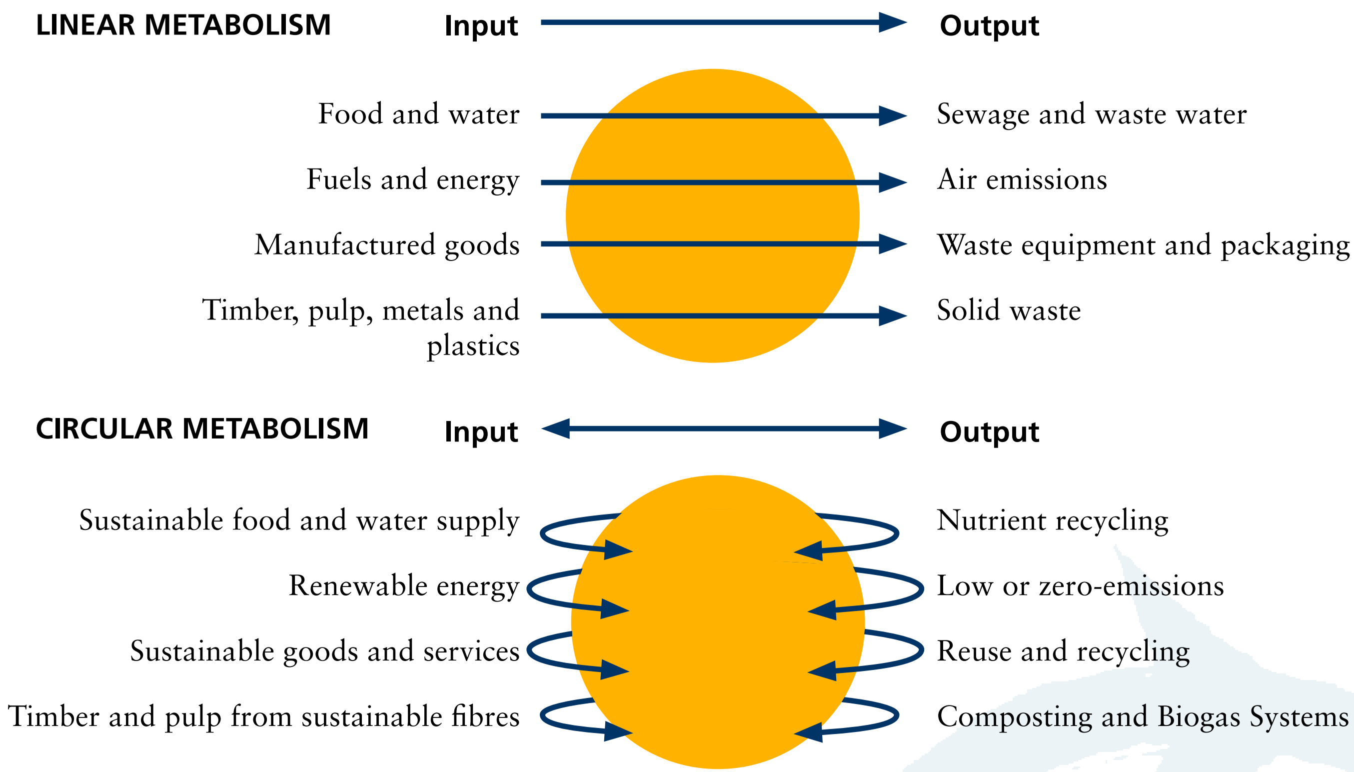
3. Develop reuse and recycling systems at the local level so that nutrients, used water and materials re-enter the productive process, rather than being released into watercourses or being sent to landfill. This also reduces demand for external resources.

4. Avoid chemicals, materials and items that are difficult to reuse or recycle (sustainably) or that are toxic.

Circular systems can be described as closed loop food, water and energy systems. Closing the cycle creates a stable, autonomous structure that is self-maintaining, self-renewing and self-sufficient (Figure 25; Ho, 2007).

Figure 25.

Settlements with a linear and a circular metabolism



Source: adapted from Girardet, H (1996)

The aim of the initial stages of the Designing Resilience project has been to identify the key characteristics of these localised, closed loop, low external input systems (Table 3).

Table 3. Examples of the type of systems and projects considered in Designing Resilience

Sustainable food production	Ecological and low external input agriculture, polyculture, agroforestry, organic and permaculture systems
	Urban and peri-urban food and non-food production
	Aquaculture: particularly land-based systems Also possibilities for biomass production for biogas systems
Sustainable water systems	Rainwater harvesting, grey water reuse, sustainable flood control systems, targeted and drip irrigation, and desalination powered by renewable energy
Sustainable energy	Biogas, bagasse, coppicing, solar hot water and photovoltaics, small-scale hydro, wind and sustainable biofuel production
Sustainable construction	Natural materials (such as bamboo, lime, stone, slate, adobe and timber), natural ventilation and passive solar heating and lighting
Natural and organic materials	Fibre, furniture, dyes, inks and medicine
Sustainable waste management	Reducing demand, avoiding certain materials that are difficult to reuse or recycle and/or are toxic
Sustainable sewage systems	Composting toilets, biogas systems and constructed reed beds
Ecotourism	Sustainable management of hostels, hotels, resorts and restaurants
Sustainable markets	Sustainable pro-poor value chains for food, fibre, art and crafts: supplying hotels, resorts, restaurants, urban areas and fair trade

These systems are very different to those in the industrial, globalised, fossil fuel world view. The way that these systems are implemented and integrated with other systems varies enormously in terms of their structure, how they function and their geographic and physical scale, as they are adapted to local conditions, capacities and culture. However, common themes that we have identified were found to contribute to resilient, sustainable and integrated food-energy-waste-water-fibre-housing systems:

a. self-reliance and the proximity principle (see below)

b. low external input, regenerative systems

c. appropriate scale and technology

d. diversity, multifunctionality and complexity

e. stability, security and safety

f. high levels of reuse and recycling so that a large proportion of resources and "wastes" remain in the system or locality

g. local organisations to sustain circular systems

These functions form an integrated whole as they are in many instances interrelated and reinforcing. For example, the proximity

principle implies a more localised food system—if more food is sourced locally, production systems will need to diversify in order to supply sufficient quantities and to maximise variety and continuity of food supplies. When the proximity principle is applied to farm inputs and energy supplies this will encourage sustainable practice in the form of decentralised renewable energy and local waste management systems such as biogas and composting, as well as agroecological approaches to soil fertility (green manures, rotation and livestock manure) and pest management (biopesticides and companion planting to repel pests and attract beneficial insects).

These important and interrelated factors that form the basis of sustainable systems and communities are described in more detail in the sections below and illustrated with stylised diagrams. In Section 4 we then provide examples in the form of case studies of such systems.

The proximity principle: why local?

> *"Regenerating localised food systems means shifting away from uniformity, concentration, coercion and centralisation towards diversity, decentralisation, dynamic adaptation and democracy. This is what the struggle for 'food sovereignty' and 'agroecology' is all about."* (Pimbert in Cohn et al., 2006)

If we are to tackle peak oil and climate change, sooner or later supply chains for food, energy and other materials will have to relocalise as this is the only option if carbon emissions and fossil fuel use are to be minimised. If not, when the price of transport fuels, energy and electricity increases, perhaps very sharply and rapidly, or supplies are disrupted, the whole food and energy system will be in jeopardy. If the shift to sustainable and localised food, renewable energy and material supplies does not take place, there is no way that significant reductions in greenhouse emissions during the next few decades will be achieved (ISIS, 2010c).

Circular systems for food, energy, water and fabrics can be optimised when they are based on a localised model. In this, a large proportion of the goods consumed both in and out of the home are produced using low external input techniques and renewable energy and would then be reused or recycled. The products that cannot be supplied by local producers are sourced within the district or province or through fair trade initiatives.

There are many ways that food systems can be kept local (Box 14). All of the systems described in the case studies in Section 4 are localised. In certain cases, for example generating energy at the household level, the food and energy producer is also the consumer, or else foodstuffs and energy supplies are sourced and distributed at the local level.

The modern food distribution system has become energy intensive, and because freight transport by sea, air and road is completely dependent on fuels derived from crude oil it is particularly vulnerable to high oil prices.

Most countries import and export more food than they did a few decades ago. Between 1968 and 1998, world food production increased by 84%, population by 91% and food trade by 184% and international trade is expected to triple by 2020, based on 1995 levels (UNEP, 2002). However, the food crisis has highlighted the danger of relying on food imports, particularly staples. A sensible policy would be to reduce dependency on food imports in uncertain times. The UN's special rapporteur on the right to food, Olivier de Schutter, has warned of a rerun of the 2008 food price crisis in 2010 or 2011, noting that many developing countries, previously exporters of food, have become net importers because they were convinced they could always buy food at cheap prices on the international market, an illusion shattered by the global food crisis of 2007/8. He says those countries are now reorienting investments toward feeding themselves as it is vital for them to "decrease their dependency on the international market" (ISIS, 2010b).

Box 14. Types of local food schemes

Community supported agriculture (**CSA**) schemes come in a number of different forms, for example:

Subscription: The farmer "recruits" local customers who subscribe to a scheme and are supplied with a box of seasonal produce on a regular basis. The farmer is paid before the growing season to guarantee an income for the harvest.

Farmer co-operatives: A collaborative effort by a number of farmers to supply and market their produce.

Box schemes can be CSA schemes as above although they are not necessarily so. They often supply organic produce and can be run by the farmers themselves, consumer groups, or distribution/marketing companies.

Consumer co-ops can be informal or formal groups in which people come together to purchase food collectively, enabling them to benefit from cost savings and/or improved food quality. They can be effective in improving access to, and affordability of, better food and many operate distribution schemes to disadvantaged groups.

Producer co-ops in which farmers come together to supply and market their produce. Collective bargaining can often bring a better price for their produce.

Growing your own edible gardens, allotments, and community food projects. Many people grow some of their own food, either in back gardens, on allotments, community gardens, or unused land. This gives their families a supply of fresh, seasonal produce which would often be expensive or unavailable at retailers. Added benefits are greater household food security and saving money.

Local shops often stock local food as this contributes to a sense of community, supports the local economy, and is easy to do.

Farm shops and **"pick your own"** provide one of the most direct links between consumers and producers. Farm shops can source a proportion of the produce on sale from other local farms and market gardens.

Farmers' markets are set up for the benefit of farmers and the local community. They normally sell farm produce from within a certain radius of the market. There has been a rapid growth in the number and scale of farmers' markets in Europe and North America. In South America most towns and cities have several fresh produce markets; however, their survival is threatened by rapid increases in the number of large supermarkets.

Public procurement of local food by institutions such as hospitals, schools and government departments can provide a boost to the local economy.

Barter markets such as those which operate in the Andes provide an important meeting place where ideas and experiences are also exchanged.[a]

a Andean barter markets help sustain local food systems and the ecosystems in which they are embedded. Action research generated new evidence on the importance of barter markets for giving some of the poorest social groups in the Andes better food security and nutrition; conserving agricultural biodiversity (genetic, species and ecosystem) through the growing and exchange of native food crops in barter markets; maintaining ecosystem services and landscape features in different agroecological zones; and enabling local, autonomous control of production and consumption—and more specifically control by women over key decisions that affect both local livelihoods and ecological processes (Argumedo and Pimbert, 2010; Marti and Pimbert, 2006; Pearson, 2003; Seyfang, 2004)

Figure 26 shows that local and regional sourcing of food through home delivery box schemes or independent retailers is environmentally efficient, as are farmers‘ markets, particularly when shopping is not done by car. If the product is imported and purchased at a supermarket there will be at least four transport stages, resulting in carbon dioxide emissions of between 431 and 5,298 grams per kilogram of product. When imported by air the environmental impact increases significantly, as this stage alone results in an average emission of over 5 kilograms of CO2. If locally sourced produce is bought through a home delivery box scheme, the carbon dioxide emissions are 300 times less than if they were imported by plane 9,000 kilometres from Mexico and purchased in a shopping trip by car at a supermarket (Lucas and Jones, 2003; Pretty *et al.*, 2005).

Figure 26. Local, continental and global sourcing in the UK

		To Britain	To Wholesale / Distribution Centre	To Store	To The Home
Source	Mexico	5060	13	6	183
Total CO_2	5298				
Outlet	Multiple Retailer				
Source	Sicily	154	13	6	183
Total CO_2	356				
Outlet	Multiple Retailer				
Source	New Zealand	230	13	6	183
Total CO_2	431				
Outlet	Multiple Retailer				
Source	Regional			12	183
Total CO_2	195				
Outlet	Independent Supermarket				
Source	Local				17
Total CO_2	17				
Outlet	Box Scheme				
Source	Local			12	183
Total CO_2	187				
Outlet	Farmers’ Market				
Source	Local				183
Total CO_2	183				
Outlet	Farm Shop				

The significance of airfreight has been highlighted in another study that compared the energy use of importing green beans from Kenya and of UK sourcing (Jones, 2007). The energy consumption of green bean production (up to the farm gate) is similar in Europe (0.8–1.4 MJ/kg) and Kenya (0.7–1.7 MJ/kg). When the energy consumed in transporting green beans from Kenya to the UK by plane is included, the difference between the two supply chains becomes considerable. Energy use is 12 times greater when beans are sourced in Kenya rather than the UK, a difference of between 57 and 59 MJ/kg of beans. If imports from Kenya to the UK were transported by sea (2 MJ/kg beans) rather than by plane (58 MJ/kg beans) would result in a significant transport energy saving of 56 MJ/kg beans.

A shift to sourcing more produce locally would certainly not preclude international trade. In fact in a sustainable and just food system there would be a significant increase in fair trade products. However, wherever possible these products would be imported by ship rather than plane, to reduce environmental impacts.

The problem with the international trade in food is that it often leads to industrialised, specialised (monocrop) farming. As discussed earlier, systems of this type require large quantities of external energy inputs and energy use and carbon emissions are high. When a particular foodstuff is produced in large quantities on a farm, in a region or in a food processing plant the consequence is that the inputs will be sourced, and the product itself distributed, on a national and global scale. This trend is related to specialised production and has been facilitated by low energy and transport fuel costs.

If sustainable circular systems are implemented, then the house, neighbourhood and city, as well as rural town and village, become more productive, self-reliant units. This was the case before the development of petroleum-based transport systems and the advent of cheap transport fuels. It is likely that there will be a shift back to this arrangement, whether this is planned (as we advocate) or not.

The shift from a high input, transport intensive and linear system to one that is based on low external input, low transport and a circular metabolism will require a fundamental change in how systems are structured and operate.

Low external input, regenerative systems

Pretty (2006) describes highly sustainable agricultural systems as those that aim to make the best use of environmental goods and services whilst not damaging these assets. He defines the key principles for sustainability as:

- integrating biological and ecological processes such as nutrient cycling, nitrogen fixation, soil regeneration, allelopathy, competition, predation and parasitism into food production processes;
- minimising the use of those non-renewable inputs that cause harm to the environment or to the health of farmers and consumers;
- making productive use of the knowledge and skills of farmers, so improving their self-reliance and substituting human capital for costly external inputs;
- making productive use of people's collective capacities to work together to solve common agricultural and natural resource problems, such as for pest, watershed, irrigation, forest and credit management.

In the case of food production, the aim of circular systems is to minimise inputs which have to be brought in from outside the system or locality. These include synthetic pesticides and fertilisers, animal feed and energy (electricity and fossil fuels). The environmental costs associated with the use of these inputs as well as their manufacture and distribution are therefore reduced, as are financial costs for farmers when they are no longer required. Instead, the principles of agroecology (Altieri,

1998) and permaculture (Mollison, 1988) can apply to all scales of food production: from growing a few plants in containers in a small city garden to relatively large farm holdings. Manure and other biodegradable material (crop residue, paper and card) from the farm and the local community are composted or passed through a biogas system to provide nutrients, trace elements and minerals and energy. Nitrogen levels can be raised organically through green manures—legumes which have a symbiotic relationship with nitrogen-fixing bacteria.

Minimising external inputs also applies to energy. The shift to local renewable energy supplies benefits the local economy and reduces transport demand and the ecological impact of fossil fuel mining, processing and use, and the energy costs for households and farms.

Linked to the aim of minimising external inputs is that of maximising reuse and recycling by developing closed loop systems for ”wastes”. The aim is to develop zero-waste systems in which resource inputs are reduced and the materials that are currently treated as waste re-enter the production process. What this means in practice is agroecological and other forms of low input farming, sustainable packaging and processing systems and a large-scale shift to the use of local renewable energy supplies. Ultimately, the aim is to replace the “hydrocarbon” with the “carbohydrate” economy, to substitute renewable materials for non-renewable or hazardous ones and to design circular systems to switch materials from the technical to the biological cycle.

Locally sourced wood and plant material can in many instances replace plastics, metals and fossil fuels. Sustainable biomass production is possible; however, a prerequisite is tree planting on a massive scale followed by sustainable woodland and forest management. Sustainable harvesting of trees and coppicing and pollarding can provide fuel wood, charcoal, and timber. Plant-based solvents, dyes, lubricants, paints and coatings are also an option. Plants grown on waste and marginal land in urban and rural areas can meet these needs and also be used as biofuel feedstocks. Trees are an integral part of eco-communities. They reduce pollution, stabilise the ground, thus reducing flooding and soil erosion, provide shade for livestock and have a cooling effect when planted around farm houses and in cities. If trees are introduced that produce nuts, fruit and edible mushrooms this contributes to the abundance of the harvest. While the best soil will be earmarked for crops or grazing, woodland may thrive on poorer land.

The discussion on biofuels above highlights another important issue that is directly related to declining fossil fuel supplies. This is the increased competition for land between different uses. Fossil fuels provide many things: energy for heating, cooking and lighting; transport fuels; and electricity and feedstocks for thousands of products including fertilisers, pesticides and plastics. As oil and gas prices increase, the only options available in relation to the provision of these products and services are to reduce demand or to find alternatives or, ideally, both.

The transition from a fossil fuel to a carbohydrate economy is possible and in many ways, as described in this book, desirable. However, the unsustainable introduction of industrial biofuels, which led to higher food prices, has highlighted some of the problems of this major shift. There will be further problems if the move from fossil fuels to renewable energy and natural materials is not planned carefully, based on sustainable low-carbon approaches and accompanied by a significant reduction in energy demand.

One of the main drivers of change during the next few decades will be increasing costs and reduced availability of fossil fuels: therefore the products that are energy intensive to produce and distribute or that currently use fossil fuels as feedstocks will also become more expensive. This will have a significant impact on the structure of food, energy and water systems and the changes described in Figure 27 are inevitable. However, even with broad political support, these transitions will take several years or perhaps a decade or longer to implement. If policies and systems are not introduced now to prepare for this monumental change,

then problems relating to food and energy security will be widespread and severe.

Appropriate scale and technology

Scale, and the most appropriate physical and geographical scale to achieve sustainability, is an issue that has been discussed since the 1970s following the publication of Small is Beautiful by E.F. Schumacher.

In the contemporary food system, the main driver of change during the last 50 years has been increased economic efficiency through economies of scale. This has led to the application of industrial practices and a culture of “bigger is better” that permeates every link in the food chain—from farm to fork to landfill site. Farms need to become larger to remain competitive and to use ever larger farm machinery and employ fewer people; smaller, more localised processing facilities, such as abattoirs, mills, bakeries and dairies are replaced by fewer and much larger industrial units. Concentration in retailing means that multiple retailers are in a position to dictate terms to suppliers, scour the planet for the cheapest produce and as their market share increases, to deal with a small number of suppliers that are able to provide the large quantities required. Food and packaging waste is collected and buried in large landfill sites.

Similarly, energy, fuel and electricity supply chains are large-scale, centralised and rely on fossil fuels. As discussed earlier the financial and environmental costs of these systems are high compared to renewable energy systems. Contrast these with Figure 28, which illustrates a circular system in which leftover food, livestock manure, human excreta and crop residue are fed into a biogas system that produces methane for cooking and other energy needs and solid and liquid fertiliser. Biogas systems can provide the link between animal husbandry, sewage treatment, the production of crops and fruits, and aquaculture systems. In Section 4.3 further information is presented on the benefits of biogas systems.

Figure 27. Food production and peak oil

The Post-Oil, Post-Supermarket Era

Where will we get our food from when crude oil and natural gas run out (and before then when price increases sharply or when there are disruptions in supply)?

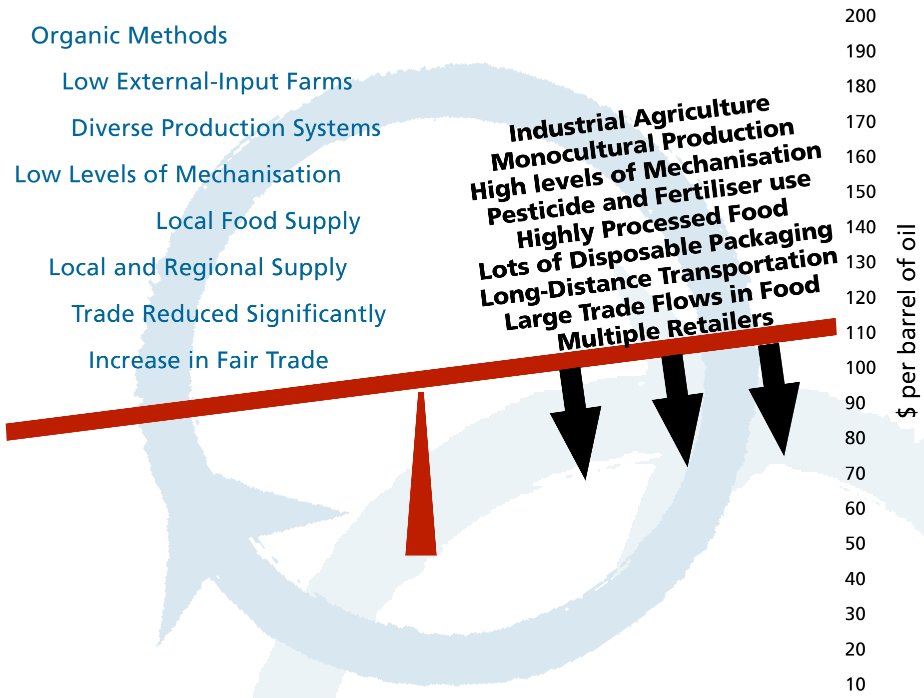
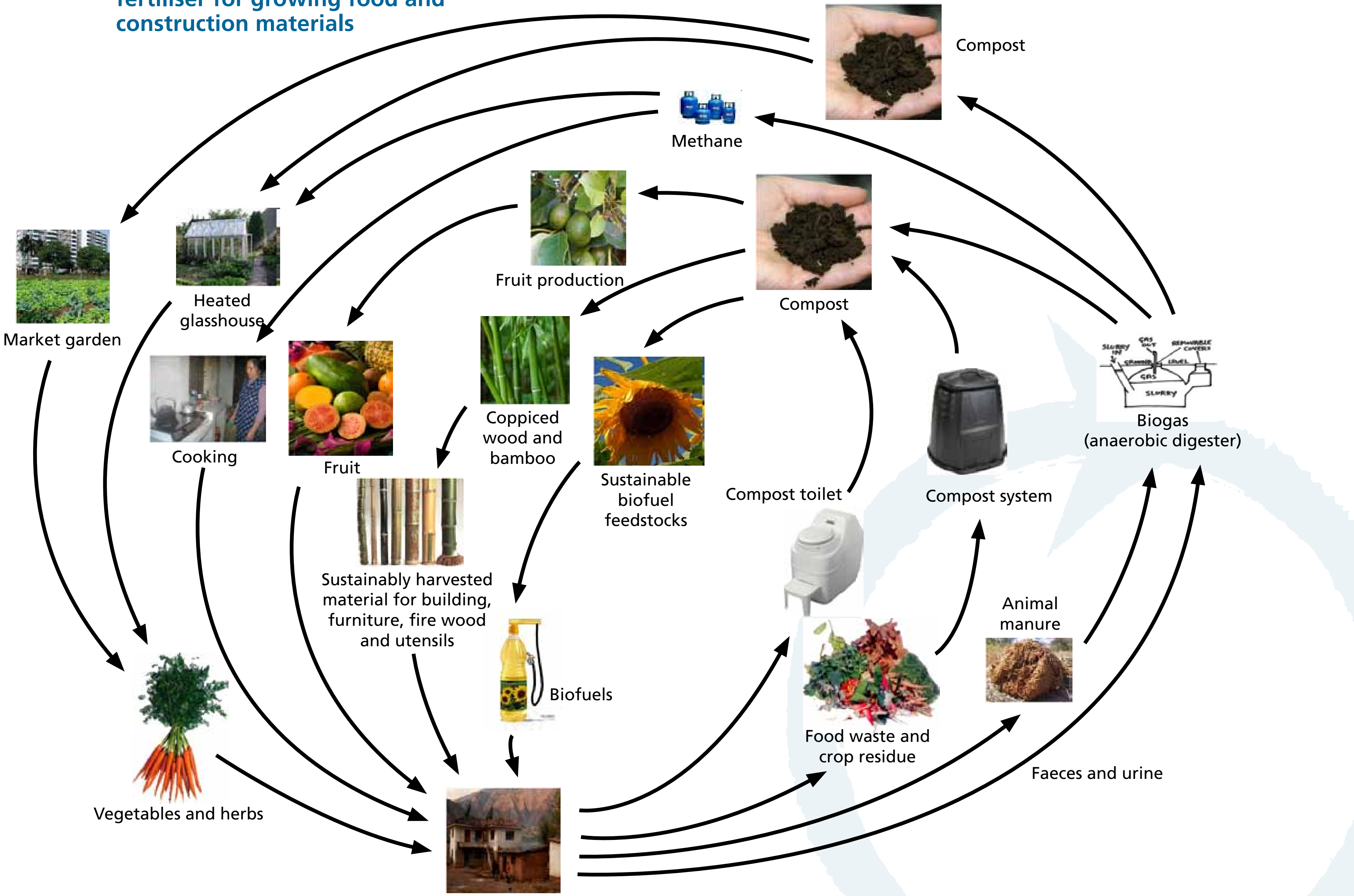


Figure 28. A composting and biogas system to provide household and farm energy needs and fertiliser for growing food and construction materials



A small household biogas digester with a capacity of six to eight cubic metres is sufficient to meet most of the cooking and lighting needs of a household. In Asia the installation cost is typically several hundred dollars, for example from US $250 to $800 in China, which in some cases can be covered by interest-free or low-interest loans (Ho, 2007). Once the loan is paid back, which often takes no more than three years, the energy and fertiliser from a biogas system is free, apart from some low maintenance costs. Alternatively, finance could be provided at no cost to the farmer or household through EU or OECD Aid and Development grants, the Clean Development Mechanism or Carbon Offset schemes. In this approach to energy supply, self-reliance and energy, food and financial security are increased. Environmental impacts are minimised, time is freed up so that children and women can attend to other tasks or go to school, and local pollution and risk of disease are greatly reduced. Net carbon emissions are reduced significantly, as are methane emissions (also a GHG) from livestock and sewage. Carbon losses through deforestation and soil erosion are reduced and the emissions associated with the production, transportation and use of synthetic fertiliser are avoided. The multiple benefits of biogas are described in more detail in a case study in Section 4.3.

Contrast this with the financial and environmental cost of constructing and operating a large fossil fuel or nuclear power station, a centralised electricity grid and global transport of fossil fuel and uranium. Gas and coal power stations typically cost several hundred million US dollars to construct, nuclear power stations costs over a billion, and hundreds of millions more to operate and decommission. Centralised electricity grids require billions to construct and maintain. A policy to implement biogas systems instead of coal power stations would mean that for every fossil fuel power station not built, over a million household biogas systems could be introduced and families could gain access to environmentally benign, secure and essentially free energy.

Biogas systems are only one of many sustainable renewable energy options that we describe below. It is possible to integrate several systems to optimise supplies, for example solar hot water, micro hydro, sustainably produced biomass, photovoltaic cells and micro wind power. These can be combined with reduced energy demand through sustainable architecture, design and construction, such as insulation, passive solar heating and natural ventilation. The combination of systems chosen will depend on local needs and capacity, resource availability, geography and climate. This non-prescriptive and flexible approach is a stark contrast to the predominant approach of development banks and foreign investors—one in which the same technological packages are prescribed for all countries and locations.

Diversity, multifunctionality and complexity

In sustainable food and energy supply chains, specialisation and centralisation are replaced by diverse localised food and energy production. Agroecology, forest gardening and agroforestry encourage diversification and multipurpose land use. Food production systems consist of layers of crops, shrubs and trees in various combinations to provide many food and non-food products. When all outputs are considered, yields are far higher than in industrialised monocrop systems in terms of energy use per unit output, as well as in absolute terms such as traditional measures of crop yield per area.

As farm and energy inputs are sourced and food products distributed locally, a reduced geographic scale is accompanied by the production of a wider range of foodstuffs in urban, peri-urban and rural areas in gardens, allotments, on farms and in market gardens. Food is processed on the farm or in small local processing units and there is a significant shift away from large-scale, centralised electricity generation to decentralised small-scale renewable energy systems.

The examples in Figures 28 to 30 highlight the options available and the possibilities for integration; however, as mentioned earlier, the approach should not be prescriptive. The most appropriate systems and technology will depend on local conditions (cultural, geography, climate etc.) and should only be implemented following dialogue with all parties, in particular the local community.

The aim of increasing diversity applies to:

a. Different physical scales of production—small, medium and relatively large farming and energy units. The urban agriculture systems that have been developed in Havana (see Section 4.4) consist of patios (small household scale), *parcelos* (small to medium community projects) and fairly large co-operatively run market gardens and farms of up to 20 hectares. Similarly for energy, biogas systems can operate at the household, farm, or neighbourhood level.

b. Various geographic scales (from the household or farm level through to neighbourhood or village, district, province, country, continent and global levels). For example, food and other material can be distributed or sourced from each of these locations; however, based on the proximity principle, and the aim of reducing transport and fossil fuel demand, local sourcing takes preference.

c. Diversification of farming systems to maximise variety and year-round availability of produce, combined with local food processing and preservation. This will require a shift away from monocultures in which large areas are devoted to the production of a small number of (or perhaps a single) crops or types of livestock. Diverse food production systems are planned using permaculture, agroecological and traditional home garden design.

d. Diversification of energy, fuel and electricity supply systems. Sustainable, decentralised energy systems include biogas, solar photovoltaic, solar thermal, passive solar heating and cooling, biomass, micro hydro, tidal and wind power.

e. Various water storage, supply and reuse systems e.g. for water storage, rainwater collection and waste water treatment. Collection and storage can be at the household level (in water butts) through to landscape scale (large ponds or reservoirs).

f. Increasing the options for the sale of produce, such as the multitude of options for marketing food locally described in Box 14.

Diverse food production systems, based on permaculture and agroecological approaches, minimise environmental impact, maximise economic benefits and minimise risks, as well as ensuring a diverse food supply throughout the year.

In the case of energy, diverse, local renewable supplies mean that households, farms and communities can avoid the costs and risks associated with the purchase of imported electricity and fossil fuel supplies. In many cases, once the construction costs of renewable energy systems have been repaid, energy is then available at very low cost and supplies are guaranteed.

An example of how diverse food production systems can become is the home gardens that exist in many countries in Asia and Central and South America. One study considered plant use and diversity, micro-zonation (area allocation to specific uses and management), occupation, labour investment, and product, benefit and income generation at 20 home gardens in Masaya, Nicaragua (Méndez, *et al.*, 2001). Ten different micro-zones and nine plant uses were identified. Plant diversity was found to be very high, with a total of 324 species, with families obtaining at least 40 different plant products from their home garden. Home gardens functioned as a consistent, flexible resource used to meet a diversity of food, medicinal, construction and other material needs.

Stability, security and safety

Security applies to household and farm income as well as employment. It also relates to systems that can ensure food, energy and water security.

Economic security for farmers is improved through direct links between themselves and the consumer—locally through direct marketing (farm shops, fresh produce markets, box schemes and community supported agriculture) or internationally through fair trade initiatives. Food producers can develop a loyal and local market for their produce. This security allows food producers to diversify and expand their product range which contributes, both directly and indirectly, to local employment and regeneration. This provides a viable and sustainable alternative to dealing with the multiple retailers, exporters and middlemen. As a result, returns to the grower are increased and secured and money circulates within the local economy. Food and energy security are also improved and dependency—on oil, food imports, farm inputs, the whim of supermarket buyers and fluctuating prices on international commodity markets—is minimised. The uncertainty of sales covering the costs of production, let alone providing a decent margin, is therefore reduced.

There is mounting evidence in OECD and non-OECD countries of the economic benefits and increased security for food producers when the shift to local direct marketing is made. Research also suggests that local food systems and eco-farms provide a more secure livelihood for the farmer and that they generate new jobs. Many local food enterprises, for instance Community Supported Agriculture schemes, do not generate large profits, but are initiated with the aim of increasing business security, since they guarantee a fair return for the producer. Selling produce direct to the consumer means that the producer receives 80-90% of the retail price, as opposed to the 8–30% when they sell their produce to supermarkets, processors or exporters.

In one survey in the UK, 84% of businesses involved in local food trading said that their local food sales were "significant" for the business and another found that 38% of small food businesses had created new jobs in the previous year (Working Group on Local Food, 2003). This is consistent with research by the New Economics Foundation into the "work" done by money when it is retained within a local economy, as opposed to leaking out to external economies. Their research, carried out in Cornwall (a county in the UK), demonstrated that £10 would generate £14 for the local economy if spent in a supermarket, but £25 if spent on a local organic box scheme. In Cornwall, it was calculated that if every tourist, resident, or business switched just 1% of their spending to local items or services, that would put £52 million of additional direct spending into the local economy every year (Ward and Lewis, 2002).

The improved income and employment security generated by local food markets is in stark contrast to the current insecure situation in the conventional food market. In recent years farm gate prices for most products have fluctuated significantly; from one season to the next prices can drop by as much as a half. The increase in the market share of the large supermarket chains often coincides with increases in food imports. The threat of imports allows retailers to make unreasonable demands of producers, leading to wastage when produce is rejected, produce being sold at a loss and many growers and smallholders going out of business.

In the South, even when food prices increase, smallholders are often not able to reap the rewards and achieve higher prices for their produce—as happened during the increase in food prices during 2007/08 (Phoonphongphiphat, 2008). However they still had to pay for the higher costs of inputs such as fertiliser, pesticide and animal feed.

In Section 4 there are several examples of increased income resulting when farmers diversify and introduce sustainable circular systems. These include the introduction of biogas systems, fish, poultry and mushroom production in Vietnam. These provide alternative income sources as well as reducing energy costs.

Increased stability is achieved by developing systems that, in the case of food production, gradually evolve and become more resilient, diverse and productive. Stability also applies to costs, economic viability and the shift away from the purchasing of external inputs in the form of electricity, fuels and farm inputs such as synthetic fertiliser, pesticide and animal feed. The costs of all of these inputs have increased sharply in recent years—a trend that will continue as oil and gas prices rise during the coming decade. Stability is a major goal during the planning and design of sustainable circular systems because these systems are designed to be self-reliant and are built for permanence.

Health and safety on farms and in the home is improved when circular systems are adopted because the aim is to eliminate toxic, carcinogenic and ecologically damaging chemicals and substances. The threat of disease is reduced significantly when sustainable water and sanitation systems are introduced.

Reuse and recycling

> *"Our enormously productive economy.... demands that we make consumption our way of life, that we convert the buying and use of goods into rituals, that we seek our spiritual satisfactions, our ego satisfactions, in consumption.... We need things consumed, burned up, worn out, replaced, and discarded at an ever increasing rate."* Quote from a U. S. marketing consultant in the mid-1950s, cited in Moss (2010)

The predominant systems for the supply of goods and services, because of their linear structure, result in vast amounts of solid waste. Only a very small fraction of this waste is recycled, reused or composted: this applies to OECD countries and countries in the South.

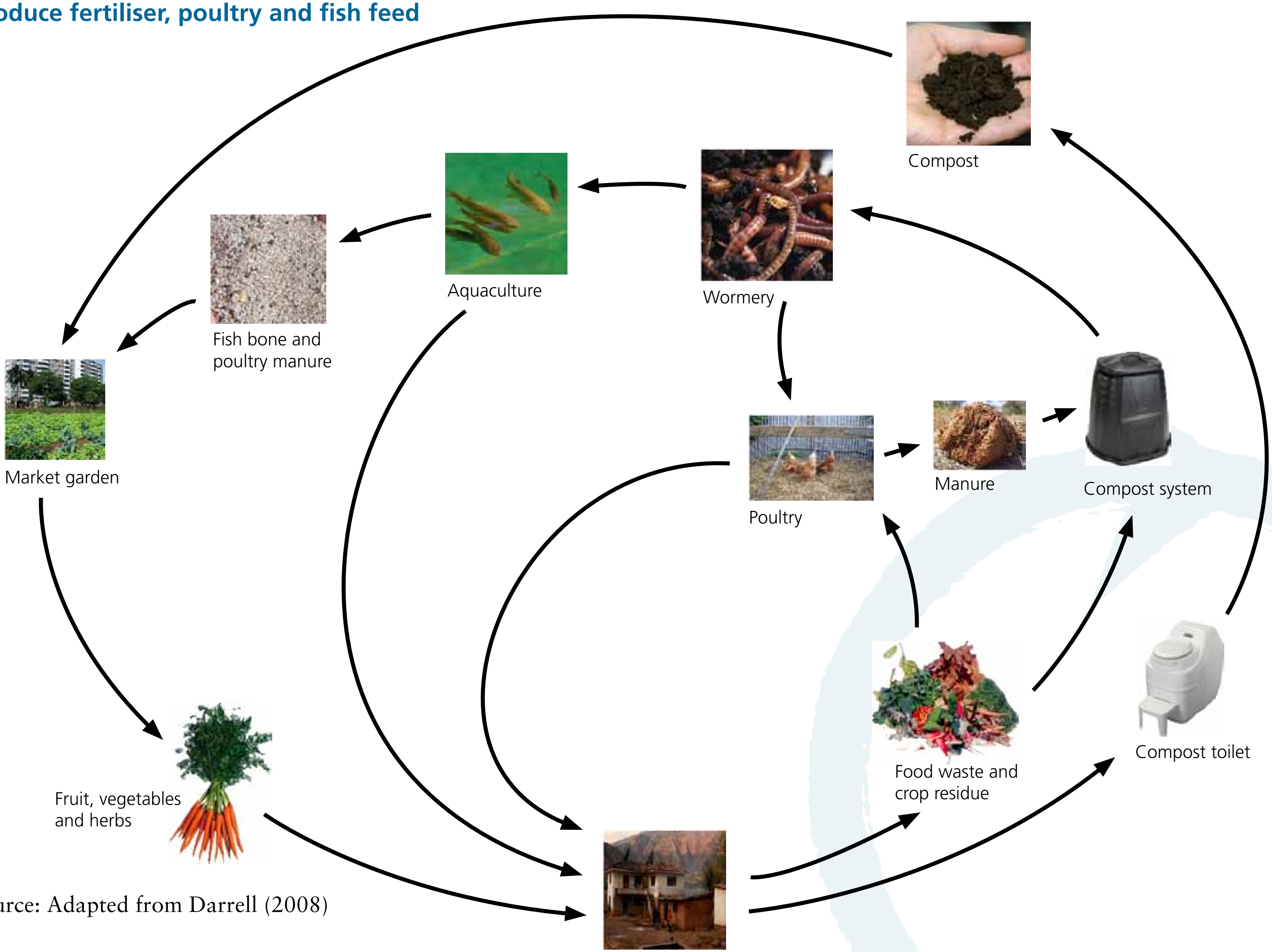
Solid waste in the food system includes packaging, crop residue and food "waste" and uneaten food throughout the food chain. Food packaging and food waste now account for a large portion of household waste in most countries: typically, organic waste makes up 40% and packaging over 20% of household waste.

Most of this "waste" is buried in landfill sites, a process which, in the case of organic material, produces methane – a potent greenhouse gas. In countries in which municipal waste collection services are not available, this material is either burnt in the open or simply discarded in streets, local waterways and fields.

In circular systems the aim is to develop zero waste by reducing external resource inputs, and re-using and recycling materials (organic matter, sewage, animal manure, metals, glass and plastics) that are currently treated as waste. When this is not possible, as is often the case with plastic material, they are replaced by alternative materials. As the goal is to develop closed-loop systems, toxic elements would be avoided. Packaging waste is significantly reduced, as is biodegradable waste (organic material such as paper, card, crop residue and food waste from farms, households, restaurants, other catering businesses etc.).

The biogas system described earlier is one way of dealing with waste. Another involves the composting of faeces, food and other organic waste (Figure 29). In this system urine and faeces can be separated and the urine diluted and used as a liquid fertiliser, with a fraction added to the compost system as this hastens the compost process. A wormery can also be established to provide valuable feed for poultry and fish.

Figure 29. A compost and wormery system to recycle human, food and other biodegradable waste to produce fertiliser, poultry and fish feed



Source: Adapted from Darrell (2008)

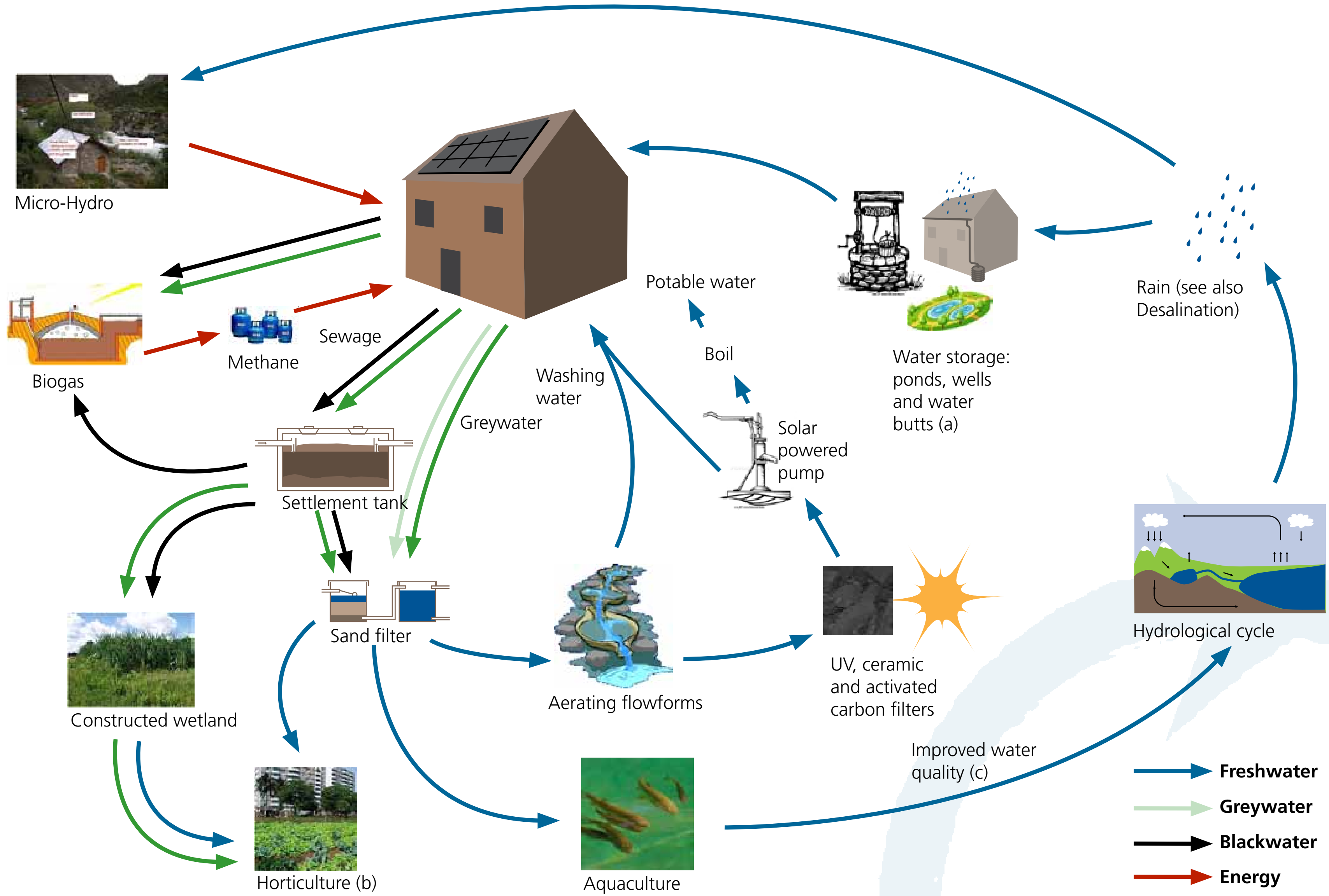


Figure 30. Circular and integrated water, energy, sanitation and food systems

(a) Ponds, Swales, Low impact earth and sand dams etc also function as flood defence. Rainwater capture occurs at these landscape scales as well as collection from roofs in water butts and wells

(b) Drip irrigation systems are used on farms and in market gardens. Water use is minimised due to water retention in soils through high % organic matter; the extensive use of mulch (leaves, waste paper and card etc); and swales and other permaculture techniques

(c) Organic farming systems avoid synthetic pesticide and fertiliser runoff, thus reduce groundwater pollution, eutrophication and occurrence of toxic algal blooms.

In Figure 30 water, energy, sanitation and food are integrated. Grey water from kitchen sinks and from washing (shower, bath or basins) passes through a series of processes, including one or more of the following: sand filters, aerating flowforms and UV, ceramic or carbon filters. It can then be supplied back to the house using a solar, wind or hand pump and used for washing, or boiled so that it is potable. Grey water can also be used directly to irrigate crops. Alternatively, grey and black water (sewage) can pass through a settlement tank and then be treated in a constructed reed bed. Further information on rainwater harvesting, water storage, recycling and use is provided in the Katalysis case study in Section 4.2.18

Local organisations to sustain circular systems

For as long as people have engaged in livelihood pursuits, they have worked together on resource management, labour sharing, marketing and many other activities that would be too costly, or impossible, if done alone. Local organisations have always been important in facilitating collective action and co-ordinated management of food systems and their environments at different spatial scales (Borrini-Feyerabend *et al*., 2007). Negotiated agreements on the roles, rights and responsibilities of different actors in a common enterprise are at the heart of the forms of mutual aid and collaboration that sustain the circular systems described here.

Local organisations—individually and collectively—play a key role in:

- sustaining the ecological basis of circular systems that combine food and energy production with water and waste management in rural and urban areas;
- co-ordinating human skills, knowledge and labour to generate both use values and exchange values in the economy of these multifunctional circular systems; and
- the local governance of circular systems, including decisions about people's access to food, energy, water, clean air and other resources.

Some of the main roles which local organisations play in sustaining circular systems are summarised in Box 15 and further discussed elsewhere (Pimbert, 2009).

It is particularly noteworthy that the management of dynamic complexity is often achieved through the combined actions of "nested organisations". Indeed, several organisations with different functions, powers and responsibilities are usually needed to co-ordinate different activities within circular systems and their wider environment. Such nested organisations operate at different scales and act in complementary ways. These interlinked organisations provide the institutional landscape that is needed to manage dynamic complexity in the social and ecological realms in which circular systems are embedded. Moreover, this web of interacting organisations provides the basis for decentralised governance and autonomous circular systems.

The food sovereignty movement is an international network of local and regional organisations which has emerged as a response to the crisis in the food systems and the growing threat of multinational food processors, traders and retailers to the livelihoods of smallholders, to the health of consumers, and to a stable environment (Box 9, Section 2 and Annex 3).[19] This

18 For further information on rainwater harvesting and sustainable water management as well as renewable energy, sustainable agriculture, irrigation and food processing and storage see the Practical Action website at www.practicalaction.org.

19 For further information on food sovereignty see Annex 3; Mulvany, (2007); La Via Campesina website (http://viacampesina.org); Pimbert, (2009a, 2009b); La Via Campesina (2003) and Food First (2002).

Box 15. The roles of local organisations in sustaining circular systems

Local groups enforce the rules, incentives and penalties needed for the sustainable management of landscapes, environmental processes and resources on which circular systems depend. Such adaptive management is mediated by local groups that co-ordinate planning and action at different spatio-temporal scales. Local organisations are particularly well-placed to monitor and respond adaptively to environmental change—they have often learnt to rely on a sophisticated set of biological and physico-chemical indicators to track, respond to and adapt to environmental change and ensure the resilience of their combined circular systems of food, energy, water and waste management. This is important because daily, seasonal and longer-term variation within and among the environments in which local circular systems are embedded is enormous.

Local organisations also use diversity to reduce risks and mitigate impacts of natural disasters and long-term environmental change. Many adaptive responses to environmental change draw on the huge pool of biodiversity available. Local organisations which manage circular systems often harness diversity within and between species to adapt to environmental change in their fields, forests, wetlands, rangelands and landscapes. For example, many different types of agricultural biodiversity ("cultivated", "reared" or "wild") are used by different people at different times and in different places. The resilience of food systems depends on such creative use of biological diversity by local organisations of producers and consumers to minimise risk and realise new opportunities created by dynamic change.

Local organisations help to govern people's access to land, food, energy, water and other means of life. Locally developed and informal resource access agreements are constantly negotiated among a variety of parties through local institutions in both rural and urban settings. Among many rural communities, agreements on who can access food, energy, water and other resources—and how—are usually enforced through social sanctions according to customary law, with decision making in the hands of local organisations.

Throughout the world, local organisations are also directly involved in efforts to reclaim rights to lost lands. Indeed, many local organisations are centrally involved in confronting the legacy of colonisation, imperialism and unequal relationships embedded in mainstream conservation, industrial food and agriculture, and in new forms of commodity capitalism. This has become a high priority everywhere today because both rural and urban people—and especially the poorest among them—are increasingly pushed off their land by the combined effects of three modern forms of enclosure: a) an expanding network of national parks and protected areas; b) the spread of industrial monocultures and livestock farming; and c) financial investments and speculation on land and ecosystem services.

Federated organisations have an important role in projecting the voice and concerns of citizens dependent on circular systems for their livelihoods. New energy and creativity are often released when different federations and networks of local organisations learn to better communicate and work together. Many such federations of the rural and urban poor are well placed to promote non-state-led forms of deliberative democracy aimed at making national and global institutions accountable to citizens—particularly those most excluded from decision making. Local organisations and federations thus increasingly seek to have a greater say in the governance of circular systems. In so doing, they challenge liberal

Box 15. The roles of local organisations in sustaining circular systems

understandings in which citizenship is viewed as a set of rights and responsibilities granted by the state. Instead, citizenship in the context of locally determined circular systems is claimed, and rights are realised, through the agency and actions of people themselves. Local organisations and federations are thus increasingly becoming expressions of an emergent citizenship in the governance of circular systems that re-integrate food and energy production with water and waste management to better meet the needs of people and planet.

Source: modified from Pimbert, 2009a.

vision has emerged from the changes that smallholders, peasants and communities would like to see, and from their own views on how they would like to lead their lives.[20] The food sovereignty

20 See, for example: CNOP, BEDE and IIED (2008) which is a multimedia publication that captures the deep concern among West African farmers about the privatisation of seeds and knowledge (as well as land). The publication (a book and CD with audio and video links) reports back on an international workshop held in Bamako in 2007, where farmers from 11 countries in West and North Africa exchanged experiences with their peers from India, Indonesia, Iran and Peru. The book contains a transcript of the "Bamako Declaration"—a call for agriculture, agricultural research and markets that reflect the needs of local farmers, farm workers and consumers, rather than those of multi-national companies. The workshop in 2007 and this publication are the result of a collaboration between the CNOP (Coordination Nationale des Organisations Paysannes), IIED (International Institute for Environment and Development, London, UK) and BEDE (Biodiversité Echange et Diffusion d'Expériences).

Table 4. The dominant model versus food sovereignty model

Issue	Dominant Model	Food Sovereignty Model
Trade	Free trade in everything	Food and agriculture exempt from trade agreements
Production priority	Agroexports	Food for local markets
Crop prices	'What the market dictates' (leave intact mechanisms that force low prices)	Fair prices that cover costs of production and allow farmers and farmworkers a life with dignity
Market access	Access to foreign markets	Access to local markets an end to the displacement of farmers from their own markets by agribusiness
Subsidies	While prohibited in the Third World, many subsidies are allowed in the US and Europe – but are paid only to the largest farmers	Subsidies that do not damage other countries (via dumping) are okay, i.e. grant subsidies only to family farmers, for direct marketing, price/income support, soil conservation, conversion to sustainable farming, research etc.

Issue	Dominant Model	Food Sovereignty Model
Food	Chiefly a commodity; in practice, this means processed, contaminated food that is full of fat, sugar, high fructose corn syrup, and toxic residues	A human right; specifically, should be healthy, nutritious, affordable, culturally appropriate, and locally produced
Being able to produce	An option for the economically efficient	A right of rural peoples
Hunger	Due to low productivity	A problem of access and distribution; due to poverty and inequality
Food security	Achieved by importing food from where it is cheapest	Greatest when food production is in the hands of the hungry, or when food is produced locally
Control over productive resources (land, water, forests)	Privatised	Local; community controlled
Access to land	Via the market	Via genuine agrarian reform; without access to land, the rest is meaningless
Seeds	A patentable commodity	A common heritage of humanity, held in trust by rural communities and cultures; 'no patents on life'
Rural credit and investment	From private banks and corporations	From the public sector; designed to support family agriculture
Dumping	Not an issue	Must be prohibited
Monopoly	Not an issue	The root of most problems; monopolies must be broken up
Overproduction	No such thing, by definition	Drives prices down and farmers into poverty; we need supply management policies for US and EU
Genetically modified organisms (GMOs)	The wave of the future	Bad for health and the environment; an unnecessary technology
Farming technology	Industrial, monoculture, chemical-intensive; uses GMOs	Agroecological, sustainable farming methods, no GMOs
Farmers	Anachronisms; the inefficient will disappear	Guardians of culture and crop germplasm; stewards of productive resources; repositories of knowledge; internal market and building block of broad-based, inclusivee economic development

Source: Rosset cited in Pimbert (2009a).

movement offers an alternative model based on: a) a new set of values, principles and rules involving autonomy, resilience, knowledge-sharing and fairness; and b) an alternative vision of food and farming systems that are ecologically, socially and economically sustainable. Table 4 provides a summary of the main differences between the dominant and food sovereignty model.

3.3. Integrating circular energy, food and water systems

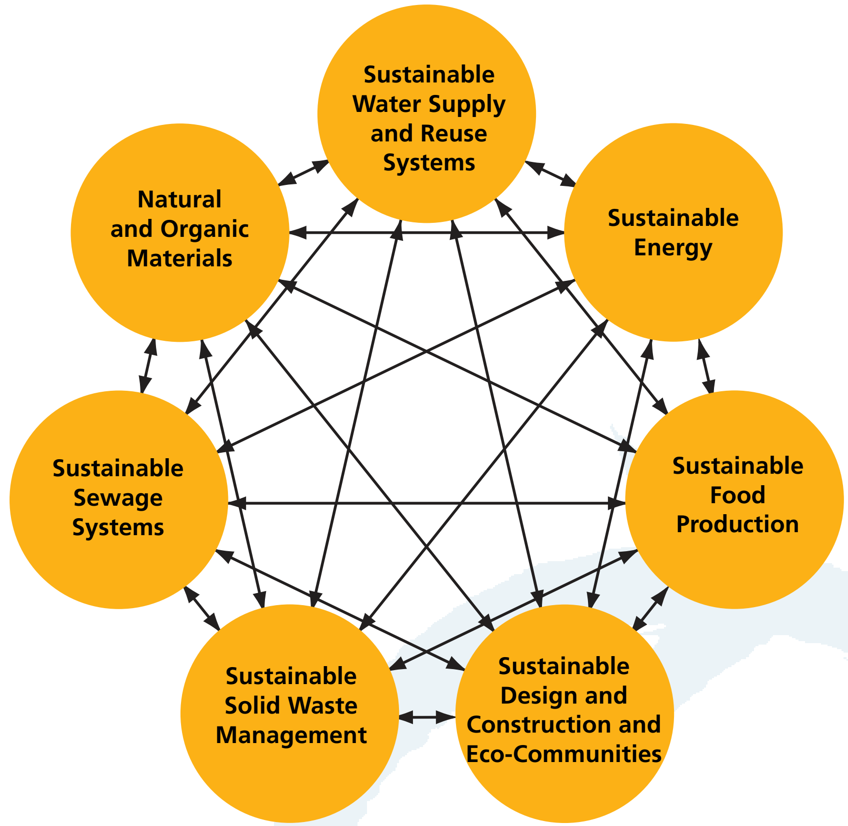
Most sustainable food, water, energy and waste systems have been implemented in isolation. However, greater synergy can be obtained when ecological agriculture, renewable energy systems and sustainable water and waste management systems are all integrated (Figure 31). This can contribute to food, water and energy security and also to financial security and poverty reduction through localised supply chains and fair trade initiatives.

The aim of Designing Resilience is to highlight the synergy involved when all of these factors are considered from the outset and these systems are integrated and developed simultaneously. Each of the examples in Figures 28 to 30 could be linked to renewable energy systems, non-food agricultural products and water management systems.

For example, adding a fish pond to the livestock-crop system can be a very big step forward, not only through increased fertilisation from fish wastes, but also increased income from significant and rapid fish yield (Chan, 2003). A deeper pond results in higher fish yield. Manure is added to the pond for fertilisation and the fish can also be fed on worms produced from the composting of manure.

Introducing a biogas system not only produces methane for cooking and lighting but also means that the filtrate can be added to the pond without using any of the dissolved oxygen, thus

Figure 31. Integrated approaches to food, water, energy and fibre supply



avoiding pollution (eutrophication). The methane can be used to produce heat or electricity and this energy used to process and preserve farm produce thus adding value and reducing spoilage.

Duck, geese and other wildfowl can be added to the pond system, as can mushroom production, sun-dried herbs and spices. There are numerous other possibilities, with each new cycle bringing increased availability of food for the family and/or higher income

through sales of the additional produce. Increasing diversity also increases the strength and resilience of the farming system.

This integrated agricultural system brings about many environmental and socio-economic benefits by being an effective, intelligent, adaptable and low-cost production system. Farm income increases, as does viability and quality of life for the farming family.

Integrated approaches come together in a "Dream Farm"[21]

The Dream Farm is a model of an integrated, zero-emission, zero-waste and highly productive farm that maximises the use of renewable energies and turns "wastes" into food and energy resources, thereby completely avoiding the need for fossil fuels. It is based on an idea introduced by Mae Wan Ho (Institute of Science in Society) in which sustainable systems are viewed as organisms, and on Professor George Chan's Integrated Farming and Waste Management Systems (IFWMS) which has revolutionised conventional farming of livestock, aquaculture and horticulture in some countries, especially in tropical and subtropical regions. This approach could lead to the integration of human housing and infrastructure and production, consumption and waste management systems into one seamless matrix of synergistic interactivity. The farms are very diverse, the only limiting factors being the availability of local resources, ingenuity and imagination. Something very similar to this model of sustainable systems as organisms is part of the official Chinese mainstream discourse, known as the "circular economy" (Box 16).

In Dream Farm 1 an anaerobic digester (biogas system) takes in livestock manure plus wastewater, and generates biogas, which provides all the energy needs for heating, cooking and electricity. The partially cleansed wastewater goes into an algal basin, where the algae photosynthesise to produce all the oxygen needed to detoxify the water, making it safe for the fish. The algae are harvested to feed chickens, ducks, geese and other livestock. The fishpond supports a compatible mixture of five or six fish species. Water from the fishpond is used to "fertigate" crops growing in the fields, greenhouses or on raised dykes. Aquaculture of rice, fruits and vegetables is possible on floats on the surface of the fishpond.

The anaerobic digester yields a residue rich in nutrients that is an excellent fertiliser for crops. It can also be mixed with algae and crop residues for culturing mushrooms after steam sterilisation. Crop residues are fed back to livestock. Livestock are fed on crop and food residues and their manure used to grow earthworms to feed fish, poultry and fowl. Compost and worm castings help to condition the soil. Livestock manure can also go back into the anaerobic digester, thus closing the cycle. The result is a highly productive farm that is more than self-sufficient in food and energy.

"Dream Farm 2" is an extension of George Chan's IFWMS concept, in that it consciously integrates local food and energy production. Most significant of all, it runs entirely without fossil fuels.

21 Section based on Ho (2007). For a more detailed explanation of these concepts see Ho (2008, 2007 and 2006) and Ho and Ulanowicz (2005). The theory of "sustainable human systems as organisms" has been corroborated and practically implemented in Günther Pauli's zero-emission production systems. George Chan's Integrated Farming System is explained in Chan (1985, 1993, 2003) and at www.emissionizero.net/Integrated_Farming_System_-_George_Chan.html and http://ecosyseng.wetpaint.com/page/Integrated+farming+aqua+fonics with a slideshow at www.slideshare.net/whatamelon23/rs-450-intgrated-farming-ppt-2695562.

Box 16. Integrated systems in China

Sustainable circular systems are part of the official Chinese mainstream discourse and a Circular Economy Law was introduced in 2009. Chinese farmers have perfected circular systems over the past two thousand years, especially in the Pearl River Delta of southeast China. This integrated agriculture and fish farming system is a key component of George Chan's Dream Farm 1 (see above). These systems dispose of the myth that there is a constant carrying capacity for a given piece of land in terms of the number of people it can support. There is a world of difference between industrial monoculture and farming based on circular systems and integrated approaches. The Pearl River Delta sustained an average of 17 people per hectare in the 1980s, a carrying capacity at least ten times the average of industrial farming, and two to three times the world average.

One of the aims of Dream Farm 2 is to combine the best of indigenous and western science to serve people in all local communities. One project that achieves this is in the northwest of Yunnan Province in Southern China covering 69,000 square kilometres (the size of Ireland) of high mountains, deep gorges, and virgin forest containing some of the world's most diverse and threatened plants and animals. The area also contains the upper reaches of important rivers like the Yangtze, Mekong, Salween and Irrawaddy on which the livelihoods of many millions of people further downstream depend. About 3.2 million people live in the region, from 15 distinct ethnic groups. One of the main threats to livelihoods and the ecology of the region is tree felling, mostly for fuel wood.

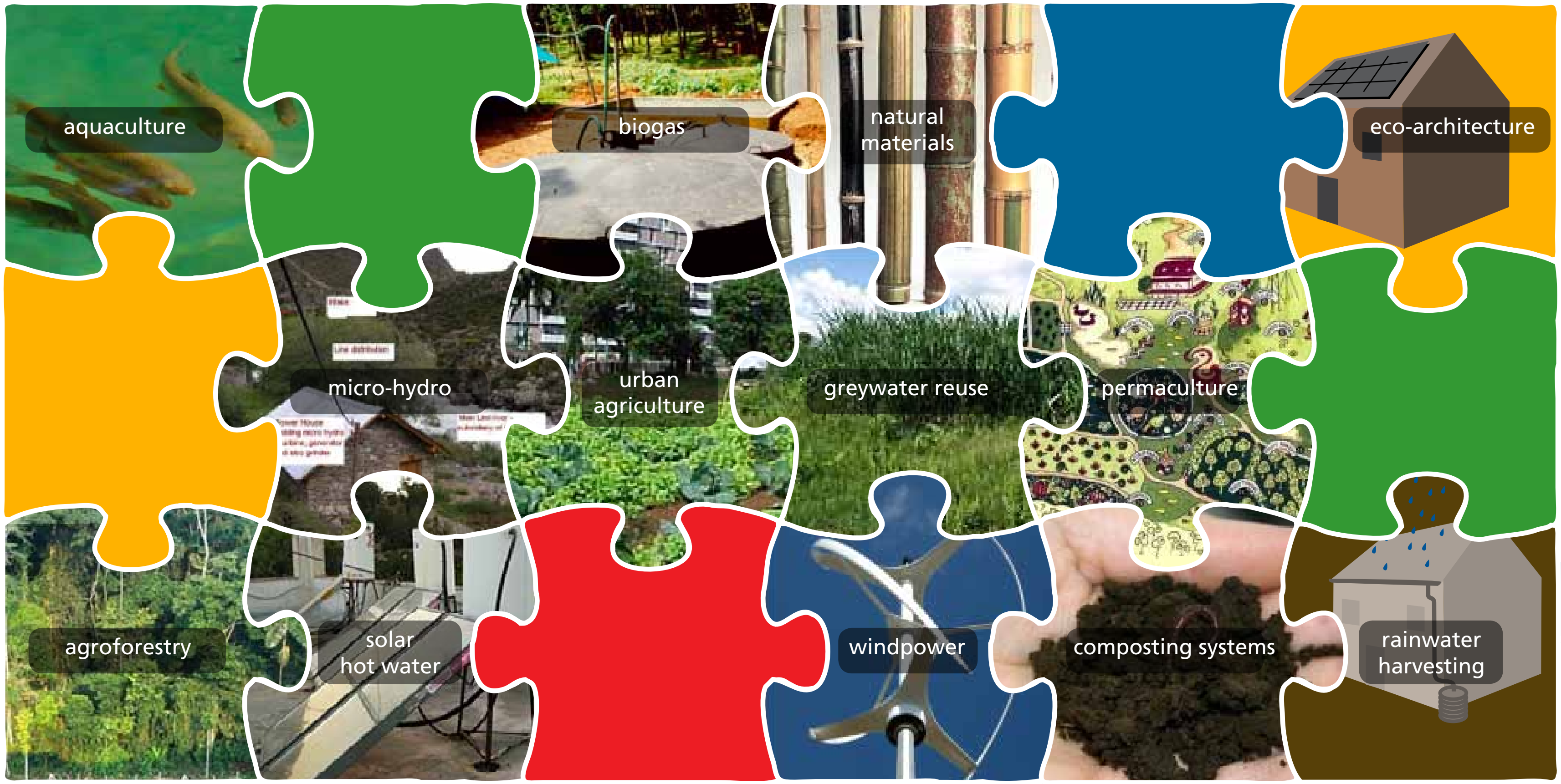
The Chinese branch of the international conservation organisation, The Nature Conservancy, helped set up the China Rural Energy Enterprise Development programme, working with local entrepreneurs to develop businesses making, selling and installing fuel-efficient cooking stoves, fuel briquettes made from crop wastes, and "four in one" biogas digesters, solar water heaters, solar cookers and micro-hydropower plants. They are implementing Dream Farm 2 on a household scale.

The "four in one" biogas production incorporates an underground biogas digester, a greenhouse for growing vegetables, a pig pen and a latrine. The open cover for the digester is close to the pig pen and latrine. The greenhouse also covers this area, so it gets heated and this accelerates the fermentation process in the digester. Human excreta falls directly into the digester from the latrine and a shovel is used to put the pig waste into the digester.

The biogas digester has a capacity of six to eight cubic metres. This is sufficient to meet most of the cooking and lighting needs of households. The cost of the four in one system varies from US $250 to 800, depending on the size of the greenhouse.

Source: Ho (2007).

4. Circular Systems in Practice



4.1. Introduction

There have been many positive developments in the implementation of sustainable circular systems in recent years. In this section we present several case studies of successful projects that have adopted systems with a circular metabolism, and in which social, environmental and economic performance is optimised. Our aim is to describe the projects, find out why they were successful and provide data on the beneficial outcomes, which include increased yields and availability of food, water and energy; reduced input and household costs; higher income and employment levels; and reduced environmental impact.

4.2. Katalysis: increasing food and water security in the Andes through rainwater harvesting, sustainable water management and agroecology[22]

22 The data and information in this section are based on project visits, interviews and the following presentations and reports: Sherwood *et al.* (2009); Oyarzun (2007); CPWF/IWMI (2006); Narváez-Mena (2007); Oyarzun and Sherwood (2007); Larrea and Sacco (2009); Sherwood and Bentley (2009).

Background

Through trial and error over centuries, Andean farmers have domesticated robust species of plants and animals—potato, lupine beans, quinoa, and llamas—adapted to the harsh conditions of an upland environment. They have also developed sophisticated knowledge that has enabled them to interpret and forecast climate and adapt planting schemes and cultural practices to their local environment. They have learned to "read" weather patterns through monitoring the flowering times of certain species, the brightness of stars, and the behaviour of animals. However, faced with changing weather patterns, in particular irregular rainfall and drought, such time-proven

Box 17. Andean glacial shrinkage and disappearance

Although two-thirds of the Earth is covered in water, only about 2.5% of this is fresh water, and less than 0.01% is drinkable and renewed each year through precipitation. Seventy percent of the worlds freshwater is frozen in glaciers. Glaciers are ancient rivers of compressed snow that creep through the landscape, shaping the planet's surface. They are the Earth's largest freshwater reservoir but have been retreating worldwide since the end of the Little Ice Age (around 1850); in recent decades glacier melting rates have increased (Combes *et al.*, 2003).

Although only a small fraction of the planet's permanent ice is stored outside of Greenland and Antarctica, these glaciers are extremely important because they are particularly susceptible to climate change and their loss directly affects human populations and ecosystems. Glacier retreat and possible disappearance as a result of global warming is putting millions of people at risk from floods, droughts and lack of drinking water, and sea level rise.

In Bolivia, Ecuador and Peru, the effects of global warming are likely to be of a greater magnitude, and experienced sooner, than in many other parts of the globe. The northern Andes contain the largest concentration of glaciers in the tropics, but these glaciers are receding rapidly and losses have accelerated during the 1990s. The temperature increases brought about by climate change have resulted in the retreat of glaciers that have for thousands of years been critical to providing freshwater and sustaining the livelihoods of millions of people in rural and urban areas of the region (CARE, 2010).

Since 1970, glaciers in the Andes have lost an estimated 20% of their volume. For example, the Chacaltaya glacier in Bolivia lost nearly half its area and two thirds of its volume during the mid-1990s alone (Figure 32). This dramatic loss of glacial volume threatens highland communities as well as large cities in the region that are dependent on glacial runoffs for their water supply. The capital cities of La Paz, Bolivia and Quito, Ecuador draw 30% and 50% respectively of their water supply from the glacial basins.

Glaciers are the world's natural water towers, assuring year-round water flows. In the dry Andes, glaciers feed rivers all year round—meltwater contributes more to river flow than rainfall, even during the rainy season (Wagnon et al., 1999). On the Pacific side of Peru, 80% of the water resources originate from snow and ice melt. Many communities are already experiencing shortages and conflicts over use. Of the 218 ongoing and sometimes violent conflicts recorded in Peru, 48% stemmed from environmental issues, many related to *"problems with water management"* (Oxfam International, 2009).

Box 17. Andean glacial shrinkage and disappearance

Many basins, including large areas of glaciers in the Cordilleras, have experienced an increase in runoff in recent decades, while precipitation has not changed, or tended to decrease. This can be interpreted as the consequence of glacier retreat—there may be more water in the rivers, but at the cost of reduction in the storage of frozen water in the glaciers. Hence, the recent increase in runoff is not likely to last very long. This is not good news for future generations (Courdain *et al.*, 2005).

Rapid melting of glaciers can lead to flooding of rivers and to the formation of glacial meltwater lakes, which may pose an even more serious threat. Continued melting or calving of ice chunks into lakes can cause catastrophic glacial lake outburst floods. In Peru, a chunk of glacier ice fell into Lake Palcacocha in 1941, causing a flood that killed 7000 people; recent satellite photos reveal that another chunk of loose ice is poised over this lake, threatening the lives of 100,000 people below (Steitz and Buis, 2003).

Projected climate change over the next century will further affect the rate at which glaciers melt. Average global temperatures could rise by 1.4 to 5.8°C by the end of the 21st century. Simulations project that a 4°C rise in temperature would eliminate nearly all of the world's glaciers. Even in the least damaging scenario—a 1°C rise along with an increase in rain and snow—glaciers will continue to lose volume over the coming century (Combes *et al.*, 2003).

Figure 32. Shrinkage of the Chacaltaya Glacier in Bolivia (16°S)

Observations and projections. Highest altitude of the glacier in 1940: 5395 m.a.s.l.; surface area of the glacier in 1940: 0.223 km2, in 2001: 0.048 km2. (Photo, dated 2001, and estimates of the glacier extent are by Bernard Francou). In 2005 Chacaltaya became divided into three parts and the whole glacier may disappear around 2010.

Source: Courdain *et al.* (2005)

practices are becoming less useful, and traditional farmers are beginning to suffer increased crop failure and water shortages, making livelihoods in the highlands increasingly difficult. These problems are exacerbated in many areas by severe erosion—the result of livestock over-grazing and the clearance of vegetation to produce charcoal.

The Intergovernmental Panel on Climate Change (IPCC) predicts that food production and livelihoods for 28 million highland Andean farmers will become increasingly difficult in the coming years because water supplies from rainfall and glacial melt will become less reliable (Box 17; Sherwood and Bentley, 2009). Moreover, IPCC reports and other studies point to increased droughts and flooding, more wind and cyclone events, outbreaks of disease and pests, and accelerating soil erosion. The latter is of particular concern due to the importance of soils in capturing and filtering water in highland environments as well as being the basis for food production. In sum, climate change is leading to increased water stress, crop failure and uncertainty of rural life for Andean communities, in which livelihoods are already difficult in environments that are often highly vulnerable and degraded.

Geographic focus

Katalysis has been piloted in the highlands of the Andes, working initially with 200 farmers from eight rural communities in Wapage and Potosí in Bolivia and the Chota Valley and Ilalo in Ecuador. The project area is geographically and culturally diverse and highly representative of the semi-arid Andes. As a result, the approaches developed here will contribute to grassroots climate change initiatives elsewhere.

Aims and approach

During 2005 and 2006 EkoRural (formerly World Neighbors) began working with several partner organisations, including the Ecuadorian Network for Community-Based Natural Resource Management (MACRENA) and the Bolivian Programme for Integrated Development of Potosí (PRODINPO). The aim was to develop a people-centred approach for inspiring and enabling smallholder farmers living in semi-arid mountain areas of the Andes to advance their food security during an era of increasing climate uncertainty. Katalysis enables farmers to address system-level production challenges and implement resilience-based management strategies. Innovation in agroecology, rainwater harvesting and water storage and use allows farmers to mitigate rainfall variations during the wet season, in particular dry spells between rainfall events, as well as to effectively extend crop production into the dry season.

Katalysis's approach is a genuine third way in terms of innovation, development and improving lives and livelihoods. The project seeks to avoid dependency and assure local accountability and relevant outcomes by nurturing and strengthening local individual and collective capacities. The project uses local knowledge, creativity, resources and skills rather than externally-based knowledge and technology.

This approach and the technologies involved also facilitate multiplication (i.e. spontaneous spread) of efforts. By limiting technologies at the outset and introducing them through small-scale experimentation, this approach enables farmers to understand and manage alternatives before scaling up to larger populations through farmer-to-farmer processes of dissemination.

At the heart of the project is knowledge-intensive capacity building for the purpose of strengthening problem solving and organisational skills among intended beneficiaries and their communities. A key aim is to avoid the problems that can arise from the application of external expert science, and in some instances to overcome the barriers associated with local beliefs and science, described below.

Local science

Essentially, the life experiences and emergent myths in the region had produced a *cultura de secano* —literally, a dryland culture—that effectively blinded people to the water that surrounded them (and the rainwater that could be captured and stored). In such processes of "myth construction" communities build "truths"—explanations that may go unquestioned and become embedded in local culture. Over time, collections of such truths produce higher order explanations, leading to coherent bodies of knowledge—essentially a local science. Local knowledge production, described by Katalysis researchers as "people's science", is expressed in the practice of everyday life and emerges as diverse forms of localised change or endogenous development. People's science is richly expressed through the practice of agriculture.

Expert science

Agricultural scientists and development practitioners can also be seen as members of myth-producing networks, favouring certain realities and suppressing others. The institutional response to "development" or environmental and social problems is often based on "external" solutions in which scientists claim through their proposals and projects that single best practices exist, and that by virtue of being informed and knowledgeable they are capable of determining or devising them. The problem is that externally based knowledge and technology often do not "fit" local socio-environmental circumstances, despite sometimes tremendous efforts to make them fit. Thus externally based knowledge and technology tend to be rejected by local ecologies, be they social or environmental, leading to the creation of new and sometimes worse conditions or the eventual abandonment of technologies.

Knowledge sharing: new discovery and understanding

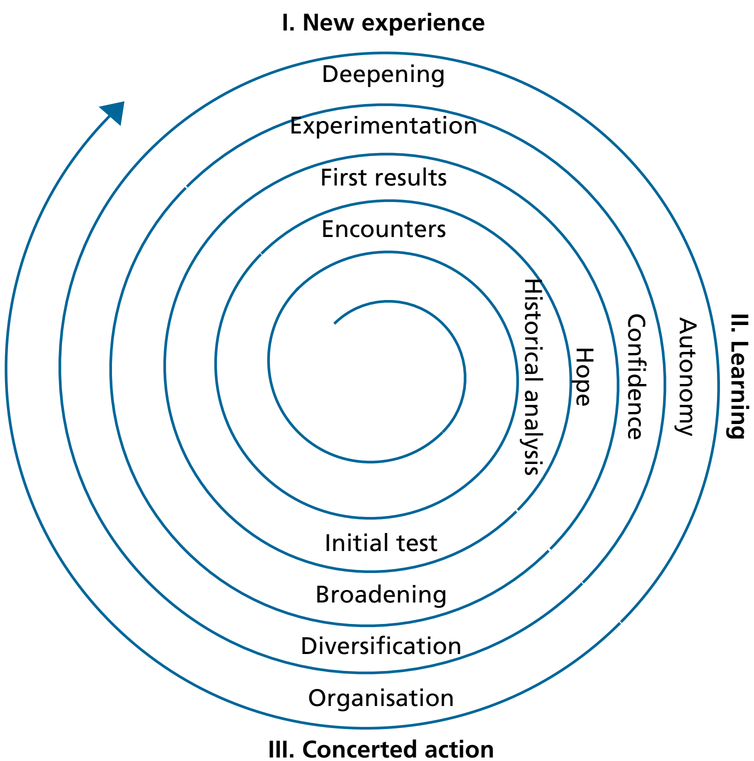
Katalysis emphasises working within the local context to co-produce new cultural practice and knowledge, in this case around the existence of water and its use. This approach avoids the problems associated with the introduction of inappropriate externally based knowledge and technology and allows people and their communities to have more control over water and food supplies.

The aim of the Katalysis project is to develop localised responses based on an interactive learning-action process (Figure 33). Strategies are developed with small groups of farmers in a discovery-based approach to social learning to help individuals and communities to fundamentally change their perspectives on water. Through guided learning on "the water that surrounds us", farmers can come to see new sources of water, which, through technological development, can increase food production and improve livelihoods.

Farmers stated that access to water represented their greatest opportunity for surviving climate change. In a series of discovery-based learning exercises, "hidden" sources of water were identified and methods introduced to creatively use plants and animals in ways that could bring new wealth to farms. Early exercises included studies on precipitation. For example, water runoff from rooftops was measured, which commonly reached thousands of litres per rainfall event for a single household. This was then valued, applying the local market price for bottled water. Through this exercise farmers learned that effectively they lost tens of thousands of dollars each year. Similarly, the water-holding capacity of soil organic matter (SOM) was assessed by weighing socks filled with organic matter before and after immersing them in a bucket of water. Participants discovered that their fields held millions of litres of water and that increasing SOM by 1% across a hectare could capture an additional 100,000 litres during each rainfall event. They

Figure 33. Katalysis

Katalysis involves groups in self-directed learning and problem solving on issues relating to water and climate. Through an interactive process of experiential learning and concerted action, the thematic agenda progresses from field-level to increasingly complex watershed-level concerns.



determined that the best way to increase on-farm water-holding capacity was through SOM and cover crops in particular because soils stored water where it was needed: in the fields. Further studies on water-use efficiency, for example comparing canal irrigation with sprinklers and drip tapes, allowed farmers to gain a new appreciation for seemingly expensive micro-irrigation alternatives, which in fact were 20 times more efficient than sprinklers. Such learning enabled farmers not merely to survive climate change, but to also increase their income.

Technologies

Agroecological approaches

Several agroecological methods have been employed, including the use of cover crops, green manures and compost. Through such methods, evaporation of water from the soil is reduced, as is the overheating of soils through direct contact with sunlight. Organic matter in soils increases, thus improving their water holding capacity. Additionally, targeted and drip irrigation systems were introduced. These measures reduce the amount of water required and the time spent watering.

Many other benefits were observed; including the suppression of weeds and therefore less time spent weeding, improved soil structure, increased soil fauna and reduced soil erosion. Overall,

Cover crops/green manure

Mulch

Harvesting moisture from mist and fog

Agroforestry and multilayered/tiered cropping

Rainwater harvesting

Various methods to collect and store rainwater were introduced at different scales.

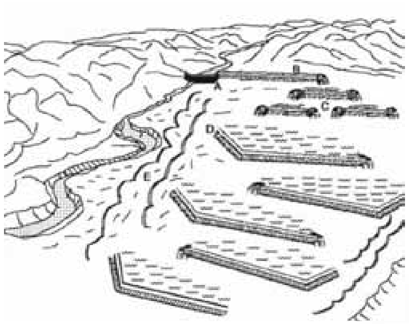
Containers made from old tyres

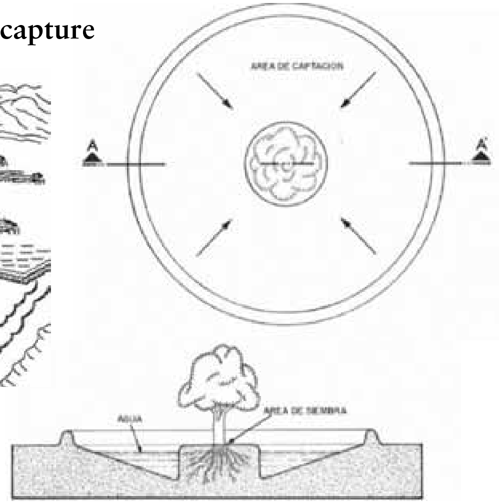
Storage ponds for individual smallholdings

Landscape methods with runoff from higher ground

From road runoff

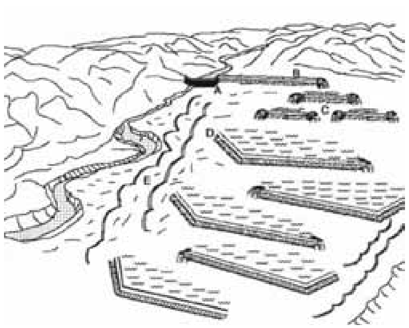
Landscape level and micro-capture



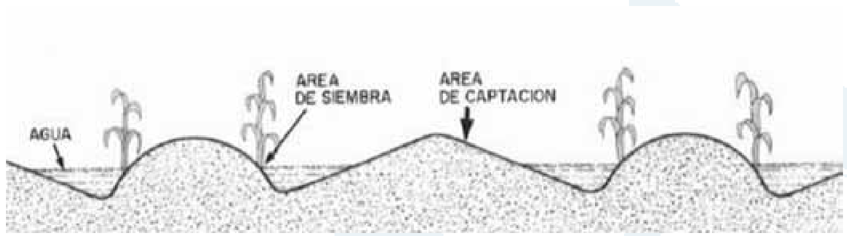


Interceptor dykes and terraces

Micro rainwater capture: Individual terraces



The "W" model



Rainwater collection from roofs and the reuse of grey water

these methods resulted in increased production and income—food supplies to the household or for sale increased and diet improved through the increased availability of fruit.

Financing

A key component of Katalysis is to place resources in the hands of participants through locally managed investment and innovation funds as self-financing mechanisms. This approach was tested in the Chota Valley, Ecuador. Once communities appropriate the funds, it was found that they are managed with great care and members are willing to go to extraordinary lengths to capitalise funds so that more people may benefit from loans. To date, a dozen such funds have been established, 90% of which continue and several have grown significantly. In multiple cases, after water access is obtained in smallholder systems through cheap technologies, families increase on-farm production many times and this allows them to pay off loans in less than one year.

Evaluation

In order to evaluate project outcomes, a participatory monitoring and evaluation system was established in which participants conduct before and after evaluations of individual farm production economies. Additionally, each participant produced a before and after map of their farm, carefully noting innovations in water technology, complementary practices, and cropping systems. Participants also conducted seasonal food security assessments, registered financial investments in technologies, and conducted cost-benefit analyses.

Results

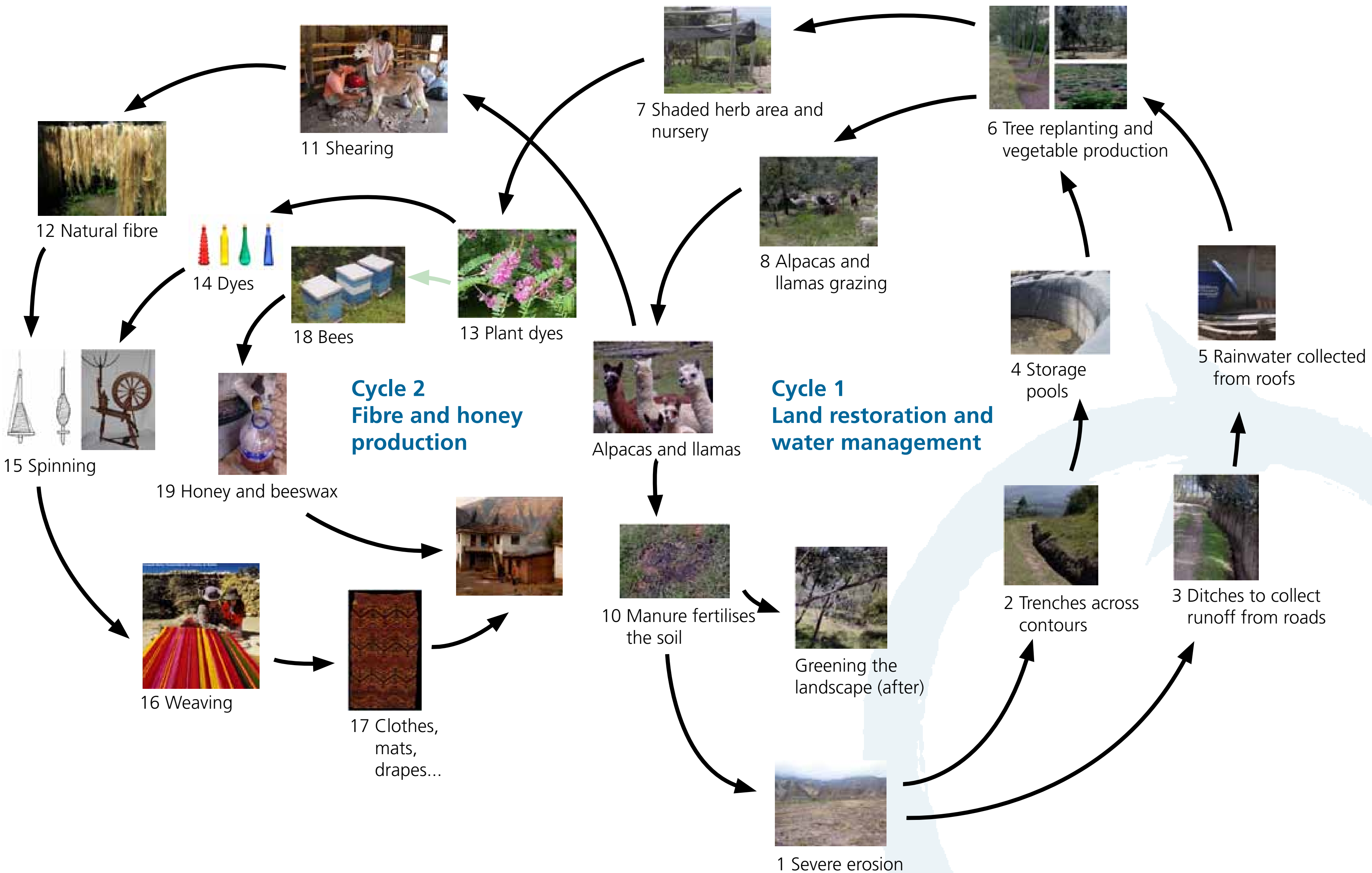
Katalysis and similar initiatives demonstrate that the problems of insecure water supplies and severe erosion can be overcome by adopting sustainable practices. Figure 34. describes the processes involved in projects co-ordinated by John Danne and Ekorural on the Ilalo mountain area near Quito in Ecuador. To harvest rainwater, trenches are dug across contours in the landscape (2) as well as ditches to collect runoff from roads (3). These are linked in a network of trenches and storage pools (4). This, together with rainwater collected from roofs (5) provides water for household use and to irrigate the trees, plants and grasses that have been reintroduced (6).

Alpaca and llama are now able to graze (8) and there is sufficient water for herb, flower and vegetable beds (7). The Alpaca and llama manure (10) together with mulch, compost and biogas fertiliser improves soil structure, fertility and water retention.

The animals are sheared to produce natural fibre. Alpaca and llama hair comes in many colours, but can also be dyed using natural plant dyes (13). The fibres are spun (15) and woven (16) into clothes and other fabrics (17). Bees (18) can also be introduced to produce honey and beeswax (19) and to pollinate plants and fruit trees.

In many places rainwater collection, storage and use can be based on gravity where water flows into a series of pools then to areas requiring irrigation. If this is not possible solar, wind or hand pumps are used. Water can be channelled to where it is required, connected to drip irrigation and sprinkler systems and piped under roads and paths. Settlement tanks are used to reduce blockages and trap valuable nutrients. These are cleared as required and the sediment used as compost on nearby beds.

Figure 34. Harvesting rainwater and greening the landscape to produce natural fibres, fruit, vegetables and honey in the Andes



There have been three specific outcomes:

1. At least 200 households have developed and adopted new water harvesting technologies.

2. At least 200 households have sustainably increased incomes by at least 30%.

3. At least 1,000 farmers have visited the project and at least 10 agencies have adopted the Katalysis approach as a means of enabling marginalised smallholder Andean farmers to effectively adapt to climate change.

These farmers have begun a process of "greening the landscape" with annual crops, perennials and reforestation in arid areas that were suffering from soil erosion and desertification. The words of Afonso Juma, a farmer from the semi-arid Chota Valley of Northern Ecuador reveal Katalysis's potential:

> *"Once I learned where the water was, I could grow that small plot of alfalfa. With the alfalfa, I could have* cuy *[Kichwa for guinea pig]. The cuy produced manure for my soil. We still have a long way to go, but with just the cuyes, we have already paid back our $200 investment in materials. When I started we had no cuy. Today we have 300 cuyes that are worth about $5.00 each or $1,500 in all. That is much more than I used to earn in the city. Now I can stay home with my family. With the manure, I've planted 75 mango and avocado trees. My farm has become an oasis. Every year it will grow greener and greener. My farm used to be barren of plants. My biggest problem today is that I've run out of land to plant."*

These results are very promising, though application has been limited in scale and scope. Before attempting to scale up, EkoRural proposes both a deeper and wider application of Katalysis in diverse social and geographic settings of northern Ecuador in order

to more carefully document experiences and refine the approach and its emergent technologies. Because of its effectiveness and low external inputs, within five years it is hoped that the project will benefit at least 14,000 vulnerable families living in 660 marginalised rural communities in the Andean highlands. The experiences and technologies generated through this initiative will also be used to inform similar initiatives in other arid and semiarid regions, including those in Asia and Africa.

A number of support mechanisms have been introduced, including farmer-led experimentation, farmer-to-farmer exchanges and locally managed water investment funds. Katalysis does not depend on large external investments, but rather knowledge and new experience that can expose farmers to new realities and opportunities. There are therefore strong possibilities for multiplication and self-spreading without

dependence on external resources so that an increasing number of people may benefit from technical and organisational changes. Over time, growing community technical and organisational capacities can be applied to resolving increasingly complex problems, from farm/household level concerns to community and multi-community matters. Strategies, including the continual application of learning and innovation processes, allow for the development of increasingly mature organisational capacities so that participants have greater understanding and control over their resources and livelihoods.

4.3. SNV: promoting biogas systems in Asia

Background

Many people in developing countries lack access to clean energy for cooking and must rely on biomass fuels like firewood, agricultural residues and dried dung. More than 2.4 billion people, mainly in rural areas, rely on these energy sources for cooking. This depletes local environmental resources, is a waste of valuable nutrients and forces women and children to spend hours gathering firewood. Tree felling is one of the major causes of soil erosion and increased incidence of flooding as well as major ecological impacts such as climate change and loss of biodiversity. Burning biomass fuels also generates indoor fumes that are a serious health risk: worldwide around 1.6 million people (mostly women and children) die annually as a result. Over 1.6 billion people have no access to electricity for lighting or to other basic energy needs. Kerosene is used where it is available and affordable, but this also results in indoor pollution and produces greenhouse gases.

In urban areas in particular, organic waste such as food leftovers, paper and card are often not recycled but taken to landfill sites where it decomposes and produces methane. This contributes to climate change as methane is a greenhouse gas that is 21 times more powerful than carbon dioxide.

There are also many health and ecological problems in places where there are no or inadequate water supplies and sanitation systems (Section 2.4). In Section 3 we considered some of the options for sustainable water supply, sanitation systems and nutrient flows. In this section we focus on biogas systems to supply clean energy and treat sewage and other biodegradable wastes.

Aims and approach

The Dutch international development organisation SNV has been one of the leaders in biogas implementation in Asia (Nepal, Bangladesh, Vietnam [see Box 18], Cambodia, and Laos PDR) and started supporting the formulation and implementation of national programmes on domestic biogas in 1989. Nepal was the first country of engagement in 1992, followed by Vietnam in 2003. By the end of 2009, 300,000 households in Asia had been equipped with biogas plants, improving the quality of life of more than 1.8 million people. More recently, SNV's activities have been expanded to Africa to demonstrate the potential of domestic biogas. The national programme in Rwanda has been running since 2007. Another six countries (Ethiopia, Tanzania, Uganda, Kenya, Burkina Faso and Senegal) are targeted as part of the "Africa Biogas Partnership Programme". The aim is to provide 2.2 million people with sustainable energy between 2005 and 2012, contributing to human development, especially income generation, environmental protection, health improvement and gender equality.

SNV assists in the formulation and implementation of national programmes, with a focus on household biogas systems. The Vietnam Biogas Programme started in 2003, based on tri-partite co-operation between the Vietnamese and the Netherlands Governments and SNV. The programme is implemented by the Ministry of Agriculture and Rural Development (MARD), through its Biogas Project Division (BPD), with technical assistance from SNV.

SNV begins its programme development services by carrying out participatory assessments of the most suitable biogas option, any constraints and potential partners. Biogas systems come in many forms and can operate at different scales—from the household to a whole urban neighbourhood. The digester can be made from metal, concrete, clay or brick and often consists of an underground dome. Once an intervention is agreed, a national strategy is formulated in co-operation with the potential clients and partners. The strategy includes output targets, costs and financing.

Technologies

Biogas systems, sometimes called anaerobic digesters, have considerable potential in every country to address all of the problems described above. In a biogas system nutrients are recycled. Most organic material can be used to feed the system, including crop residue, livestock manure, food leftovers and human excrement. The "digestion" takes place in a sealed tank, which allows the bacteria to ferment organic material in oxygen-free (anaerobic) conditions. This system produces:

1. Biogas (with a high methane content): used for cooking and lighting. Cooking with biogas is clean, quick and easy.

2. Biogas slurry, used for fertiliser. This is rich in the main plant nutrients—nitrogen, phosphorus and potash (NPK)—and can contain up to four times the levels contained in untreated dung (when converted into farmyard manure (FYM); see Table 5). A tonne of biogas manure replaces 37 kg of urea, 94 kg of super phosphate and 17 kg of potash. This fertiliser can be applied to trees, crops, and water plants and fish ponds.

3. Fibre which can be used as a nutrient-rich soil conditioner.

Table 5. Amount of NPK in various raw materials

	N	P_2O_5	K_2O
Bio-Gas Slurry	1.5-2.5	1.0-1.5	0.1-0.3
Fresh Cattle Dung	0.3-0.4	0.1-0.2	0.1-0.3
Farm Yard Manure (FYM)	0.4-1.5	0.3-0.9	0.3-0.9
Town Compost	0.5-1.5	0.3-0.9	0.8-1.2
Poultry Manure	1.0-1.8	1.4-1.8	0.8-0.9
Cattle Urine	0.9-1.2	Trace	0.5-1.0
Paddy Straw	0.3-0.4	0.8-1.0	0.7-0.9
Wheat Straw	0.5-0.6	0.1-0.2	1.1-1.3

Financing

National and local governments as well as donors are invited to co-finance the programme and SNV maintains close contacts with them through an integrated approach in which the capacities of all actors in the sector are strengthened. The aim is to involve a maximum of organisational and institutional capacities already available in the country and to strengthen these through local capacity building organisations, rather than SNV taking responsibility for implementing the programme.

In Asia the cost of installing a household biogas system is between Euro 300 and 400, depending on size and location. The cost of installation and maintenance could also be covered by:

- international aid and development agencies;

- low- or no-interest loans to farmers and households (in Vietnam a saving on fuel of €10 per month means that a household biogas project can break even within 2.5 years; Box 11)

- national taxation; and/or

– other international funding streams such as the Clean Development Mechanism (CDM).

Results

Table 6 provides an overview of the main benefits of an average biogas plant realised through the Biogas Support Programme (BSP) in Nepal.

Table 6. Benefits of an average biogas plant

Reduction of workload (especially women)	1,100 hours per year (3 hours per day)
Improvement of sanitation and health	no indoor pollution; attachment of toilets to the biogas plant (for 72% of all plants); and improved dung management.
Saving of firewood	2,000 kg per year
Saving of kerosene	32 litres per year
Reduction of greenhouse gas emissions	4,900 kg per year (as per 2005 Clean Development Mechanism rules)
Increase of agricultural production	availability of agricultural residue (1,000 kg per year) and dried manure (500 kg per year) originally used for cooking
Saving of chemical fertiliser per year	39 kg nitrogen 19 kg phosphates 39 kg potash

Source: SNV (2009), based on data from Bajgain and Shakya (2005).

Each biogas system can reduce greenhouse gas emissions by 4.9 tonnes of CO_2 per year. These reductions come from:

- Reduced methane emissions from animal manure and the decomposition of putrescible material in landfill dumps;
- Reduced carbon emissions from the use of fossil fuels to provide household energy directly (e.g. kerosene and natural gas) and indirectly (e.g. in power stations to produce electricity);
- A reduction in the use of firewood;
- Avoidance of the emissions associated with synthetic fertiliser manufacture, transportation and use. The production of fertilisers is particularly energy- and therefore carbon-intensive.

In summary, the introduction of biogas systems can reduce current problems (Figure 35) including:

- Result in significant economic savings at both the household and national level by providing cheap or even free energy in rural and urban areas – in the form of methane for cooking and lighting, thus reducing energy costs.
- Replace synthetic fertiliser, thus reducing farm input costs— in the 10 years up to 2008, the price of synthetic fertiliser increased 4- to 7-fold (see Figure 10, Section 2).
- Reduce dependency on crude oil and natural gas, and foreign exchange deficits.
- Significantly reduce incidence of respiratory and eye diseases resulting from indoor air pollution.
- Provide a social benefit by storing and processing dung and human excrement in a sealed container, thus avoiding the

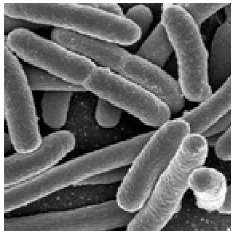
Figure 35. Problems avoided by installing biogas systems

The high cost and environmental impact associated with the use of synthetic fertiliser

Smoke related illnesses associated with the use of dung and firewood for cooking

Slash and burn farming

Flush and Forget, loss of nutrients, eutrophication and other ecological impacts



Ill-health and deaths associated with poor or no sanitation

The cost, inefficiency and external control of centralised electricity systems

Deforestation, soil erosion and flooding

The time spent and energy expended collecting firewood.

The cost and environmental impact of fossil fuel use

Increasing costs and unavailability of phosphorus. Also the environmental impacts associated with phosphorus mining

Box 18. Biogas in Vietnam

Vietnam is now one of the countries taking the lead in biogas technology and implementation. However, the experience over the last few decades has been mixed. Until a structured programme was introduced progress was slow and there were many failures. The story of biogas development in Vietnam highlights the importance of institutional support and co-operation among experts, academics, government departments (at local, regional and national level) and the community.

Following its support to biogas development in Vietnam, SNV expects to achieve results in several areas by 2011 (SNV, 2010):

Income & employment

- 164,000 biogas plants installed in 58 provinces. Up until 2009, the program has built 57,000 plants;
- reduced workload for women by 109 million hours per year (1.8 hour per day);
- increased amount of livestock for 67% of biogas households;
- 10-14 Euros per month saved on fuel—household costs reduced by 65% for 164,000 households;
- increased yield of crops by 5-20% due to the use of slurry as fertiliser, saving on chemical fertilizer cost;
- 1,200 mason teams of 5-7 people established;
- 80-96 mason team man-hours per digester; nearly 9,000 man-hours created;
- 1.5-3 tonnes tradable emission rights per year per digester.

Health & sanitation

- Clean farms established; no animal dung pollution, no smell;
- important health advantages in kitchen, food safety, and surface water established;
- 75,000 toilets attached to biogas plants.

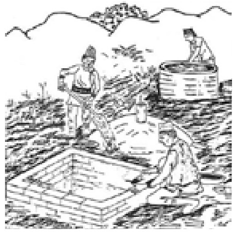
Environment

- Large reductions in greenhouse gas emissions;
- ecological and closed loop farming systems established that use less fertiliser and chemicals.

Figure 36. Biogas systems: benefits, positive outcomes and savings

Free organic compost


Reforestation with the use of fertiliser from biogas system


Job creation – constructing biogas units


Clean water and decontamination of human excrement


Clean and reliable cooking fuel


Free Energy

problem of flies, insects and infections when this material is disposed of in the open and enters the environment untreated.

- Contribute to a reduction in the contamination of watercourses, groundwater and oceans, so water supplies are safe to drink.
- Avoid the ecological impacts of fertiliser manufacture, transportation and use, including water pollution from farms (eutrophication).
- Improve soil quality by providing material rich in organic material.
- Decontaminate and allow for the reuse of "wastes" rich in organic matter and nutrients.
- Reduce fossil fuel use and resulting greenhouse gas emissions.
- Reduce need for biomass and thus improve forest protection, as the felling of trees is significantly reduced.
- Provide safe and sustainable sanitation.
- Create jobs in rural areas in biogas unit construction, establishment of biogas extension services and the possibility of income generation through the sale of organic compost.

- Ease hard work for women and children.
- Generate revenue through the Clean Development Mechanism.
- Improve the quality of life of those involved.

There are many other positive outcomes described in Figure 36. These include multiple financial, health and ecological benefits that can be quantified when biogas replaces firewood, dung and fossil fuels.

4.4. Sustainable urban and peri-urban agriculture in Cuba

> *"Over the last fifteen years, Cuba has developed one of the most successful examples of urban agriculture in the world. Havana, with a population of over two million people, has played a prominent, if not dominant role in the evolution and revolution of this type of agriculture. As a result, more than 35,000 hectares (over 87,000 acres) of land are being used in urban agriculture in the City of Havana. In Cuba the distinction between organic and urban is hardly worth making, as almost all urban agriculture follows organic practices"* Koont (2009)

Background

In Latin America and the Caribbean there has been a steady flow of people from rural to urban areas in recent decades as the poor, often landless, have migrated to the cities out of necessity or in a search for higher incomes. Cities in the region have grown rapidly, and for the first time in history there are more poor people living in urban rather than in rural areas.

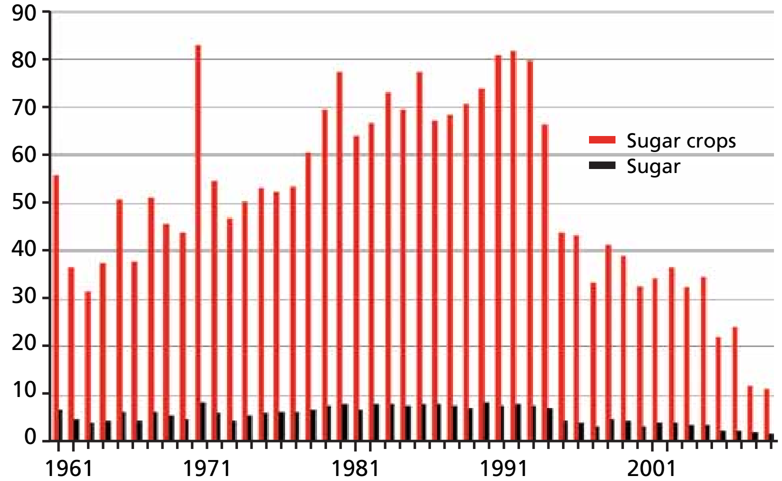
Urban agriculture contradicts the belief that people in cities are merely consumers of food. Food production within urban areas and on the outskirts of cities can minimise environmental impacts associated with food supply, improve biodiversity and create employment and income generating opportunities. Perhaps most importantly it can help to increase community pride and resilience, as has proved the case in Cuba, the first country to experience peak oil-like conditions: a sharp and rapid decline in supplies of crude oil and industrial agriculture inputs.

In 1989 Soviet aid to Cuba was withdrawn. Up to this point, Cuban agriculture had been highly industrialised and was dependent on food and agricultural imports including farm machinery, fuel, fertilisers and pesticides. In 1988, for example, it imported 100% of its wheat, 90% of its beans, 94% of its fertiliser, 82% of its pesticides and 97% of its animal feed (Wright, 2006, 2008). The withdrawal of Soviet aid meant that 1.3 million tonnes of chemical fertilisers, 17,000 tonnes of herbicides and 10,000 tonnes of pesticides could no longer be imported; between 1989 and 1993, for example, there was a five-fold drop in synthetic fertiliser imports from 537,880 to 96,500 tonnes.

Highly industrialised fuel- and capital-intensive farming came to an end. Cuba lost 85% of its foreign trade, including food, agricultural imports and petroleum. Already crippled by the US embargo, the country was financially devastated, with its food supply hit hardest.

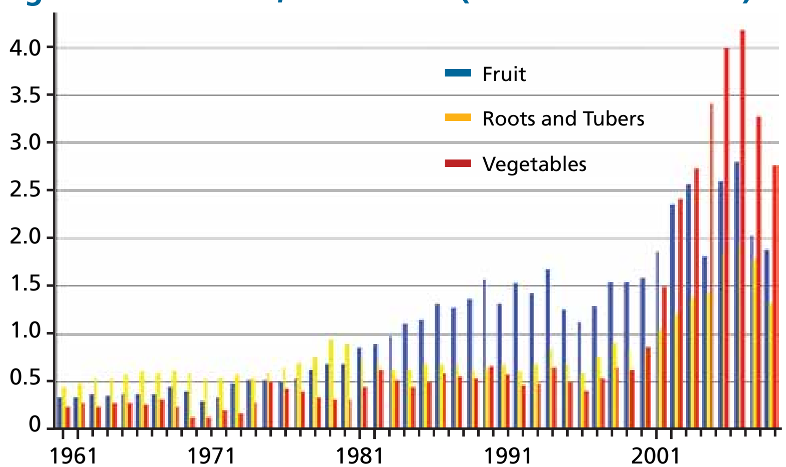
Farming had also been highly specialised and based on monocultures—the country produced large amounts of sugar and tobacco for export, while importing many other food products; approximately half of all foodstuffs in 1990. Since the beginning of the 1990s (known as the Special Period) there has been a significant diversification of agricultural production. Between 1991 and 2006 there was a seven-fold decrease in sugar cane output (Figure 37) and between 1989 and 2004 there were large increases in the production of fruit (114%), cereal (44%), vegetable oils (593%), pulses (842%), roots and tubers (182%) and vegetables (631%) (Figures 38 and 39).

Figure 37. Sugarcane production in Cuba, 1961-2006 (millions of tonnes)



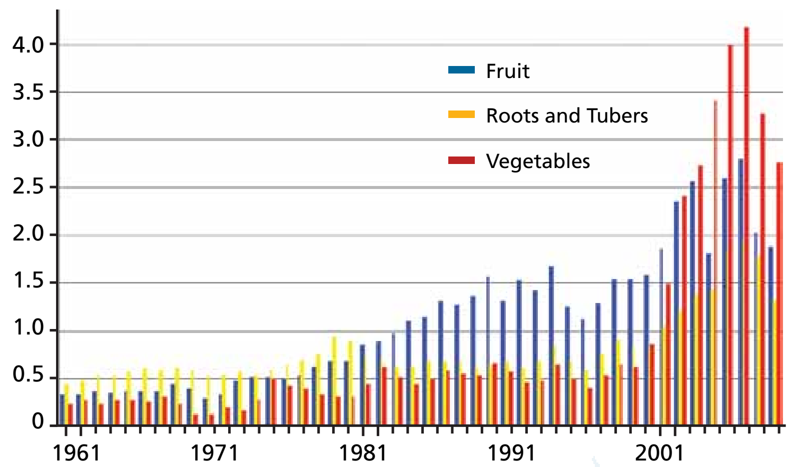
Source: Based on data from FAO statistical databases

Figure 38. Production of fruit, roots and tubers, and vegetables in Cuba, 1961-2006 (millions of tonnes)



Source: Based on data from FAO statistical databases

Figure 39. Production of cereals in Cuba, 1961-2006 (millions of tonnes)



Source: Based on data from FAO statistical databases

Initially, food supplies decreased significantly and the crisis made the shift of food production to cities unavoidable, partly due to the cost and availability of transport fuel. In Havana, the largest city in the Caribbean with a population of over 2 million, land was distributed to individuals and co-operatives as *parcelos* or plots and over 200 biopesticides production centres were set up. New co-operative farms—with or without a collectively cultivated, jointly held area—came into being and replaced some state farms. *Organoponico* units of between one-half and several hectares in size were established, together with intensive kitchen gardens on patios, rooftops and waste ground. *Organoponicos* typically consist of raised beds roughly 30 metres by 1 metre and contain a mixture of soil and organic material such as compost (see example below).

On patios and plots, traditional gardening and farming practices predominate, with the partial introduction of some of the

techniques used in *organoponicos*. Greenhouses are also used, as are shading techniques to block the intensity of the sun so as to increase yields, improve quality, and make year-round production of vegetables possible.

Indeed, urban food projects in Havana are extremely diverse in terms of their organisation, scale, production methods and food products cultivated and raised.[23] Several different types of food production systems have been developed including: *organoponicos* (market gardens), *huertos* (gardens), *parcelos* (plots), patio and roof gardens and peri-urban *fincas* (farms). Examples of several different projects are described in the sections below.

Organoponico Vivero Alamar

Organoponico Vivero Alamar, in the suburbs to the east of Havana, was established during the Special Period by five visionaries, including a carpenter, an agronomist and a chemist. At that time travel was difficult as transport fuel was in short supply and expensive. They wanted to work within walking distance of their homes and decided to look for land close by and to begin their experiment. The project started in 1999 on a small plot of land (0.06 hectares) with very poor soil. A decision was taken to form a co-operative as the organisational basis for the project.

Progress has been impressive. The number of workers has increased to 140 and their average salary is more than double the national average. The area of the market garden has increased to 11 hectares and between 1999 and 2006, vegetable production increased 1100% from 20 tonnes to 240 tonnes and income 5000% from 100,000 to 5.3 million Cuban Pesos (Table 7).

23 Food production in and around Havana is extremely heterogeneous, but can roughly be divided into four main groups; *huertos populares*, *autoconsumos*, *organoponicos*, and state enterprises, ranging in size from a few square foot to several acres. Havana also has an urban *campesino* (small farm) sector, with 2,200 small farms inside city limits (Murphy, n.d.).

The approach has out of necessity been incremental, but problems were minimised because the right principles were in place from the start. Any obstacles or opportunities have been assessed and discussed; thanks to the extensive experience of the members—and their commitment—the correct decisions have usually been taken. The co-operative members also conduct small-scale trials to determine the best methods and systems before implementing them on a larger scale.

Opportunities to diversify, expand production and increase income have been embraced. Examples include the production of ornamental plants, mushrooms, ornamentals, fruit and other tree seedlings, tropical fish and the processing and packaging (reusing bottles collected locally) of sun-dried herbs and spices. The result has been a rapid increase in the number of co-operative members—an average of 17 each year between 1999 and 2006.

Planning and strategy have had to be flexible in order to respond and adapt to external factors. An example of this is the plan currently being implemented to introduce 30 bulls. The main reason for this is not the income that will be generated from meat sales, but for the 300 kg of organic fertiliser that they will produce each day. Until 2008, manure had been purchased from other farms. However, the quality was often poor and it was expensive to transport this bulk material. Additionally, some of these other farms used chemical herbicides and Organoponico Vivero Alamar is certified organic.

The bulls will be purchased at 200 kg and sold when they reach 400 kg. They will be fed on elephant grass cultivated on site. This will increase the self-reliance of the project and also add another sustainable circular loop into the system (Figure 40). Ploughing is carried out by a pair of oxen and weeding and harvesting are done by hand, so fossil fuel use is minimal. Most of the produce (90%) is sold directly to the public at five markets adjacent to the growing areas so the energy and carbon emissions associated with post-harvest transport are also low.






Figure 40. Virtuous cycles operating at Organoponico Vivero Alamar

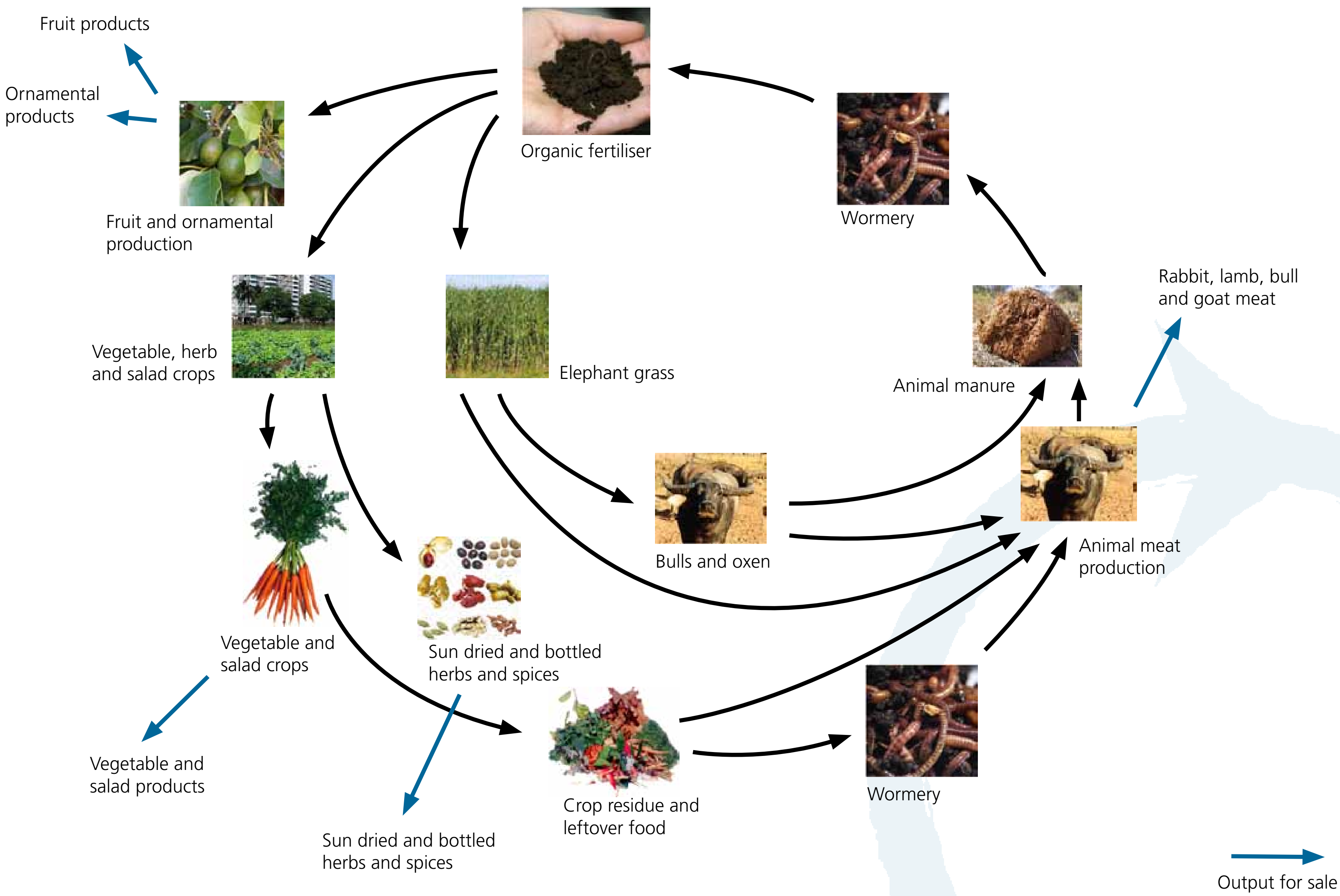


Table 7. Performance of Organoponico Vivero Alamar, 1999-2006

	1999	2002	2005	2006
Area (ha)	0.06	1.5	10.8	10.8
Vegetable production (t)	19.9	74.4	145	240
Vegetable seedling production (millions)	1.11	2.12	2.76	3.44
Other seedlings	11565	21995	28419	28100
Dried spices and herbs (kg)	0	200	1191	1400
Income (million Cuban pesos)	0.102	2.332	3.454	5.282
Profit (million Cuban pesos)	0.102	1.005	1.162	1.65
Number of members of the cooperative	10	40	102	131
Female workers	5	12	26	34
Average income per member (Cuban pesos/ month)	425	550	650	950

Source: Organoponico Vivero Alamar, Cuba

Production on the 14 hectare site is already extremely diverse: many different vegetable, salad, herb and spice crops are produced in rotation throughout the year, including lettuce, swiss chard, tomatoes, cucumbers, and cabbage, beets, eggplant, carrots, green beans, celery, cauliflower, mint, parsley, green peppers, artichoke, bok choi and okra. Additionally there are many different types of fruit, as well as 35 African sheep, 200 egg-laying chickens, 12 goats and 100 rabbits.

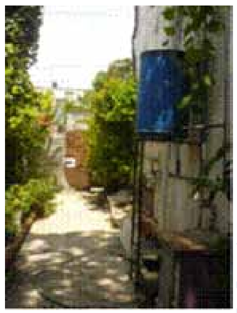
Due to its environmental, social and economic success, this *organoponico* is in many ways a model of a post-peak oil and low-carbon food system.

Patios and plots

Patios are privately-owned home gardens producing food primarily for family consumption, to share with neighbours and exchange or sell locally. Plots are either operated on an individual, co-operative or community basis. Two patio projects are described below.

Growing Up: *Proyecto Patio Comunitario Barrio Canal*

Justo Torres started his patio project after attending a permaculture course. This experience is evident in his design and the way the project functions: every bit of space is used (including vertically as space is limited), materials used include local material that most would regard as being rubbish, and there is a huge diversity of plants. The project began at ground level and literally grew upwards as Justo negotiated with neighbours to use their unused space to establish a second and third level.



Rainwater harvesting

Climbing plants and shrubs

Showing second and third levels with grapes on third (top right of photograph)

A variety of fruit and vegetables are produced, as well as rabbits, whose meat provides an important income—rabbits can grow to 7-12 lbs (3-5 kg) at 1 Cuban Convertible Peso (CUC) a pound. Over 400 lbs (184 kg) of grapes are also harvested each year.

Proximity principle

Justo explains that a key goal of his project is to become more self-reliant in food, water, nutrients and materials. This involves producing a wide variety of food products on his patio, recycling nutrients, rainwater harvesting and grey water reuse (Figure 41). It also requires improvisation. Materials used to construct various components of the system—such as pergolas, pathways and raised beds—are sourced within the neighbourhood whenever possible, for example wood and plastic waste from factories and neighbours. Other inputs, such as animal feed, are exchanged with other local projects for products from Justo's project. In this way costs are minimised, as are environmental impacts in the form of transport emissions and also the quantity of solid waste generated—waste that would otherwise be sent to landfill.

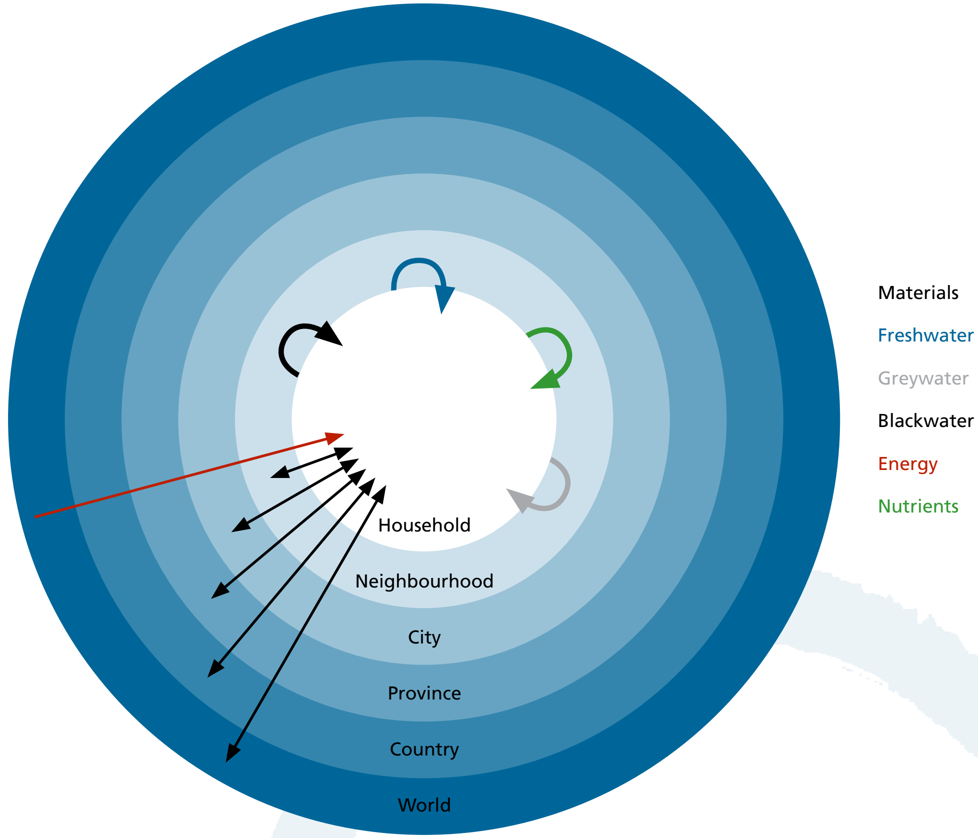
Farming on a roof[24]

Nelson Aguilar's plan of keeping rabbits on the roof of his house began in 2002 when he attended a series of training courses on the principles of permaculture. Here he learnt about diversified and integrated food production systems and recycling organic residue and waste.

His production system involves both animals (rabbits, guinea pigs and chickens) and plants, all located on a 136 m² roof. Rabbits are the most economically important component. More than 100 rabbits, including 2 bucks, 23 does and their offspring are kept in an area of 68 m². Underneath the rabbit cages there

24 This case study is based on Sánchez *et al.* (2005)

Figure 41. Applying the proximity principle in Proyecto Patio Comunitario Barrio Canal



A shaded meeting place

Justo's patio also acts as a meeting place—a location where invited speakers, visitors and the local community can meet, discuss issues and share ideas or just come to relax in the shade and have a chat.

is another area, with 40 guinea pigs, and in a nearby area Nelson keeps 15 chickens of a local breed. The rest of the roof is used for growing plants: mainly condiments such as red pepper, basil, garlic, small onion and oregano, but also medicinal plants like aloe, noni and some ornamental plants. These make the place attractive and provide shade for the animals. In the winter, cabbage, tomato and other vegetables are grown.

The design allows all waste products to be recycled back into the system. In this way, the limited feed resources are used as efficiently as possible. The rabbits eat fresh grass cut from gardens and green areas in the city, as well as fresh vegetable waste from the kitchen, a nearby canteen, vegetable markets and food stores. The fresh feed is complemented with dry feed prepared at home using a home-made device. This improves the quality of the feed, extends storage time to six months (which is important in Cuba's hot and humid conditions), and allows a reserve stock of animal feed to be built up during periods when organic residues are abundantly available.

The rabbit and guinea pig manure is collected and part of it is dried. This then makes up 70–80% of the chickens' diet (with the homemade dried feed accounting for the remainder). The remaining manure is used as a fertiliser for the plants cultivated on the roof, and any excess manure is given to other vegetable growers in the neighbourhood.

The system provides significant economic benefits for the Aguilar family. The sale of rabbits constitutes the main source of income. The chickens produce 4-7 eggs each day, sufficient to cover family needs and to sell or give to neighbours. Guinea pigs are occasionally sold as pets or for breeding, and occasionally some homemade feed is also sold. The net income generated through the system is 1.4 times the average per capita salary in the city. At the same time, the system provides the household with eggs, meat, condiments and medicines, which saves a significant amount of money.

Of equal importance are the social benefits of the system. Nelson has strengthened his relations with his neighbours and the surrounding community, who support his production system by providing him with a range of inputs. The people who provide these inputs also benefit, because they get rid of organic residues that would normally require time and effort to dispose of. People in the neighbourhood also obtain easier access to healthy products that can be bought cheaply or bartered. Local vegetable growers also benefit by receiving free manure. The local environment is improved as waste products are being reused and recycled, avoiding nutrient losses, water pollution and solid waste.

Farms (*fincas* and ranches)

On the outskirts of Havana and other cities there are farms of varying sizes, many of which are as diverse as *organoponicos*. Products include guinea fowl, rabbits, chickens, pigs and cattle as well as many varieties of vegetable and fruits such as coconut, banana and mango.

Production from State Co-operative Supply Unit (CSU) farms is destined for Work Centre cafeterias; however, surpluses are sold to their workers for their household. In Cuba the majority of workplaces have cafeterias where for a small charge a meal is offered. The 316 CSU farms occupy an area of 40,126 hectares where they cultivate a diverse range of crops, such as vegetables, grains and fruits, but they also produce meat, fish, eggs and milk. These are intermingled with cattle ranches which produce meat and dairy produce for urban centres and 74 hydroponics units that amount to 56 hectares (Novo, 2003).

The Various Products Company occupies the fringe between the more urbanised and agricultural zones. It is organised into municipal farms and 390 other farms with 13 to 20 hectares of land. These larger farms are formed by a union of various smaller *fincas*. The company dedicates the majority of its land to

the production of fruits including citrus, coffee and vegetables. Among its fundamental objectives is the supply of fresh agricultural produce to the increasing numbers of tourists within the city and its surrounding areas.

There are also state-run organic herb farms, such as the Finca Provincial Plantes Medicinal in Pinar del Rio province. This 200 acre farm grows medicinal herbs used by the Cuban Ministry of Public Health for distribution throughout pharmacies, hospitals and clinics in the Cuban healthcare system. This is one of the largest medicinal herb farms and according to its director Sergio Travieso Sanchez, this farm and many others like it are growing by 20 to 25% a year. From a modest four crops in its first year, 45 crops are now cultivated on the farm, which employs 45 workers and uses no machinery. The herbs grown include oregano, calendula, Japanese mint, German chamomile, aloe vera, eucalyptus, banana leaves, and turmeric (D'Arcy, 2004).

Herbal medicine in Cuba is not a consumer trend, but was born of the stark economic reality when Soviet pharmaceutical imports ceased and pharmacy and hospital shelves became empty of medicines. To make things worse, the 1992 Torricelli Act in the US extended the existing US trade embargo, curtailing shipments of food and medical supplies from subsidiaries of American companies. For the last ten years, the Cuban government has endorsed and aggressively promoted cost-effective herbal medicine. In 1995 the Office of Natural and Traditional Medicine was created within the Ministry of Public Health.

Results

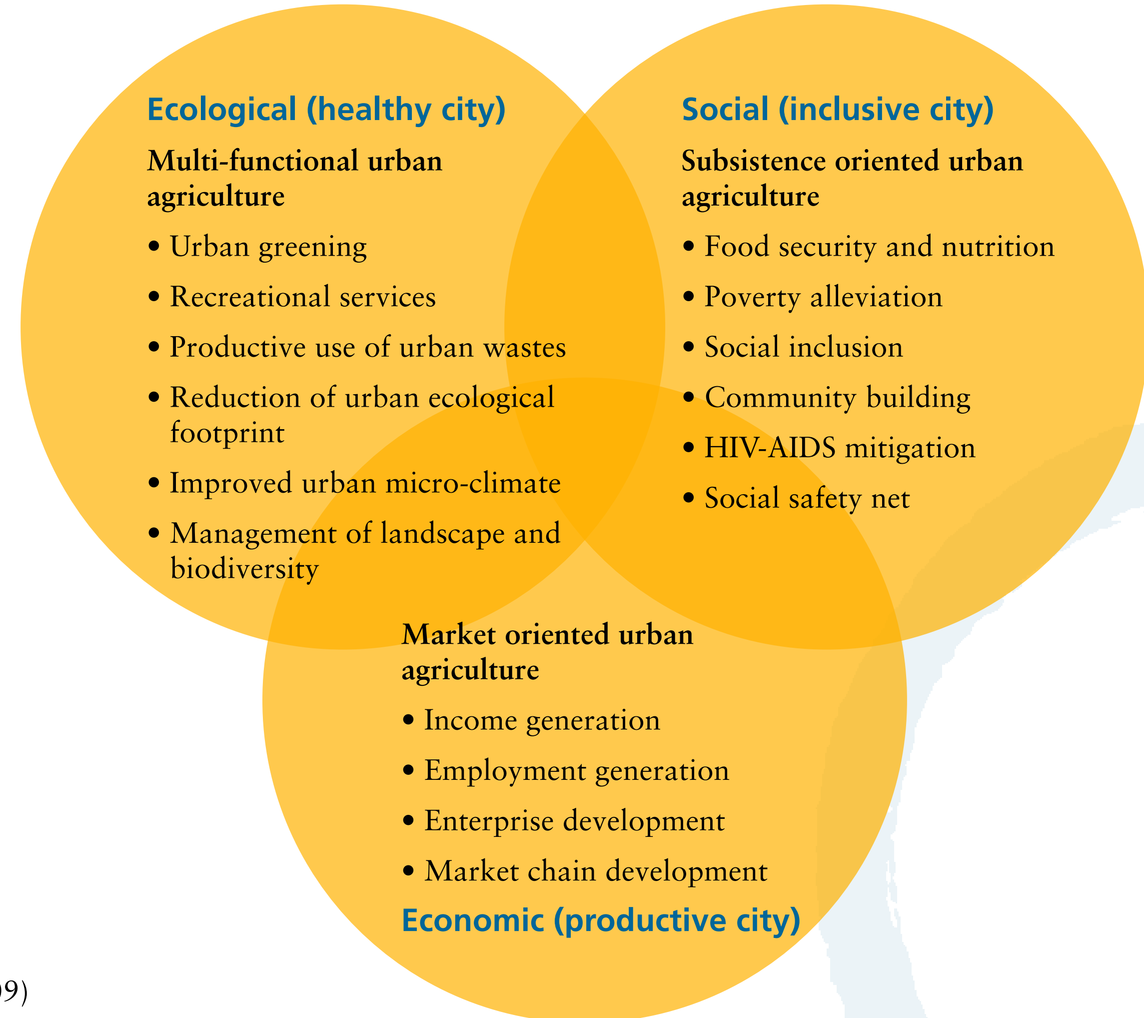
> *"Cuba's organic farming system is successful, and Cubans appear to be breaking apart the myth that 'although organic farming is good for the planet, yields would not sustain Earth's population.' Here, yields have been increased through organic farming techniques, a much cheaper alternative to conventional agrochemicals. Cuba's farming is cocooned and tucked away from the world, in an environment free of the pressures and demands of the agro-business marketplace. Lessons have been learned in this experiment that can be shared with farmers around the world"* D'Arcy (2004)

Urban agriculture and equitable access to land can help to address important urban (and wider) challenges:

- increasing urban poverty and social exclusion;
- growing food insecurity in cities (nutritious food is more difficult to access by the urban poor and food crises especially affect the urban poor); and
- developing strategies for more sustainable and resilient cities (to mitigate climate change and reduce the "foot/food-print" of cities (de Zeeuw, 2009).

– Many other social, economic and ecological benefits can be realised, such as agri-ecotourism and non-agricultural services such as the recycling of wastes, urban greening, GHG and heat reduction, and improved landscape, biodiversity and water management (Figure 42).

Figure 42. The benefits of adopting urban agriculture



Source: de Zeeuw (2009)

Some of the economic advantages to the urban poor are described in Tables 8 and 9.

Table 8. Income from urban agriculture

City	Typical monthly net income in US$ for irrigated urban vegetable production
Accra	40-50
Bangui	320 (producers), 330 (wholesalers), 140 (retailers)
Brazzaville	140-170 (producers), 120 (retailers)
Cameroon	69 (above minimum wage)
Lagos	120
Ouagadougou	25-70 (100)
Yaoundé	34-67
Ho Chi Minh City	40-80 (125)
Jakarta	30-50

Source: de Zeeuw (2009)

By 1997, urban farms and gardens in Havana provided 30,000 tonnes of vegetables, tubers and fruits, 3,650 tonnes of meat, 7.5 million eggs, and 3.6 tonnes of medicinal plant material. In March 1998, it was estimated that 50% of vegetables were grown within urban areas (Murphy, n.d.).

Forward-thinking national, regional and city administrators recognise the importance of urban agriculture and support its development as part of a strategy to achieve food security, improve diet, create employment, reduce poverty and minimise environmental impact. Urban agriculture is now a central feature of food, farming and social policy in many countries including Sierra Leone (Operation Feed the Nation), Brazil (Zero Hunger Campaign) and Sri Lanka as part of a national campaign to increase domestic food production.

In Rosario, Argentina, 60% of the 1 million inhabitants experience poverty and 22% live in extreme poverty. An urban agriculture project in the city has increased food security and improved the diet of the 10,000 families that participate in the program. Each household now earns an additional US $90-150 a month from their agricultural activities on reclaimed waste land (de Zeeuw, 2009).

The organised system of urban food production began in Cuba in 1994 and had taken its more or less final form by 1997. With it, Cuba has achieved results that would have seemed quite implausible in 1991. One major achievement of note is the raised yields in the *organoponico* systems from 1.5 kg per square metre in 1994 to 25.8 kg per square metre in 2001, a 17-fold increase.

The increase in the cultivated area—reaching 70,000 hectares in Havana by 2006—within and around cities is also important, because it means significantly less fuel to package and transport food to an urban population. This in turn helps to reduce air pollution and greenhouse gas emissions. This “greening of the city” also increases biodiversity and provides an outdoor classroom for all.

The vegetable, herb and small-scale animal production units that have been established in Havana make use of locally available resources, have minimal environmental impact and strengthen communities. Other environmental benefits achieved in Cuban

Table 9. Urban food supplied by urban and peri-urban agriculture (UPA)

City	Percentage of urban demand met by UPA					
	Leafy vegetables	All vegetables	Eggs	Poulty	Milk	Pork
La Paz (2000)		30				
Dakar (2000)		70-80		65-70		
Dar Es Salaam (2000)		90			60	
Accra (2003)		90				
Nouakchott (1999)	90					
Shanghai (2000)		60	90	50	90-100	50
Hanoi (2000;2004)	70-80	0-75 seasonal variation	40	50		50
Vientiane (2004)	100	20-100 seasonal variation				

Source: de Zeeuw (2009)

urban agriculture relate to the use of agroecological methods. Pests are controlled by diverse rather than monocultural production and through interplanting—the use of plants to repel pests—as well as by hand picking in the case of slugs and snails. For example, oregano is a pest repellent and corn attracts beneficial insects. Frogs and dragonflies can also be encouraged to control mosquitoes and slugs. Biopesticides, prepared from plants such as mango, neem, and nonni leaves, are also used to control pests.

The social and economic benefits include the creation of significant levels of urban employment including for women and young workers—important for the long-term sustainability of urban agriculture—as well as retirees, bringing income and health benefits to the latter. The urban agricultural workforce in Havana has grown from 9,000 in 1999 to 23,000 in 2001 to more than 44,000 in 2006. Finally, the community-building and therapeutic side effects of urban agriculture are also significant (**Koont,** 2009).

4.5 Canastas Comunitarias: challenging modern food in Ecuador[25]

Background

From food security to sovereignty in Ecuador

Since the 1960s, the socio-technical system around food production, distribution, retailing and diet in Ecuador has undergone major transformations. Following land redistribution, the government introduced 'agricultural modernisation' policies built on ideals of externally-based knowledge, the distancing between growers and consumers, and the use of currency as essentially the sole mediation device. In the 1980s, international food companies intensified their activity in Ecuador, becoming important economic, social and political agents. They bought local companies and their product labels, leading to monopoly control over markets. For example, in 1991 Coca-Cola bought out Fioravanti, one of the oldest soft drink companies in the world. Similarly, Nestlé aggressively acquired the most popular national chocolate and candy companies, and Frito-Lay purchased the major national potato chip company as well as other snack food suppliers. Since the mid-1990s, the supermarket chain Super- and Mega-Maxi has grown exponentially, consolidating and expanding control over retail markets and supply chains. In the process, restrictive demands on suppliers have increasingly constrained the informal small-scale farm and business sectors that dominate the country.

Not unlike the experience in Europe and North America, the emergence of "modern food" in Ecuador has come to mean new layers of intermediation between rural-based producers and urban-based consumers. It has become increasingly difficult for urban populations, in particular low-income populations, to access affordable, healthy food due to a combination of geographic, financial and social factors. The arrival of a modernised food system in Ecuador has led to harmful consequences that are similar to the "food desert" phenomenon and the obesity epidemic in OECD countries. In addition, a shift towards market-driven, input-intensive production and mechanised tillage on hillsides has generated severe environmental decline, placing into question the long-term viability of modern agriculture.

Growing awareness of this situation has fuelled public protest. In 2006, tens of thousands of people joined forces across the country to rally against the US-led Free Trade Agreement (FTA), which was perceived as advancing the interests of large-scale producers and the international food industry. Three years later, the national assembly in Ecuador drafted a food sovereignty law, which among many things proclaims a universal right to healthy food and a healthy environment. Meanwhile, a previously little-known movement of neighbourhood purchasing groups has gained in popularity to the point where it is viewed as a promising grassroots force for change and has been chosen as the national representative of consumer interests: *Canastas Comunitarias*, or 'community food baskets'.

Aims and approaches

The *Canastas Comunitarias* movement emerged as a response to modern food products, retailing and trading systems. To avoid the social, economic and environmental damage associated with modern food systems, direct links between rural farmers and urban consumers have been developed. The movement has close links with the agroecology and food sovereignty movements in Ecuador and beyond. The guiding principles are solidarity, healthy food, responsible consumption and shared responsibility. The way in which these principles are translated into practice is described below.

25 In this case study we use photographs, data and text from Kirwan and Sherwood (2009).

Solidarity:

- co-operation over competition
- avoiding lucrative, for-profit endeavours
- finances and accounting that are transparent and self-managed
- mutual understanding of urban-rural lifestyles
- respect and commitment by those involved

Healthy food:

- food comes from family farmers who protect the soil, water, and plant biodiversity, and avoid using agro-chemicals or genetically-modified seeds
- varied, nutritious diet
- products are purchased in good condition

Responsible consumption:

- direct purchasing from smallholders to eliminate intermediaries and stimulate local economies
- fair prices and payment for commodities and services

Shared responsibility:

- the *Canasta* is autonomous and independent; members control and maintain it themselves
- members are self-selected and contribute to common interests
- all members are expected to contribute equally and to participate in decision making

The movement began in the highland city of Riobamba in 1987 and has since spread to provincial cities and the capital Quito, with particularly rapid expansion in the last two to three years. Although originally organised to save money through bulk purchases, since their foundation the *Canastas* have diversified their activity to include "healthy food systems", and have emerged as an urban-based leader of the national food sovereignty movement. In this respect, there are similarities with the local food movements in Europe and initiatives such as farmers markets, co-operative/collective buying and community-supported agriculture.

The focus on food emerged through discussions over their diets, during which the *Canasta* members discovered that their families were increasingly replacing fresh products with less nutritious but more expensive processed foods such as white rice, crisps, soft drinks, and other "fast food" snacks. Participants discovered that the seemingly cheap modern food carried hidden costs. It threatened family nutrition, the livelihoods of peasant and smallholder farmers, local economies, the environment, and ultimately the wellbeing of their people. The organisers' insights gained through this "deepening" process led to new ways of thinking, organising, and doing.

Over the last two decades, *Canastas* has became redefined as a platform for ambitious social change: *"an alternative form of commercialisation based on agro-ecology," "the creation of social meeting spaces that can build a new culture based on mutual respect and solidarity between the farm and the city"* and *"a new economic model that will be adopted by society."* Many in the movement call for political action around food systems and society (Gortaire and Ruíz, 2007).

A *Canasta Comunitaria* can range from 15 to 100 or more member families. Groups make bi-weekly bulk purchases; individual shares include an average of 20 foodstuffs per family. Initially, products came from the local open market,

Second from left: A member of Cuenca's *Canasta Comunitaria* collects her biweekly *canasta*. Behind her, products are divided up ready to be loaded into the sacks

Above: Producers displaying their goods at the *Primer Encuentro de las Canastas Comunitarias de Quito*, a fair held by Quito's consumer network in November 2007

which is controlled by intermediaries. However, as a result of a "deepening" process, many Canastas establish direct purchasing arrangements with local growers, which can lead to better prices, greater control over food quality (e.g. pesticide use), and increased benefits for marginalised families (Utopía, 2009).

Food sovereignty in Ecuador

Inspired by a constitutional assembly and President Correa's call for a re-organisation of society around the Andean concept of *Sumac Pacha* (*Kichwa*, or the "good life", which in Andean cosmovision evokes spiritual, economic, social, and environmental harmony), in 2008 leaders from a number of peasant farmer organisations, indigenous movements, and non-governmental organisations proposed a fundamental shift in national agriculture policy from food *security* to *sovereignty*. The latter is a concept promoted by the regional *Via Campesina* movement since the late 1990s.[26]

Members of the Ecuadorian alternative food movement, loosely organised as the *Colectivo de Agroecologia*, sought to influence the Constitutional Assembly's Agriculture Commission by calling attention to the contradictions of modern food. In particular, they presented studies to expose concern over: the relationship between industrial agriculture and global warming, the human health consequences of pesticides, and the soaring prices of fertilisers as a result of increasing petroleum costs. They called attention to risks associated with the loss of genetic diversity and the nutritional and cultural values of traditional Andean roots and tubers, such as potato and quinoa. They also raised concerns over the recent growth of supermarket chains and the loss of competitive markets for smallholder producers.

As a result of this and similar activity, the Agriculture Commission drafted a complex 15-page proposal calling for "healthy food systems", taking into consideration production, consumption, environmental, and other considerations. During

26 For further information on Food Sovereignty see Box 9, Annex 3 and Mulvany (2007); La Via Campesina website (http://viacampesina.org); Pimbert (2009a, 2009b); Via Campesina (2003) and Food First (2002).

2008/09, the proposal was undergoing a nine month process of expert and public consultation throughout the country and the Commission elected a six person Advisory Board representing the diverse interests of civil society. As a result of heavy lobbying by the *Colectivo de Agroecologia*, a representative from the *Canastas* was selected on the Advisory Board—the first time that consumer interests had been explicitly included in agriculture policy.

The Food Sovereignty Organic Law in Ecuador was approved by the National Assembly with President Rafael Correa's partial veto in March 2009: *"The Food Sovereignty Organic Law of Ecuador elaborates on the constitutional law proposed in September, 2008 with the duty to promote and guarantee nutritious and culturally appropriate food to its population by providing mechanisms to convert to agroecological practices. Through public credits, subsidies and mitigation efforts, the State will prioritize on the internal market and national availability of food supply. Land will serve its social and environmental function; generating employment, equitable distribution of income, productive utilization and conservation of biodiversity"* (Peña 2009).

4.6. Joining the dots: scaling up for a sustainable future

Based on our research, we conclude that circular systems, together with the local organisations, sustainability planning and design tools upon which they are based, have the potential to facilitate the transition to sustainable settlements. As George Chan explains, they could eventually tie together human infrastructure, production and consumption systems into one seamless matrix of synergistic interactivity.

In Section 3 and in the case studies above the shift to sustainable systems—urban agriculture in Cuba; agroecological farming, localised food systems and sustainable water systems in Ecuador; and biogas systems in Asia—has resulted in significant beneficial outcomes. The environmental and socio-economic benefits are summarised below.

Socio-economic benefits

– increased levels of stable, secure and meaningful employment

– avoiding the risks, costs and debt associated with high input farming systems – resulting in increased farm income

– increased food, water and energy security by providing these needs locally - reduced incidence of malnutrition and energy poverty

– reduced household and farm costs for food, energy and water

– improvements in public health

Resources, waste and pollution

– minimise fossil fuels use

– significantly reduce greenhouse gas emissions

– lower levels of local air and water pollution – resulting in improved health and a significant reduction in diseases related to poor sanitation and indoor air pollution

– increase biodiversity

– achieve large reductions in solid waste

In all four of the case studies above, raising awareness and sharing knowledge—of the root causes of the problems communities were facing and the sustainable alternatives that could alleviate these—was a key issue (Figure 43). Most of the projects that we have considered have involved one or more of the following approaches: participatory learning and action; co-production of ideas and plans; and farmer-to-farmer approaches to learning and dissemination. All have made progress by strengthening local organisations and their horizontal networks.

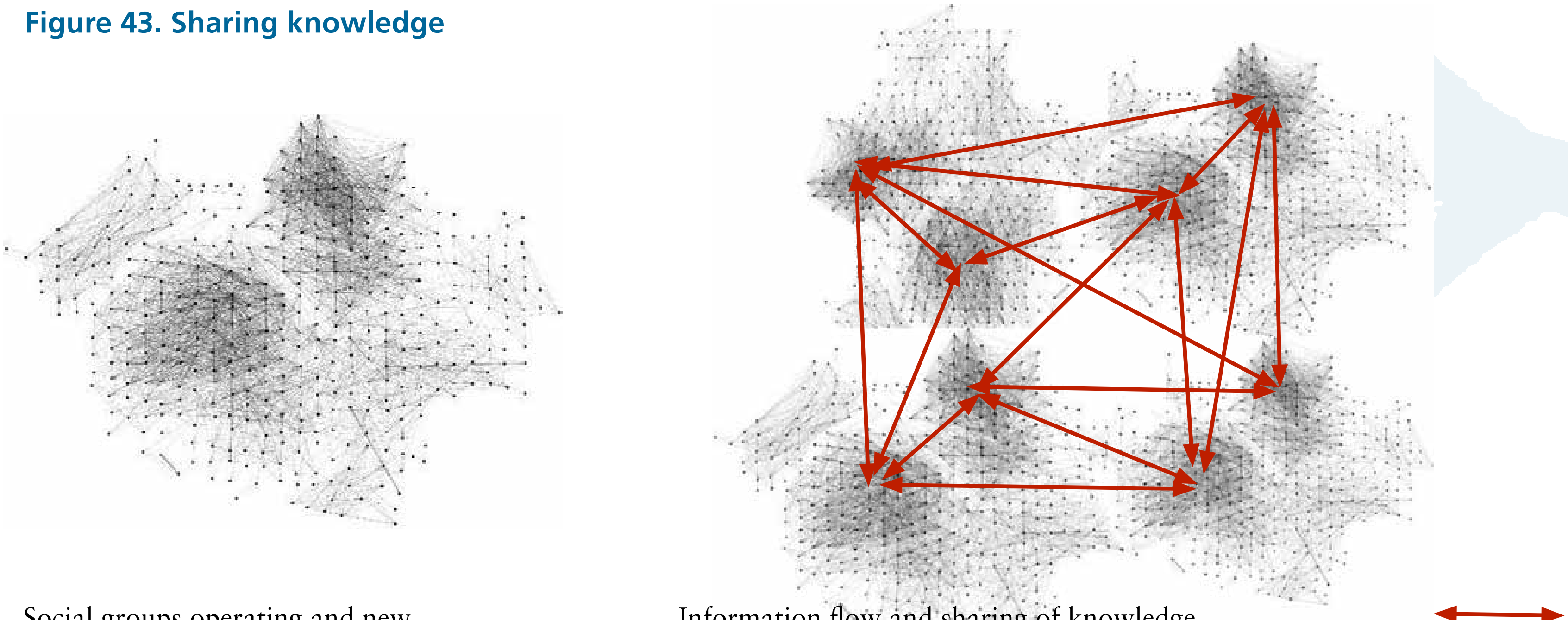
In this dynamic process, involving awareness-raising, knowledge transfer and peer-to-peer training, the aim is to:

- Discover what is possible—by assessing the options and considering what has worked in other places, which systems are most appropriate and how they can be adapted to local conditions and capacities.
- Highlight any important issues that could affect project success during planning, design and implementation.
- Identify any technical and financial support that may be required which could be provided by local universities, research organisations and NGOs and international donors.

These processes are crucial in inclusive and informed decision making, and were the key to project success in the case studies that we assessed. If sustainable systems are to become more widespread then knowledge exchange will be vital through peer-to-peer learning; local research, demonstration and training centres; and by re-training trainers, teachers and development workers.

In the final section we explore some of the policy and paradigm changes needed if the isolated examples such as those explored here are to become the norm.

Figure 43. Sharing knowledge



Social groups operating and new ideas developing largely in isolation

Information flow and sharing of knowledge between individuals and various social groups

Information flow

5. The Shift to Sustainability

> *"The major struggle that will determine the future is not between the doctrines of the dominant political parties or special interest groups, but between, on the one hand, those who try to prop up, defend and preserve the core institutions of industrial mass consumption society and, on the other hand, those who recognize that today's most urgent problems, including the unsustainability of our food system, cannot be solved within the existing framework. Central to this situation is the struggle between the pulls for centralization and decentralization and between those who strive to repress diversity and those who fight to accommodate and legitimize it"* A. Tofler (1980), The Third Wave, quoted Stuart B. Hill

When a situation appears too complicated to even begin to address, or a problem seems intractable, it is often useful to begin with the basics, question all assumptions and think the unthinkable. In many ways this is where we are in terms of sustainable development and the sustainability of food, water, energy and other material supplies.

In the case of the food systems, four key issues that need to be addressed are:

1. The food system is environmentally unsustainable and socially unfair.

2. The era of cheap and reliable fossil fuel energy supplies is about to end, which will require a large reduction in energy consumption together with a widespread shift to renewables.

3. Significant cuts in greenhouse gas emissions will be required in coming decades.

4. Access to food for the poorest needs to improve and any increasing production has to address the three drivers of change above, as well as decreasing water supplies, soil degradation and possibly a decline in phosphorus supplies.

It is the relationship between these issues that requires further analysis, and which could lead to a viable solution. The objective is to identify the most appropriate structure and geographic scale for food chains in order to minimise fossil fuel inputs, solid waste and GHG emissions and at the same time improve food security.

We have concluded that there is very limited potential for minimising negative impacts in existing food chains. Instead, we need a shift from a high external input model that results in significant levels of pollution and waste to one that is based on low external inputs and a circular metabolism. This will require a fundamental change in how the food system is structured and operates. While some of the problems are beginning to be acknowledged and proposals being put forward, the current approach is inadequate in terms of the scale of the challenges that lie ahead and the urgency required.

There are several reasons for this slow response:

- The fundamental causes of the problems are being ignored. There is insufficient information on the environmental impacts of the contemporary food system and analysis of the factors that have contributed to its evolution. This applies to individual food products, alternative supply chains and the total impact associated with national food supplies.

- Mainstream responses to the multiple crisis undermining food, water, and energy security are at best reformist and tokenistic at worst. They are neither transformative nor deep enough to shift society towards sustainability (see Box 19).

Box 19. Reform or transformation in food, agriculture and land use

Change and learning are central issues for the individuals and organisations involved in designing sustainable food and agricultural systems based on circular economy models and principles of eco-literacy and food sovereignty. At its simplest level, learning is a process through which new knowledge, values and skills are acquired. At a deeper level, learning involves "a movement of the mind" (Senge, 1990). Different orders or levels of change and learning are involved here:

- First order change and learning. This takes place within accepted boundaries and involves adaptive learning that leaves basic values unexamined and unchanged. This single loop learning poses "how" questions. How can we deal with the problem we face? How can we avoid the mistakes we are making? Much of the focus of first order change is on making adjustments to the existing system—doing more of the same, but doing it better (emphasis on efficiency) or by reorganising components, procedures and responsibilities (emphasis on effectiveness).

- Second order change and learning involves critically reflective learning, examining the assumptions that influence first order learning. This double-loop learning focuses on "why" questions. The organisational culture and facilitation continuously encourage the questioning of existing practices, rules, procedures and regulations. Such learning seeks to expand collective knowledge and understanding by understanding the assumptions and goals behind existing routines, practices, theories and policies. This is sometimes called "learning about learning" or "thinking about thinking".

- Third order change and learning happens at a deeper level, when organisations and individuals see things differently. This is creative learning and involves a deep awareness of alternative world views and the possibility of doing things differently. This triple loop learning articulates the deeper 'underlying why' questions related to will and being. It focuses on underlying paradigms, norms and values that frame and legitimise the purpose of knowledge, policies, organisations, technologies and practice. It involves "seeing things differently", "doing better things" and re-thinking whole systems on a participative basis. As such, it is a shift in consciousness and is a transformative level of learning. This learning process will usually "see" that individuals and organisations need to engage in fundamental change in order to facilitate deep change in the wider system, i.e. there is a need to transform in order to be transformative.

The individual and organisational learning responses to the social and ecological crisis of modern food systems thus span the following:

- No change: no learning. Denial, tokenism or ignorance.

- Accommodation: first order learning. Adaptation and maintenance of the status quo.

- Reformation: second order learning. Critically reflective adaptation.

- Transformation: third order learning. Creative re-visioning and fundamental re-design of whole system.

Source: Pimbert, 2010.

- The contemporary food system is viewed by many policy makers—in OECD countries and increasingly in the South—as a success story in terms of convenience, the choice of produce available and the logistical systems that allow for this.

- Agri-business (fertiliser, pesticide and seed corporations), merchant traders, and the large food retailers and processors have become extremely powerful and because of the number of people they employ and their fiscal contribution to national economies, have gained significant political influence.

In this section we outline some methods and steps for tackling some of these deep-seated obstacles to the paradigm shift needed to bring about a circular approach to basic needs' provision.

5.1. Measuring sustainability: revealing the hidden histories of products and services

One of the first steps on the road to sustainability will be to deal with the "out of sight, out of mind" culture at the heart of our current economic system, and especially the process of globalisation. We need to reveal the "hidden histories" of food products; a phenomenon that arises because food supply chains have become extremely complicated and geographically dispersed. Consumers are provided with little or no information on the origin of produce and the farming, processing, packaging and distribution system associated with the products that they purchase (Box 20), or of where their waste goes to. As a result they have very little knowledge of their environmental, social and economic impacts.

Information is required to overcome these distancing effects that keep the consumer unaware of the origin of foods and other goods and services and their impacts. The onus is on government and the key actors in the food, energy and water systems to provide information on the environmental impacts of their policies and an action plan to minimise these. If, as has been argued here, the potential for improvement in existing systems is limited, this should be acknowledged. The alternative—the closed loop, renewable energy and localised model described above—which shows far greater potential to minimise fossil fuel use and greenhouse gas emissions, should then form the basis of a framework for change.

In order to make informed decisions and develop policies and strategies to facilitate the shift to sustainability, reliable data and 'clean and clear' information are required. We have identified the tools that allow for this.

Our overall approach is based on systems analysis and the toolbox includes: carbon footprinting, energy analysis (including energy returned on energy invested—EROEI, see footnote 6), life cycle analysis, means-end analysis, value chain analysis and commodity chain analysis. These analysis techniques can provide data that feed into the decision making process at the household and community level right through to the national and international level. In doing so, analyses can also help to uncover the hidden histories of products and services by describing, quantifying, and drawing attention to social, environmental and economic impacts that are often unseen.

Although each of the techniques listed above provide a rigorous framework for the analysis of all products and services, only one method includes a component that is crucial for the identification of sustainable systems. The approach is called means-end analysis and in this the important issue that is recognised and addressed is that there are many "means" to achieve each "end". In other words there are numerous options for the supply of food, energy, water etc. to a household.

The key tenets of means-end analysis are (Jones, 2002):

Box 20. The modern food system: 40,000 product lines, 40,000 secrets and lies

> *"If you want sustainable food chains, you have to get consumers to buy more wisely, so producers and retailers must provide more information about what's behind their products and services,"* Richard Wakeford, Sustainable Development Commissioner (SDC, 2004).

If you were to walk into a supermarket, pick up a food item and ask the manager if s/he could outline its main social and environmental impacts, they would almost definitely be unable to respond. If the item is an unprocessed meat, fruit or vegetable product then its provenance may be displayed on the packaging, as would a symbol if it was produced organically. However, if you were looking for products with low greenhouse gas emissions, or to compare the emissions for a particular product from a supermarket and another outlet, for example, a farmers' market or a box scheme, this would not be possible.

The fact that so little information exists on the environmental and social impacts of the food system seems to suit the large retailers, for what you don't know you don't worry about and, more importantly, you can't change. What this means is that it is difficult to determine which aspects of contemporary supply chains are particularly environmentally damaging. It also makes it virtually impossible to compare the environmental impacts associated with supermarket supply chains for particular foodstuffs and those of the alternatives.

The multiple retailers and the food and drink industry spend billions of dollars each year on advertising what they perceive to be their strong points—price, convenience and choice (Story and French, 2004). Could it be that they regard food miles, as well as their relationship with suppliers, the working conditions on farms and in food factories, and the energy use and pollution associated with the supply chains they have developed as a weak point and something to hide?

Graphic images of appalling levels of animal welfare, degrading conditions for migrant workers on factory farms and in food factories, the plight of smallholders and farm workers in the South, and the environmental impacts of industrialised food production and distribution may not appear on the label of food products or in commercials or adverts in glossy magazines, but these are the realities of the modern food system. *"It would be commercial suicide for any supplier to give a true and honest account of all aspects of relationships with retailers."* (Supplier giving evidence to the Competition Commission).[a]

a. Food and Farming Conference. 23rd November 2002 at www.organic.aber.ac.uk/events/foe/supermarkets.shtml

- All options for meeting a specified human need are considered, including the alternatives to the predominant production, sourcing, distribution, marketing and waste management systems.

- The analysis is based on consumption and includes the impacts associated with the production and transportation of imports. In this approach the data collected are based on exact distances and reflect real life examples of current practice within production systems, the supply chain and consumer behaviour.

- All stages involved when moving the product from source to the consumer (and subsequent waste management stages) are assessed—so that the analysis covers all processes involved in the production and delivery of a product or service.

This comprehensive approach leads to an accurate value for the carbon footprint, embodied energy or other indicator of the environmental performance for each option to supply an item of consumption. The total embodied energy or GHG emissions of a product or service include all stages of the manufacturing process, from the mining of raw materials through to processing and packaging and the distribution process, to the final product provided to the consumer and then waste management. Economic aspects can also be assessed—see for example Figure 12. The key actors in supply chains can be identified as well as power relationships.

Means-end analysis: approach

The first task is to determine all options for the delivery of the product or service being assessed. For example in the food supply chain there are many variables for each stage: organic, low-external input or industrial farming methods; sourcing food locally, nationally or globally; and purchasing food at a farmers' market, supermarket or restaurant (Figure 44.).

The second stage of the analysis is to produce a detailed process diagram for each possible supply chain (see tomato ketchup case study, Figures 45, 46 and 47). In the case of food products for example, the food supply chain (FSC) comprises all of the stages involved when delivering a food product to the consumer, and the subsequent waste management processes. In terms of an individual fresh food product, the FSC will therefore involve one or more of the following functions: production and supply or farm inputs; cultivation; sorting, processing and packaging; retailing; storage, preparation and consumption; and waste management as well as all of the transport stages which link these subsystems, as they are often geographically dispersed.

Data on the energy use, GHG emissions or economic aspects are then obtained for each stage in the supply chain – either from published data or empirical data collected by the researcher. The sum of the impacts for each stage provides an environmental or socio-economic profile of the product.

In the Designing Resilient Food Systems programme the indicators of environmental and socio-economic performance that are used to assess initiatives include:

– greenhouse gas emissions;

– energy or fossil fuel use;

– solid waste;

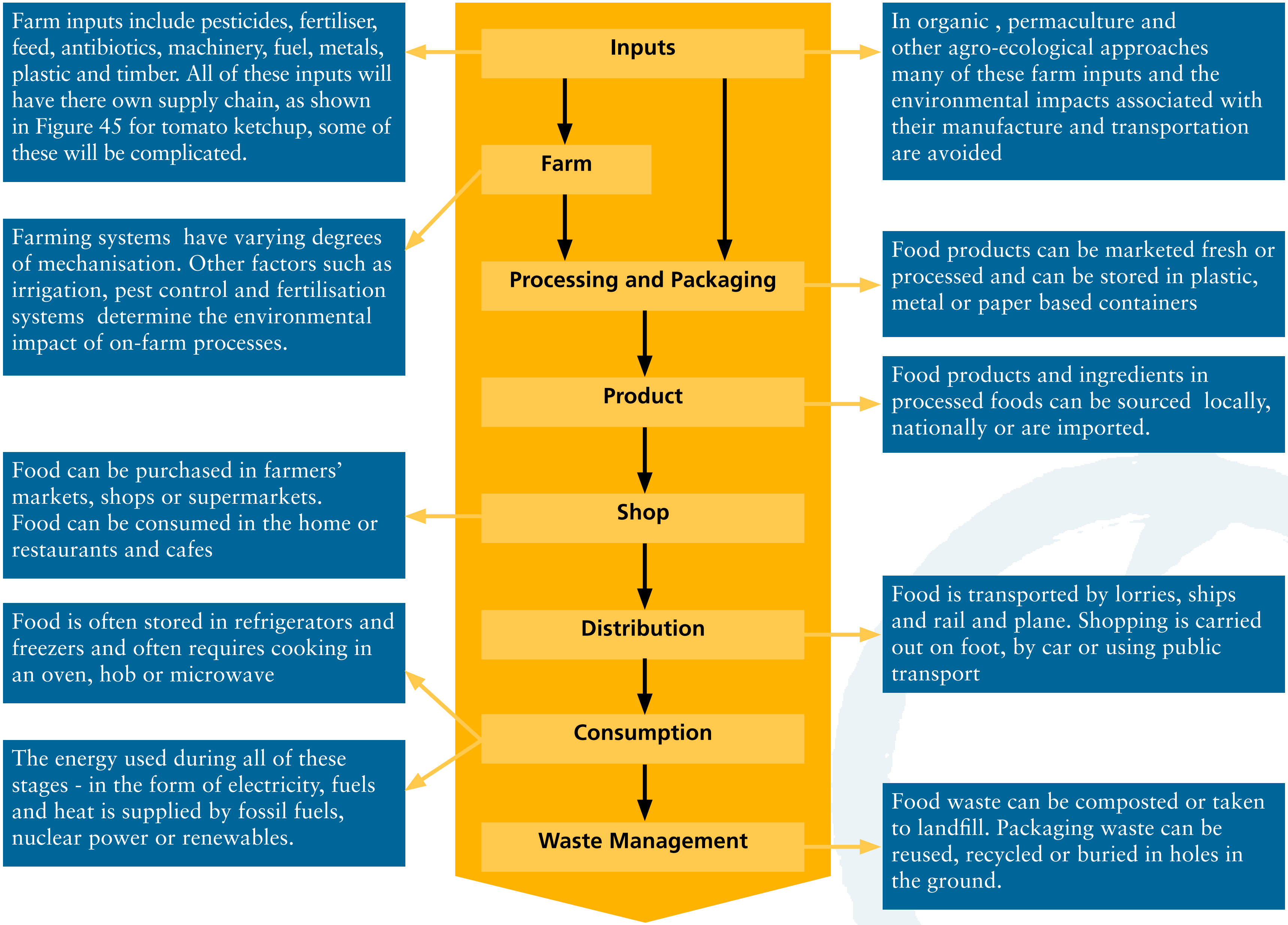
– air pollution;

– water emissions;

– reduced household costs;

– reduced cost of inputs to farming systems and/or increased income;

Figure 44. Options during each stage of the food supply chain



Box 21. Resilience Values

1. **Diversity.** Promotes and sustains diversity in all forms (biological, landscape, social, and economic)
2. **Ecological variability.** Embraces ecological variability rather than control it, e.g., flowing rivers, fires.
3. **Modularity.** Maintains a degree of modularity or disconnectedness, e.g., patches within a landscape, nodes within a network.
4. **Acknowledge Slow Variables.** Recognises the importance of slow variables like nutrient, carbon and water cycles
5. **Tight Feedbacks.** Creates tighter feedback loops between human actions and environmental outcomes.
6. **Mutual aid and solidarity.** Promotes trust, well-developed social networks, cooperation, and leadership
7. **Innovation.** Emphasises experimentation learning, locally developed rules, and change
8. **Overlap in Governance.** Develops overlapping institutions to increase response diversity and flexibility to change.
9. **Ecosystem Functions.** Includes all the un-priced ecosystem functions in development planning and assessments
10. **System Reserves.** Unused resources such as seed banks and human knowledge are mobilized in response to disturbance.
11. **Openness.** Source of novel ideas to enhance the development and diversity of knowledge

Source: Modified from Jones (2011), Gunderson and Holling (2002), Borrini-Feyerabend *et al.*, (2007).

– increased availability of food, water and energy;

– increased employment;

– improved public health;

– increase in equity and gender inclusion; and

– enhanced democratic control and oversight.

In addition to the above, the program on *Designing Resilient Food Systems With, By and For People* also uses a series of attributes and values to assess the socio-ecological resilience of different systems (Box 21)

Each option will have a specific set of environmental, social and economic impacts as well as resilience values (Box 21). For example environmental impacts will include an inventory of resource inputs, and the outputs include solid waste and water and air emissions. Each supply chain can be compared and the most sustainable option can be identified. In the next section we demonstrate the approach using the example of a bottle of tomato ketchup.

Unravelling supply chains: the case of tomato ketchup

By delving into the "history" of a product, useful information can be obtained on the structure of contemporary food supply chains. Unfortunately, very little research has been carried out in this area. The analysis of commodity chains has provided

an insight into the power relationships in food chains and the small number of detailed analyses of food products based on a life cycle perspective have shed some light on the complicated structure of contemporary food chains and demonstrated how unsustainable they have become. This has been done, for example, for the manufacture and supply of yoghurt and orange juice (Kranendonk and Bringezu, 1993; Böge, 1995; Browne and Allen, 2004). Here we give the example of tomato ketchup, which reveals how complicated production and supply chains have become, our dependency on fossil fuels and other resources, and the limitations to any environmental improvement that doesn't involve a shift to a circular systems approach.

In 1996 researchers at the Swedish Institute for Food and Biotechnology presented the results of a detailed analysis of tomato ketchup manufacture (Andersson *et al.*, 1996). The study considered agricultural inputs, tomato cultivation and conversion to tomato paste (in Italy), the processing and packaging of the paste and other ingredients into tomato ketchup in Sweden and the retail and storage of the final product.

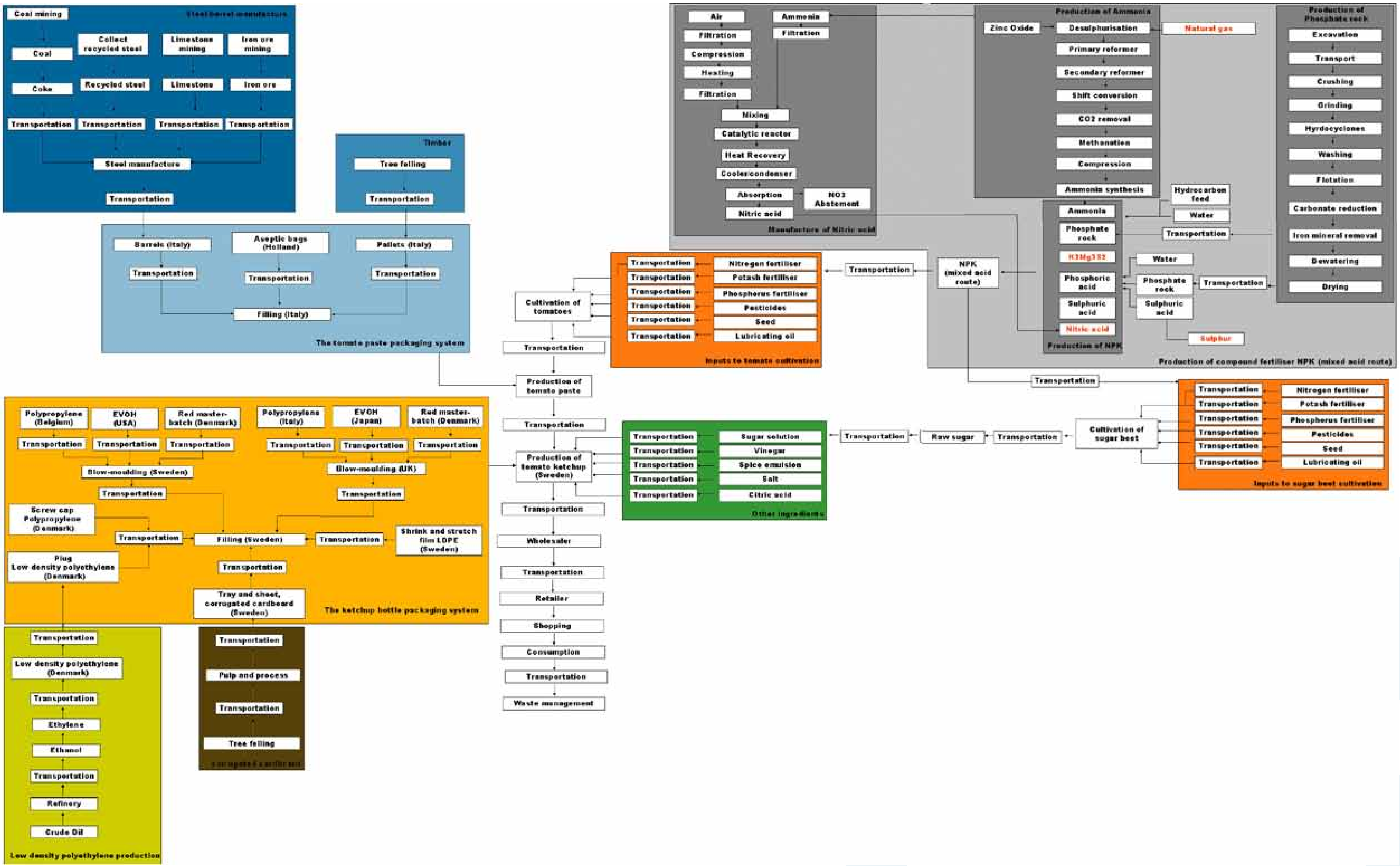
The aseptic bags used to package the tomato paste were produced in the Netherlands and transported to Italy to be filled, placed in steel barrels, then moved to Sweden. The red bottles consist of five layers and are produced by blow–moulding, either in the UK or Sweden, using materials from Japan, Italy, Belgium, the US and Denmark. The layers of the bottle include ethylene vinyl alcohol (EVOH), red masterbatch and polypropylene. EVOH is commonly used in food applications to provide an oxygen barrier for improved food packaging shelf life. EVOH is typically co-extruded or laminated as a thin layer between cardboard, foil, or other plastics. A masterbatch is used to add colorant to bulk uncoloured polypropylene. It comprises highly concentrated pigment, mixed with a carrier plastic, in a granule or pellet form. The carrier material is compatible with the polypropylene in which it will be blended during moulding, whereby the final plastic product obtains the colour or properties from the masterbatch. The polypropylene (PP) screw-cap of the bottle and plug, made from low density polyethylene (LDPE), were produced in Denmark and transported to Sweden. Additionally, LDPE shrink-film and corrugated cardboard were used to distribute the final product.

The Swedish study demonstrates the extent to which the food system is now dependent on national and international freight transport. However, there are many other steps involved in the production of this everyday product that were not included in the study. These include the transportation associated with the production and supply of nitrogen, phosphorus and potassium fertilisers; pesticides; processing equipment; farm machinery and the ketchup bottle labels, glue and ink. In Figure 45 some these processes are included together with other stages involved in the manufacture of this product and inputs into the production process. The diagram includes other inputs: such as the mining and processing of crude oil, natural gas, coal, iron ore, phosphorus and the manufacture and supply of intermediary products such as steel, sulphuric acid, ammonia, plastic polymers, transport fuels, vehicles and machinery.

Other ingredients that were not included in the Swedish study of the ketchup—sugar, citric acid, vinegar, spices and salt—are also imported. For example, China produces 50% of all citric acid. Allspice is likely to come from Jamaica or countries in Central America, cinnamon from Sri Lanka, cloves from Indonesia and pepper from India.

The study provides an interesting insight into the structure, geography and environmental impacts of modern food chains. In the expanded process diagram for tomato ketchup manufacture and distribution, which still excludes some stages, there are over a hundred process stages and more than fifty transport steps: a total of over 150 separate processes across several continents.

Figure 45. The processes involved in the manufacture of tomato ketchup



Most of the processes listed above will also depend on derivatives of fossil fuels—crude oil, gas and coal. Apart from the fuel used to operate machinery on the farm and during the production and distribution process, crude oil is also required as a feedstock to produce plastics and pesticides, and natural gas as a feedstock for fertiliser production. This product is also likely to be purchased in a shopping trip by car.

The system for the manufacture of ketchup is based on industrial processes—for tomato cultivation, processing and packaging—that are highly mechanised, globalised and transport- and energy-intensive (Figure 46). The result is that when this linear system as a whole is considered, large quantities of resource inputs are required and significant quantities of greenhouse gas emissions as well as other pollutants and solid waste are the resulting outputs.

This example shows how the ketchup manufacturing system, and that of most food products available in OECD countries (and increasingly in transition and developing countries), makes a significant contribution to resource use and climate change. In countries such as the UK, for example, 80% of food is now pre-processed and a third of meals are pre-prepared. These food chains are also highly dependent upon other industrial systems and processes, including the extraction and processing of metal ores, the production of industrial chemicals and gases, plastics manufacturing, the mining and refining of fossil fuels and industrial timber production.

If we consider the potential to reduce resource use and pollution in this supply chain for ketchup, we find that the possibilities are extremely limited if processes remain industrialised and the geographic and physical scale remains the same. The shift to decentralised renewable energy systems is not feasible because of the size and energy demand in fertiliser, pesticide, plastic manufacturing plants—this also applies to the processing of tomato paste and manufacture of the ketchup. The plastic bottles cannot be reused and in most countries they are not even recycled. In the case of transport, there is very little scope to increase the efficiency of engines to reduce fuel consumption and GHG emissions, so if distances remain the same, nothing can be done to reduce the impacts of transportation. The use of industrial biofuels, as discussed earlier, is not feasible and even if it was, this would have a significant impact on food prices and food security and would not result in a reduction in GHG emissions.

From a circular perspective, however, there is an alternative. This involves agroecological approaches to cultivating tomatoes locally, small-scale processing using renewable energy, reusing glass bottles and minimising transportation by developing a localised system (Figure 47). If agroecological approaches are used, then this eliminates the need for the manufacture and supply of synthetic fertiliser and pesticide. In cooler climates tomatoes can be produced in a glasshouse and yields increased and the season extended using renewable energy to provide heat, for example by using methane from a biogas system. Glass bottles can be used as the ketchup container instead of plastic—these can be reused bottles and need to be sterilised. Some spices will be imported through fair trade arrangements and by ship; however, the number of transport stages and the quantity of intermediary and transport packaging can be substantially reduced.

In this system, environmental impacts – resource use, pollution and waste – can be minimised. It involves a restructuring so that the number of transport stages and the distances involved are reduced to a minimum. In this localised system, geographic and physical scale is reduced.

There are also local social and economic benefits—less mechanised tomato cultivation requires more labour and local jobs, as does an increased number of small-scale ketchup processing facilities. The reduction in fossil fuel use and external

Figure 46. Transportation involved in the manufacture of tomato ketchup

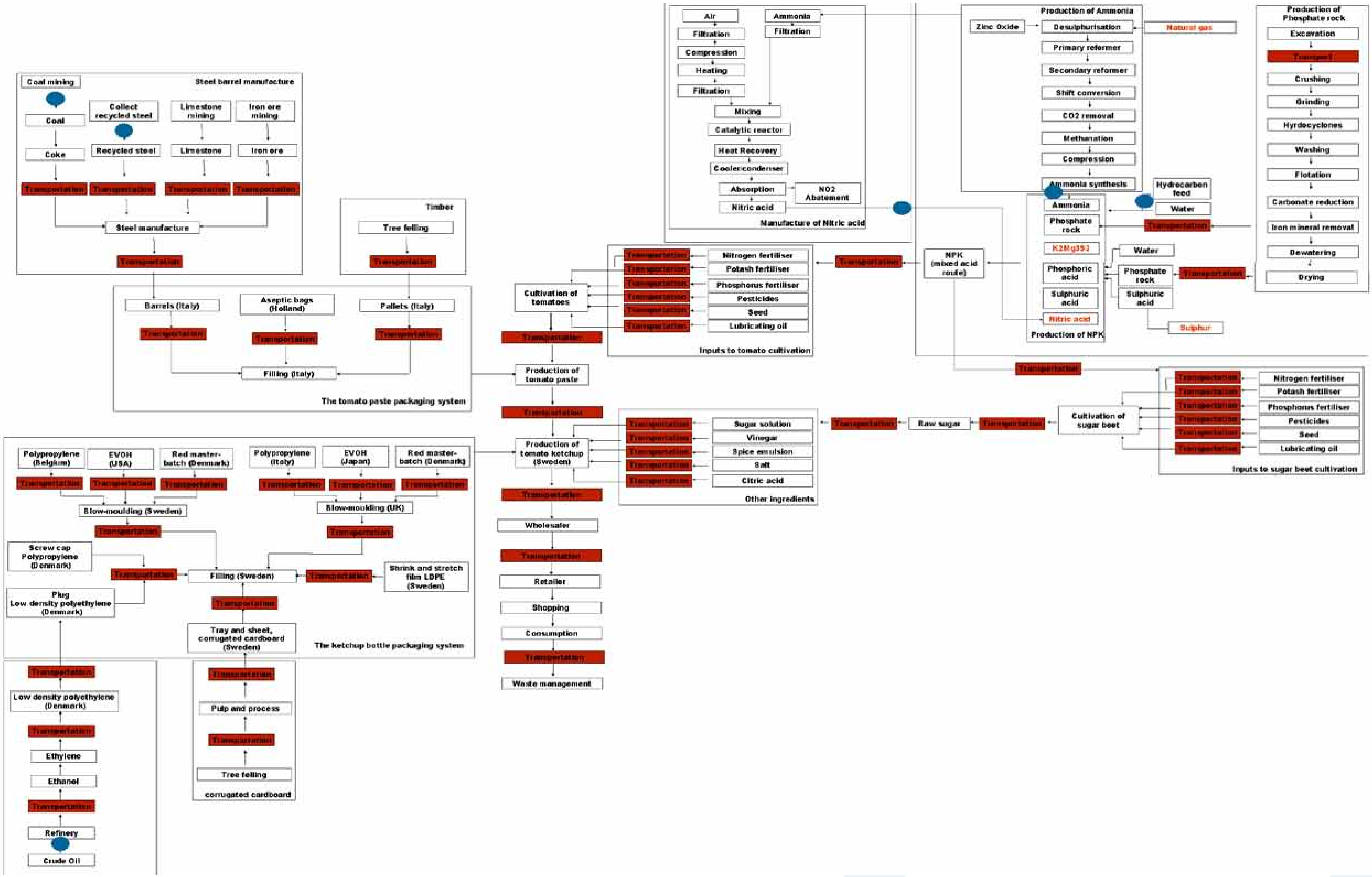
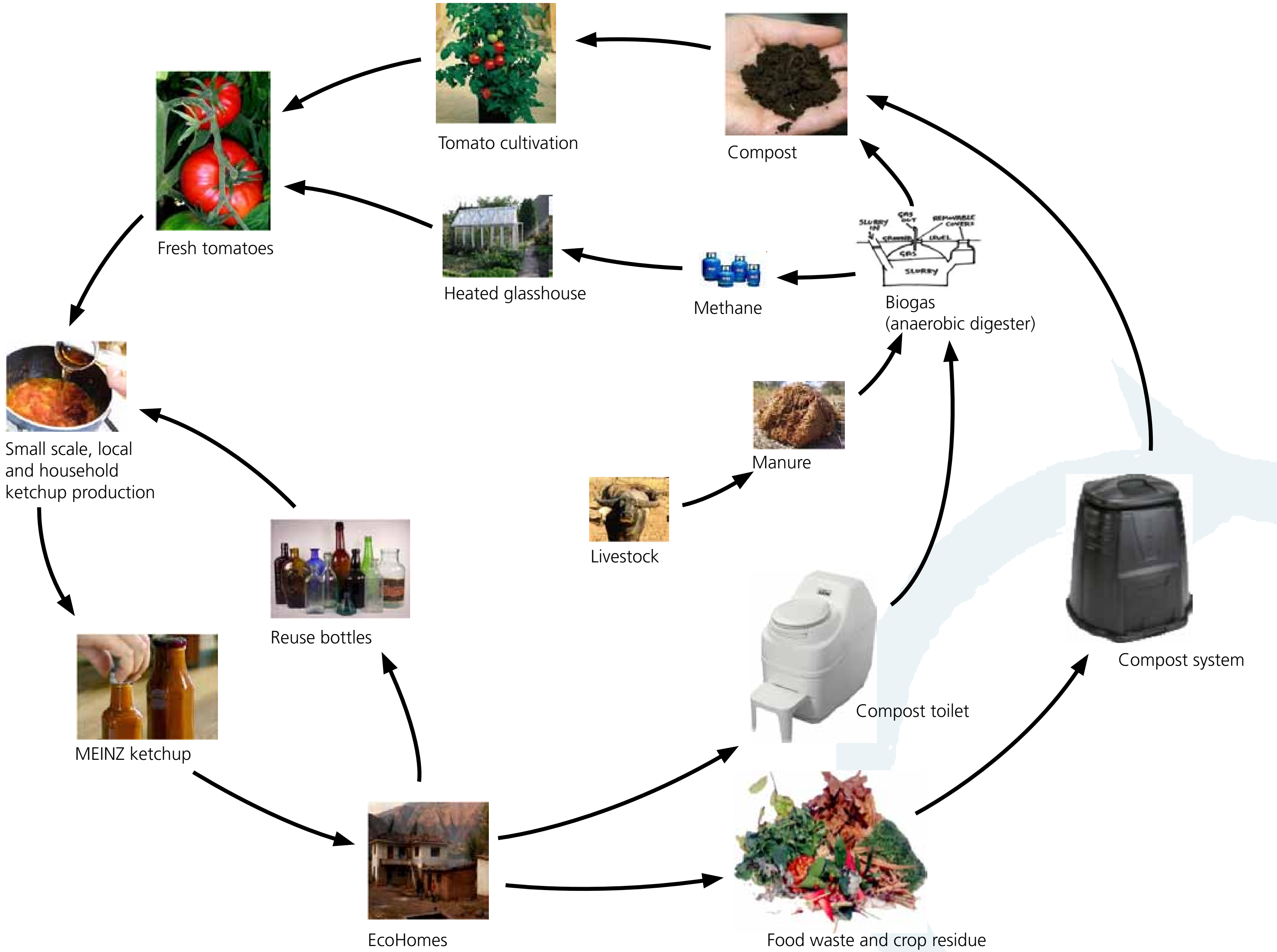


Figure 47. A circular systems approach to the production of tomato ketchup



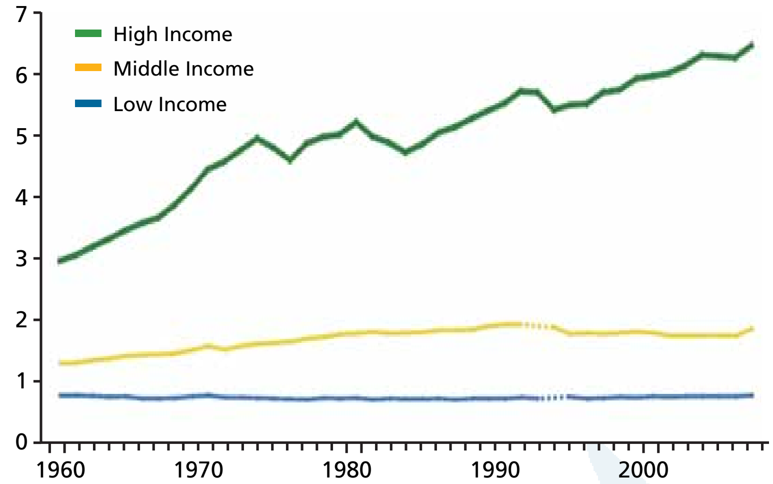
agricultural inputs, together with the reuse of containers, reduces production costs and therefore the price of the product.

Footprint analysis

Another approach for revealing hidden histories is to use footprint analysis, for instance carbon footprinting (see Annex 1 for an example from China). This measures environmental impacts of a product or sector in terms of GHG emissions, no matter where they occur, and allocate these to the consumer (at the individual, household, city or national level). So, for example, the GHG emissions associated with producing and transporting goods imported to the UK would appear on national UK GHG emission accounts, rather than on the accounts of the country exporting them, and this provides a more accurate picture.

What becomes very clear when these more realistic and fair consumption based measurements are used is that almost all of the increases in GHG emissions over the last 50 years are due to consumption of goods and services in OECD countries (Figure 48). The footprint of middle income countries has increased only slightly and has remained constant in low income countries since the 1960s, whereas the consumption-related footprint in high-income countries has more than doubled and accounts for 70% of the total.

Figure 48. Total ecological footprint of nations by income group, 2003



Source: Kitzes *et al.* (2008)

5.2. Making information available

Without the relevant information on the environmental and social impacts of products the consumer is unable to make an informed purchasing decision and policy-makers cannot make the comparison between alternative food, energy and other material supply chains, which is required to inform environmental and development policy. This void needs to be filled and companies need to be forced to provide the information required. The importance of developing sustainable and secure food supplies far outweighs the need for commercial confidentiality, which is the excuse often given for withholding information.

The information that has been made available on the "hidden history" of food products has been largely due to celebrity chefs and the investigative work of journalists. The articles and books of journalists and investigators such as Raj Patel, Marion Nestle, Eric Schlosser, Felicity Lawrence and Joanna Blythman help overcome deliberate distancing effects by providing an insight into the processes and practices in contemporary food chains.[27] One innovative approach to address this lack of information in order to raise awareness levels is the Story of Stuff.

This process of collecting and sharing knowledge also applies to sustainable alternatives. Disseminating information on sustainable food, energy and water systems to communities, policy-makers and international development organisations is essential. In many instances these actors may not be aware of the options that exist and of the benefits and costs associated with each. For example, a community may be consulted on a particular development, perhaps to improve water supply and sanitation, and their views taken into account. However, often only one option is considered and the community's only choice is to accept or reject it. If a community is aware of the alternatives available, this information empowers the community, who could perhaps help develop a project that is more acceptable and sustainable.

In the communication component of Designing Resilience we are exploring methods to increase awareness of the problems within the dominant food, energy and water systems, as well as the sustainable and fair alternatives available. We intend to work with artists and designers to produce video, animation, photography, installations, images and an exhibit. The aim is to raise awareness and influence decisions at all levels, so that the benefits of sustainable systems are better understood and they

are adopted on a wide-scale. In order to achieve this, alternative communication methods and channels will be tested with the aim of reaching those who are normally outside the decision making process and for those that are, to present the information in innovative ways. To make the information more appealing and accessible—to a wide audience and to all age groups—it will be tailored and presented using new media techniques.

5.3. Reforming the decision making process

Another critically important step is to demonstrate to policy makers that circular food, energy and water are not only feasible but essential. This is likely to require an entirely different approach to communicating ideas to policy makers and to society. Sustainable schemes are few and far between and will remain the exception unless policy measures are introduced that provide direct support and incentives, while at the same time penalising unsustainable practice. This will not be easy as there are powerful organisations with a vested interest not only in maintaining the *status quo*, but also in paving the way for

27 See, for example: Patel (2008); Blythman (2007, 1998); Rogers (2005); Lawrence (2004); Lang and Millstone (2008); Tansey and Worsley (2008); Nestle (2007); Schlosser (2002).

further trade liberalisation, deregulation, consolidation and the discounting of external environmental and social costs.

At whatever level a decision is taken, and whether it relates to an analysis of a problem or an assessment of an opportunity, there are several factors that should be taken into account:

- Consider all of the options available when assessing a particular problem and/or opportunity. Whatever the issue or need being assessed, there will be many possibilities that could be explored. In effect there are many 'means' to achieve each 'end', which in this instance is meeting a particular need for food, energy, water and housing. Once the options have been identified they need to be assessed and the most sustainable options selected. This has been discussed in the previous section.

- Ensure inclusive processes when making the decision. Policy makers and businesses often have minimal or no interaction and dialogue with the community who will be affected by the decision. As a result any decision can be viewed as being imposed. The outcome is more likely to be unwelcome, unacceptable, unworkable and unsustainable (Figure 49). This is the subject of this section.

Non-inclusive approaches to policy formulation and developments in food and farming have led to a response from community groups, peasants and farmers' representatives and unions in the form of the food sovereignty movement (Section 3). Food sovereignty is an example of a democratic, inclusive approach, based on participation and in which farmers, peasants and the farming and urban community or community representatives are involved during all stages of the decision making process. Indeed, one of the clearest demands of the food sovereignty movement is for citizens to exercise their fundamental human right to decide their own food and agricultural policies.

Enhancing such "citizen inclusion" and "democratic deliberation" in the policy process suggests the following reforms:

- **Opening up policy processes to more diverse forms of knowledge.** The issue here is not to choose between popular knowledge and scientific expertise, but to recognise the legitimacy of a variety of systems of knowledge, and to give them all a place in the decision and policy-making process. The intent is also to demystify scientific knowledge, bringing it closer to the lives and realities of people and making it more transparent and less threatening.

- **Recognising that knowledge is not separated from values.** The world views and ideologies of those who possess or produce knowledge are woven into it by virtue of the questions asked, the answers provided and the conditions under which the knowledge itself has been generated. In the decision making process, knowledge must therefore be complemented and guided by the opinions, aspirations and values of the people and institutions concerned with these policies.

- **Embracing participatory decision making approaches.** Methods and procedures exist that allow for the involvement of people and organisations in policy-making processes (e.g. citizens' juries, future search and visioning). This is particularly important for the people normally excluded from planning and decisions. Creativity and courage are required to use such methods and procedures, and to thereby combat exclusion, offering to all concerned people a fair chance to participate, including men, women and children.

- **Understanding that policy-making is more than formulating policies.** In order to be meaningful and durable, policy processes ought to introduce monitoring, evaluation and feedback mechanisms and place the responsibility of managing policies in the hands of those who are supposed to be served

by them. At all stages of the policy process there is also a need to enhance transparency, accountability and credibility.

Inclusive and participatory processes of policy-making are likely to be more effective because of their potential to: (a) build ownership among participants; (b) encourage change and make implementation easier; (c) empower citizens through information-sharing, capacity and confidence-building; and (d) create space and demand for new policies.

Throughout the world however, exclusionary and narrow policy processes seem to act to reinforce the values and interests of the more powerful. How can this trend be reversed? There are no unique or full answers to these questions. But experience reviewed elsewhere (see Pimbert, 2010) suggests that at least six complementary pathways can help empower citizens in policy processes and the governance of circular systems:

1. **learning from history to re-imagine citizenship for the 21st century.** From the Athenian assembly of ancient Greece to the revolutionary movements in 19th Century Europe to the hundreds of tribal councils that exist today, history is peppered with examples of how government by discussion, citizens' deliberations and reasoning can work. Much can be learnt from this rich history of democratic deliberation and active citizenship.

2. **building local organisations.** Local organisations such as *Sanghams* or fishermen's associations often play a critical role in supporting citizens to manage and govern their own food systems. But in many countries, their strength and in some cases their very existence has been undermined by centralising state policies or market interventions. Regenerating and building local organizations is key for socio-ecological resilience to shocks and stresses, including climate change.

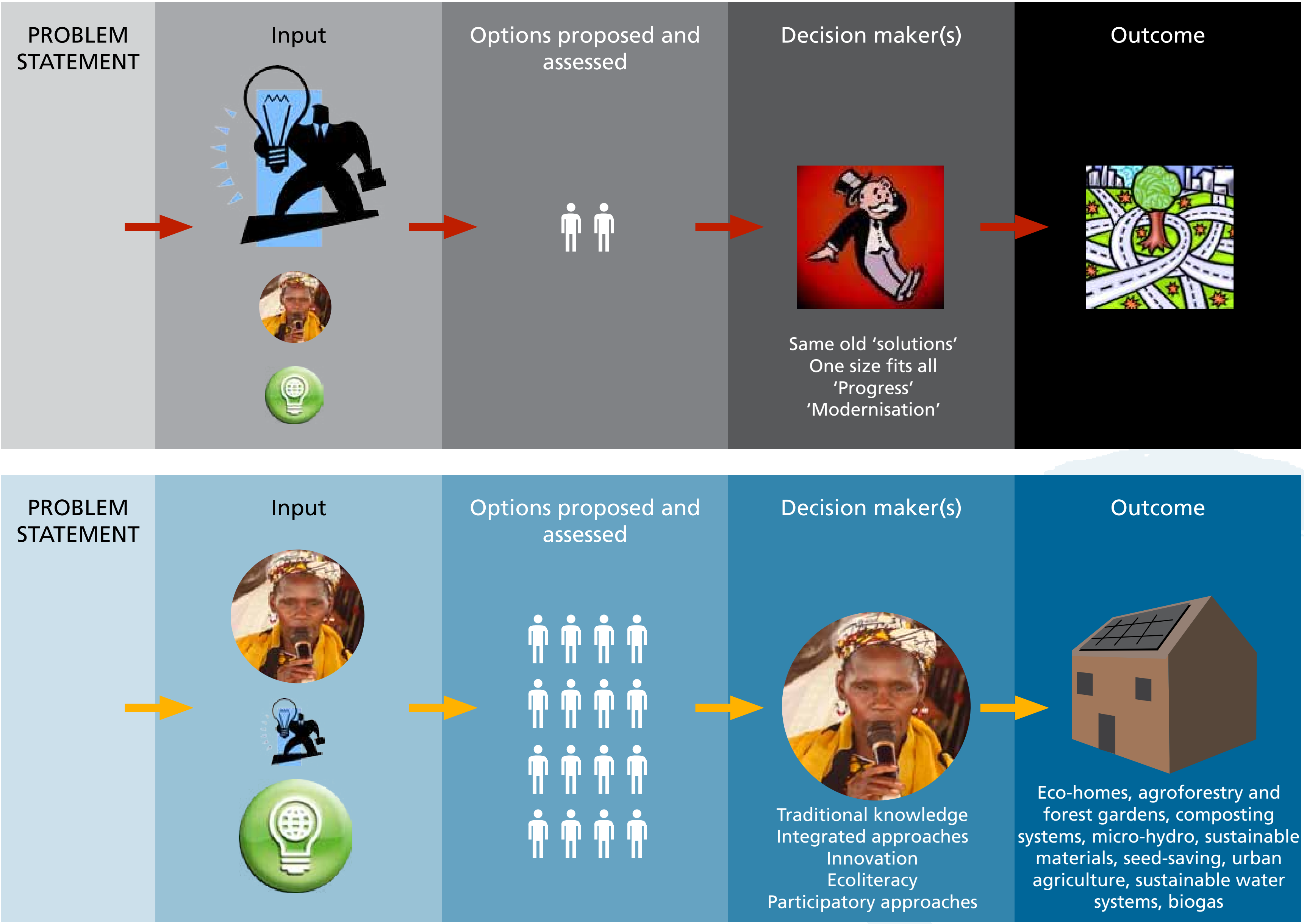
3. **strengthening civil society.** A strong civil society helps citizens get organised to reclaim power from below. Creating one relies on various combinations of the following: establishing supportive links between government and society; helping local and external civil society actors work together; and building strong peoples' movements.

4. **using specific participatory methods and approaches to expand democratic deliberation and inclusion.** Creating safe spaces for farmers and other citizens to analyse, formulate policy and institutional choices, communicate and act — for example, through citizens' juries — can strengthen peoples' voices in decision making circles and more inclusive forms of direct democracy.

5. **enhancing information democracy through networks of citizen controlled and community based media.** By harnessing new developments in community- and citizen-controlled media — from participatory films to local radio and newspapers — and promoting these through the Internet, citizens can more easily express their reality and aspirations, - and make them count.

6. **nurturing citizenship through education.** There is no doubt that citizens can deliberate, make decisions, and implement their choices responsibly. But these practices and virtues do not always arise spontaneously; they must be consciously nurtured through careful training and political education.

Figure 49. The dominant versus the inclusive approach to decision making



5.4. Recommendations

The current crisis can and should be seen as an opportunity to discuss, design and develop truly sustainable systems to meet the need for food, water, energy and housing. However, this will require a paradigm shift and an acceptance that values, objectives, policies and economies in the North and the South will have to change dramatically and soon (Figure 50).

Reversals in policies, legislation and market rules are needed to make the following shifts to sustainability:

- From mining the soil to managing nutrient cycles.
- From managing water use to managing hydrological cycles.
- From proprietary technologies and patents on biodiversity to legal frameworks that recognise farmers' rights and guarantee equitable access to diverse seeds and livestock breeds.
- From investment policies that favour land grabs and displacement of local communities to policies that support equitable access, use, and local control over land and territories in both urban and rural contexts.
- From investments in research and development that favour energy and resource intensive systems to support for decentralised and integrated food, energy, water and waste management systems based on principles of agroecology, ecoliteracy, eco-design, bio-mimicry, socio-ecological resilience, equity, and democratic control.
- From global, uniform standards for food and safety to a diversity of locally evolved food standards that meet food and safety requirements (from seed to plate).
- From support for centralised and capital-intensive energy systems to policies and legislations that promote innovations and internal markets for decentralised, distributed micro-generation of renewable energies (solar, wind, biogas etc.).

As part of this paradigm shift we suggest the following practical recommendations for individuals, communities, non-governmental organisations (NGOs) and policy makers at the local, national and international level:

- Adopt as a key policy objective the identification and rapid development of sustainable food, energy and water systems based on circular economy models. This process should be based on clear targets including minimising GHG emissions and fossil fuel use and increasing food and energy security and sovereignty at the local level.
- Reformulate agricultural, energy, trade and development policies specifically to promote sustainable food, energy and water systems. This will include designing institutional frameworks and regulatory processes that support and sustain circular systems capable of self-renewal and high production.
- Introduce stricter measures to internalise the external environmental and social costs of food, energy and transport systems, and use the resulting revenues to support sustainable initiatives. Large corporations involved in the food, agriculture, energy, water and waste management sectors should be the main—but not exclusive—targets of these measures. This policy would act as a driver of change in terms of a shift to sustainability and the transition to a low-carbon economy.

- Introduce fiscal measures such as tax incentives to encourage the shift to sustainable systems. Relatively small taxes on financial exchange market speculations (e.g. Tobin tax and similar proposals) —and on other global money transactions— should be introduced through a multilateral agreement. This decision alone will generate immediate and substantial funding for the design and spread of circular systems that regenerate local ecologies and economies for the public good.

- Design and implement a major eco-literacy programme to raise awareness of the hidden environmental and social problems caused by our current linear systems, and the alternative options for supplying food, energy and water that minimise risks and negative impacts.

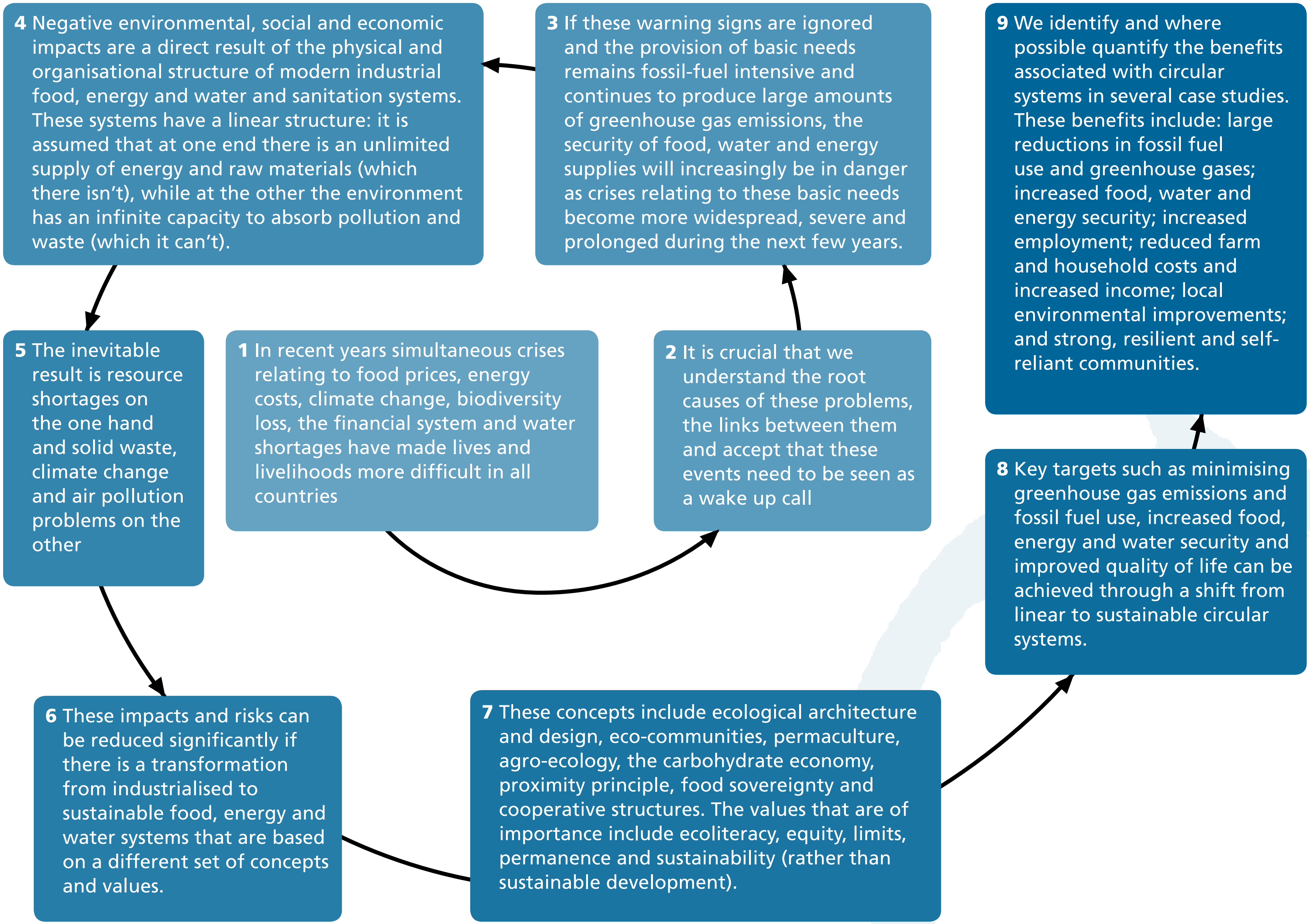
- Introduce local research, demonstration and training centres which focus on sustainable food, energy and water systems. These centres will provide advice, training and demonstrate best practice in order to develop a new skills and knowledge base. They should be designed so as to strengthen local knowledge systems, organisations and institutions, thereby enhancing capacities for local innovation and their spread to more people and places.

- Build on farmers and other citizens' proposals for transformation (such as the food sovereignty movement) as part of a larger paradigm shift towards food and energy sovereignty.

During the next few years and decades, the process of change, for which we will either plan or which otherwise will be forced upon us, will be as profound as that during the previous 50 years. The systems that have evolved to supply us with our basic needs are totally dependent on fossil fuels. The inevitable consequence of this is large amounts of greenhouse gas emissions, as well as solid, liquid and air pollution. As the era of cheap energy, crude oil and natural gas is about to end, a different approach is required.

The key principles of sustainable systems outlined in this document may be viewed by some as being too radical or unnecessary. However, the alternative to a fundamental change to the way in which food, energy and water systems are organised and function, is more alarming. As the imperative of weaning ourselves off fossil fuels and improving the lives and livelihoods of the poorest, together with the need to make significant cuts in biodiversity loss and greenhouse gas emissions, becomes more widely understood and accepted, we hope that policy and decision makers too, will recognise the need for a new approach.

Figure 50: From vicious cycles to virtuous circles



Annex 1. Carbon footprinting: an example from China

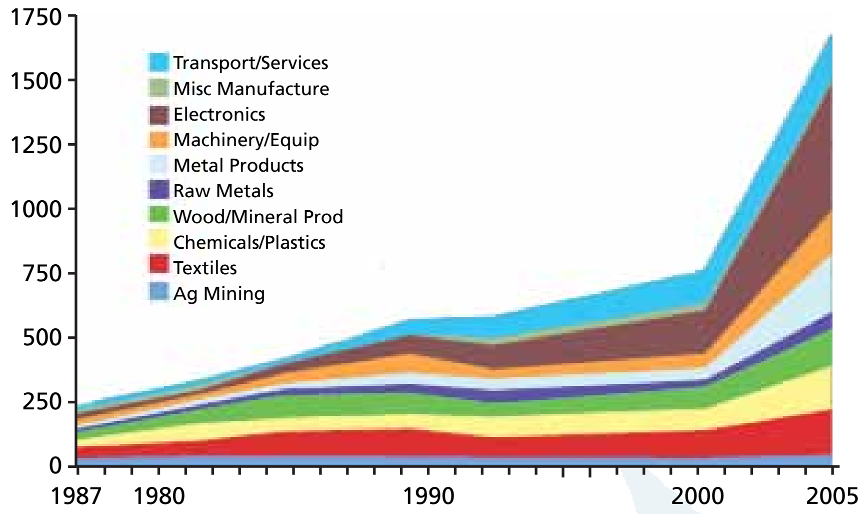
In terms of greenhouse gas emissions and international trade, there are important issues that are often overlooked but need to be highlighted and addressed.

The first is that in many instances consumption in one country can drive emissions up in other countries. The second point, which should lead to policy changes at the national and international level, is that national carbon emissions are not a fair or realistic method for GHG accounting and responsibility. A new framework is required in which the analysis of GHG emissions uses carbon footprinting. Calculations should be based on consumption, so that all of the processes involved in the production and distribution of goods and services, and the associated GHG emissions – wherever these processes and emissions occur - are assessed and allocated to the end consumer and the national accounts of the country in which consumption takes place.

We illustrate this by using the example of China.

Emissions in China were responsible for about 45% of the global growth in CO2 emissions between 1980 and 2005 (Satterthwaite, 2009). China's export-orientated production has grown 26% annually from 2002 to 2007, twice the average export growth rate since 1990, when China opened its trade with the West. China's primary energy consumption nearly doubled from 2002 to 2007 reflecting exponential growth in energy consumption and in 2007 China became the largest emitter of CO2 in the world (Guan *et al*., 2009). In just 3 years between 2002 and 2005, Chinese CO2 emissions increased by 45%. However, half of this increase was due to production in China for export, and 60% of these exports were destined for western countries (Peters, 2009). Electronic products, metals, chemicals, plastics, textiles and machinery are Chinese export products contributing most to the emissions increase (Figure 51).

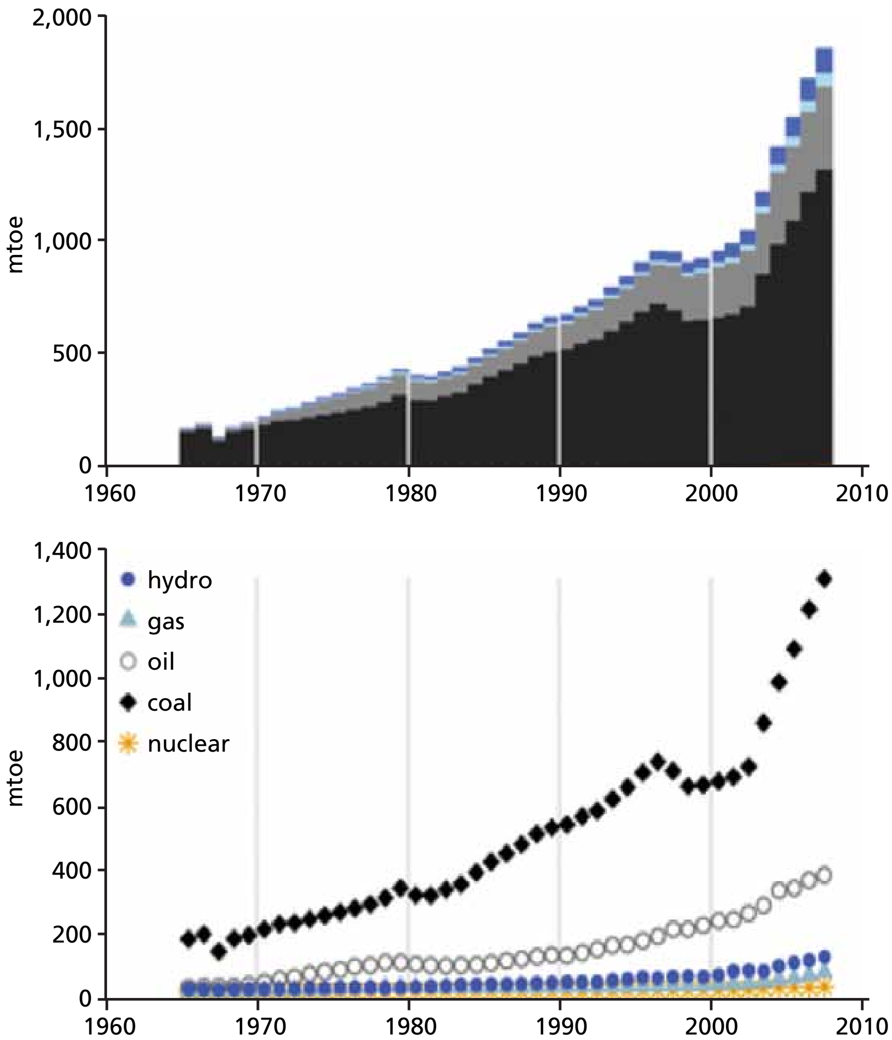
Figure 51. Chinese export emissions by major commodity group



Source: Weber *et al.* (2008)

Although this process of displacing carbon emissions to other countries when importing products is sometimes referred to—in an almost benign way—as being "carbon leakage", it is in fact a mechanism by which some countries, mainly those in the OECD, can appear to reduce their carbon emissions. In reality, importing goods is not only a way in which wealthy countries appropriate resources, but also in effect a way to export pollution and the responsibility for the GHG emissions associated with national consumption. When more goods and services are imported, the environmental impacts are actually increasing because of a) the additional transport involved and b) primary energy is often derived from the dirtiest and most carbon intensive fuels. In the case of China, for example, coal is the main source of electricity and heat, and increasing coal use in China is partly due to exports to the West (Figure 52).

Figure 52. Energy consumption in China, 1965-2007



Source: Barnes (2010)

It is important to recognise that although the final product may be manufactured in China, many of the inputs to the production process will have been manufactured or mined and processed in other countries. An analysis of the environmental impacts of Chinese exports to the West should therefore include the impacts outside China as China also imports large quantities of resources, such as timber, fossil fuels and other minerals, and metals and their ores (Figure 53).

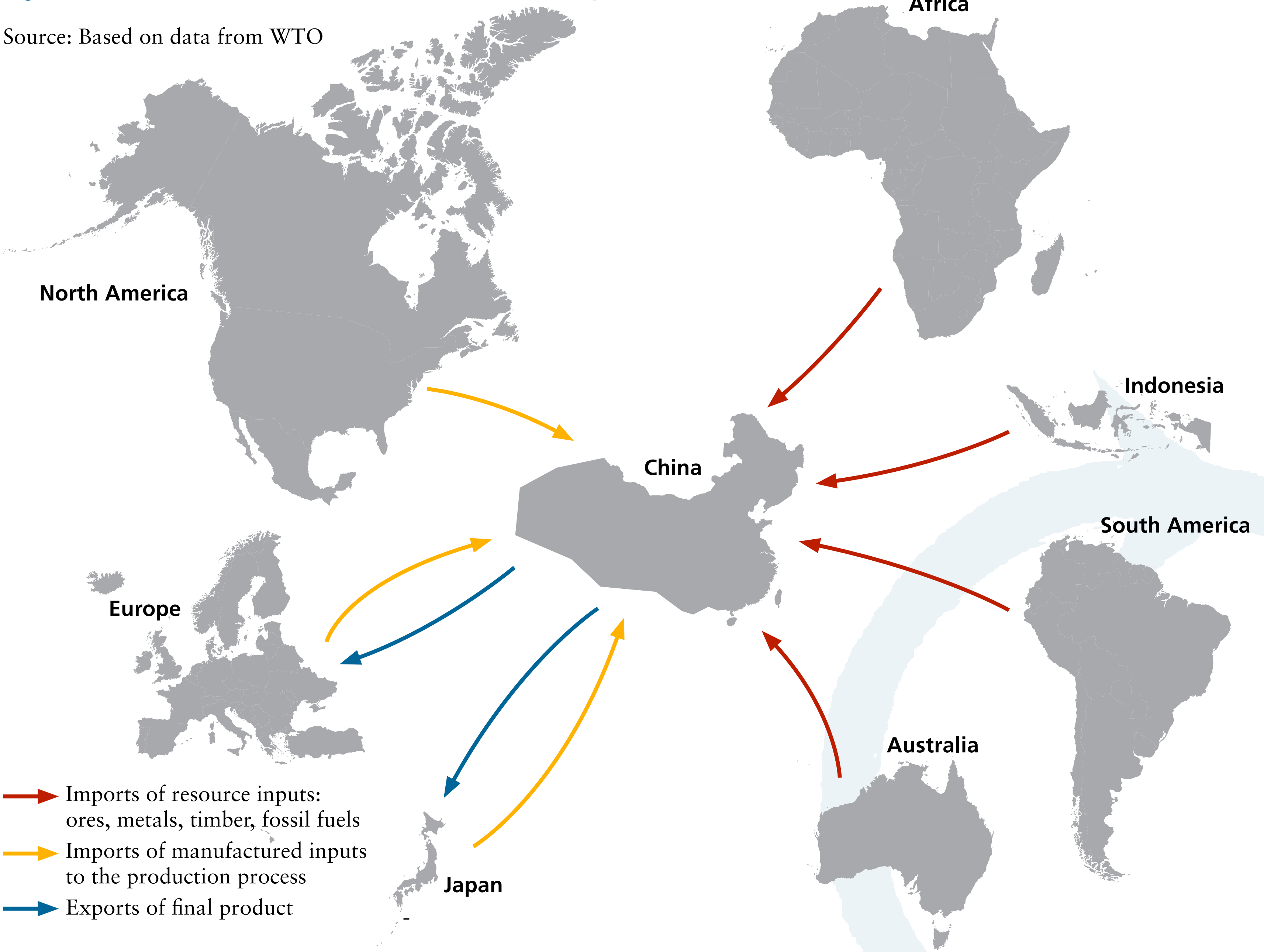
One of the main reasons that heavy industry and manufacturing has shifted to developing countries, apart from lower labour costs, is that environmental regulation is often less stringent or non-existent. The pollution that in effect OECD countries export to poorer countries is not restricted to GHG emissions, but also far more dangerous (in the short term) chemicals and gases in the form of local air, water pollution and toxic waste. This process becomes even more dismaying when another, often overlooked factor is considered—when the West has finished with its fridges, electronic goods, chemicals, packaging and other waste products, which are often toxic, they are exported back to poorer countries.

In the discussion above, the GHG emissions associated with Chinese exports to the West are, within international agreements, such as the Kyoto Protocol, allocated to China. Whether or not the country importing the goods, and the consumer who purchases the product, should be responsible for the GHG emissions is debateable. However, there is one aspect of current accounting methods and international agreements that has to be addressed. This is that under current arrangements, the GHG emissions from ships and planes associated with international trade are not included in any national GHG accounts or the Kyoto Protocol. This needs to be rectified (IISD, 2008).

These two points surrounding the responsibility of GHG's arising from international trade can be viewed as being loopholes, as in many instances national GHG policies, which are predicated on controlling emissions by reducing domestic GHG emissions, will not be very effective if imports contribute significantly to domestic consumption (Wyckoff and Roop, 1994).

Figure 53. Material flows associated with Chinese exports to OECD countries

Source: Based on data from WTO



Annex 2. A summary of some of the relevant concepts, values and principles

Agroecology	Though agroecology initially dealt primarily with crop production and protection aspects, new dimensions such as environmental, social, economic, ethical and development issues have also become relevant. Today, the term "agroecology" means either a scientific discipline, agricultural practice, or political or social movement (Wezel et al., 2009). Stephen Gliessman provides an ecological definition of sustainable agriculture: "A whole-systems approach to food, feed, and fibre production that balances environmental soundness, social equity, and economic viability among all sectors of the public, including international and intergenerational peoples. Inherent in this definition is the idea that sustainability must be extended not only globally but indefinitely in time, and to all living organisms including humans." Sustainable agroecosystems: maintain their natural resource base; rely on minimum artificial inputs from outside the farm system; manage pests and diseases through internal regulating mechanisms; and recover from the disturbances caused by cultivation and harvest (Gliessman, 2010). A detailed list of agroecological principles is provided at www.agroecology.org/Principles_List.html
Biomimicry	Biomimicry is a design discipline that seeks sustainable solutions by emulating nature's time-tested patterns and strategies in terms of forms, process and systems. Studying a leaf to invent a better solar cell or termite mounds to understand natural ventilation and fossil-fuel free air conditioning are examples: animals, plants, and microbes are the consummate engineers. It has been described as "innovation inspired by nature" and is based on the idea that after 3.8 billion years of evolution, nature has learned what works and what lasts. The core idea is that nature, imaginative by necessity, has already solved many of the problems we are grappling with: energy, food production, climate control, non-toxic chemistry, transportation, packaging, and a whole lot more. Plants and animals have found what works, what is appropriate, and most important, what lasts here on Earth.
Carbon Footprinting	A carbon footprint is the total set of greenhouse gas (GHG) emissions caused by an organization, individual, household, country or product. For simplicity of reporting, it is often expressed in terms of the amount of carbon dioxide, or its equivalent of other GHGs, emitted. An individual, nation, or organisation's carbon footprint can be measured by undertaking a detailed GHG emissions assessment.
Co-operatives	A co-operative (often referred to as a co-op) is defined by the International Co-operative Alliance's Statement on Co-operative Identity as an autonomous association of persons united voluntarily to meet their common economic, social, and cultural needs and aspirations through a jointly-owned and democratically-controlled enterprise. It is an organisation owned and operated by a group of individuals for their mutual benefit. Co-operation dates back as far as human beings have been organising for mutual benefit. The roots of the co-operative movement can be traced to multiple influences that extend worldwide. In the Anglosphere, post-feudal forms of co-operation that are expressed today as 'profit-sharing' arrangements existed as far back as 1795. Co-operatives are based on the co-operative values of "self-help, self-responsibility, democracy and equality, equity and solidarity" and the co-operative principles of "voluntary and open membership; democratic member control; member economic participation; autonomy and independence; education and training; co-operation among co-operatives; and concern for community" (International Co-operative Alliance, 2010) Also, in the tradition of their founders, co-operative members believe in the ethical values of honesty, openness, social responsibility and caring for others.

Eco-communities	Eco-villages are intentional communities with the goal of becoming more socially, economically and ecologically sustainable and are often composed of people who have chosen an alternative to centralised electrical, food, water, and sewage systems. Eco-villages have been defined as having the following attributes: human-scale, full-featured settlements in which human activities are harmlessly integrated into the natural world in a way that is supportive of healthy human development, and can be successfully continued into the indefinite future. Worldwide, there are many people and eco-communities striving to create truly sustainable ways of living—many groups are making significant inroads and provide examples of how we can achieve sustainability. Eco-communities—in villages, towns and cities— can act as exemplars of what is possible and their experiences can highlight the opportunities and problems associated with sustainable livelihoods. Many develop local organic food production, renewable energy systems, sustainable water and sanitation systems and eco-friendly building techniques. Ownership of land is often shared by the members, with many operating as legal co-operatives. co-communities and more recently eco-cities
Ecological economics	Ecological economics is a transdisciplinary field of academic research that aims to address the interdependence and co-evolution of human economies and natural ecosystems over time and space. It is distinguished from environmental economics, which is the mainstream economic analysis of the environment, by its treatment of the economy as a subsystem of the ecosystem and its emphasis upon preserving natural capital. In ecological economics there is an emphasis on "strong" sustainability; the proposition that natural capital can be substituted for human-made capital is rejected. Ecological economics was founded in the works of Kenneth E. Boulding, Nicholas Georgescu-Roegen, Herman Daly, Robert Costanza, and others. The Earth's carrying capacity is central to this theory, and a primary objective of ecological economics is to ground economic thinking and practice in physical reality, especially in the laws of physics (particularly the laws of thermodynamics) and in knowledge of biological systems. The goal of improvement of human well-being is achieved through sustainable societies.
Fair trade	Fair trade is a trading partnership based on dialogue, transparency and respect, that seeks greater equity in international trade. It is based on an organised social movement and market-based approach that aims to help producers in developing countries and promote sustainability. The movement advocates the payment of a higher price to producers as well as social and environmental standards. It focuses in particular on exports from developing countries to developed countries, most notably handicrafts, coffee, cocoa, sugar, tea, bananas, honey, cotton, wine, fresh fruit, chocolate and flowers. Fair trade addresses the injustices of conventional trade, which traditionally discriminates against the poorest, weakest producers. Fair trade enables them to improve their position and have more control over their lives. In 2008, fair trade-certified sales amounted to approximately US $4.08 billion (€2.9 billion) worldwide, a 22% year-to-year increase, but it represents only a tiny fraction of world trade. In June 2008, it was estimated that over 7.5 million producers and their families were benefiting from fair trade funded infrastructure, technical assistance and community development projects

Food sovereignty	Food sovereignty is emerging as a very useful policy framework to strengthen the autonomy and resilience of more localised and sustainable food systems (Leahy, 2008; Pimbert, 2009a, and Annex 3). One of the aims is to give farmers, pastoralists, indigenous peoples, fisherfolk, food workers, small-scale agri-food processors and food consumers a greater say in what is produced, how it is produced and where the produce is marketed. Other issues that are addressed include trade and markets, land rights, gender equality, ecological models of food provisioning, access to and local control over knowledge and resources, and the right to food. Food sovereignty is at least in part a response to unfair trade rules and the growing influence of multinational food processors, traders and retailers which can threaten the livelihoods of smallholders.
Life cycle analysis	Life cycle analysis (LCA) is the investigation and evaluation of all environmental (and social) impacts associated with the delivery of a product or service. The goal of LCA is to compare the full range of environmental and social damages assignable to a product or service, to be able to choose the least burdensome one. The term "life cycle" refers to the notion that a fair, holistic assessment requires the assessment of raw material production, manufacture, distribution, use and disposal including all intervening transportation steps caused by the product's existence. The sum of all those steps—or phases—is the life cycle of the product. Common categories of assessed damages are global warming (greenhouse gases), acidification, smog, ozone layer depletion, eutrophication, eco-toxicological and human-toxicological pollutants, habitat destruction, desertification, land use as well as depletion of minerals and fossil fuels.
Living machines	A living or eco-machine is a form of biological wastewater treatment designed to mimic the cleansing functions of wetlands. It is an intensive bioremediation system that can also produce beneficial by-products such as edible and ornamental plants, and fish. Aquatic and wetland plants, bacteria, algae, protozoa, plankton, snails, clams, fish and other organisms are used in the system to provide specific cleansing or trophic functions. In temperate climates, the system of tanks, pipes and filters is housed in a greenhouse to raise the temperature, and thus accelerate biological activity. The initial development of living machines is generally credited to John Todd, and evolved out of the bioshelter concept developed at the New Alchemy Institute. Living machine systems fall within the emerging discipline of ecological engineering. The scale of living machine systems ranges from the backyard experiment to public works. Some living machines treat domestic wastewater in small, ecologically-conscious villages, such as Findhorn Community in Scotland. The living machine system is cellular, as opposed to monolithic, in design. If the incoming volume or makeup changes, new cells can be added or omitted without halting or disturbing the ecosystem. Photosynthetic plants and algae are important for oxygenating water, providing a medium for biofilms, sequestering heavy metals and many other services.
Localisation and the proximity principle	The proximity principle suggests that when there are clear environmental and social benefits, production should be located as close as possible to the consumer. This implies more localised food, energy and water systems; however in the case of food, relocalising supplies does not imply complete self-sufficiency. What it does imply is the replacement of transport intensive foods with locally sourced produce whenever possible. For example, there are many food and drink products that cannot be produced sustainably in Europe, such as coffee, bananas and tea. Imports of these products and others, which can be produced in Europe during certain times of the year only, are inevitable and, provided they are imported under fair trade conditions, often desirable. However, the land–take and water footprint of food exports to Europe should not be at the cost of local food and water provision in the exporting country.

Participatory diagnosis, learning, action and development	An approach to development that empowers individuals and communities to define and analyse their problems, make their own decisions about directions and strategies for action, and take the lead in those actions. The approach is contrasted with "top-down" development processes, in which outsiders with greater socioeconomic and political power make the key decisions about local resource use and management. Participatory learning and action brings together the strengths of modern science and local knowledge. Development without local participation is often characterised by biases (Eurocentrism, positivism, and top-downism) which are disempowering. The overarching tendency is to equate development with "modernity" which means the modernity as achieved by 'western' societies. Hence, development has often meant copying these "advanced" countries. Since the 1970s, it has become apparent that many development programmes have yielded limited benefits, and criticism of the top-down approach has increased.
Permaculture	Permaculture (permanent agriculture or permanent culture) is the conscious design and maintenance of agriculturally productive ecosystems which have the diversity, stability, and resilience of natural ecosystems. Permaculture offers solutions to the myriad problems associated with industrialised farming by introducing intelligent design into agriculture in order to create permanent high-yielding farming ecosystems. Beyond agriculture, permaculture is about creating sustainable human habitats by providing a framework for people to develop their own sustainable solutions. It is the harmonious integration of landscape and people to provide food, energy, shelter, and other material and non-material needs in a sustainable way. The philosophy behind permaculture is one of working with, rather than against, nature; thoughtful observation; thinking before you act; considering systems in all their functions. Permaculture design involves assembling conceptual, material, and strategic components in a pattern which functions to benefit humans and biodiversity. Emphasis is placed on local solutions that consider local culture and capacity as well as local climate, land form, soils, and the combinations of species which will thrive.
Resilience	Resilience is the capacity of an ecosystem to respond to a perturbation or disturbance by resisting damage and recovering quickly. Such perturbations and disturbances can include stochastic events such as fires, flooding, windstorms, insect population explosions, and human activities such as deforestation and the introduction of exotic plant or animal species. Disturbances of sufficient magnitude or duration can profoundly affect an ecosystem and may force an ecosystem to reach a threshold beyond which a different regime of processes and structures predominates. Human activities that adversely affect ecosystem resilience such as reduction of biodiversity, exploitation of natural resources, pollution, land-use, and anthropogenic climate change and are increasingly causing regime shifts in ecosystems, often to less desirable and degraded conditions. Interdisciplinary discourse on resilience now includes consideration of the interactions of humans and ecosystems via socio-ecological systems, and the need for shift from the maximum sustainable yield paradigm to environmental management which aims to build ecological resilience through "resilience analysis, adaptive resource management, and adaptive governance.

Territorial rather than functional development	Territorial development is an integrated and proactive approach to shaping the future of communities, towns, cities—to some degree it can also be referred to as spatial planning. It brings together economic, social and environmental opportunities and concerns as well as other factors which influence where activities take place and how different places function and are connected. In the territorial or endogenous development model the importance of local actors' initiatives and their participation in defining and implementing policies is recognised. Within territorial strategies, the local economy takes centre stage and the options to increase local and regional self-reliance—in relation to resources, investment and generating income—are assessed. This approach is sometimes linked to local currencies and alternative local exchange and trading. It is therefore a "bottom-up" development strategy that embraces development potential within the territory. The endogenous development approach is characterised by specific features such as development processes based on local savings and investment and is one that pays attention to a territory's human and resource capacities, local innovation and for the diffusion of innovation throughout the local productive system. Furthermore, this approach is based on the idea that all identified territorial issues should be placed on a negotiation table around which to gather all the concerned actors in order to discuss area-related problems and opportunities. The viewpoints of different actors and an historical analysis contribute to a coherent understanding of the territorial system. This method requires the definition of a new role for experts, who act as mediators/speakers and facilitators of the whole process.
Traditional local knowledge	In many parts of the world production is based on systems developed over hundreds of years, perhaps millennia, in which approaches have been tested, refined and perfected. These systems and those who manage them can provide an insight into sustainability. A good example is tropical home gardens - traditional agroforestry systems characterised by the complexity of their structure and multiple functions. Home gardens have attracted considerable research attention because they are a model for the design of sustainable agroecosystems, including efficient nutrient cycling, high biodiversity, low use of external inputs, soil conservation potential and because they have been shown to provide a diverse and stable supply of socioeconomic products and benefits to the families that maintain them.

Annex 3. Food Sovereignty: Summary of policies and actions to eradicate hunger and malnutrition. An open letter, November 2009

We, small-scale farmers and fisher peoples, pastoralists, women, youth, indigenous peoples, other social movements and civil society organisations, have taken the challenge together to propose policies and actions that would lead to the eradication of hunger and malnutrition in our world.

We strongly believe that the actions to eradicate hunger and malnutrition must be based on a vision of a world where:

- food sovereignty is recognised and implemented by communities, peoples, states and international institutions;
- all peoples, societies and states determine their own food systems and have policies that ensure availability of sufficient, good quality, affordable, healthy, and culturally appropriate food;
- there is recognition and respect for women's rights and their crucial contribution to food provision, and representation of women in all decision making bodies;
- terrestrial and aquatic environments and biodiversity are conserved and rehabilitated based on ecologically sustainable management of land, soils, water, seas, seeds, livestock and aquatic organisms;
- the diversity of traditional knowledge, food, language and culture, are all valued and respected;
- the way people organise and express themselves is accepted and peoples' power to make decisions about their material, natural and spiritual heritage is defended;

We are proposing the policies and actions recognising that hunger and malnutrition have reached outrageous levels in the world today and that this is not accidental. When the prevalence of this scourge is seen in the context of the multiple crises in the world today, it is very clear that existing polices have compounded the problem and that there is a need for a new approach

We have also taken into consideration the known fact that this situation is not a result of a lack of food in the world, as enough food has consistently been produced for decades. Solutions have been, and are being, offered by states and international institutions, in the name of increasing food production and availability, without dealing with the root causes of the multiple crises. They are proposing solutions using the same framework that caused the problems in the first place.

Eradicating hunger and malnutrition requires mechanisms that incorporate social and environmental as well as economic measures. To implement these requires the decisive involvement of the organisations of small-scale food providers and consumers in any policies and programmes designed to address the problems

We welcome the working document, Policies and Actions to Eradicate Hunger and Malnutrition, which outlines our proposals for the needed changes and how these might be realised. The working document contains a number of polices and actions in the following areas:

- Sustainable, ecological food provision and access to territories and natural wealth
- Environment, climate change and agrofuels

- Market, trade, price polices and subsidies
- Ensuring access to adequate food
- Finance, debt and development aid
- Governance

We endorse the summary of the working document annexed to this letter with the conviction that it will be useful for governments and institutions and peoples and their organisations in efforts to eradicate hunger and malnutrition and to ensure the attainment of food sovereignty including the human right to adequate food.

The world does not need to stay locked up in a dead-end that only has the potential to lead us into deeper levels of problems. We therefore urge states and international institutions to work with us - the movements of small-scale farmers and fisher peoples, pastoralists, Indigenous Peoples, other social movements and civil society organisations - in a common endeavour to tackle and end the scourge of hunger and malnutrition.

(This letter and the summary as well as the working document are available online. To sign on, see the list of signatories and download the documents in English, French and Spanish, please go to www.eradicatehunger.org)

Summary of the working document on policies and actions to eradicate hunger and malnutrition.

1. Background to the working document

The working document provides proposals for policies and actions to eradicate hunger and malnutrition. It is based on the experiences and political work of social movements, non-governmental organisations (NGOs) and others from all over the world during past decades and currently. It is based largely on the food sovereignty framework that embraces the human right to adequate food.

These policies and actions have been prepared to inform governments, institutions and others, who are committed to eradicating hunger and malnutrition. They may also be helpful in discussions on these key issues within and between governments, institutions, social movements and NGOs. And they could be used by social movements, organisations and individuals in all regions as an input to their own proposals at local, national, regional and global levels.

2. Why change is needed

A billion people are hungry because they do not have the means to produce food for themselves or purchase it. The majority of these hungry people are rural small-scale food providers, workers and their families, who are unable to grow sufficient food or earn enough income from their production and labour to meet their food and health needs.

Women are especially hard hit. They are the principle providers of food for their families and communities, playing central roles in food production, processing and preparation. Yet they are subject to multiple forms of social, economic and cultural discrimination, which prevent them from having equality in access to food and control over productive resources and natural wealth.

Hunger and malnutrition are chronic structural problems and worsening in the wake of the food price, financial, energy and climate crises. The food price crisis has hit particularly hard those who depend on markets affected by global prices for their access to food.

Not only have most governments and international institutions failed to reduce hunger and poverty and build on the findings of international processes designed to find ways forward (e.g. the International Assessment of Agricultural Knowledge, Science and Technology for Development - IAASTD), but they have, instead, adopted and implemented policies that have exacerbated the problems.

There is an urgent need to change the power and economic structures and policies that have caused the current crises.

3. Vision

Actions to eradicate hunger and malnutrition must be based on a vision of a world where:

- food sovereignty is recognised and implemented by communities, peoples, states and international institutions;
- all peoples, societies and states determine their own food systems and have policies that ensure availability of sufficient, good quality, affordable, healthy, and culturally appropriate food;
- there is recognition and respect for women's rights and their crucial contribution to food provision, and representation of women in all decision making bodies;
- terrestrial and aquatic environments and biodiversity are conserved and rehabilitated based on ecologically sustainable management of land, soils, water, seas, seeds, livestock and aquatic organisms;
- the diversity of traditional knowledge, food, language and culture, are all valued and respected;
- the way people organise and express themselves is accepted and peoples' power to make decisions about their material, natural and spiritual heritage is defended;

To realise this vision, a series of policies and actions are proposed that address the key issues which are needed to eradicate hunger and malnutrition. These are summarised below.

4. Sustainable food provision

There should be a shift from high input industrial agriculture and livestock production and industrial fisheries towards smaller-scale ecological food provision that secures local livelihoods and strengthens organisations and communities. Ecological food provision conserves nature, rehabilitates and values local and traditional knowledge and uses socially just and appropriate technologies, excluding GMOs. It maximises the contribution of ecosystems and improves resilience and adaptation of production and harvesting systems, especially important in the face of climate change. Conversion towards smaller-scale ecological food provision requires support. Research systems need to be reframed and use inclusive and participatory methods. Losses post-harvest should be minimised.

Sustainable food provision also requires that gender equity is at the heart of genuine agrarian and aquatic reforms and that all local small-scale food providers – women and men and especially young people, small-scale farmers and fishers, pastoralists, indigenous peoples and workers – have secure access to and control over territories, lands, water, fishing grounds, seed varieties, livestock breeds and fisheries resources. This access should be respected by state and societal actors, in accordance with customary laws, governance and benefits rights. On no account should access to hitherto common property resources be privatized for the benefits of a privileged minority.

5. Environment, climate change and agro fuels

The production of food is increasingly vulnerable due to climate change, ecosystem destruction, loss of biodiversity, land conversion and agrofuel production. Thus, the adaptive ecological systems outlined above, that are more resilient to environmental shocks must be the foundation for environmentally-sound food provision. These systems will better secure food supplies and will also regenerate soil carbon and restore natural and developed habitats for water security.

Production systems must minimise greenhouse gas emissions (GHGs). In all countries GHGs must be kept at or reduced to a sustainable level (about 1 tonne CO_2 per capita per year). The most effective way to reduce GHGs in food provision is to localise production and consumption, reduce the use of chemical fertilisers, reduce fossil fuel use and increase energy efficiency, including use of decentralised, alternative energy technologies and systems. To enable people and communities to tackle climate change effectively and sustainably, countries in the North must pay compensation and reparations of at least 1% of annual GDP to countries in the South.

An immediate moratorium on the production, trade and consumption of agrofuels, is called for, together with an in-depth evaluation of their social and environmental costs. This is required because, in general, the use of industrial agrofuels does not reduce GHG emissions and the corporate driven, industrial-scale production of agrofuels is converting land from food production and displacing local communities.

6. Markets, trade and price policies and subsidies

New market, trade and price policies and redirected subsidies that prioritise local and national production and consumption and the needs of people for food, are needed. Government procurement systems, publicly owned and managed food stocks, supply management policies and sound market regulation are essential to guarantee good and stable prices for small-scale food providers and to avoid speculation, hoarding and food price escalation.

Governments and international institutions should not finance and facilitate the operations of agribusiness corporations but should formulate and enact laws to reduce their power and, in the short-term, make them socially, environmentally and economically accountable to the public.

New international trade rules are urgently needed. These should be based on the rights of peoples and their governments to determine their desired levels of self-sufficiency, market protection and support for sustainable food provision for domestic consumption. The ongoing negotiations in the World Trade Organisation (WTO), on Free Trade Agreements (FTAs) and Economic Partnership Agreements (EPAs) should be stopped and all trade and investment agreements that impact negatively on local and national food systems should be revoked.

Equally urgent are the prevention of dumping of low priced imports and a ban on all direct and indirect export subsidies. If available, subsidies should be provided for localised ecological food provision that creates employment, protects the environment and strengthens local and national economies.

7. Ensuring access to adequate food

In addition to the measures outlined above, assuring decent work for all and universal social security nets, especially for those who are most vulnerable, are crucial. Urban food insecurity is also a serious problem that cannot be addressed in isolation from the crisis in the countryside. Hunger and malnutrition in urban areas can be reduced through sustainable food provision through

urban and peri-urban farms and gardens, and building "urban-rural linkages" in which cities are fed through sustainable provision from surrounding regions. All these will also drastically reduce the need for emergency food aid and humanitarian actions.

Emergency food aid will, however, still be necessary in the short-term but resources needed must be made available in sufficient quantities and in ways that do not undermine local economies and structures.

Peace, based on justice, civil and political rights, is a precondition for any lasting solution to wars, occupations and conflicts. Special support to people in all areas of conflict is needed to help them to maintain food production and secure access to food.

8. Finance, debt and development aid

Speculation and derivatives trade in sensitive sectors, especially food, agriculture, fisheries, water, weather conditions and climate must be heavily penalised and banned. Equally important is preventing corporate concentration in the insurance, credit and banking sectors. Financial institutions and conglomerates should not be allowed to become "too big to fail."

The unconditional cancellation of the external debts of countries in the South and immediate dismantling of Structural Adjustment Policies (SAPs) and neoliberal policy regimes are crucial. Also important is repayment by countries in the North of their massive ecological debts and historical exploitation.

Aid donors must immediately fulfil their commitments to pay at least 0.7% of gross national income (GNI) in development assistance, without conditionalities other than programmes supported should be based on the priorities and plans of peoples and communities in the aid receiving countries, in ways that do not create aid dependency. The power of multilateral financial institutions and IFIs over development aid and credits must be removed, and aid programmes and arrangements must be subjected to national and sub-national democratic and public scrutiny.

9. Governance

The world's food supplies and food producing natural wealth should be governed through transparent and accountable multilateral fora and regional and international agreements that are forged, implemented and monitored democratically with the full participation of people's organisations and States.

States should promote policies and actions that actively support the measures outlined above that will realise food sovereignty and the progressive realisation of the human right to adequate food. Also, food providers, their communities and their organisations must have rights of access to information about policies, technologies, programmes, agreements, in appropriate and accessible forms.

All international institutions, and especially the Rome-based UN food and agriculture agencies, as well as the Consultative Group for International Agricultural Research (CGIAR) must support states to formulate and implement the policies needed to effectively tackle hunger and realise food sovereignty. They should ensure that States have the policy space and political agency to limit and discipline the operations of corporations, as well as protect their domestic food and economic systems from international markets, and trade and investment agreements.

UN agencies, in particular, should actively: implement the recommendations of the International Conference on Agrarian Reform and Rural Development (ICARRD) and IAASTD; promote the adoption of the Covenant 169 of the International

Labour Organisation (ILO) on Indigenous Peoples; implement the UN Declaration on the Rights of Indigenous Peoples (UN DRIP); implement the UN Convention on the Law of the Sea (UNCLOS); and support the formulation of international conventions that defend the rights of small-scale food providers, including fishing communities and pastoralists, along the lines of the UN DRIP and the proposed International Convention on the Rights of Peasants.

Further information:
http://www.eradicatehunger.org/en/open-letter

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ROBERT FROST, THE ROAD NOT TAKEN

Two roads diverged in a yellow wood,
And sorry I could not travel both
And be one traveller, long I stood
And looked down one as far as I could
To where it bent in the undergrowth;

Then took the other, as just as fair,
And having perhaps the better claim,
Because it was grassy and wanted wear;
Though as for that the passing there
Had worn them really about the same,

And both that morning equally lay
In leaves no step had trodden black.
Oh, I kept the first for another day!
Yet knowing how way leads on to way,
I doubted if I should ever come back.

I shall be telling this with a sigh
Somewhere ages and ages hence:
Two roads diverged in a wood,
and I—I took the one less travelled by,
And that has made all the difference.

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Our current way of providing food and other basic needs involves industrialised systems that are linear, centralised and globalised. In the linear approach, it is assumed that at one end of a system there is an unlimited supply of energy and raw materials (which there isn't), while at the other the environment has an infinite capacity to absorb pollution and waste (which it hasn't). The inevitable result is resource shortages on the one hand and solid waste, climate change, biodiversity loss, and air pollution problems on the other. An alternative to the current linear paradigm is to develop productive systems that minimise external inputs, pollution and waste (as well as risk, dependency and costs) by adopting a circular metabolism. There are two principles here, both reflecting the natural world. The first is that natural systems are based on cycles, for example water, nitrogen and carbon. Secondly, there is very little waste in natural systems. The 'waste' from one species is food for another, or is converted into a useful form by natural processes and cycles.This book shows how these principles can be used to create systems and settlements that provide food, energy and water without consuming large quantities of fossil fuels and other finite resources. In the process, greenhouse gas emissions and environmental pollution are minimised whilst human well being, food and livelihood security, and democratic control are enhanced.

The Reclaiming Diversity and Citizenship *Series seeks to encourage debate outside mainstream policy and conceptual frameworks on the future of food, farming and land use. The opportunities and constraints to regenerating local food systems based on social and ecological diversity, human rights and more inclusive forms of citizenship are actively explored by contributors. Authors are encouraged to reflect deeply on the ways of working and outcomes of their research, highlighting implications for policy, knowledge, organisations and practice. The* Reclaiming Diversity and Citizenship *Series is published by the Agroecology and Food Sovereignty Team at the International Institute for Environment and Development.*

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