Material Flows and Mass Balance Analysis in the United Kingdom

Implications for the 10-Year Horizon of Waste Management

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January 2006 saw the release of the European Union's revised strategy statement on waste and the incorporation of this debate into a more holistic approach, centered on life cycle issues for particular goods and services in society. Such an approach presages the likelihood of waste not being seen as an end-of-pipe issue, to be managed in isolation; rather, there is a presumption that to understand the pattern of waste flows, we must look to how products are designed, manufactured, and delivered into the system. The need to track the flow of resources through product life cycles is assuming greater significance for policy makers, as there is a need for greater understanding of where it might be most effective to intervene economically to improve the level of resource efficiency.

In the move from end-of-pipe to front-of-pipe thinking, of particular importance is the presumption that energy, agricultural, and waste resource markets are subject to distinct, often unconnected supply- and demand-side influences on costs and prices. Yet the movement of resources between them is linked by the reality that they all "modify" fossil and renewable carbon in different ways to achieve an economic return on investment from different market participants.

Under the UK Landfill Tax Regulations, £11 million in funding, managed by Biffaward, was provided for 63 material flow studies (1999–2008).[1] These studies, called "mass balance accounting" in the context of the UK project, approach resource flows from one of three dimensions—region, sectoral supply chain, and material type. A fourth dimension was added later that looks at interactive software data capture systems. *The Mass Balance Movement: The Definitive Reference for Resource Flows Within the UK Environmental Economy* (Biffaward 2006) is a summary of that work. *The Mass Balance Movement* attempts a superficial assessment of each study in the form of the so-called "graphic equalizer," evaluating each study in terms of content, support information, economics, and other relevant issues. The main thrust of the study lies in broadening and developing an understanding of the process, rather than in seeking to produce a full set of technically correct assessments from a standing start.

The absence of an online material flow mapping system severely limits the quality of debate and policy making in relation to environmental strategy regarding waste, carbon flows, and

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resource efficiency. The UK government is in a position to develop a national framework of resource flow data. The UK's Department for the Environment, Food and Rural Affairs (DEFRA) commissioned the independent Policy Studies Institute to look into the efficacy of such a proposition and, more specifically, to examine the relevance of the work already funded by Biffaward to the policy development debate (Wiedmann et al. 2006).

Waste policy in the United Kingdom in the last 20 years has been reactive. An alternative approach is based on establishing a consensus of probability around known economic, technological, and sociopolitical policy interactions in the 5-to-10-year horizon for markets in waste disposal, resources (as recyclate, electricity, heat, transport fuels, or soils) coupled to regionally specific extant or predicted "sinks," or markets for different materials in these applications.

In the move from end-of-pipe to front-of-pipe thinking, of particular importance is the presumption that energy, agricultural, and waste resource markets are subject to distinct, often unconnected supply- and demand-side influences on costs and prices. Yet the movement of resources between them is linked by the reality that they all "modify" fossil and renewable carbon in different ways to achieve an economic return on investment from different market participants. As such, they will increasingly cross-compete or interreact for that carbon feedstock in ways that, to individual operators in each market, appear erratic, illogical, and unpredictable due to the operators' lack of knowledge of these underlying price determinants. Those interactions will accelerate, due (mainly) to the following:

- probable significant real-price increases in the global price of fossil carbon resource;
- nationally driven taxation or traded pollution permit regimes applied to carbon and resources to improve resource efficiency and reduce global warming risks;
- continued escalation in the UK landfill tax to £80 per tonne by 2012, which will drive carbon-based waste to more cost-effective technologies (biochemical and thermochemical as well as mechanical);
- closure of obsolete coal-fired and nuclear electrical generation capacity, (equivalent to 33% of total UK electrical supply in 2008–2015), which will create a market opportunity for renewable energy;
- international treaties committing the United Kingdom to supplying 15% of total energy from renewables by 2020. Due to the extant and committed investment profiles in Transport and Heat systems this effectively means that at least 30% of electricity supply must be sourced from renewables to achieve this composite target by that date; and
- the Carbon Reduction Commitment, which creates obligations on all major UK corporations and an internal carbon trading regime by 2011 (HM Government 2009).

Material flow analysis lies at the heart of proactive waste policy. In a group working under my chairmanship on behalf of the West Midlands Development Agency in the United Kingdom, work centered on carbon and the potential for waste-to-energy conversion is now at an advanced stage. This work comprises four broad stages, as detailed below.

Stage 1: Mapping Generation of Scrap Carbon

Stage 1 consists of mapping the tonnages and finances of scrap carbon, including household waste, food, commercial and industrial waste, sewage and organic effluents, agricultural arisings of biomass, and forestry residues. This biomass resource can then be analyzed or credibly extrapolated through identified factual or academic assessments by sector, area, calorific value, mass, volume, or other relevant parameters. These inputs of scrap carbon need translation to "financial equivalence" according to current and predicted values per tonne for 2010 and, for instance, 2012, 2015, and 2020. This will produce a market value map by type of scrap carbon and the parameters selected.

Stage 2: Identifying Candidate Reprocessing Sites

When virgin carbon point-of-use tonnages are mapped (as fossil coal, oil and gas, and

electricity), the distribution of large single-point "sinks" or concentrations of fossil energy retail end users is built up (e.g., airports, food processing points, distribution depots, hospitals, leisure centers, transport interchanges, factories). These "exits" for fossil energy can then be correlated to the availability of "scrap" carbon from the waste and agricultural sources of Stage 1. Where there is a correlation, those locations form points where it might be most environmentally and economically appropriate to locate innovative waste conversion technologies, which could result in a net reduction of carbon dioxide emissions and an expansion of "renewable" (second time around) carbon energy (as gas, electricity, hydrogen, transport fuel, compost, recyclate, or heat) (Shmelev and Powell 2006).

In the energy context, such mapping needs to take account of additional investment to remove known blockages in the existing infrastructure (e.g., the UK grid distribution network is acknowledged to have bottlenecks due to demographic changes or localized increases in energy intensity). Thus, instead of considering "waste" (scrapped solid material flows) as a problem to be solved reactively, this viewpoint considers it for its retained resource value in terms of energy displacement. The technology required to achieve displacement of fossil-based energy is either available or at the final stages of development, in both the logistics and the process phases. In the latter phase, it comprises mechanical engineering (recycling and material separation), biomechanical engineering (composting aerobic systems, anaerobic digestion, algal utilization), thermochemical systems (incineration, gasification, pyrolisis), or mixtures of all the above.

Stage 3: Choosing Reprocessing Sites

This stage requires the assessment of the narrowed-down list of sites deemed suitable on current or forecast economic, spatial, and social grounds. These short-listed locations should represent the best possible (i.e., least risky) means to establish integrated carbon resource reprocessing activities. Colocation is important, because the cost of new pipes or cables is of the order of £1 million per kilometer. Such sites should have sufficient extra space for aerobic composting, recycling, and recyclate material reprocessing activities colocated to permit the movement of materials among the different emergent technologies on a weekly, seasonal, or structural basis as market conditions move. Such sites may be owned by single investors, energy supply companies, or multiple independent participants acting as shared tenants (UK Government's Business Taskforce on Sustainable Consumption and Production 2008).

Electricity and combined heat and power (CHP) are presumed to be the strongest economic driver. Such CHP locations are most likely to present economically attractive investment routes to the private sector and will become the highest probability "anchor" sites for waste carbon management. In the United Kingdom, however, the available energy from around 40 million tonnes of carbon content waste from municipal, commercial, and industrial sources is unlikely to produce more than six or seven gigawatt (GW) electrical (8% current baseload demand) or 15 GW electrical plus heat (on the basis of estimates by the UK Institution of Civil Engineers; Lee, Fitzsimons and Parker 2005). This is after the withdrawal of economically viable routing of other biomass to composting and recycling purposes due to reasons of end-market value or location.

Stage 4: Defining Reverse Logistics

Once the market-driven probability profile is established in stages 2 and 3, it is feasible to define the reverse logistics infrastructure in terms of intermediate feedstock processing centers (material recovery facilities, transfer stations, and feedstock blending activities.). Then it becomes possible to backcast on how to collect material at source and reengineer the vehicle fleet. Common sense suggests that separation at the source is likely to be more economic on the basis that it is cheaper to blend or integrate separated material for a variable series of exit routes—mechanical, biochemical, or thermochemical—than it is to separate collected mixed materials to a required specification of moisture, calorific value, heavy metal and contaminant content, or cleanliness.

In short, the strategy for waste management in the United Kingdom could be reversed if policy makers can understand carbon scrap material flow mapping from an end-of-pipe attitude to a market-led substitution effect. This comprises the following:

- targeting extant fossil fuelled energy sites above the 1 Mw (8500 MwH) scale as the most economically viable market,
- understanding that the energy profile of the site (materials, gas, heat, electricity, road fuel) determines which waste process technology best fits that profile,
- choosing appropriate technologies (recycling, anaerobic digestion, incineration, gasification, pyrolisis),
- understanding that the choice of recovery technology defines the appropriate presentation of the fuel feedstock,
- understanding that the feedstock defines the waste industry logistics (collection) methodology, and
- understanding that the preferred method of separation of waste by householders and businesses at the point where waste is first created is driven by the selection of the collection system and the recovery technology.

As the capacity of these new technologies extends beyond the available supply of scrap carbon waste, their gate (tipping) fees will probably begin to weaken and fall, much as they did when German incineration capacity outstripped the supply of waste after 2006 and in Sweden in relation to District Heating waste demand in 2009. This will make long-term public sector contracts with price indexation look increasingly foolhardy, particularly if the process technology and the back-up logistics supply infrastructure is carbon dioxide—intensive relative to these other emergent options, which have a reduced carbon footprint via higher conversion efficiencies.

Note

1. See www.massbalance.org/projects/.

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Until May 2008, **Peter T. Jones** was a Director of Biffa Plc., the facilitator for the United Kingdom's "mass balance" project. He is now advisor to the mayor of London and has chaired a select committee for the West Midlands Region of the United Kingdom, which has produced a plan for streamlining the recovery and recycling of carbon-linked wastes to substitute fossil fuel inputs.

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