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D6.4: Quantification of the potential contribution of biogas from food waste as a second generation biofuel to energy security and diversification in the EU

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D6.4 Quantification of the potential contribution of biogas from food waste as a second generation biofuel to energy security and diversification in the EU

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Technical terms

Base Load: The available energy required to meet the minimum demand. It is therefore the quantity of energy that must be available at all times.

Carbon intensity: Establishing carbon intensity in units of grams of CO_2 per MJ of (end) energy is a way of quantifying environmental performance of an energy supply technology. The IEA operates a carbon intensity tracker at http://www.iea.org/etp/tracking/esci/

Diversity: A key concept usedin several fields such as nature, finance (asset management), society and energy security. Diversity of fuels and energy supply systems acts as a safeguard against risk of supply interruptions; diversity is regarded as an essential contributor towards energy security although diversity should not be used as the sole indicator of energy security; various diversity indicators have been developed such as probabilistic indices (e.g. mean variance index) or the Shannon-Wiener diversity index (Stirling 1994). Energy diversity comprises three subordinate properties – variety, balance and disparity (Stirling 1994, Stirling 1998, Jansen et al 2004).

Diversification: The process of becoming more diverse.

Energy (import) dependency: The large majority of EU member states have to import energy to satisfy national energy requirements; the EU measures import dependency by the net imports over the national consumption plus the energy consumed in sea going ships (source: EU energy roadmap 2011)

Energy intensity: With national economies energy intensity is often measured as total primary energy consumed in a member state per GDP produced. The aim is to reduce or de-couple energy consumption from economic growth and activity;

Energy securityor **security of energy supply:** A number of definitions exist (Winzer 2011). From an economic supply point of view energy security indicates the capability to meet all current energy needs in a reliable fashion by either internal, national sources or from other, partner countries. The IEA coined the following definition of energy security:"an uninterrupted availability of energy sources at an affordable price".

Energy portfolio: National governments strive to source energy from a number of (diverse) sources in order to avoid dependency on a single supplier; ideally a wide variety of suppliers form an energy portfolio or energy supply mix;

Final energy: This is the energy that arrives at the consumer (e.g. the householder or vehicle driver); the final energy is the energy available to the consumer; it is always less than the primary energy of the source due to losses in the production/generation and in the delivery/transmission to the end user; final energy can be regarded as primary energy minus the energy consumed in the refinery and in the delivery of the energy;

Final energy consumption: This is the energy that the consumer actually consumessuch as the kilowatthours shown on a householder electricity meter or the amount of fuel in litres used for driving a car; final energy consumption is always less than the primary energy consumption; final energy consumption is often given in sectors such as transport, industrial, or households.

GDP: Gross Domestic Product

Gross inland consumption: This is the total energy consumed within the borders of a EU member state including parasitic energy consumed to transform, process and deliver energy to the end user. Gross inland consumption is always greater than the final (metered) energy that is consumed by the end user.

Herfindahl-Hirschman index HHI: A metric that is routinely used in economics and anti-trust law as a measure of company dominance or competition in the free market (Orris Clemens Herfindahl, 1918-1972). The metric can also be applied to energy suppliers and be used as an indicator of energy diversity. The index is defined as:

$$HHI = \sum_{i=1}^{N} \mathbf{s_i}^2$$

where $\mathbf{s_i}$ is the market share of supplier i with s given as a fraction between 1/N and 1 and where N is the number of companies (or energy suppliers).

Because the market share s is squared, larger suppliers are given more weighting. For example, a HHI index of 0.01 stands for fierce competition whereas a HHI index of 0.25 and higher indicates little competition where a single supplier dominates the market. The HHI index has also been used to indicate crude oil supplier diversity. Also http://en.wikipedia.org/wiki/Herfindahl_index or http://www.unclaw.com/chin/teaching/antitrust/herfindahl.htm

IEA: International Energy Agency, based in Paris; founded in the wake of the 1973 energy crisis, in order to coordinate a response to the severe disruptions of crude oil supplies; the IEA's main mission is energy security.

Ktoe: kilotonnes of oil equivalent, a non-SI unit common in energy statistics; one tonne of oil equivalent corresponds to 41.868 GJ;

Mean variance portfolio MVP or simply **portfolio theory:** Portfolio theory is a probabilistic method that was originally developed to reduce risk in financial investments (Markowitz 1952; a Nobel laureate). Can also be used as an indicator of diversity (and therefore energy security) of fuel supply for electricity power stations (Awerbuch and Berger 2003, Awerbuch 2006). Briefly reviewed in Kruyt et al 2009. In assessing energy security risk,the metric takes into account (a) the (generating)fuel cost, (b) the variance in fuel cost and (c) the correlations between fuel costs (Bar-Lev and Katz 1976). This information is often hard to obtain which is the main critique of Andrew Stirling with this method.

OECD: Organisation for Economic Cooperation and Development – the goal is to "build a stronger, cleaner, fairer world"-http://www.oecd.org

Primary energy: This is energy held in the original, natural source such as coal,gas or crude oil before the material enters the refinery. Also applies to alternative energy sources such biomass, wind or solar energy.

Primary energy production: The quantity of energy derived from a primary energy source.

Renewable energy ('renewables'): Energy from sources that do not run out with time. Examples of renewable energy are energy from biomass, solar, wind, water and geothermal. Fossil fuels are non-renewable. They are being depleted and can not be restocked under short time frame.

Self-sufficiency in %: A national valuedefined as the ratio of national energy produced inland, by the total primary energy utilised the country times 100. A country that generates all energy itself within its boundaries, and does not rely on imports, is fully self-sufficient. Its' self-sufficiency is 100 percent. A value below 100 percent indicates that some energy needs to be imported in order to meet national demand.

Shannon-Wiener diversity (index) H: Is an attempt of an objective diversity metric. H is an index of diversity of energy supply systems defined by $\mathbf{H = -\sum p_i \ln p_i}$.The proportions of each of the i energy sources (p_i) are summated over all source options from i = 0 to i = n (Stirling 1994, p.201, Stirling 1998). The higher the value of H, the more diverse is the energy supply system. The indicator attempts to incorporate issues such as variety and balance of fuels. Andrew Stirling used H to measure diversity in electricity supply. He lists resource diversity for all 24 OECD countries with H values ranging from 0 (Iceland) to 1.55 (Japan). The H metric can be seen in competition with earlier probabilistic portfolio methods to quantify diversity (Jansen et al 2004).

Volatility (in price): In the energy supply context the price of raw fuel such as crude oil, gas or coal is subject to market dynamics as well as geopolitical tensions. This phenomenon is denoted as (price) volatility. A constant or predictable price forraw materials is desirable but hard to achieve in practice.

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1. Introduction

The European Commission, as has most national states, has set out a number of key areas and problem hot spots that are critical toits future and need to be addressed. Some of these key areas are energy supply, and waste management.

Energy supply security presents a focus of national and international politicsever since fossil fuels have been mined on a large scale. It is well known that the transition to renewable energy sources leads to various environmental benefits. Less understood arethe potential impact an increase of renewablescan have on energy security.

This report discusses the issues that arise from the current energy production portfolio in Europe and indicates the contribution that biogas can have in addressingthe issues raised. In particular, the following questions are addressed:

1. What is wrong with the current energy portfolio?
2. What fraction of our current consumption can biogas energy cover?
3. What can renewable energy, and in particular biogas do for overall energy security and energy diversity?

The study is based around a critical review offossil and renewable energy supply pathways that Europe in particular has adopted in recent history.

1.1. What is wrong with the current energy portfolio?

Ever since the industrial revolution, but particularly since the 1950s, Western societies have continuously raised their living standard. Unfortunately, the rise of wealth and welfare has gone hand in hand with a steady increase in energy consumption. Energy literally fuels our lifestyles (e.g. Smil 1994). The point is now being reached with developed countries, where this excessive energy demand is threatening the living standard through the back door. The demand for primary energy sources is depleting resources and, as is now beyond doubt,, causing climate change – with impacts on nature at an unprecedented scale.It is now generally accepted that we no longer can turn a blind eye on the necessity to de-couple wealth and energy demand.

So what is wrong with the current European energy portfolio? The first few chapter headings of a recent reference book on energy security reads as follows (Luft and Korin 2009):

Chapter 2 The epidemic of energy terrorism
Chapter 3 Troubled waters: Energy security as maritime security
Chapter 4 There will be blood: Political violence … over contested energy sources
Chapter 5 No blood for oil
Chapter 6 OPEC: An anatomy of a Cartel
Chapter 7 Russia: The flawed energy superpower"
etc.etc.

Whilst these chapter headings are rather emotive, this table of contentsconveys the essence of the issues that lie beforeenergy policy-making in the EU.Dependency on fossil sources, a single source of supply or a single technology gives rise to risk in energy security and ultimately in potential for environmental disaster. Certain energy pathways carry considerably more environmental and societalrisk than others – not all countries have coal resources and those that do and use them without carbon sequestration create climate change impacts; however carbon sequestration and capture is not yet a fully developed technology. Oil production carries environmental risk (eg.2010: BP Deepwater Horizon (http://en.wikipedia.org/wiki/Deepwater_Horizon_oil_spill)) and its availability is concentrated in specific regions of the world – some of which are politically sensitive and even unstable. Nuclear power has a very low climate change impact , but carries riskof substantialenvironmental impact when unexpected events occur (eg. 2011: Fukushima nuclear power plant disaster).A terrorist attack on centralised energy facilities on a large scale has not happened yet but is entirely possible (Toft et al 2010, http://www.nactso.gov.uk).

> The fundamental issue is that much of energy production in the is still based around technology developed almost a century ago when the understanding of these threats was not what it is today.
>
> "In Europe and the US, national energy planning agencies value resource alternatives using outmoded techniques, conceived around the time of the Model-T Ford."

(Awerbuch 2000).

Energy supply across much of the EU is centred around finite fossil fuels and relying primarily on imports. The European Commission has recognised that things need to change:

> "Only a new energy model will make our system secure, competitive and sustainable in the long-run." (G. Oettinger, European Commissioner for Energy, in a 24 page "Energy roadmap 2050" by the European Commission)

Modernising our energy landscape and addressing energy security requires further harmonisation of energy policies across Europe (Umbach 2009, LeCoq and Paltseva 2009). In Europe the dependence on petroleum fuel imports has increased from 76 to 85 % in the last decade alone,as illustrated in Figure 1:

- More and more imported petroleum is consumed in the EU.The increasing dependence on petroleum imports is due to increased per capita consumption and partly due to the decline of internal EU (e.g. North Sea oil) reserves.
- With increasing imports, petroleum security is decreasing steadily.The increasing oil import dependence makes us vulnerable economically and socially.

Energy security goes hand in hand with the capacity to supply energy from domestic sources. From Figure 2 it is clear that this capacity varies widely across European member states. Denmark is in an enviable position of being able to export energy. Many member states however can only supply a fraction of their primary energy demand from national sources. Too much energy is imported and this increases the risk of fuel shortages and fuel interruptions.

After oil, electricity is the other commodity that we so much rely on to meet our energy demands. Without electricity public and personal life breaks down. Telephones, computers, electric cookers, any form of communication and even food supply comes to a halt. Even drinking water supply relies on pumps powered by electricity. What is the solution? The by far most potent tool to overcome this vulnerabilityis by maximising the use of renewable energy, coupled with a demand management strategy.

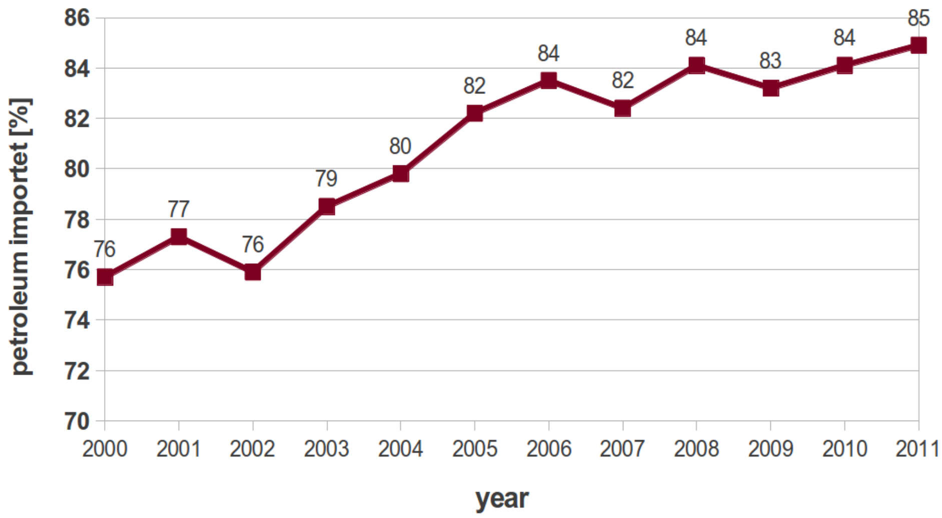

Figure 1Percentage of imported petroleum from the total petroleum (fuels) consumed in EU27 between 2000 and 2011. Source: Eurostats.

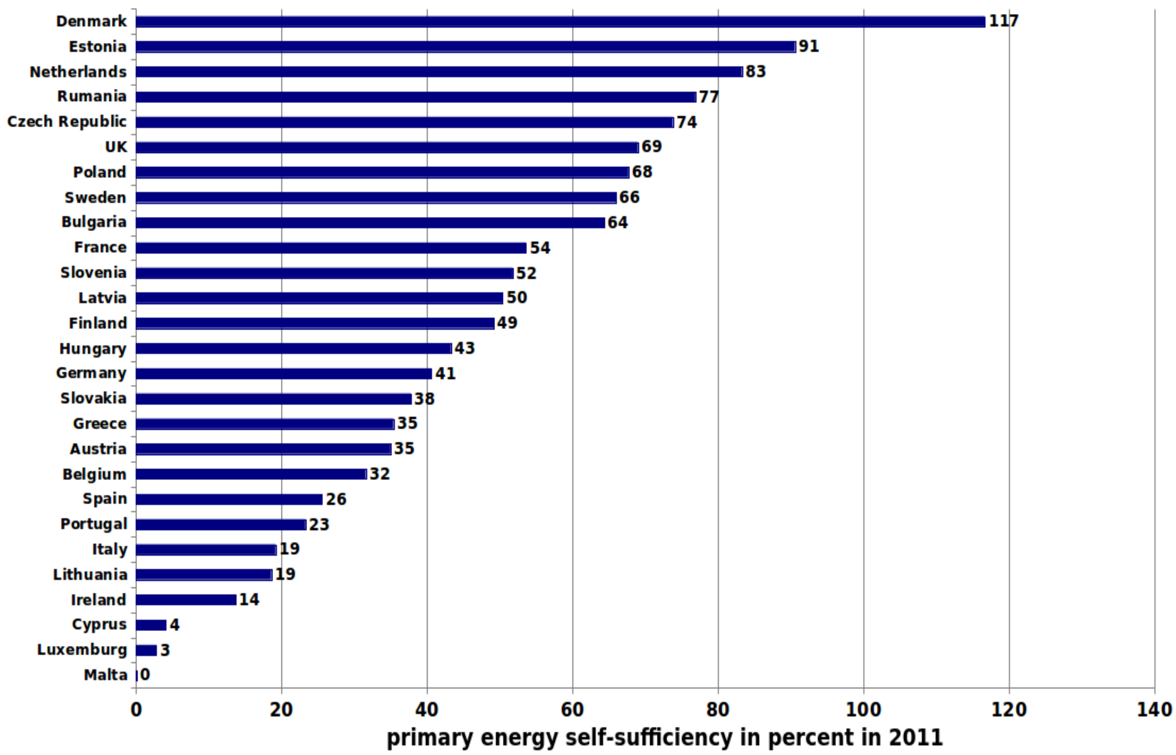

Figure 2Primary energy self-sufficiency in percent across EU member states in the year 2011. The higher the self-sufficiency value, the more secure the national energy supply. Data from http://www.irena.org

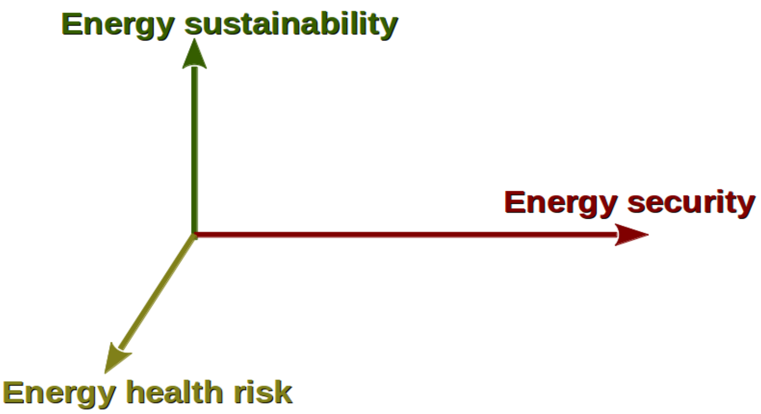

Figure 3Key dimensions for a modern energy policy. Dimensions should not be regarded in isolation. If it was possible to quantify all three axes, a policy point in three dimensional space is obtained.

1.2. The pillars of energy policy

Securing a safe and continuous energy supply is regarded as a mainstay of a successful energy policy. However, energy security must not be the only goal. It is essential that energy security is not taken in isolation but is combined with environmental protection (Rozenberg et al 2010, CriquiandMima2012), whilst at the same time facilitating a free market in the energy sector. An integrated approach is necessary that contains four key elements (e.g. McCollum et al 2011, Bollen et al 2010, http://www.iiasa.ac.at/web-apps/ene/GeaMCA/McaTool.html):

1. **Climate change mitigation / low carbon intensity:**There is now widespread acknowledgement that human activity is creatingclimate change and is very likely to be fuelled by the use of huge amounts of fossil fuels that took millions of years to form. Energy policy must be to develop energy sources that have as low as possible climate change impact and consequently are of low carbon intensity.
2. **Health and environmental risk:** The energy pathway derived from the sources must be safe, with no long term hazards.
3. **Security of supply:**The portfolio of energy sources covered by the policy must be diverse and not rely on single category of source, nor a single pathway (and thereby a single technology).
4. **Energy equality (avoidance of energy poverty):**The consumer market pricing mechanism must be progressive to ensure that low income groups are not placed in energy povity - simply increasing prices or taxing carbon intensive electricity penalises the low income population.

To achieve long-term energy security it is essential, therefore, to increase the share of renewable sources – possibly to beyond 50 % of consumption – and combine it with a .demand management strategy, including smart grids.

1.3. Energy security

Energy security is a much discussed topic around the world. For example, in China, economic growth heavily relies on cheap energy in huge quantities (Leung 2011, Zhang 2011). It is, therefore, very much in the interests of the Chinese government to protect its supply and ensure that it cannot be interrupted by another nation, nor terrorist action. Energy security ensures a continuous, uninterrupted supply of energy to society and industry. It therefore has similar gravity as national security and henceboth rely on military capability and threat (Flaherty and Leal Filho 2013). To ensure safe supply of energy, national governments are willing to use force. This constellation has brought about conflict and war. Arguably, the intervention of the Western Allies into Iraq was related to this. Revenues from the saleof crude oil are also known in some instances to have funded terrorists. No such fallacy exists with renewables.

Security of supply is vital for the industrial sector and it can be defined as "a system's ability to provide a flow of energy to meet demand in an economy in a manner and price that does not disrupt the course of the economy" (Grubb et al 2006). A similar definition of energy security is "the availability of a regular supply of energy at an affordable price." (IEA). The term 'affordable' is highly disputable – an energy source may be affordable today, but not tomorrow. Or an energy source may be affordable financially, but not environmentally, for example if it produces toxic waste for years to come. A form of energy may be affordable today, but if generations after us need to clear up what we leave behind, it is not affordable, nor ethical to them.

Various academic disciplines have carried out studies on energy security, the three most prominent ones being (Jerp and Jewell 2011):

1. **Political science:** The key issue is political sovereignty to ensure the political and societal functioning of the state.
2. **Engineering:**To provide a robust and reliable infrastructure or supply system to ensure that the energy demand can be satisfied at all times. Issues are resource depletion, adequate infrastructure, technical reliability/failures, and safe technologies (Zerriffi et al 2004, Dobson et al 2007, Yu and Pollitt 2009).
3. **Economics:** The key issue here is to tailor a supply system that provides resilience. Issues are political stability and dependencies, supply disruptions and associated risks. Diversity against disruptions. Complex system analysis can be employed.

It is clear that energy security should not be limited to a single discipline or perspective – a holistic, interdisciplinary approach is required.

Security is the overarching desirable characteristic of an energy supply portfolio which depends on a number of criteria, and one of them is diversity.

National policy decisions have established short term fossil fuel oil and gas storage solutions which can iron out short term shortages. However, these reserves are not able to ensure long term security. To provide long term energy security, the energy policy needs to target the following requirements:

1. Demand management including behavioural changes
2. Renewables
3. Diversification
4. Technological advances

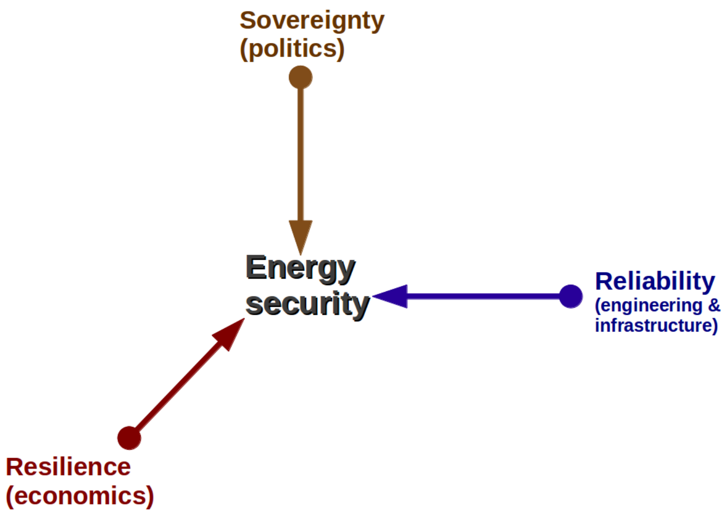

Figure 4The three overarching perspectives and disciplines that have analysed the energy security issue (after Jerp and Jewell 2011).

But even with a completely renewable energy source portfolio no single technology can ensure a secure energy supply. Renewables also must be diversified. Compared to other renewables such as wind and solar, biogas has the advantage that it can be stored and therefore turned on and off any time. For example, in a smart electricity grid biogas could be turned on at peak demand times which is impossible with wind or photovoltaics (Grave et al 2012). This can add an amplified de-carbonisation benefit as peak electricity is typically more polluting than base load electricity.Not being intermittent, however, if so required, can also contribute to "base load".

A number of authors have identified energy security dimensions that constitute various aspects of energy security:

1) **Sovacool and Brown 2010:** Identify four key criteria that contribute towards energy security. These are
    (a) Availability: The geological or physical existence of an energy source.
    (b) Affordability: Economy of exploitation (e.g. price)
    (c) Accessibility: Geopolitical conditions that allow exploitation of the source.
    (d) Acceptability: Environmental performance of the energy pathway

The above four elemental dimensions are well established and are also adopted in Kruyt et al 2009, Greenleaf et al 2009 (Table 2.1 page 41), and the Asia Pacific Energy Research Centre (APERC) http://www.ieej.or.jp/aperc.

2) **Cherp and Jewell 2010:**The three perspectives of energy security are
    (a) Sovereignity (national interest to oil supplies), rooted in political science
    (b) Robustness: Rooted in engineering; threat of accidents, blackouts, resource scarcity
    (c) Resilience: This perspective is rooted in economics

3) **Pfluegler 2012:** (FriedbertPfluegler, www.energlobe.eu or http://www.energlobe.eu/energy-security-turns-100-thoughts-on-resilient-energy-systems) Identifies seven risk factors that make up a resilient energy supply system:
   (a) Conflict - the national and social stability of fossil fuel supply is inadequate.
   (b) Blackmail - governments
   (c) Energy imperialism - the majority of fossil fuel suppliers are state owned companies and therefore depend on the good will of their governments. Lack of competition raises the fuel price.
   (d) Terrorist attack
   (e) Cyber terror attacks
   (f) Natural disasters
   (g) Technical failure

4) **MOSES model** of the IEA: MOSES is short for Model Of Short-term Energy Security. MOSES is the IEA attempt to measure short term energy security of national energy portfolios. MOSES differentiates energy security into the three classic sectorsof transportation, industry and domestic/residential. MOSES classifies the two dimensions risk and resilience into national home (under direct control of the national government) and international foreign areas (beyond the direct control of the national government).MOSES (a) measures national energy security over time and (b) analyses the effect of particular energy policy on the nation's energy security. The MOSES model covers 7 primary energy sources and two secondary fuels. The MOSES model quantifies energy security in four dimensions:
   (a) external(foreign) risk
   (b) external(foreign) resilience
   (c) internal (domestic) risk
   (d) internal(domestic) resilience

Energy security is then quantified in these four dimensions with almost 30 individual indicators most of which are currently available from IEA statistics. It is clear that with biogas no external risk and resilience needs to be examined. All energy sources (such as biowaste or energy crops) are locally sourced.

1.4. Energy diversity

Diversity is a characteristic that features prominently in a variety of fields and scientific disciplines:

- **Ecology and biology** (eg. McIntosh 1967, Peet 1974, McCann 2000): The natural food chain in the biosphere is built upon the enormous diversity of fauna and flora.
- **Finance and economics** (e.g. Haughton and Mukerjee 1995): In order to minimise risk, a financial investor should seek to spread her/his assets. The overall risk of losing everything is thereby reduced compared to the risks of the individual assets.

- **Energy policy** (e.g. Llerena and Llerena 1993, Bielecky 2002): Energy diversity is one contributor towards the quality of the energy supply system and it is something intuitively desirable. "No matter how great the resources, nor how complete the knowledge, nor how sophisticated the decision making process, only fools put all their eggs in one basket." (Stirling 1994)

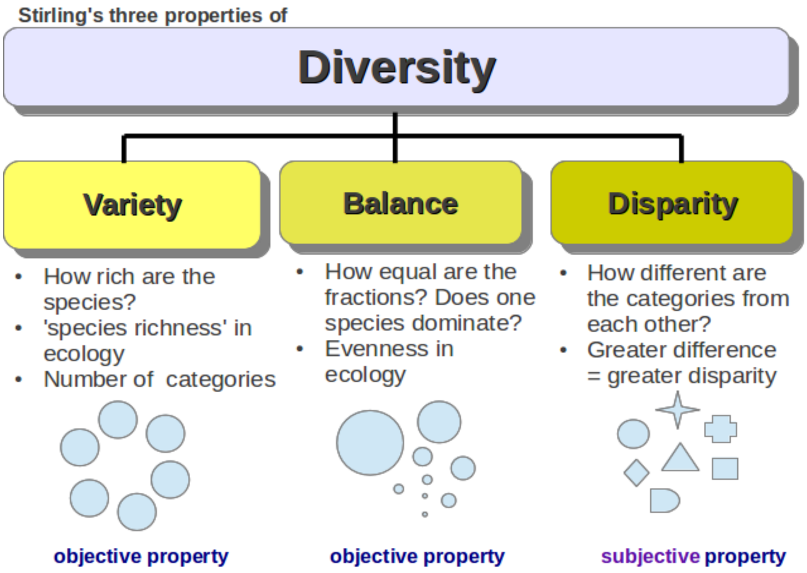

Figure 5Three subproperties of diversity (Sterling 1994, Sterling 1998, Jansen et al 2004)

Despite this well developed theory, the energy diversity postulate is being violated on national scales. France, for example, produces a large proportion of its electricity from a single source - nuclear power. Even though it is intuitive that diversity of supply is something desirable as it reduces vulnerability if the main supply fails, it can be argued that economies of scale favour theadoption of a single supply route or technology. Maintaining one technology is less demanding than managing a variety of technologies (Llerena and Llerena 1993). In the 2011 Fukushima disaster in Japan, it was recognised that "... they have put a lot of eggs in the nuclear-power basket''(Tollefson 2011).

For energy diversification to be effective two areas need to be addressed:

1. Fuel sources (such as coal, gas, oil, solar, wind)
2. Energy conversion pathways (such as coal to electricity, coal to liquid fuel, solar thermal, solar electric etc.)

Diversity can be measured quantitatively in a formal way and a number of approaches have been developed. A total of 16 simple indicators and five aggregated, more complex indicators are listed and reviewed in Kruyt et al 2009. None of these indicators can cater for all possible factors that contribute towards energy security.To ensure diversity in energy supply, at least three subordinate conditions must be met (Stirling 1994) as shown in Figure 5:

1. **Variety:** This represents different fuels such as coal, gas, nuclear, solar, wind.
2. **Balance:** Indicates the degree of spread across the various fuels (variety)

3. **Disparity:** Indicates the degree of difference between the fuels. Fossil oil and fossil gas are much less different than oil and solar for example. If the oil price goes up, the gas price is likely to go up – they are correlated. If the oil price goes up, then solar electricity or solar heat will not follow. The two energy sources are muchless related to each other. Disparity is needed to ensure prices do not go up across all sources.

1.5. Review of the effect of renewables on energy security

Lack of energy security and fossil fuels come hand in hand. Fossil fuels are more concentrated in certain areas of the world than in others. Energy security is something that renewables are meant to address. But do renewables indeed improve energy security? A large body of literature exists on the topic of energy security across various academic disciplines, but only a few studies specifically address the effect on energy security of moving renewable energies from a marginal position to center stage within Europe. These are listed below.

Awerbuch 2004: In an application of mean-variance portfolio planning the author states that "compared to existing, fossil-dominated mixes, efficient portfolios reduce generating cost while including greater renewables shares in the mix, **thereby enhancing energy security**."

Oelz et al 2007: States that "renewable energy sources are typically indigenous resources and can reduce dependence on energy imports." Point out the advantage of a distributed system: "Centralised power generation is exposed to a larger set of supply security risks relative to distributed generation." Their claims are based on energy modeling:

> "The IEA has developed an energy security indicator which complements a physical availability component derived from the notion of import dependence, with a price component based on calculations of market power and concentration (IEA 2007, Energy Security and Climate Policy – Assessing Interactions, IEA/OECD, Paris). Modeling results suggest that increasing the role of renewables in electricity generation, which will most likely displace fossil fuel fired generation, reduces both the price and volume (physical availability) components of the energy security index – in other words**, an increase in energy security** (ibid)."

Allas 2007: A powerpoint presentation at a research seminar in December 2007 on the effect of increased renewable energy in the UK on security of supply for electricity and gas. It is claimed that more renewables can lead to both increased and decreased security of supply. As electricity from wind is intermittent, this could lead to less energy security. This is a classic argument, contested by some as not being an issue (Barnham 2006, Barnham et al 2012) - or one that can at least be solved (Grave et al 2012). The author argues that the following factors play a role for energy security if the renewable electricity share is raised:

- **Spare capacity:** negative effect on energy security as lower load factors may reduce the incentive to maintain spare capacity
- **Diversity of generating plants:** Positive effect on energy security as a large number of smaller units are unlikely to be faulty at the same time.
- **Diversity of fuels:** Potential negative effect on energy security as in the event of dependency on wind, ' … conditions across the UK are correlated''
- **Diversity of technology:** Positive effect on energy security as a range of technologies are employed which guards against type failure.

- **Reliability of plants:** No effect or increased energy security as more modern plants are less prone to failure.
- **Reliability of fuel supply:** Either negative or positive effect on energy security as many renewable fuels sources are intermittent. However, in the long term renewables guard against resource depletion.

The author also makes an unsubstantiated claim that the "impact of higher renewables … on gas security of supply (is) likely to be relatively small." It is hard to imagine something more secure than the supply of renewable biogas from organic waste.

Department for Business, Enterprise and Regulatory Reform (BERR) 2008: UK renewable energy strategy - consultation, June 2008, p. 39:

"increasing generation from renewables will contribute to security of energy supply, reducing gas imports by between 12-16% in 2020 – with increasing benefits as these fossil fuels become more scarce and expensive".

On page 169 it states:

"Biofuels can contribute to energy security by diversifying energy supply sources for transport, reducing our heavy dependency on a single energy source and increasing the number of supply sources and routes. Achieving the renewable energy target in the transport sector could reduce UK consumption of fossil fuels by 6%-7% in 2020. Displacement of petroleum fuels by biofuels reduces exposure to the risks associated with the international oil market."

"However, the production and supply of biofuels is not risk free as there are a number of factors that could limit or disrupt supplies. These are:

- the competition for feedstocks used in biofuels for other uses such as food;
- the availability of agricultural land;
- variations in supply due to climatic conditions and seasonal cycles;
- risks of crop failures from disease and pests;"

Greenleaf et al 2009: In a 352 page report for the EU Commission, it is made clear that energy security will change with new climate policies:

> "…the introduction of a number of existing and proposed climate change related policies … will change the structure of the energy system significantly in the future (e.g. via greater use of renewables to meet emissions targets), thus altering these associated risks."

More interestingly, the study argues that energy security will improve with an increase in renewables:

> "The result of our quantitative analysis shows that … both the climate package and CCS (carbon capture and storage) policy lead to an overall improvement (i.e. decrease in vulnerability) in energy security at the EU-27 level across the indicators."

Umweltbundesamt 2010, page 6: The German Environment Agency (= Umweltbundesamt) published a report in 2010 which concluded that the German electricity supply can be generated completely from renewable energies by 2050: "An electricity supply system completely based on renewable energies can provide the security of supply for today's high level of demand and at any hour of the year."

Criqui and Mima 2012: "One key outcome of the study is thus that a strong European climate policy may create a double dividend in terms of energy security, even in the case of weak global climate coordination."

Virtually all studies conclude that increasing renewables leads to improved energy security.

1.6. Biogas status in the EU

Even though renewable energy is growing in the EU over more than a decade, a large variability exists across member states. Figure 6 shows the total amount of biogas (including landfill and water treatment plants) in **kg of oil equivalent per capita** in the year 2011. Data from Figure 6 are plotted into a map in Figure 8. Biogas production per capita differs by about a factor of 60 between trailing (Romania and Cyprus) and leading member states (Germany and the UK). Biogas has become one of the three pillars (photovoltaics, wind and biogas) that have catapulted renewable electricity in Germany to beyond 20 % of total electricity generation. The remarkable growth of renewable electricity in Germany is illustrated in Figure 7.

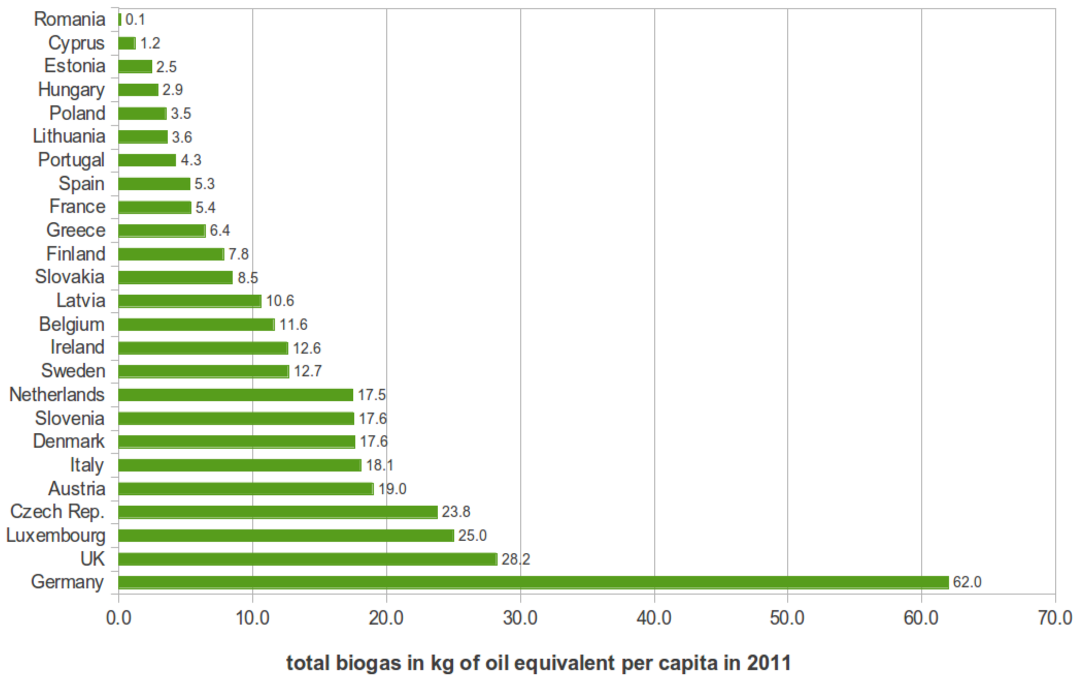

Figure 6 Total biogas (including landfill gas and sewage gas) generated per EU27 country in kg of oil equivalent per capita in the year 2011. Source: Adapted after http://www.eurobserv-er.org/

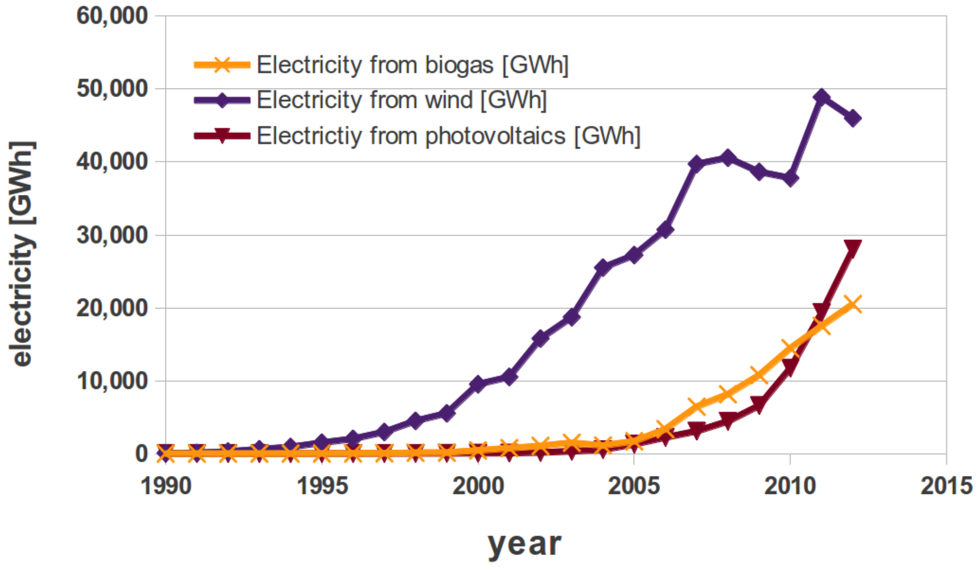

Figure 7 Renewable electricity generated in Germany between 1990 and 2012 from wind (blue) photovoltaics (red) and biogas (orange/yellow). Source: http://www.erneuerbare-energien.de/die-themen/datenservice/zeitreihen-entwicklung-ab-1990/

1.7 Milestones of EU Biowaste Policy

Biogas is a potent renewable fuel. Biogas from waste ticks yet another box – it helps move our household waste streams into a more sustainable position – an issue that is high up on the European agenda. The major milestones in EU biowaste policy can be summarised as follows:

- **26 April 1999:** Council Directive 1999/31/EC on the landfill of waste; the directive introduces a mandatory reduction of the amount of biodegradable waste landfilled in 2016 by 65% compared to 1995 levels in the member states.
- **3 Dec. 2008:** The Commission publishes the 'Green Paper on the management of biowaste in the European Union 'COM(2008)0811'
- **12 Dec. 2008:** Revised Waste Framework Directive (2008/98/EC) comes into force. Member states are required to bring into force by 12 December 2010, the laws, regulations and administrative provisions necessary to comply with the revised Directive, which replaces three older directives:
    - the existing Waste Framework Directive (2006/12/ EC):
    - the Waste Oils Directive (75/439/ EEC):
    - the Hazardous Waste Directive (91/689/ EEC).

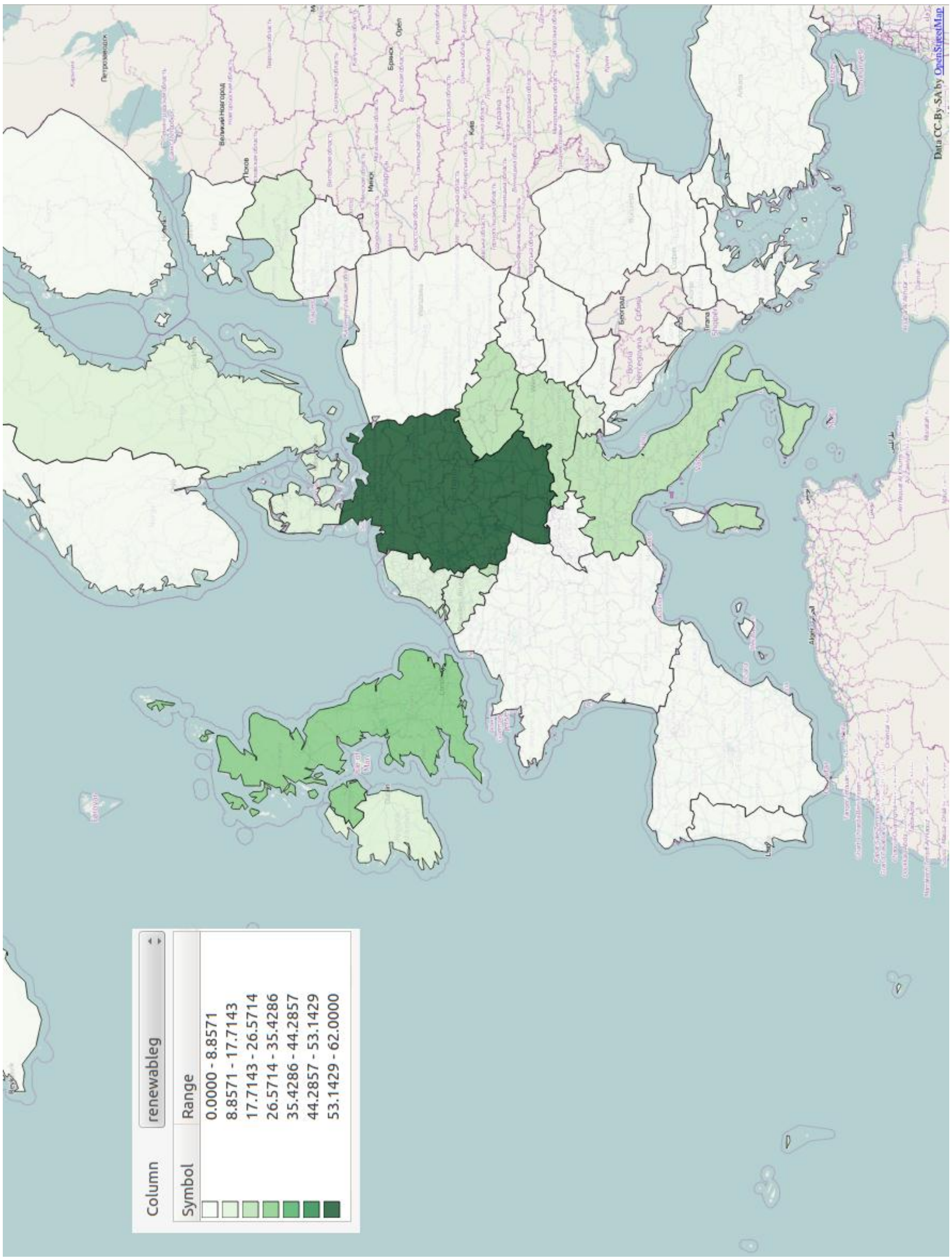

Figure 8 Sametotal biogas data per capita in 2011 as in Figure 6 but plotted as linear levels of green into member states.

- **9 and 10 June 2009:** Biowaste Conference in Brussels on the topic “Is there a need for separate EU legislation on biowaste?”; member state representatives, EU policy officers and stakeholders meet in Brussels in order to discuss the need for stricter EU legislation of biowaste; organized by the German and Czech Ministries of Environment, the Public Waste Agency of Flanders, OVAM, and the EU Commission Environment Directorate-General; took place in the Permanent Representation of Germany in Brussels; more than 200 participants from 23 European Union countries and Croatia with 30 presentations.

- **15 Feb. 2010:** Conference in Barcelona on the recycling of biowaste in Europe, with the Council, the Commission and members of the EU Parliament;
- **4 March 2010:** The European Commission tempers ambitions on a new EU organic waste law; EU Commissioner Zambrzycki favours a simpler option in form a modification of the current Waste Framework Directive (WFD) – either Article 11 on collections of different waste streams or Article 22, which currently encourages separate collection and treatment of biowaste. There is "no difference between whether we redraft Article 11 or do a separate directive," "After two decades of intensive legislating, what more do we need? What are the barriers? Why is biowaste recycling not happening?" asked Jos Delbeke, deputy director-general of the Commission's environment department, at a biowaste conference on 9 June. "We already have the tools," Delbeke claims and names six existing EU legal instruments regulating the treatment of biowaste: the revised Waste Framework Directive, directives on landfill, pollution prevention and control, incineration and renewable energy, and the regulation on animal by-products. Several member states are against a new directive.
- **18 May 2010:** European Commission communication to the Council and Parliament COM(2010)235 on future steps in biowaste management in the EU. Biowaste options are summarised and positive effects on climate change, soil quality and renewable energy are acknowledged. Composting and anaerobic digestion are identified as the best options; source separate collections are the way forward.
- **6 July 2010:** European Parliament resolution on the Commission Green Paper on the management of biowaste in the EU (2009/2153(INI)). "Directive 1999/31/EC on the landfill of waste does not provide sufficient instruments for the sustainable management of organic waste". The Commission is asked to review the existing biowaste relevant legislation and to draw up a proposal for a new biowaste directive by the end of 2010. The parliament instructs the President to forward this resolution to the Council and the Commission. The resolution, which is not legally binding, was drawn up by Portuguese centre-right MEP José Manuel Fernandes (European People's Party) in the Parliament's environment committee.
- **2011:** EU Commission commissions a preliminary impact assessment on bio-waste management

1.8 Data sources, assumptions and limitations

Statistical background data such as

- current energy consumption levels; and
- population numbers in the EU27 member states

are taken from http://epp.eurostat.ec.europa.eu/portal/page/portal/eurostat/home/. Excluding Croatia, the EU population in 2013 is assumed to be 504 million people (http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2013:016:0016:01:EN:HTML).

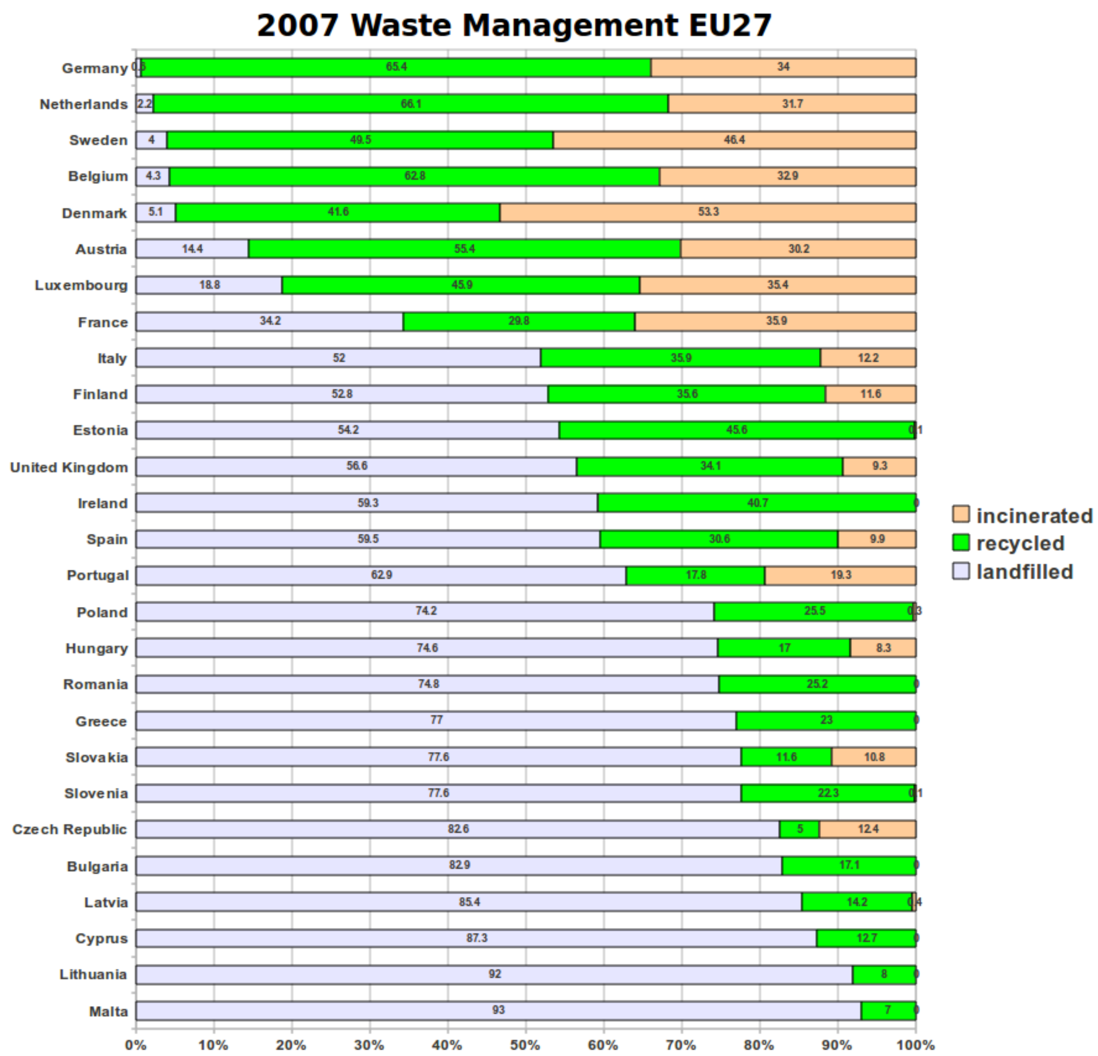

Figure 9Waste management in the EU exhibits large performance differences across member states. Source: Eurostats.

Data on food waste captured have been gathered throughout the VALORGAS project. To estimate the potential of renewable energy from biogas in Europe, the following assumptions are made:

1. **Food waste/organic waste yield:** The total organic waste yield per person per year is assumed to be 100 kg. This is higher than currently achieved capture rates across Europe (see Figure 13), but may be justified if collection methodology is improved and behavioural changes have filtered through the EU population. Behavioural changes should concentrate on both minimising food waste as well as capturing more. The aim is less contamination and more capture of unavoidable waste.
2. **Energy demand for waste collection:** This project has established that Diesel fuel consumption for waste collections is in the range of 5 to 20 litres of Diesel per tonne of organic waste collected. For simplicity, this parasitic demand is not taken into account.

3. **Current consumption baseline:** The potential contribution of energy from biogas is made against current consumption levels, which are unsustainable. If, for example, the potential contribution of biogas electricity is 1% of current demand, and current demand is cut by half through technological advances or behavioural changes, the contribution of biogas would double to 2 %.
4. **Fertiliser value:** Digestate can effectively replace mineral, fossil fertiliser which saves fossil gas resources but this benefit is not taken into account.
5. **Gas yield:** It is assumed that one tonne of food waste can generate a total of 97m^3 of purified methane gas. In reality gas yield will slowly be increasing with technological progress.
6. **Current liquid fuel consumption in EU27:** Liquid fuel consumption per capita per year in EU27 was taken from (EU 2012). The pocket book lists total liquid fuel consumption in the transport sector in EU27. This value was divided by the number of EU27 inhabitants and then converted to kWh and litres of liquid fuels. For simplicity, 1 litre of liquid fuel was assumed to contain 10 kWh of energy.

1.8.1 Electricity consumption per capita per year in the average EU household

Food waste amounts reported in the previous section are from householders. The assumption is that 100 kg of organic waste are collected per person per year both from domestic households and businesses generating organic waste. The amount of electricity generated from that waste is then compared against the householder average electricity consumption per capita. Household electricity consumption emanates from the use of electrical appliances but includes electricity for space and water heating. Figure 10 shows that householder consumption per capita in the EU comes close to 2000 kWh per year. For comparison, the electricity consumption per capita in UK households is plotted in red. Assuming that three people live in a household, the household electricity consumption in the year 2011 would amount to almost 3 × 1599 kWh = roughly 4800 kWh per year. The dip in the year 2011 is likely to be caused by the economic recession.

The graph was generated by converting the total electricity consumption in EU households from the units TOE into kilowatthours and dividing by the number of citizens. The IEA/OECD as well as Eurostats define one TOEas 41.868 GJ or 11.63 MWh and this conversion was used here.

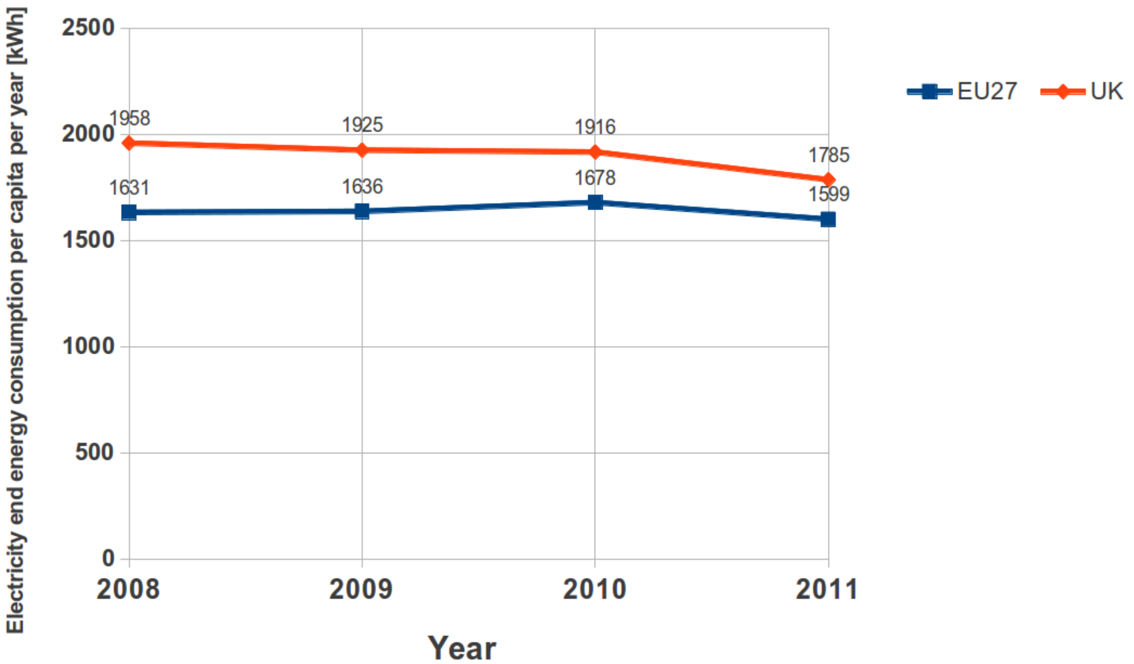

Figure 10: Electricity consumed in European households in the years 2008 to 2011 per year per capita in kWh. Plotted are end-energies, i.e. what is clocked on the householder electricity meter. Source: Eurostats

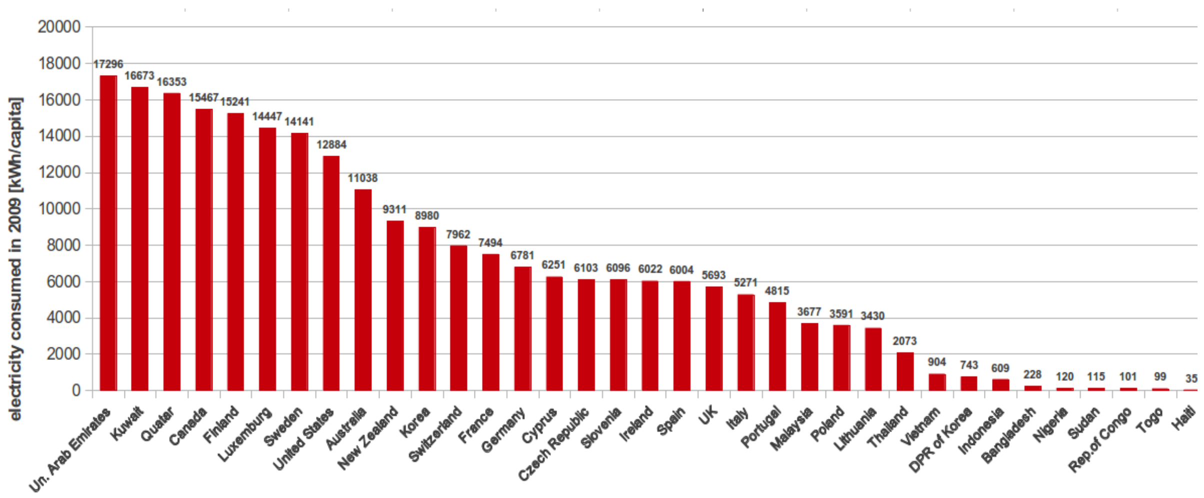

Figure 11: Electricity consumed in the year 2009 per capita in kilowatthours in various countries around the world. This graph includes total electricity consumed in a country rather than householder electricity only as shown in the previous Figure. Source: www.iea.org

1.8.2 Food waste yield from EU households

In order to estimate the potential energy contribution of biogas in Europe, the amount of food waste that is potentially available needs to be known. We only have knowledge of what is being collected - the real amount of food waste that arises in households is not known. Two types of evidence can be used to estimate the amount of food waste and organic waste from households:

1. **Amounts that were actually captured** per authority: The amount captured is not identical to the amount generated, but it is the best indicator of food waste available.
2. **Total amount of wastes collected** where organic waste is one (estimated) fraction.

A number of authorities in more than 6 countries have been investigated in detail in the VALORGAS project and Figure 13 gives an overview of food waste captured across authorities in some of these authorities in kilograms per person per year. A wide range of food waste yield is found from around 30 kg to almost 100 kg per person per year.

A householder in the EU27 generated an average of 436 kg of household waste per capita in the year 2010 (Source: http://epp.eurostat.ec.europa.eu/portal/page/portal/waste/introduction) as shown in Figure 12. The amount of food waste could be taken as a percentage of the total waste as shown in Figure 1. If 20 % of the total waste is organic in nature this amounts to 0.2 × 436 kg = 87.2 kg per capita per year. If it is assumed that a quarter of this waste is organic in nature, then a typical EU citizen would produce a total of 0.25 × 436 kg = 106.5 kg of organic waste per year.This excludes organic waste that this EU citizen would produce indirectly in restaurants, cafes and retail by eating out. This is a potential upper limit and actual capture is lower than that. Actual capture rates across Europe range from around 20 to 90 kg per capita per year as shown in Figure 13. There are two competing arguments about future trends for food waste yields:

- **Increasing food waste** yield with time: Householders are becoming used to source separating food waste which leads to more source separation and therefore an increased food waste yield.
- **Decreasing food waste** yield with time: As householders are educated and trained to reduce food waste this may be reflected in decreasing food waste rates.

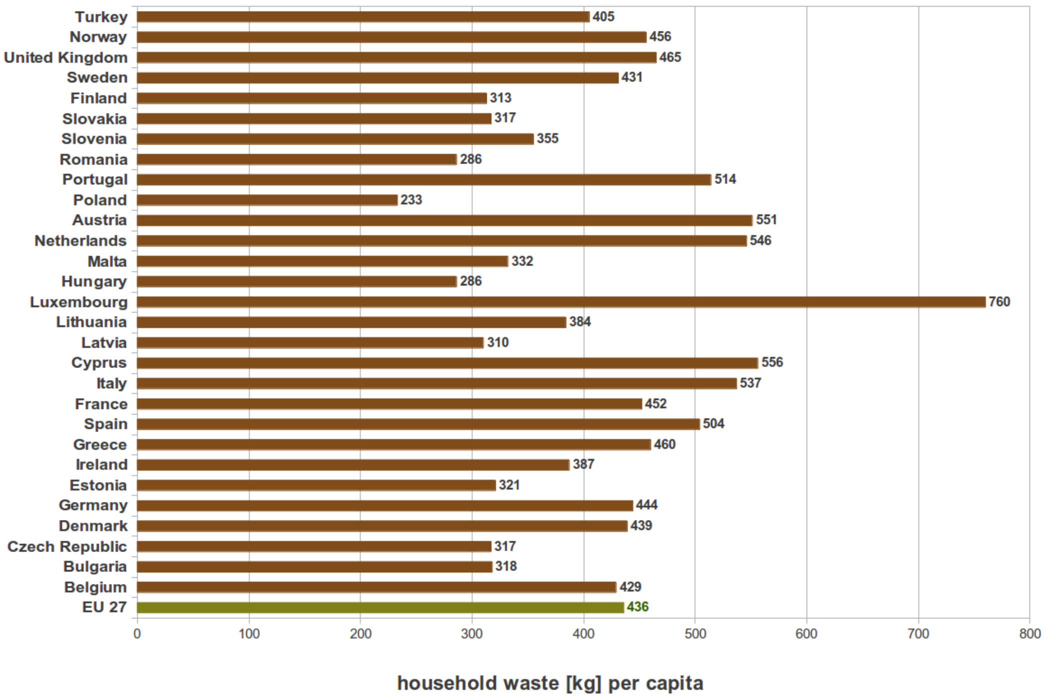

Figure 12 Capturedhousehold waste in EU member states in the year 2010 per capita. Source: Eurostats.

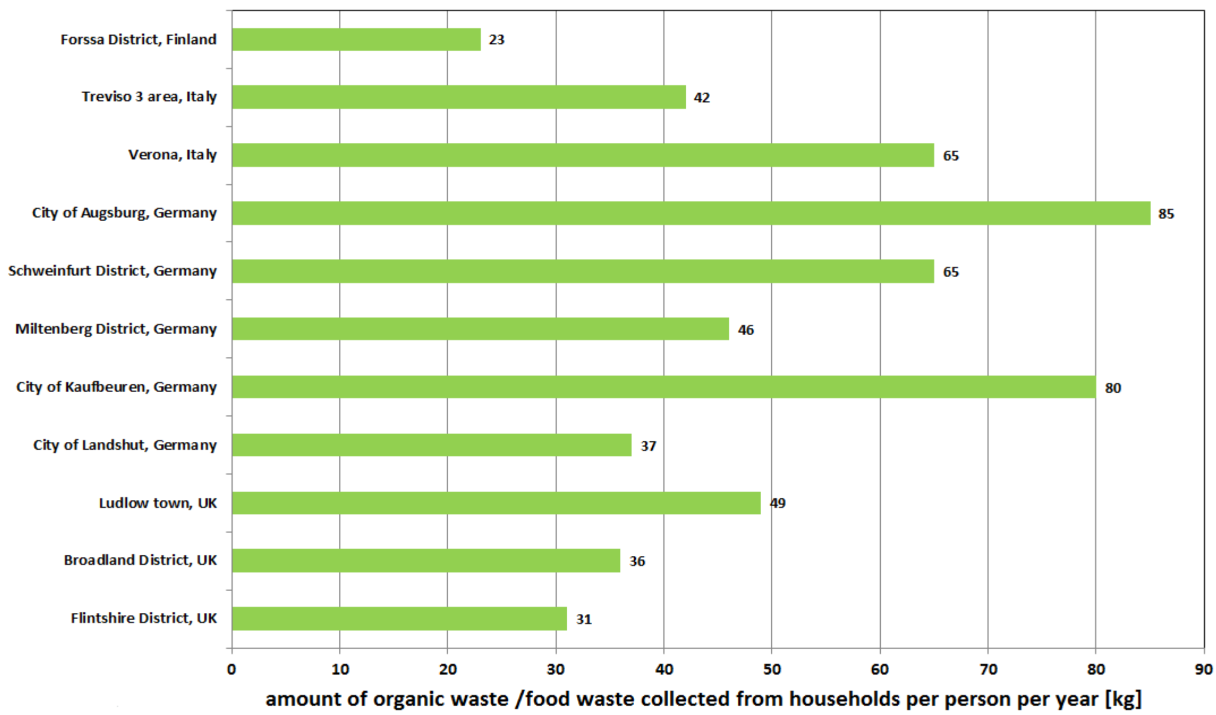

Figure 13 Actually captured organic waste / food waste for various local authorities across Europe in the years 2010 and 2011 (Source: VALORGAS research).

2. Methods

The two most prominent approaches to measuringenergy security using quantitatively in an supposedly objective manner, are:

- **Probabilistic methods:**These require previous knowledge but in a state of ignorance, probability distributions are hard to come by. These methods do not work without reliable, prior knowledge. A looking-into-the-future-from-previous-knowledge conundrum.
- **Shannon-Wiener index:** Some elements of this metric include undesirable subjective elements. Also, in some cases diversity of highly sustainable systems comes out very low, even if such as system is, in fact, sustainable (such as 100 % hydroelectricity or 100 % geothermal).

In view of these shortcomings, a more qualitative analysis of the contribution of biogas to energy security is carried out here.This is done by rating biogas against subordinate properties that contribute towards energy security. Secondly, the potential contribution of biogas towards the current energy demand is established using simple "back of the envelope" calculations.

2.1. Energy security dimensions applied to biogas

A number of properties have been identified that contribute towards energy security of fuel and energy supply pathways (eg. Sovacool and Brown 2010, FriedbertPfluegler, http://www.energlobe.eu):

1. **Fuel cost** (affordability): Can society pay for the fuel?
2. **Fuel cost fluctuation** (variations in affordability): Is the price constant or at least predictable over longer periods of time?
3. **Availability:** Is the fuel being depleted or can it be restocked? Resource depletion leads to less energy security.
4. **Degree of distribution/concentration:** Are power stations concentrated or geographically distributed? Conventional, large scale nuclear and coal power stations carry a risk and this is why they are always placed away from aggregated urban settlements. It is now clear that centralised power generation and distribution is sub-optimal (Lovins and Hunter-Lovins 1982, Hewett 2001, Sykes et al 2005, Wolfe 2008). Technical failure of a single plant is less severe in a more distributed system.[1]
5. **Potential to level out peak demand:** Some renewable such as solar photovoltaics are intermittent, whereas biogas can be switched on and off. On the other hand photovoltaic yield coincides with daily demand (Barnham 2006, Barnham et al 2012), which is advantageous for energy security.
6. **Potential for conflict:** Political stability in oil exporting countries is often low or oil revenues are used for warfare.
7. **Potential for blackmail:** Governments and societies can be blackmailed if they rely on a fuel that is mine in a region that is beyond their control.
8. **Potential for energy imperialism:** More powerful countries may not always behave fairly towards smaller, oil exporting countries. In turn, cartels such as the OPEC may not behave fairly towards certain countries.
9. **Potential for terrorist attack:** How prone is the energy pathway and technology to attract terrorist attacks?

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[1] In biogas research, the terms centralisation and decentralisation have a further meaning compared to the standard term used in the national utility sector. Two approaches are generally put forward of how to advance biogas electricity nationally (Walla and Schneeberger 2008, Zubaryeva et al 2012):

1. Distributed system: Via a non-centralised system as, for example, advocated in Germany with several thousand farm based digesters. The catchment area for organic material is purely local. This way distances and parasitic energy needs for transport and disposal are kept low.
2. Centralised system: An example for the a centralised biogas plant policy is Denmark with a few centralised, large scale plants that take in organic waste from a wider geographic coverage (Hjort-Gregersen 1999, Raven and Gregersen 2007). Transport distances and logistics need to be planned with care.

Which approach is more sustainable is a matter of debate (e.g. Jianguo et al 2005, Dresen and Jandewerth 2012, Berruto et al 2013). In the earlier meaning of decentralisation in the utility sector, the above two biogas approaches can both be regarded as de-centralised systems and retain an advantage for overall energy security.

10. **Potential for cyber terrorist attack:** Is the energy pathway and electrical power network prone to internet attacks?
11. **Risk of natural disaster:** Can earthquakes, tsunamis or extreme weather events damage the energy supply ?
12. **Risk of technical failure:** How mature and reliable is the technology?

All of the above dimensions will contribute towards energy security of a particular energy supply pathway, and can be used to rate biogas against its fossil counterpart.

2.2. Establishing the biogas potential

A number of biogas end uses exist and have been implemented with success. In order to establish the potential contribution of biogas to the energy portfolio, the following three questions are answered:

- What fraction of primary energy produced in 2011 in the EU27 per capitain can biogas cover?
- What fraction of electricity consumed in 2011 in the EU27 per capita can biogas cover?
- What fraction of transport fuel in the EU27 per capita in 2010 can biogas provide?

Quantities were established per capita as this is most effective in conveying the fuel intensity every citizen has, and illustrates the scale of current consumption from an individual viewpoint. It also illustrates the necessity for behavioural changes. The currently dominating energy mode for biogas in Europe is electricity generation but transport fuel is increasing.

2.2.1. Biogas potential for primary energy in EU27

The total primary energy production in the EU27 countries in the year 2011 was 1595 kg of oil equivalent per capita –Figure 14. The density of petrol is 745 kg per m^3 (http://www.biograce.net) and this amounts to a volume of 2140 litres. From 100 kg of food waste the equivalent of 10 litres of petroleum can be produced. Thus the fraction of total primary energy that can be covered by biogas is 10/2140 = 0.005 or 0.5 %. At current (unsustainable) consumption levels, energy from organic waste is able to cater for 0.5 % of the total primary energy consumption.

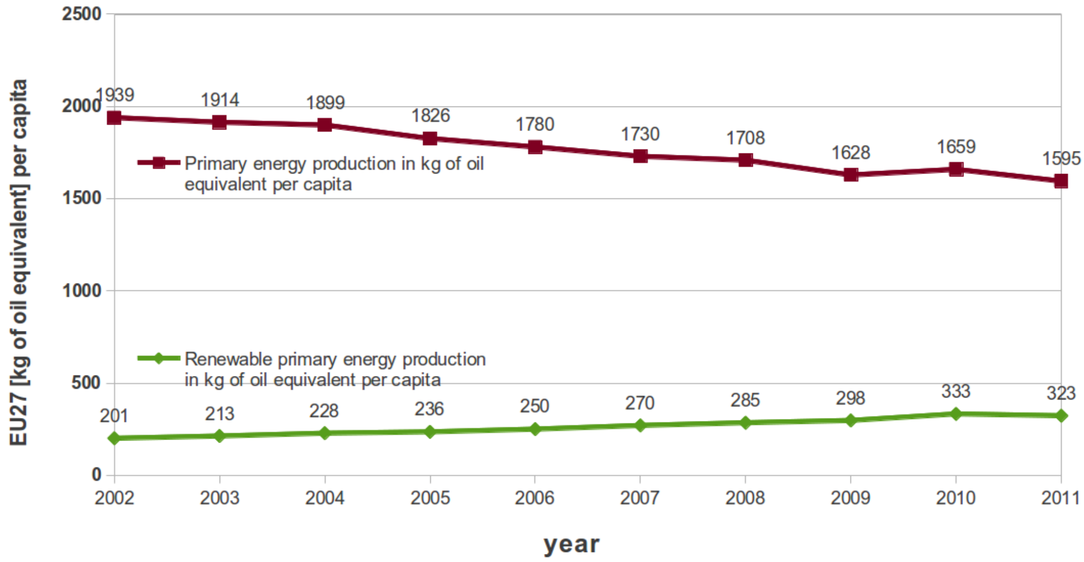

Figure 14 Top graph (dark red): Total primary energy produced in EU27 from 2002 to 2011 per capita in kg of oil equivalent. Bottom graph (green): Total renewable primary energy produced in EU27 per capita in kg of oil equivalent. Source: Eurostats.

2.2.2. Biogas potential as a vehicle fuel

Globally, the transport sector is currently fuelled by more than 95 % from fossil sources . The first major option for biogas end use is as a transport fuel - for example by fuelling the waste collection vehicles. An approximate calculation can be made for a transport fuel scenario. Underlying assumptions are as follows:

- One tonne of food waste generates 97 m^3 of methane . Assuming that one m^3 of methane is roughly equal in energy content to one litre of Diesel, 10 litres of Diesel equivalent energy is produced from 100 kg of food waste.
- Parasitic demand for the biogas plant is taken into account.
- Diesel consumed for collection is not taken into account.

The average liquid fuel consumption in the EU per person per year is almost 1000 litres per year. According to EU 2012 (page 49 of 117), the total transport fuel demand in the year 2010 in EU27 was 343661 ktoe. One toe is 11630 kWh, and then total transport fuel demand amounts to 3.99678E+12kWh. Dividing by the EU citizen population of 502623021 gives 7951.8 kWh, assuming one litre of fuel contains 10kWh - a total of 795 litres of petrol and Diesel. This is the total liquid fuel consumption in transport across all sectors in the EU per capita in the year 2010.) The percentage of liquid transport fuel that biogas can provide is 10 out of 795 (approximately 10 out of 1000) or 1 % at current consumption levels.The calculation assumes current consumption levels and current average vehicle technology as shown in Figure 15.

2.2.3 Biogas potential for electricity generation

One tonne of food waste generates 97 m^3 of methane. With the lower calorific value of 35.82 MJ per norm m^3 of methane a volume of 9.7 m^3 of methane is equivalent to 9.7 x 35.82 MJ = 347 MJ of gas energy. If we assume an electrical conversion efficiency of 33% this generates 347 / 3 = 116 MJ of electricity from 100 kg of food waste. 3600 kJ equals 3.6 MJ equals 1 kWh and then 116 MJ are 116/3.6 = 32 kWh of electricity at the biogas plant.

So from the yearly organic waste of a EU27 householder a total of 32 kWh of electricity can be generated. From Figure 10 the current electricity consumption of an EU householder is 1650 kWh. Based on these assumptions the electricity generated from the householder's organic waste would roughly contribute 32/1650 = 0.019 or 1.9 %. In essence, biogas electricity can contribute 1 to 2 % of the per capita electricity consumption in EU households.

Note that the overall electricity consumption in all sectors (not just in households) is considerably higher than what is shown in Figure 10. Hence, the contribution of biogas to the overall electricity consumption per capita (including electricity used in industry and transport) would be closer to 1% than 2 %.

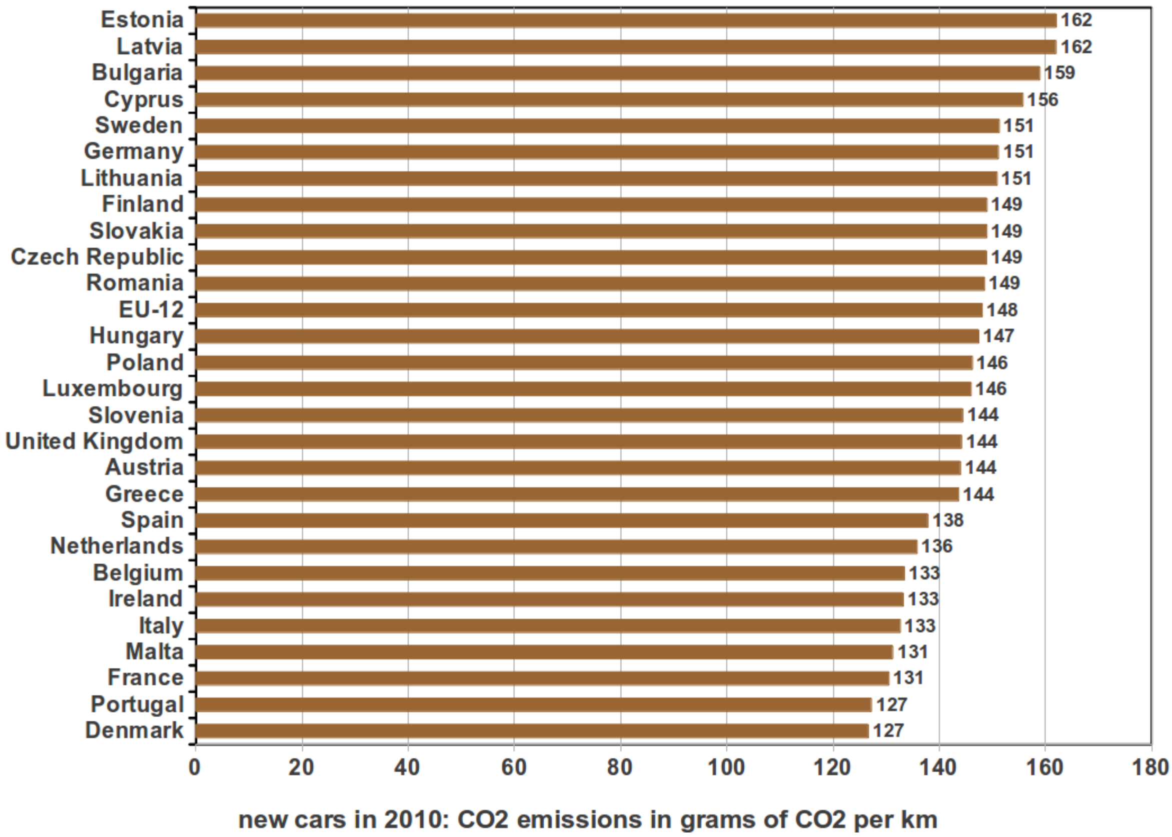

Figure15: Carbon emissions in grams per km travelled for cars bought in 2010 across Europe. Portugal and Denmark are leading. Surprisingly lower income countries such as Estonia, Latvia and Bulgaria are worst. Data source: http://www.eea.europa.eu

3. Results and discussion

3.1. Biogas rated against energy security dimensions

A simple, qualitative, but to some extent subjective analysis of twelve energy security dimensions for three types of gaseous fuels including biogas is listed in Table 1. Three levels of performance in the respective category or dimension are possible: 1 = good, 2 = medium and 3 = bad. Thus the higher the integrated score, the higher the risk associated with the energy source. The following observations can be made from Table 1:

- Biogas from waste fares best with an overall energy security score of 1.2
- Biogas from energy crops is somewhat worse with an overall energy security score of 1.5.
- Natural gas is worst with an overall energy security score of 2.4.

The result is expected due to the geopolitical burdens that natural gas brings with it. It is recommended that the method is tested with more complex renewable and fossil energy supply systems. This is, however outside the scope of this report.

Table 1Simple, qualitative analysis of twelve energy security dimensions for three types of gaseous fuels: Biogas from waste, biogas from energy crops and natural gas. Three levels of performance in the respective category or dimension are possible: 1 = good, 2 = medium and 3 = bad.

No.	**Energy security dimension**	**Biogas from waste**	**Biogas from energy crops**	**Natural gas (e.g. from Russia)**
1	Fuel cost (affordability)	1	2	3
2	Fuel cost fluctuation (variations in affordability)	1	2	3
3	Availability	1	1	3
4	Degree of distribution/concentration	1	1	2
5	Potential to level out peak demand	1	1	1
6	Potential for conflict	1	2	3
7	Potential for blackmail	1	1	2
8	Potential for energy imperialism	1	1	2
9	Potential for terrorist attack	1	1	2
10	Potential for cyber terrorist attack	2	2	2
11	Risk of natural disaster	1	2	2
12	Risk of technical failure	2	2	2
	Average:	14/12=**1.2**	18/12=**1.5**	29/12=**2.4**

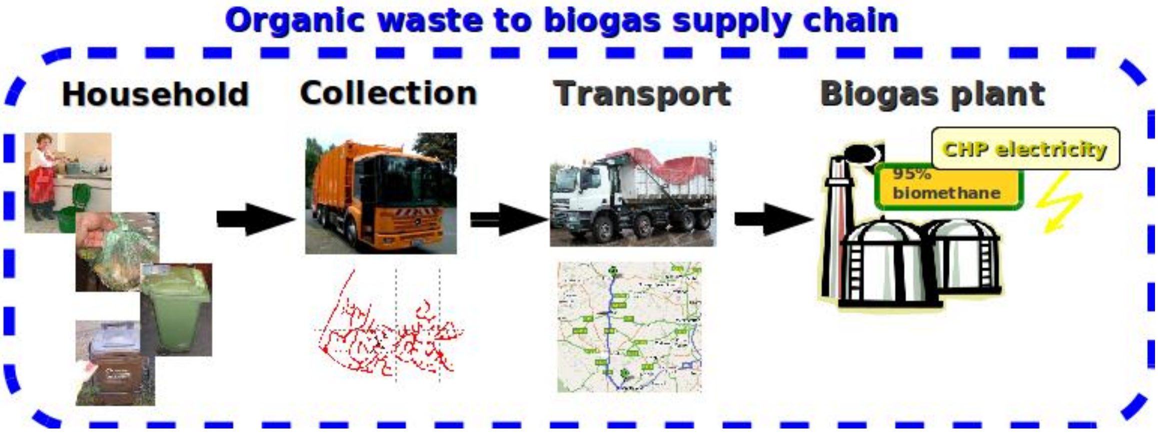

Figure 16 Typical elements of a food waste to biogas supply chain. All processes and raw material are carried out and sourced locally.

3.2. Geopolitical benefits of biogas

Geopolitical tensions remain at the core of the energy security issue with fossil fuels. The biogas from food waste supply chain is illustrated in Figure 16. Energy security advantages of biogas versus natural gas can be summarised qualitatively as follows:

- The supply chain is purely local; no national boarders are traversed; no political stability issues exist as illustrated in Figure 17 and Figure 18.
- A purely local work force and technology is employed in the biogas process chain. This strengthens local rather than remote economies.
- The commodity price for food waste is low, although its capture and collection has a cost.
- The fuel source is available continuously at a predictable cost.

3.3. Further improving energy security of the biogas pathway

Biogas is not subject to geopolitical risks but there are other, technical and behavioural areas where energy security of the biogas pathway can still be improved. Organic waste in many EU member states still ends up in landfill or incineration plants (which detracts from energy conversion efficiency due to the moisture content). Why is progress so slow? The reason why organic waste collection and processing is still behind schedule in the EU can be split into three or four problem areas as depicted in Figure 19:

1. **Technical:** Several technical problem areas can be identified such as

    - Process inhibition: There is a history of several large-scale, failing bioreactors across Europe (e.g. Neiva Correia et al 2008). The VALORGAS project has shown ways of avoiding these failures whilst running the reactors at high loading rate. A key issue in the introduction of a food waste collection system is to adopt a system that minimises contamination rates in waste stream. A high quality waste stream is highly important and the VALORGAS project has identified that systems with small bins (e.g. 25 litres) provide the lowest possible contamination rate.

- Collections: The single most energy intensive activity in the organic-waste-to-energy process chain is the waste collection operation (Larsen et al 2009). A lack of tools and knowledge hampers the introduction of best available technology that minimises emissions and labour. The collection of food waste represents the single most parasitic demand in the biowaste-to-energy process chain. The VALORGAS project has established methods to improve and optimise the collection operation.
- Digestate options: It is not clear how to best to recycle digestate in order to maximise environmental benefit.
- Heat: In too many cases heat from CHP engines is simply discharged to atmosphere.

Figure 17 European gas network is trans-national and includes geopolitically unstable regions. Map source: http://www.entsog.eu

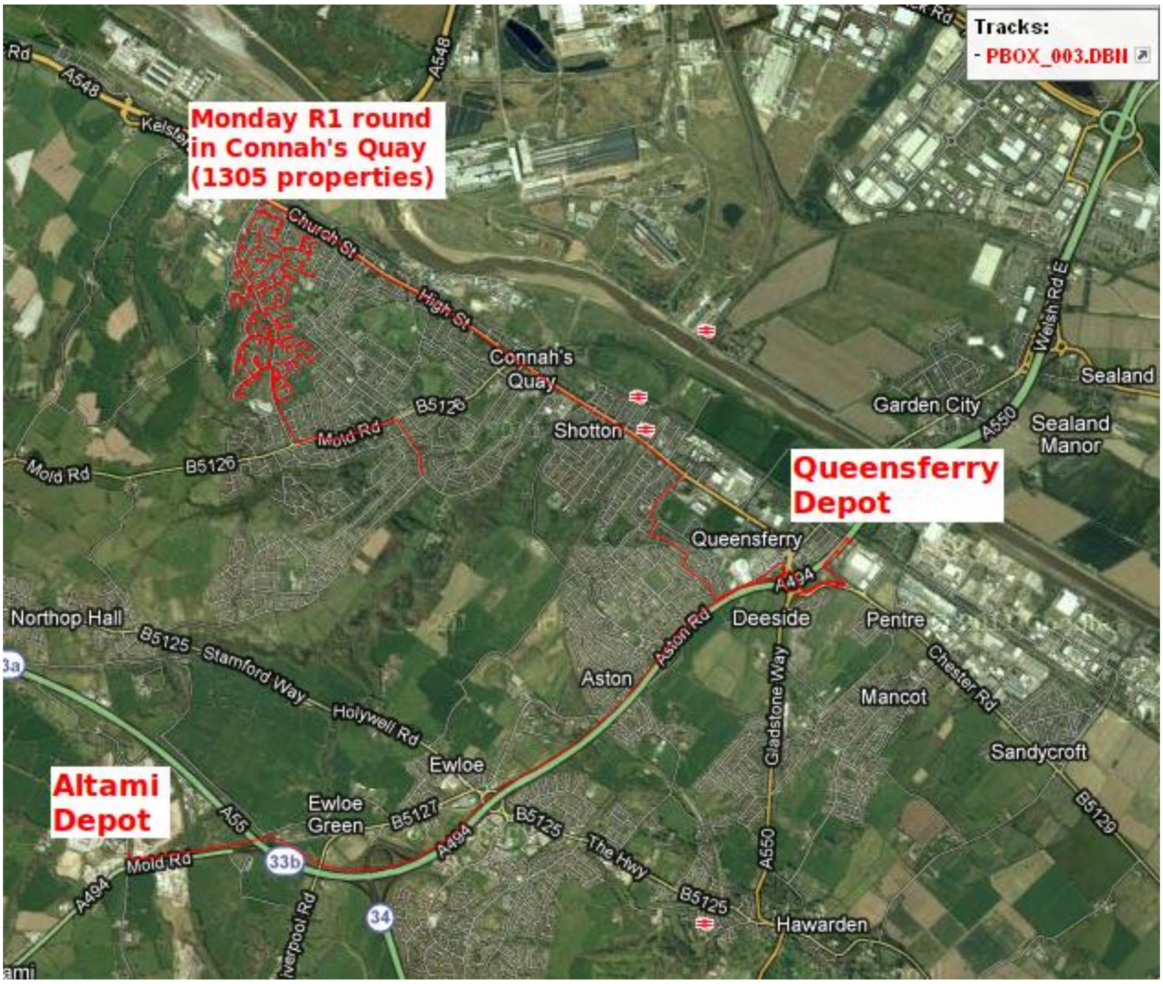

Figure 18 Example of the supply chain for biogas from food waste in the UK. No national boarders are traversed and geopolitics is therefore not an issue. Compared to natural gas this supply chain is completely local.

2. **Behavioural:** Householder discipline and householder awareness is an issue that has not been dealt with in this project but is very important. Ideally the bin system adopted should not be a factor in obtaining uncontaminated waste streams, as this complicates decision making when a collection system is chosen. However, dwellings are not designed to accommodate multiple bins and the design and functioning of the bin does affect peoples' willingness to collaborate in using it. Equally ideally, a collection system ought to be selected based on efficiency (i.e. labour and fuel minimisation) and not on contamination rates. Behavioural change with householders remains a key issue in the introduction of food waste system. Using the analogue to the built environment where "buildings don't use energy – people do" (Janda 2011) one could claim that "source separate collections work – people don't". The population can be educated so far (see below) but one must take human factors into account. If a process is seen as 'unclean' or low-status, people will not participate with it unless the alternative is drastic. A balance must be reached between efficient and acceptable.

3. **Capacity building:** Waste management is considered unattractive by many environmental engineers and the skills base may be narrower than in other disciplines . This is unfortunate since making a decision in waste management for a local authority has huge effects for years on the future of a local community. It is vital to make an informed decision and adopt best available technologies or invest into new technologies. Decision making requires skills in change management as the currently operating service cannot be interrupted and the existing infrastructure including lorries and depots need to be taken into account. Raising a new breed of waste officers is necessary to tackle these issues.

4. **Political/taxation:**There are a number of EU countries that have successfully introduced source separation of organic waste in the majority of their local authorities. On the other hand, a number of EU countries, many with low GDP, have no recycling in place at all. In some cases the introduction of source separated collection of organic waste and associated processing capacity may increase costs compared to a landfill solution that is currently in place. Particularly in countries with low GDP this presents a large obstacle. In many cases it is politically impossible to impose a tax rise to finance better waste management- even if such a move would be ethically justifiable and particularly if other carbon intensive purchase power is cut (such as purchasing and driving a car).

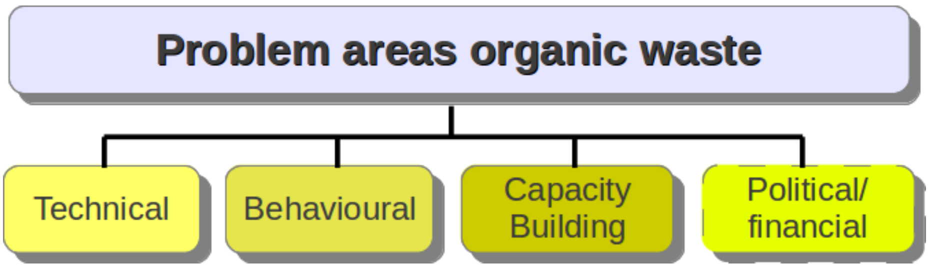

Figure 19 Problem areas in the adoption of organic waste to biogas technology in the EU.

3.4 Challenges with waste to biogas, but why it can be successful

Some uncertainties about potentially negative effects from biogas plants such as eutrophication from digestate runoff and gas leakage from biogas plants exist. These issues are not new,however. Gas leakage for example equally applies to current fossil energy supply routes, including shale gas:

> "…there are the emissions from shale gas. It has been calculated that only about 4% of shale gas would need to escape to the atmosphere as 'fugitive' emissions for the greenhouse gas emissions from the production and subsequent combustion of such gas to be as great as emissions from coal." (Professor Paul Ekins, https://ukerc.wordpress.com/)

In terms of environmental benefit, the carbon intensity of biogas electricity from biogas and transport fuel from biogas is not widely known. The carbon intensity of biogas electricity or of biogas transport fuel needs to be reviewed together with the underlying assumptions.

Despite only being a relatively small player in the energy supply market what, then makes biogas competitive? The reasons are as follows:

- Biogas is renewable. There will always be organic waste. It contributes to a more cyclic society.
- Biogas plants provide a distributed, non-centralised supply system compared to large scale nuclear or coal fired power plants. A decentralised energy source makes the overall system less vulnerable.
- Biogas is a low risk and low hazard technology compared to the low risk but potentially highly hazardous consequencesof alternative technologies such as nuclear power or fracking.
- Biogas can be considered a very low carbon technology. There are very few other technologies that can compete at this level. Biogas as a transport fuel is believed to exhibit very low carbon emissivity but very few studies exist that investigate this. As an example, Figure 20 shows CO_2 equivalent emissions for the fuel generation pathway for various fossil and renewable fuels .
- Biogas is domestic technology. Capital and labour are supplied locally rather than from remote countries.

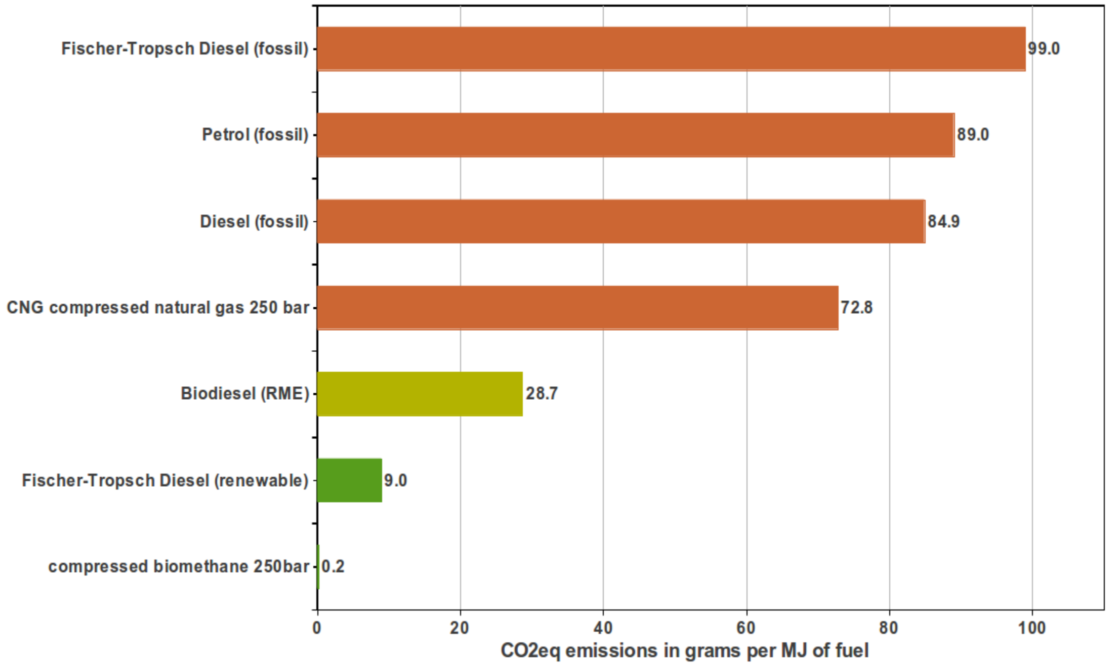

Figure 20 Specific CO_{2eq} emissions for various fossil and renewable fuels. Source: Ramesohl et al 2003.

The renewable energy share across all consumption sectors in Europe in 2010 was close to 10 % on average (http://epp.eurostat.ec.europa.eu). It is steadily increasing and biogas can contribute to this development with several added benefits:

- removing organic waste from the landfill waste stream and
- displacement of fossil based fertilisers with digestate to become a more cyclic society.
- development of markets for soil improvers
- an excellent cost/benefit ratio both financially and environmentally

4. Conclusions

In line with the findings of this paper, a literature review on the effect of renewables on energy security shows that virtually all authors report increased energy security with an increase of renewable energy sources. Biogas, together with other renewables, is able to raise energy security compared to natural gas. Rating biogas against twelve energy security dimensions demonstrates that biogas can play a valuable role in the energy mix of a new supply landscape in Europe. Multiple benefits that other energy pathways cannot offer make biogas a highly sustainable as well as secure option – generation of locally sourced energy, processing of waste and recycling of fertilisers. A simple back-of-the envelope analysis estimates the potential of biogas to EU renewable energy targets as follows:

- Based on 2011 consumption level, biogas can provide around 0.5 % of the total primary energy consumption in the EU.

- Biogas can providearound 1% of the current householder electricity consumption in Europe under the assumption that 100 kg of organic waste is captured per year per capita. If the capture rate is 50 kg per capita per year, 0. 5 to 1 % of the current householder electricity consumption can be generated from biogas. Theshare goes up if current levels ofelectricity consumption can be reduced.

- Biogas can provide about 1 % of transport fuel with current (unsustainable) life style and technology. The contribution can be increased if latest technology is introduced or current consumption levels are reduced.

Biogas from organic waste provides a level of energy security that is as good as that of solar and wind energy, but without any intermittency effects. It therefore has a role to play in both sustainable energy policy and in improving energy security.

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