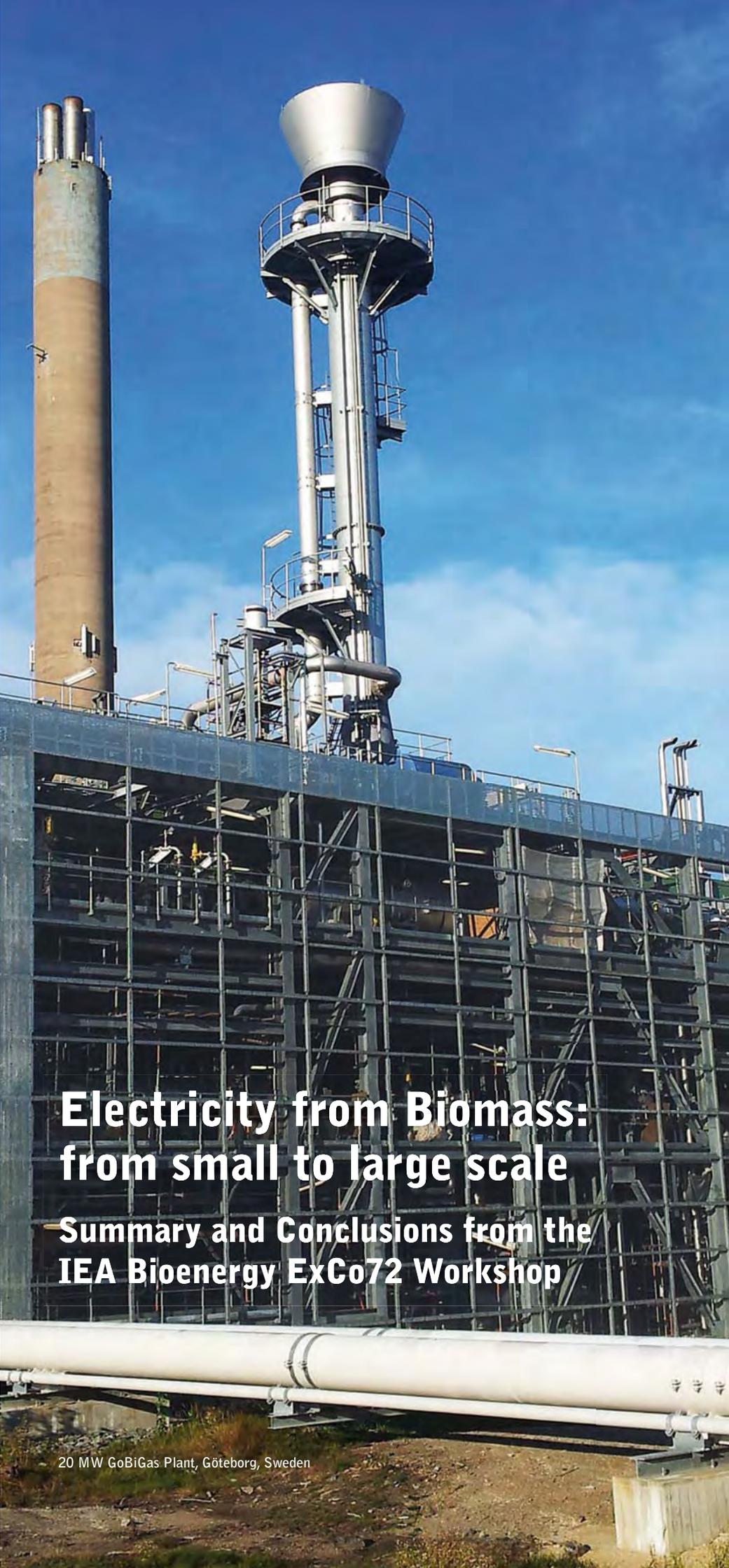


This publication provides the summary and conclusions from the workshop 'Electricity from Biomass: from small to large scale' held in conjunction with the meeting of the Executive Committee of IEA Bioenergy in Jeju, Korea on 12 November 2013.

The purpose of the workshop was to provide the Executive Committee with an overview of electricity from biomass. The aim was to stimulate discussion between the Executive Committee, Task Leaders, invited experts, and various stakeholders and thereby to enhance the policy-oriented work within IEA Bioenergy.



Electricity from Biomass: from small to large scale

Summary and Conclusions from the IEA Bioenergy ExCo72 Workshop

IEA Bioenergy

IEA Bioenergy: ExCo:2015:02

20 MW GoBiGas Plant, Göteborg, Sweden

INTRODUCTION

The Executive Committee of IEA Bioenergy held its biannual meeting on the island of Jeju in South Korea in November 2013. Alongside the meeting, a half-day workshop was organised on *Electricity from Biomass: from small to large scale*, including contributions from the host country, Europe, the USA and IEA's headquarters in Paris.

The workshop was opened and moderated by IEA Bioenergy chairman Paul Grabowski, who also led the discussion.

Session 1 – Technology and Policy background

MEDIUM-TERM OUTLOOK FOR RENEWABLE ENERGY – WHAT'S NEXT FOR BIOENERGY?

Anselm Eisentraut, IEA Paris

The contribution of Anselm Eisentraut, based on the IEA's *Renewable Energy: Medium-Term Market Report 2012*,¹ is focused on projecting global renewable energy developments over the next five years. It forecasts renewable energy generation and capacity across eight technologies: hydropower, bioenergy for power, onshore wind, offshore wind, solar photovoltaics (PV), concentrating solar power (CSP), geothermal and ocean.

Development of RE up to 2012

With profound changes in renewable energy (RE) markets and uncertainties due to both the economic crisis and subsidy reductions in some key markets, power from renewable energies faces strong challenges. On top of this, discussions on sustainability are setting another hurdle for the deployment of power from biomass. As a consequence, hydropower and onshore wind take on extra importance.

However, renewable electricity generation is growing rapidly and deployment opportunities are expanding. The year 2012 was particularly successful; total global renewable capacity and generation grew by 8%. This was due to a good hydro year in China, but, most importantly, to another substantial increase in non-hydro power production (+21%). Both onshore wind and PV grew faster than expected, spurred by declining costs and the rush to exploit still available incentives.

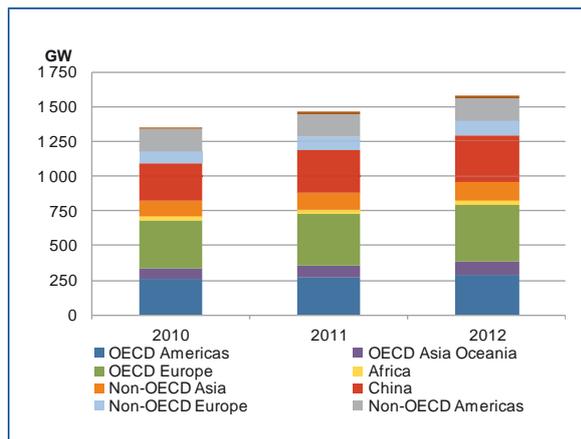


Figure 1: Global renewable electricity capacity, by region

While remaining at a high level, overall investment in renewables fell in 2012 by 12%. This is partly due to cost reductions in some of the key technologies (PV and wind), but also to the fact that, in some of the best-developed RE markets, policy uncertainties linked to the difficult macro-economic situation, reductions in incentives and competition from other sources (notably low-cost gas in the US) led to reduced investment.

Development of RE after 2012

In 2012 hydropower was the largest renewable energy technology, followed by onshore wind. Even though some people think that the wind potential has been exploited, the models show that wind will remain the largest-increasing single RE source. Hydro advances at a rather stable rate of an additional 35-40 GW per year. However, for the first time, additional generation from all non-hydro sources exceeds that from hydro (Fig. 2).

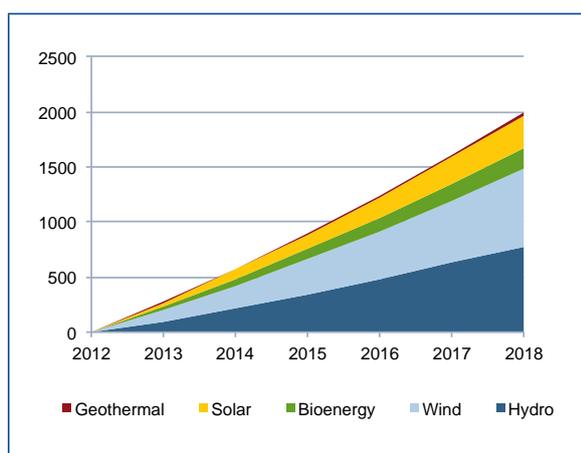


Figure 2: Forecast cumulative RE power additions (TWh)

¹ IEA, *Renewable Energy: Medium-Term Market Report 2012 – Market Trends and Projections to 2017*: https://www.iea.org/publications/freepublications/publication/MTrenew2012_web.pdf

Building on several years of strong deployment, renewable electricity growth should accelerate over the medium term. From 2011 to 2017 generation should expand by 1,840 TWh, almost 60% higher than the 1,160 TWh growth registered for the 2005 to 2011 period. Global power generation from renewable sources stood at 4,540 TWh in 2011, 5.8% higher than in 2010, and is projected to reach almost 6,400 TWh in 2017 (+5.8% annually).

Even as the annual average growth in renewable generation accelerates – to 5.8% from 2011 to 2017 versus 5% from 2005 to 2011 – expansion trends and geographies remain specific to technologies. For non-hydropower sources (PV, CSP, wind, bioenergy for power, geothermal and ocean), the average percentage increase, at 14.3% annually, is somewhat slower than the 16.2% growth from 2005-11 as technologies continue to mature. Yet absolute growth for these sources is much higher (+1,100 TWh for 2011-17 versus +530 TWh for 2005-11).

While renewable electricity is expanding across the world, its growth in the OECD areas is also noteworthy, providing the largest contribution when compared to other fuels (Fig. 3). In the Americas, renewables are second only to fossil fuels, largely in the form of natural gas. In Asia-Oceania, RE is expected to be second to nuclear (assuming the restart of part of the nuclear power plants in Japan). In Europe, RE will show more than 100% growth; fossil fuels and nuclear will show a net decrease.

More specifically, RE will be three times higher than gas, oil and coal (due to decommissioning) and larger than new gas, leading to a net negative balance for fossil fuels.

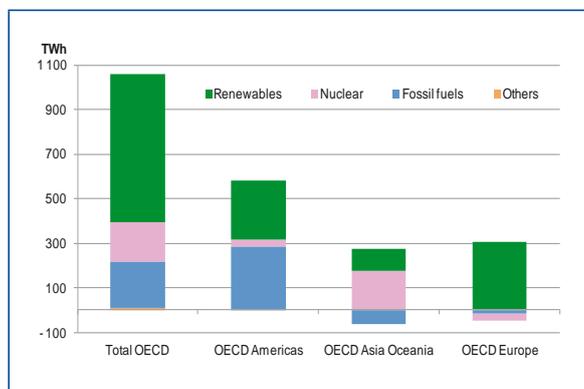


Figure 3: Changes in power generation by source and region, OECD, 2012-18

In 2018, non-OECD countries will account for 58% of total renewable electricity generation, up from 54% in 2012 and 51% in 2006. China alone is expected to account for 40% of the global growth. Other expected key markets are Brazil (wind, bioenergy), India (wind, solar, bioenergy), South Africa and Morocco (wind, solar), Thailand (bioenergy) and the Middle East (solar, wind).

The forecast for renewable electricity generation is based on the persistence of supportive policy and market frameworks as well as the increased economic attractiveness of renewable technologies in a greater range of countries and circumstances. Moreover, technology cost developments, grid and system integration issues, and the cost and availability of financing will also weigh as key variables.

Overall, however, the forecast is influenced by a high level of economic and policy uncertainty in some key areas of the world. At the time of writing, the outlook for the global economy, particularly in Europe, remains cautious, while several countries are still debating significant changes to renewable energy policy or deeper electricity market reform.

Growth of bioenergy

Bioenergy for power encompasses the use of solid biomass, biogas, liquid biofuels and renewable municipal waste for power production. Biomass is not only used in dedicated power and co-generation plants, but is also co-fired with other dominant fuels such as coal. The most efficient use of bioenergy resources for power generation involves co-generation, with full use of electricity and heat throughout the year, as in the pulp and paper industry.

In 2011, bioenergy contributed 308 TWh to global power production. The United States led the generation at 61 TWh, though growth in recent years has been slow (Table 1). Germany and China have been growing at faster rates. German growth is driven by biogas, which increased from 4.7 TWh in 2005 to 19.2 TWh in 2011. China is driven by an ambitious target of 30 GW of bioenergy-to-power applications in 2020. Other non-OECD countries are also expected to add significant new generation. Southeast Asia tops developments among non-OECD regions; Thailand accounts for half of the regional installed capacity, followed by Malaysia and Indonesia. These countries can take advantage of ample available wastes from the palm-oil and sugar-cane industries.

According to the IEA Bioenergy Roadmap, the world bioenergy electricity supply should grow more than tenfold, from a share of 1.5% today to 7.5% in 2050, or from 280 TWh today to 3,100 TWh in 2050. A total of 50 GW of the total 510 GW of biomass electricity capacity will be equipped with Carbon Capture and Storage (CCS), allowing for negative emissions.

Renewable energy use for **heat in buildings and industry** stood at 44 EJ in 2011, including 36 EJ in the building sector, covering 43% of final energy use, but only 8 EJ in industry corresponding to 10% of total heat consumption. Biomass is the only significant renewable energy source of heat in industry to date; 90% of renewable heat comes from solid biomass used in non-OECD countries.

Other than for electricity, biomass is expected to continue to lead in the heat sector. The drivers are: a mature technology that is competitive as against the alternatives; increasing commercial heat use from co-generation plants and co-firing with coal, and being generally suitable for providing low-emissions process heat in industry.

Table 1: Electricity generation from biomass

	2011	2012	2013	2014	2015	2016	2017	CAGR*
World	308	352	387	421	457	494	532	9.6%
China	34	36	59	73	87	101	114	22.2%
United States	61	67	69	72	75	78	80	4.9%
Germany	37	35	37	38	39	41	42	2.1%
Brazil	22	28	24	26	28	30	32	8.9%
Japan	18	22	24	26	28	30	32	9.6%

* CAGR: Compound annual growth rate

World biofuel production is expected to grow by 25% by 2018, to reach 2.36 Mb/d, an increase of 485 kb/d from 2012. On an energy-adjusted basis versus oil, biofuels are forecast to provide 4% of global road transport fuel demand in 2018 (Fig. 4).

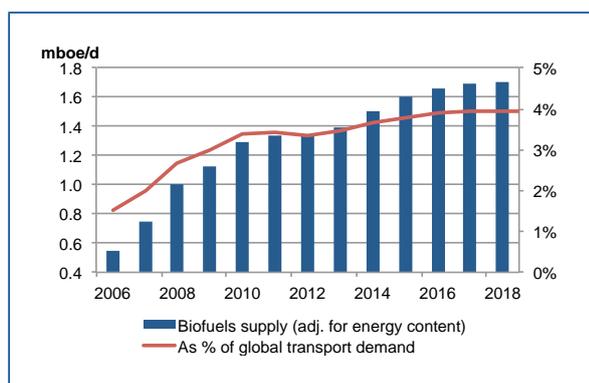


Figure 4: Biofuels share in global road transport

Uncertainty as regards support policies in the EU and the US presents an important downside risk, and might undermine the sector's growth potential. **In the EU**, draft legislation launched by the European Commission in October 2012 suggests limiting the use of food-based biofuels to 5% of energy demand in the transport sector (roughly the current average blending share in the EU), instead of a maximum 10% as currently stipulated in the Renewable Energy Directive. Although discussions on the proposal are ongoing, the industry's confidence has already been affected, with likely negative implications for future investments in the sector.

In the US, severe drought in 2012 led to increased public opposition to the Renewable Fuel Standard 2 (RFS2), the principal policy instrument to promote biofuel production and use in the US. This came mainly from livestock farmers who saw their margins disappear as a result of high corn prices. Since the beginning of 2013, the efficacy of the RFS2 has been called into question; market participants claim to have great difficulties in surpassing the ethanol 'blend wall', which represents a 10% share, approximately, of ethanol in the gasoline pool.

In the non-OECD Americas, biofuel production reached 510 kb/d in 2012, a 25 kb/d year-on-year increase. Looking ahead, the region's production should grow from 560 kb/d in 2013 to 720 kb/d in 2018, driven mainly by growth in Brazilian ethanol production.

Brazilian ethanol production should grow by 50 kb/d in 2013, as the result of an expected bumper sugarcane harvest, the setting of the domestic ethanol mandate from 20% back to 25%, and the improved competitiveness of ethanol production over sugar. The sugarcane sector is still in financial difficulties that are likely to persist as low sugar prices affect the profitability of smaller and outdated mills.

Argentinian biodiesel production is to drop 7 kb/d to 40 kb/d in 2013, as the result of an ongoing anti-dumping investigation by the EU that resulted in the introduction of import tariffs on Argentinian biodiesel exports to the region as of the end of May 2013. The investigation has already had a strong impact: biodiesel exports in 2012 declined by 7.5%, and Q1 2013 exports were down 50% year-on-year.

Policy framework

As highlighted in most of IEA Bioenergy's workshop summaries, a stable policy framework is of crucial importance for the development of any form of renewable energy. Bioenergy is especially sensitive because it depends on two important policy issues, agriculture and energy.

How major legal changes can influence the development of new renewable technologies has been demonstrated by an abrupt retroactive policy change in Spain, where the PV industry broke down completely because of a cap in 2009 and then a moratorium starting in 2013. Another example is the effect of stop-and-go politics in the US concerning wind power (Fig. 5).

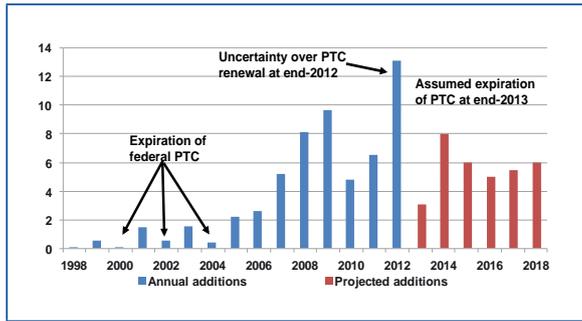


Figure 5: US onshore wind annual additions (GW)

Conclusions

Many renewables no longer require high economic incentives, but they do need long-term policies that provide a predictable and reliable market and regulatory framework. A consistent policy framework is more important than specific types of RE incentives.

Bioenergy has an increasingly important role to play in providing renewable, low-carbon energy in all sectors, and dispatchable renewable power that is competitive with fossil-fuel generation under favourable circumstances.

There are two major challenges for biomass electricity:

- 1) The cost-reduction potential is more limited than for other renewable electricity technologies (e.g. for PV). Hence, it is crucial to establish supply chains for large-scale feedstock supply.
- 2) A firm sustainability framework is needed to ensure the overall positive impact of bioenergy development.

BIOMASS IN THE ELECTRICITY SECTOR AND EU POLICY DEVELOPMENTS ON BIOMASS

Arthur Wellinger, Technical Coordinator, IEA Bioenergy, with the support of Fanny-Pomme Langue, AEBIOM

Arthur Wellinger presented the contribution, with inputs from AEBIOM, the European Biomass Association. AEBIOM, located in Brussels, was founded in 1990 and represents 36 national associations and 80 companies.

The driver: Renewable Energy Directive

The driver for renewable energy in Europe is the Renewable Energy Directive² (RED), also called the 20/20/20 Directive, meaning a reduction in Europe's overall energy consumption of 20%, a total of 20% of renewable energy in the EU's total energy consumption, including a 10% share of RE sources in transport, and reduction of CO₂ emissions by 20% – all by 2020. For each member state, a total share of RE was calculated, and each country prepared a National Renewable Energy Action Plan³ (NREAP) outlining how it planned to fulfil the target set (amount and type of RE sources). The all-European consumption targets distinguished between the three sectors of Heating & Cooling, Electricity, and Transport.

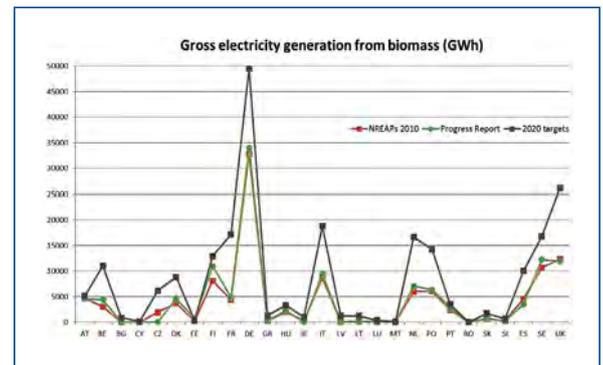


Figure 6: RED 2020 targets, intermediate targets 2010 (NREAPs 2010), and production according to Commission's progress report

In 2013 the Commission issued a first report assessing member states' progress in the promotion and use of renewable energy, and reporting on the sustainability of biofuels consumed in the EU and the impacts of this consumption in accordance with the RED. The assessment is based on Eurostat data (for 2009 and 2010), member states' RE progress reports submitted to the Commission in 2011⁴ and Commission evaluations of 2012 energy production and consumption.

² <http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2009:140:0016:0062:EN:PDF>

³ http://ec.europa.eu/energy/renewables/action_plan_en.htm

⁴ http://ec.europa.eu/energy/renewables/reports/2011_en.htm

Fifteen member states failed to reach their indicative 2010 targets for the share of renewable energy in the electricity mix. For biomass, the trend is also slightly negative – but much less than for wind and solar power. A total of 53% of the predicted total of 229 TWh by 2020 was produced in 2010. Biogas contributed 20%, bioliquids 5% and solid biomass 75% to the 2010 production of 121.2 TWh of electricity.

Figure 6 shows the 2020 RED targets, the indicative intermediate targets for 2010 (NREAPs 2010), and the real production in 2010 of electricity from biomass. The bulk of biomass electricity is produced from pellets, mostly in co-incineration plants with coal. Since Europe cannot produce enough pellets to cover needs, trade has been increasing in recent years. According to IEA Bioenergy Task 42, the trade volume of wood pellets between EU and non-EU countries totalled about 45 PJ⁵ in 2010, which is comparable to biodiesel (about 75 PJ) and bioethanol (about 16-22 PJ). The largest exporters to Europe in 2012 were the USA with 2M tonnes, Canada with 1.7M tonnes and Russia with 900,000 tonnes⁶ (Fig. 7).

The imports will continue to increase. Europe is by far the world's largest consumer of pellets. The EU consumes about 19.5M tonnes (11.4M in the industrial sector; 8M in the residential), the rest of the world about 5M tonnes⁷. In 2012 the largest nine end users consumed almost 7M tonnes (85%) of industrial pellets (RWE 2m, GDF Suez/Electrabel 1.4M, Dong 850k, Drax 700k, Vattenfall 500k, Dalkia 395k, Fortum 300k, EdF 200k and Delta 150k).

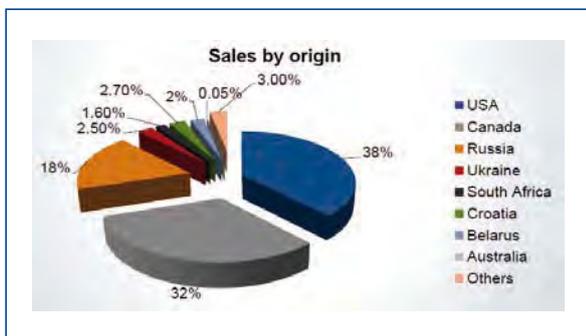


Figure 7: Share of pellets by countries exporting to Europe

Having begun a process in 2013, the UK alone will radically redraw the pellet map in the very near future: Drax Power plans to convert three of its six 660 MW units to 100% wood-pellet firing (total 2 GW) between 2013 and 2017; E.ON Ironbridge will temporarily convert one 440 MW (by 2015); Eggborough Power plans four 500 MW by 2016; International Power – Rugeley plans two 500 MW (expected in 2015). The latter three will consume up to 3M tonnes of pellets per year, while Drax will increase consumption to about 2M tonnes per year.

The barrier: Renewable Energy Directive

The Renewable Energy Directive of the European Union (RED) has contributed to the deployment of bioenergy. On the biofuels side, the situation has been more complicated due to discussions on indirect land-use change (iLUC) accounting, a relatively new method that is not scientifically well-based. In the RED, it was planned from the beginning to introduce iLUC as soon as a method and corresponding database was available. However, the time needed to elaborate scientific values was completely underestimated, so that, to be on the safe side, extremely high values were introduced.

As a result, the challenge for bioenergy was not so much based on new scientific evidence but rather on political lobbying in Brussels and in the member states.

In autumn 2012, the Commission proposed a directive to amend the RED and Fuel Quality Directive (FQD) to take into account the ILUC question.⁸ Among other moves, it is proposed to strengthen the CO₂ reduction (requiring 60%) for new bioenergy plants. In addition it was proposed to limit first-generation biofuels in transport to 5%, with the other 5% being covered by advanced biofuels and renewable electricity. Since, with this new requirement, the 10% target for fuel from RE could not be reached by 2020, it was proposed to count advanced biofuels four times. In other words, Europeans would drive on virtual fuel.

The sustainability debate also concerns solid and gaseous biomass for heat and electricity, for which there is no EU harmonised and legally binding approach, but only European Commission (EC) recommendations. Carbon accounting is part of the debate on sustainability criteria for solid and gaseous biomass; i.e. what is the payback period for the CO₂ emitted when trees are cut and used for energy only? Most non-governmental organisations (NGOs) have taken the single-tree approach; this counterfactual reasoning leads of course to a seemingly negative carbon balance. Greenpeace, Friends of the Earth and the Royal Society for the Protection of Birds (RSPB) even claimed⁹ (supposedly based on a scientific report) that, over 40 years, the use of whole trees as an energy source would increase greenhouse-gas emissions by at least 49% compared to using coal.

⁵ *Biofuels, Bioprod. Bioref.* 7:24–42 (2013); DOI: 10.1002/bbb

⁶ Dale, Arnold; 2013. AEBIOM Conference Brussels, June 2013

⁷ Blaire, Louisa; 2013. AEBIOM Conference Brussels, June 2013

⁸ COM(2012) 595 final

⁹ 'Biomass – dirtier than coal?' November 2012, http://www.rspb.org.uk/Images/biomass_report_tcm9-326672.pdf

AEBIOM (the European Biomass Association), the US Industrial Pellet Association (USIPA) and the Wood Pellet Association of Canada (WPAC) have produced a study on carbon balance, with the focus on pellets produced in south-eastern USA and British Columbia, where most of Europe's pellets come from.¹⁰ In both regions, forestry is practised under strict guidelines that help to ensure responsible harvesting and restoration of harvested sites. The cutting of trees is not driven by energy production but by high-value products such as lumber and plywood. Pellets are just a side product. The report shows that today's dominant bioenergy systems using wood pellets from Canada and south-eastern USA achieve significant GHG savings, and make a meaningful contribution to climate-change mitigation. Carbon debt and foregone sequestration in realistic bioenergy scenarios are very small compared to the carbon savings that are achieved over time. Further, there is a critical difference between a small and temporary carbon debt (where one might exist) and the permanent fossil carbon emissions savings achieved by using bioenergy rather than fossil fuels.

BIOMASS ENERGY IN NORTH AMERICA: OPPORTUNITIES AND CHALLENGES

Bob Cleaves, President, Biomass Power Association

The Biomass Power Association (BPA), founded in 1999, is the USA's leading voice for biomass as a means of generating electricity. It represents over 2,000 MW of installed capacity. The 75 BPA members include sawmills, paper companies and independent power producers, doing business in 22 states and contributing nearly \$1 billion to the national economy.

In 2009 renewable energy in the USA covered only 8% of primary energy consumption. Bioenergy accounted for half of this, ranking first before hydro, wind and geothermal (Figs. 8a and 8b).

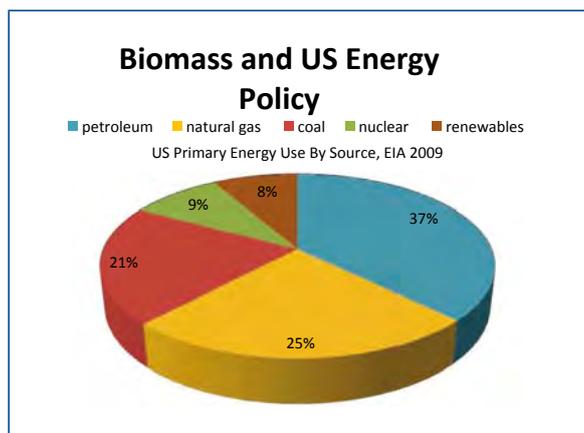


Figure 8a: US primary energy use by source (2009)⁶

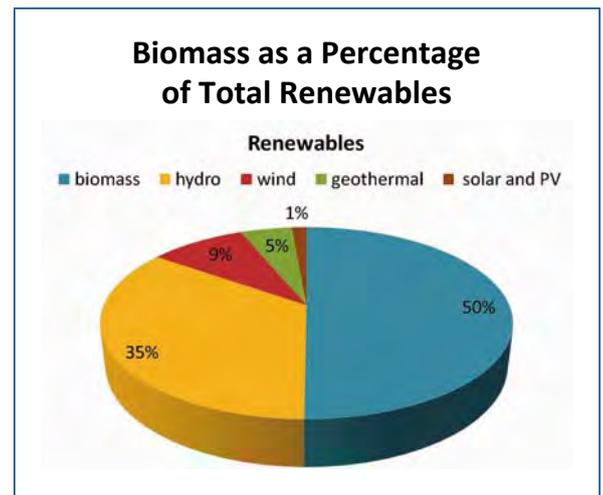


Figure 8b: Biomass as percentage of renewables

The predominant (75%) biomass fuel is paper-mill residue – i.e. 'black liquor'. The remaining 25% is wood residuals, forestry byproducts, agricultural residues, forest thinning and 'urban wood', mostly used by independent power producers.

Today, the US biomass industry is at a crossroads. The contribution of biomass power generation is only second to that of hydropower among the renewables contributing to the national energy supply. Biomass has always been used to generate power in the forest products industry, but its widespread use for supplying power to the US grid is a relatively recent phenomenon, a response to the energy crises of the 1970s. Today 121 independent biomass power generators with an installed capacity of 3,000 MW supply approximately 18 billion kWh_{el}/yr to the national electricity grid (Table 2) and, in the process, provide an environmentally superior disposal service for close to 30 million tons/yr of solid waste that otherwise would be burned or landfilled.

Table 2: Facilities injecting biomass electricity into the US national grid

	No. Facilities	MW
Operating	121	3,031
Planned	54	2,247
Under Construction	18	550
Closed/Idle	20	374
Total	213	6,203

¹⁰ AEBIOM, Sept. 2013. 'Forest Sustainability and Carbon Balance of EU Importation of North American Forest Biomass for Bioenergy Production'. www.aebiom.org

The problem is that, in the current environment of cheap fossil-fuel supplies and deregulation of the electric utility industry, biomass power generation may be unable to compete. The inherent cost of power generation from biomass is high, for two principal reasons:

- (1) Biomass is a low-density fuel, so fuel production, handling and transportation are more expensive than for fossil fuels.
- (2) Because of the dispersed nature of the resource, biomass power-generating facilities tend to be small, so they cannot capture the economies of scale typical of fossil-fuel-fired generating facilities. These characteristics leave biomass generation at a distinct disadvantage in a market that is increasingly driven by cost.¹¹

The great dilemma for public policy is that, although biomass power generation is expensive, it also provides very valuable waste-disposal services that would be lost if the industry were to fail.

Greenhouse-gas emissions are currently not regulated in the United States except in a few states, and enacting programmes to limit them is controversial. Counting greenhouse-gas emissions at zero value leaves a residual value for the environmental benefits of biomass energy production for all other impact categories of 4.0 ¢/kWh. Taking minimum estimates for the values of all impact categories included in the analysis, the computed value of the non-electric benefits of biomass energy is 4.7 ¢/kWh. Using a long-term perspective for the delayed emissions from landfills yields a calculated benefit value of 14.1 ¢/kWh. A US Department of Energy study concluded that the environmental benefits of biomass power are worth at least 11 cents per kWh:

- Power/REC Contract – 8.0 cents/kWh
- Production Tax Credit – 1.5 cents/kWh
- (Pre-tax equivalent of 1.0 cent/kWh PTC)

But the 'real world' economics for biomass producers are very different:

- Total production cost – 10.5 cents/kWh
- 4.4 cents – Capital/Construction/Return
- 2.5 cents – Operations/Maintenance
- 3.6 cents – Fuel

Profit: -1.0 cent/kWh

In addition there is a strong headwind blowing for bioenergy, from policy and the energy business. The low-cost shale gas drove away new developers. Prices for natural gas were below 4\$ per 1,000 cft (28 m³) in 2013.¹² It's hard to compete with natural gas even when gas prices are increasing due to the inclusion of supply risk factors after 2014.

Also, incentives for renewables are under attack. Refundable taxes, introduced under President Obama when the economy was low are running out. The Production Tax Credit and Investment Tax Credit expire on December 31, 2013. State Renewable Portfolio Standard (RPS) programmes are available in only half of the states; some support biomass, others do not. There is no federal feed-in tariff or national energy policy.

In mid-September 2013, the US Department of Agriculture (USDA) made a public commitment to support bioenergy, including the biomass, pellet and thermal industries. At a press conference, Deputy Secretary Krysta Harden signed a memorandum of understanding (MoU) with the Biomass Power Association and a few sister organisations. Indeed, there are a few realistic drivers:

- Biomass power now provides over half of America's renewable 'green' electricity, reducing dependence on foreign oil and providing enough electricity to light about 8.5M American homes.
- America's biopower industry provides some 14,000 quality jobs and generates about \$1 billion a year for the nation's economy.
- Each biomass power plant contributes about \$8M to \$14M annually to the local communities where they operate, in payroll, purchases and property tax revenue.

Even though not many new biomass plants have been built, power production is still increasing, either because existing units are upgraded or coal plants are turned into biomass incinerators. In Berlin, New Hampshire an old plant has been converted into a bubbling fluidised bed (BFB) boiler (Fig. 9).



Figure 9: Bubbling Fluidised Bed technology before integration into an existing boiler

The upgraded plant yielded substantially higher efficiency (Table 3) at reasonable cost. Still, the plant, with a resulting electricity price of 14.3 US cts/kWh, was not built without subsidies.

¹¹ 'The Value of the Benefits of U.S. Biomass Power', 1999. NREL/SR-570-27541, <http://www.nrel.gov/docs/fy00osti/27541.pdf>

¹² http://www.eia.gov/dnav/ng/ng_pri_sum_dcu_nus_m.htm

Table 3: Efficiency increase of the Berlin, New Hampshire boiler adapted with a BFB

Upgrading of Existing Boiler		
Steam Flow	575,000 lb/hr	40% increase
Steam Pressure	900 PSIG	6% increase
New Superheater	925F	12% increase

The key elements of success were:

- Supportive political environment
- 20-year power purchase agreement
- \$83 per MWh subject to fuel adjustment clause
- Capacity payment of \$4.25 per kW and month valued at \$1.43 billion over 20 years
- Federal Investment Tax Credit (30% under Section 1603 grant)
- 'New Market' tax credits

In Fort Drum, Gainesville, a 100 MW BFB unit replaced the existing coal-fired plant. About 1M green tons will be used per year instead of natural gas as the alternative. Drivers for the decision were the volatile natural-gas price and the creation of 1,000 jobs during construction, followed by 700 permanent jobs.

The 1M green tons of biomass fuel will be made up of forestry wood (425k to 625k green tons/yr) composed of low-value trees, treetops and branches remaining after commercial tree harvest and land clearing, urban wood (375k to 425k green tons/yr), clean wood waste consisting of urban tree, limbs, brush, pallets and structural lumber mill residues (30k to 50k green tons/yr), and residues from primary and secondary wood processing (bark, sawdust, shavings, scraps and woodchips).

There is good potential for biomass in the US, of 680M tons annually. This is equivalent to 54 billion gallons of ethanol, or 732 billion kWh of electricity, worth 19% of total power consumption. There are roughly 400M tons of energy crops; 155M tons of agricultural residues; 35M tons of waste biomass and 20M tons of forest waste biomass. A large fraction thereof is considered as sustainable even under the most stringent standards. Exploiting natural forest makes no sense on a purely economic basis.

Politically, biomass has a serious granting problem due to lifecycle assessment (LCA) reports and methods of carbon accounting. There is a chance that new Environmental Protection Agency (EPA) studies will improve the situation.

SITUATION AND STRATEGY OF BIOMASS ELECTRICITY IN ASIA

Hyung-Bae Gi and Jinwon Park, Korea Institute of Energy Technology Evaluation and Planning

According to the IEA World Energy Outlook, the use of biomass for electricity and transport fuel will continue to grow until the year 2035. In contrast, heat production from biomass will continue to decrease even more after 2020.

Between 2000 and 2010, worldwide production of electricity from biomass grew by about 6.9% per year. It is expected that, by 2020, 40% of the installed power will be from renewable energy excluding hydropower. However, the growth of bioenergy is heavily dependent on government policy.

Energy consumption in China and India accounts for more than 60% of total energy consumption in Asia, since the populations of both countries are very large (Fig. 10). Asian consumption is expected to double between 2004 and 2020; for China and India, the predicted increase is even (slightly) higher.

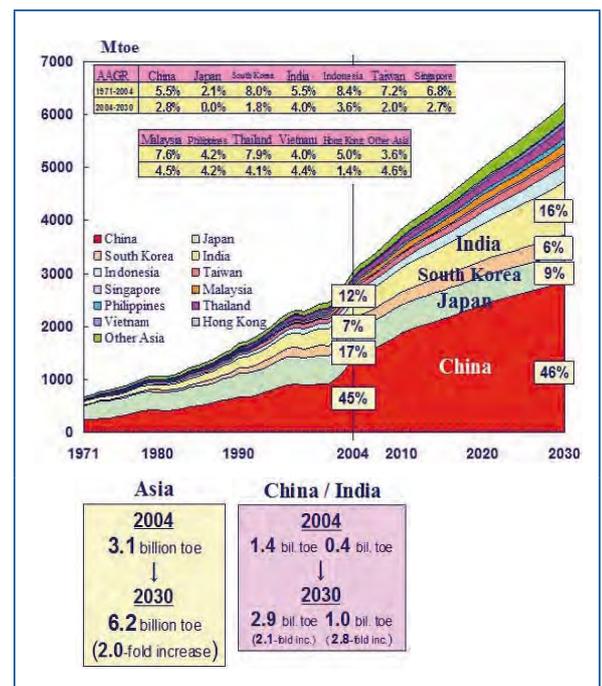


Figure 10: Asian energy outlook to 2030

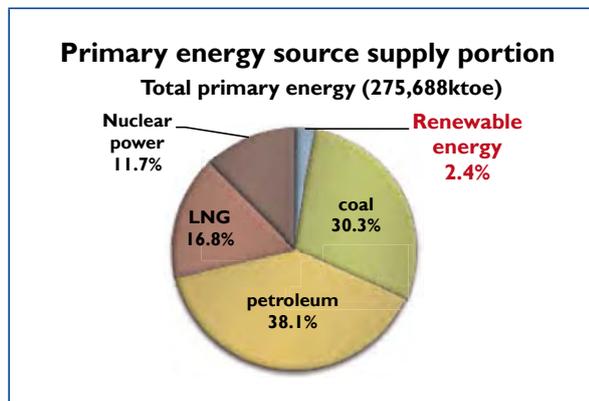
South Korean energy consumption is considerable when compared to the size of the country and the population.¹³

Most of Asia's power generation is from coal, with a share of about 60%. It is expected to decrease by only 1% by 2030. Renewable energy production is very low, at less than 1%. It is expected to quadruple, but the relative increase will remain marginal.

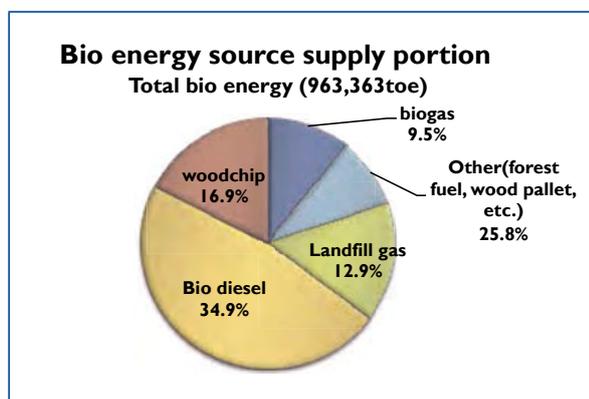
¹³ Komiya, Ryoichi; 2004. Asia energy outlook to 2030: Impacts of energy outlook in China and India on the world, The Institute of Energy Economics, Japan.

In South Korea renewable energies contribute 2.4% (2011), corresponding to 5.5 Mtoe. As a part of it, power production is in the order of 7.6 TWh. Two-thirds is produced from waste (Fig. 11). The government goal is that, in 2030, total renewable energy will supply 11%, with 7% of it produced by waste resources and biomass.

In today's renewable energy supply, bioenergy ranks third, at 12.7%. Most of it comes from imported biodiesel (35%); 22.4% is contributed by biogas, either from landfill (12.9%) or engineered biogas plants (9.5%).

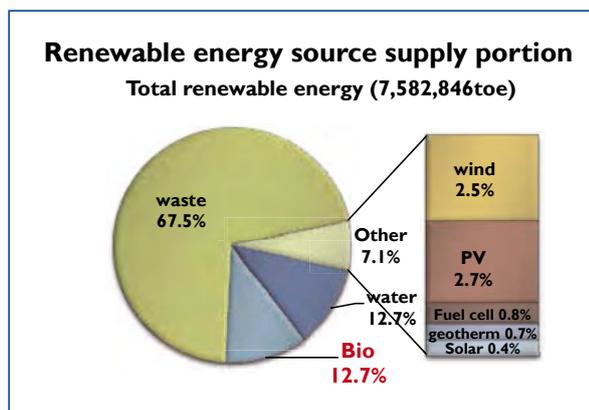


The promotional instrument for electricity production from RES has been a quota system, the Renewable Portfolio Standard (RPS), adopted in 2012. Under it, 13 major electricity companies with installed power of 500 MW or more were obliged to increase the RES share every year, following a mandatory pathway, up to a level of 10% by 2020. In 2013 RES reached 2.5%. In the first year there was financial support, which ended at the end of 2012.



The largest producer of renewable electricity is the Korean Hydro and Nuclear Power Company, with a share of 7%. This was possible because classical hydropower was accepted as RES.

Electricity from biomass is mainly produced from wood in circulating fluidised bed boilers, as in Donghae, with installed power of 30 MW, or in coal co-combustion plants with wood chips and/or dried sewage sludge, as in Dangjin, with total installed capacity of 4,000 MW (500 MW x 8), and a share of biomass in the order of 3% or a maximum of 100,000 tonnes per year. Alternatively, there is power production from landfill gas at the Sudokwon landfill site, with an installed capacity of 50 MW.



Session 2 – Success Stories: Small to medium-scale

ELECTRICITY GENERATION USING BIOGAS FROM WASTE FOOD IN KOREA

Soon-Chul Park, Korea Institute of Energy Research (KIER)

The South Korean government wants to make bioenergy – and biogas in particular – a success story. The driver behind this is the increasing amounts of (wet) food waste that have to be dealt with in South Korea. Until recently up to 70% of organic food waste was dumped into the sea, as was sewage sludge; however, this is not allowed any more. Hence, there is huge potential for biogas.

Figure 11: South Korea energy supply shares, 2011

Bioenergy is expected to increase from 0.96 Mtoe in 2011 to over 10 Mtoe in 2030, accounting for over 30% of energy production¹⁴. Waste should add an additional 33% (Fig. 12).

¹⁴ Ministry of Trade, Industry & Energy, Korea, 2012. New & Renewable Energy White Paper.

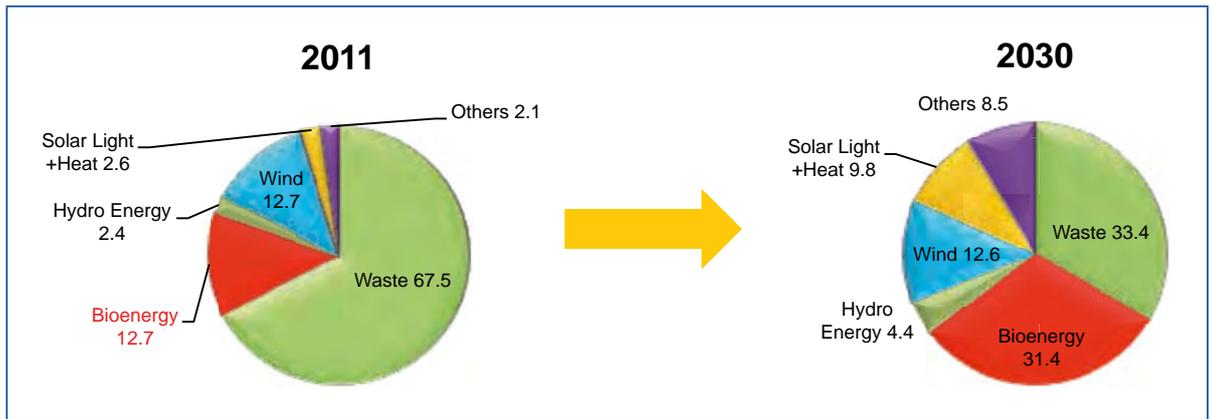


Figure 12: Development of renewable energy in South Korea, according to government white paper

A total of 129 biogas plants are currently in operation, of which 33 use food waste (Table 4). An additional 23 plants are under construction. Most of these (19) will use food waste, at least partially. Eleven more are being planned, and all but two will use food waste.

Table 4: Number of Anaerobic Digestion (AD) plants in operation in South Korea, with biogas production totals

AD Plants	Number	Biogas Production
Sewage Sludge ¹⁾	68	149,098,000 Nm ³ /yr
Biowaste (Food Waste)	12	31,270,000 Nm ³ /yr
Animal Manure	9	3,235,000 Nm ³ /yr
Industrial Waste	13	–
Landfill	18	440,814 MWh
Food Waste + Animal Manure Co-Digestion	9	13,327,000 Nm ³ /yr
Total	129	–

Co-digestion of food waste in sewage treatment plants is becoming more widespread. Thanks to the increased gas production, this can cover a far higher percentage of plants' electricity consumption.

Seoul has the largest wastewater treatment plant (WWTP) in Korea, treating some 2,700 tonnes of sludge per day. The total fermenter volume is 86,000 m³, with gas production of close to 1M m³ per year. Some of the gas is used for electricity production, and some to heat up the digesters. Seoul also has an upgrading plant and a compressor station to fuel city buses.

However, there is still considerable market potential for bioenergy, of roughly 1 Mtoe, with forestry accounting for about half and biogas most of the rest. The theoretical potential is as high as 360 Mtoe, but the technical potential is far lower, at approximately 3% of the theoretical estimation. The market potential is estimated at 0.3% – and thus lower again by a factor of 10.

Manure has high theoretical potential, but, as farms are rather small, biogas is hardly economically viable. Traditionally, the solid part of manure is composted. But, even with biogas plants, often the liquid part is digested in hybrid filters (Fig. 13) and the solid part is composted. The gas production is, of course, far lower than with full manure; the process is considered as wastewater treatment rather than energy production.

Near Seoul there are several co-digestion plants digesting food waste and the unseparated manure.

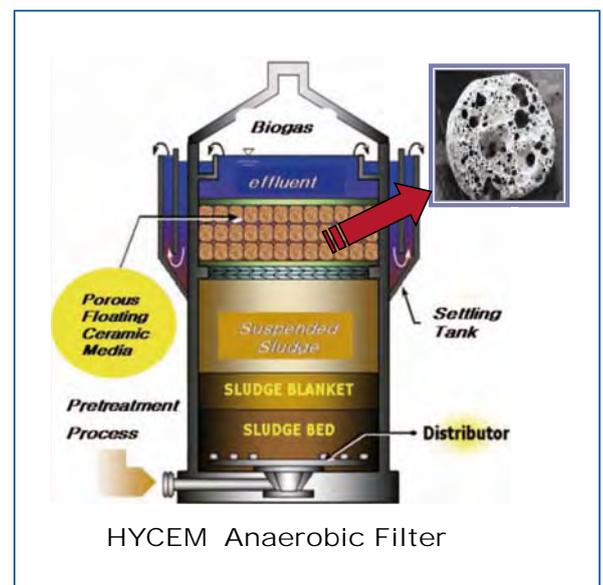


Figure 13: Digestion of the liquid part of separated manure in a hybrid filter

All but two biogas plants using food waste are liquid systems, so-called continuously stirred tank reactors (CSTRs). Korean food waste contains a lot of water. Sometimes only the leachate is digested. The two solid-waste digesters were built by the Belgium company, Organic Waste Systems.

Landfill gas is used in most places for electricity production. In total 18 landfill sites are producing electricity. The largest site is near Seoul, with an installed capacity of 50 MW. The smallest has only 330 kW. Total production is more than 500,000 MWhel.

Session 3 – Success Stories: Medium to Large-scale

GASIFICATION OF WOOD

Christian Aichernig, Repotec-Renewable Power Systems

Repotec is building some of the most successful gasifiers in the medium to large-scale range in Europe. The first plant, built in 2000, went into operation in November 2001 and has operated for over 70,000 hours. It is a gasifier with steam injection that supplies oxygen and hydrogen at the same time. Addition of steam instead of air avoids the introduction of nitrogen (N₂) and produces a gas with a three times higher energy content. When operated with wet woodchips of defined size, it produces bio-synthetic natural gas (SNG), with a fairly constant average gas composition of 40% hydrogen, 25% carbon monoxide, 20% carbon dioxide, 10% methane and 3% ethane or other higher hydrocarbons.

The disadvantage is that the process is endothermic. The necessary energy input is delivered by integrated combustion of charcoal.

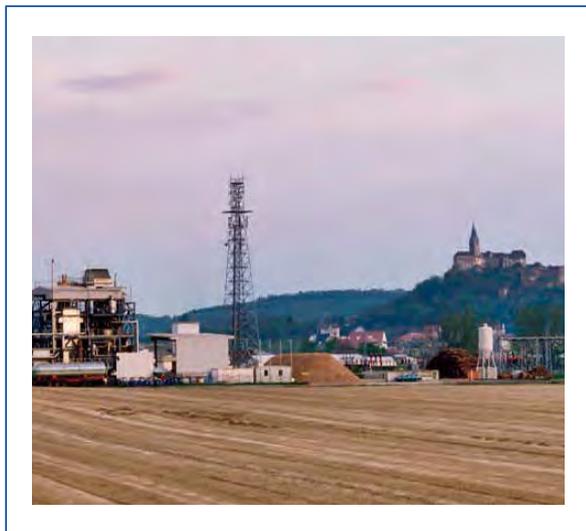


Figure 14: Güssing gasifier of 8 MW fuel power

The Güssing demonstration plant (Fig. 14) has fuel power of 8MW, electric power of 2 MW and thermal power of 4.5 MW. The electric efficiency is 25% and the total efficiency is 80%. The electricity is injected into the grid and the heat produced contributes to the village district heating system, with an additional three wood boilers and another gasifier (not operational in 2013).

The investment cost of the Güssing plant was €9m, plus €1m for optimisation.

The Güssing technology is not the end of development. A first step includes improvement of the gas engine efficiency from 25% to 27%. There is further potential by adding a turbine with an organic ranking cycle (ORC) to recover the heat in the CHP's off-gas, raising the electrical efficiency to 32% (Fig. 15).

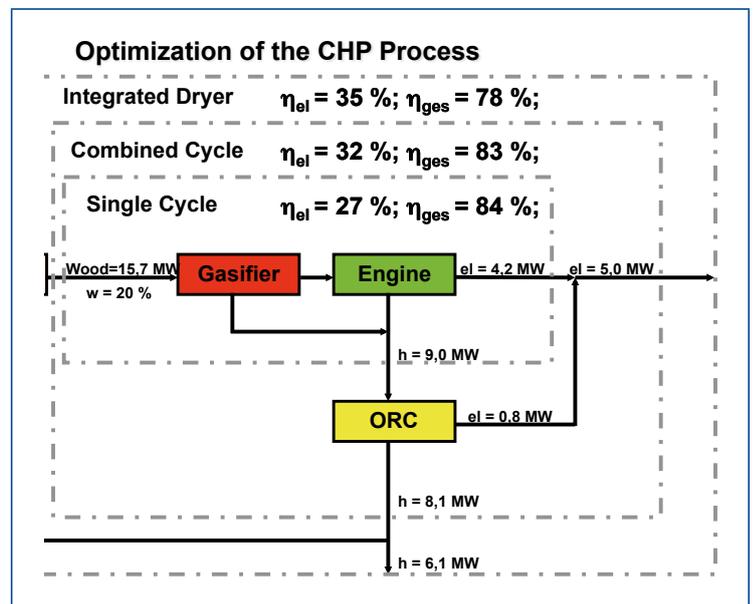


Figure 15: Measures to increase the total efficiency of the CHP process

Additional improvement of the total efficiency is possible by drying the pellets before entering the gasification unit to reduce the drying energy in the gasifier. With the same plant, the electric power can be increased by about 10% and thus the electrical efficiency can be raised to 35%.

The new concept has been integrated in the newest plant, HGA Senden (Ulm, Germany), which went into operation in November 2011 (Fig. 16). It is a fully automatic plant. Woodchips are stored in silos and fed continuously to the gasifier. The size of the installation, with 14.3 MW fuel power, is about double that of Güssing. According to the scheme shown in Figure 15, the electric power reaches 5 MW with electric efficiency of 35%. The overall efficiency, at 78%, is thus somewhat lower than Güssing.

The investment at HGA Senden at €33m is far higher than in Güssing (even relative to the power output) due to the integrated silos, large scale construction and full automation.



Figure 16: The gasification plant in Senden (Ulm)

However, gasification amounts to more than power production.¹⁵ The gas (bio-SNG) can be used to produce high-temperature heat in industry (e.g. for brick and cement production, glass melting). A simple preliminary experiment has shown that the same burners for natural gas can be used for syngas. Hence, syngas can be used as a stand-alone fuel when no gas grid is available.

Another interesting application of bio-SNG is the production of biomethane, where the raw gas undergoes a catalytic methanation, turning CO and H₂, after a shift reaction, into methane. A first 1 MW methanation pilot plant was also built in Güssing. The gas was used as car fuel. Güssing was also equipped with a gas filling station. The concept was applied to the GoBiGas (Biomass Gasification Project) plant in Gothenburg, Sweden, planned to go into operation in 2014. The GoBiGas gasifier is double the size of Senden, with 32 MW fuel power. In a second step, the plant size will be increased to 100 MW.

Bio-SNG offers more opportunities, such as the production of liquid biofuel (BtL) via the Fischer-Tropsch process. A pilot plant in operation produces one barrel per day. The challenge of the process is to desulphurise the gas down to parts per billion (ppb) levels. A micro-channel technology was operated in 2011, with positive results. The design would be ready for upgrade but the interest of the refining industry is very limited.

There is strong demand for hydrogen in the refining industry. The production of bio-hydrogen might be a sustainable alternative. A study carried out for the Austrian oil and gas group OMV examined the production of 50 MW of hydrogen for a fuel refinery. The findings demonstrated a valuable option for biomass application in refineries. The efficiency for H₂ production could be as high as 65%.

THE FIRING AND CO-FIRING OF BIOMASS IN LARGE PULVERISED COAL-FIRED BOILERS

William R Livingston, Doosan Babcock Power Systems

Bill Livingston shared with the audience his experience over the past 20 years or so with the firing and co-firing of biomass in large coal-fired boiler plants.

Introduction

The first successful conversion of a pulverised coal boiler to the firing of wood pellets was at the CHP plant at Hasselby near Stockholm in Sweden in the early 1990s. This involved the conversion of vertical spindle coal mills and pulverised coal burners from coal to 100% biomass pellet firing. This plant is still in operation using basically the same approach, although additional hammer mills for the milling of the wood pellets were installed to provide more flexibility in operation, and to permit full boiler load operation on 100% biomass.

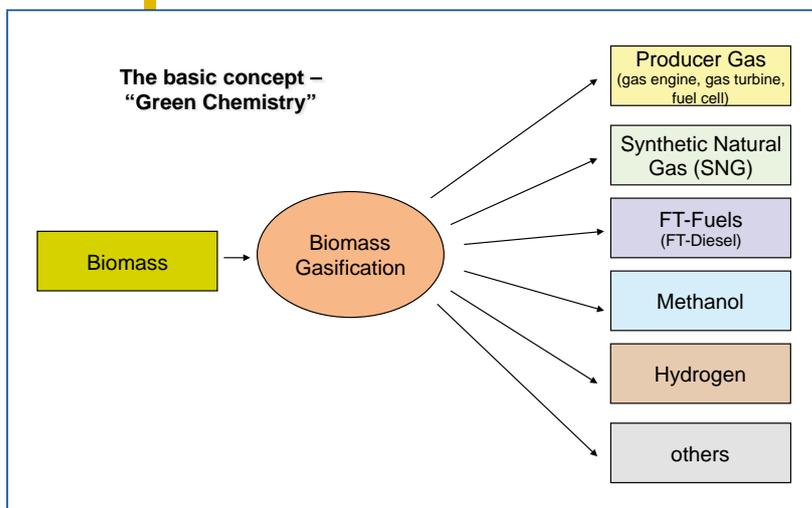


Figure 17: Possible application of bio-SNG

¹⁵ See also IEA Bioenergy: 'Thermal pre-treatment of biomass for large-scale applications' (2010), <http://www.ieabioenergy.com/wp-content/uploads/2013/10/ExCo66-Thermal-pre-treatment-of-biomass-for-large-scale-applications-summary-and-conclusions1.pdf>

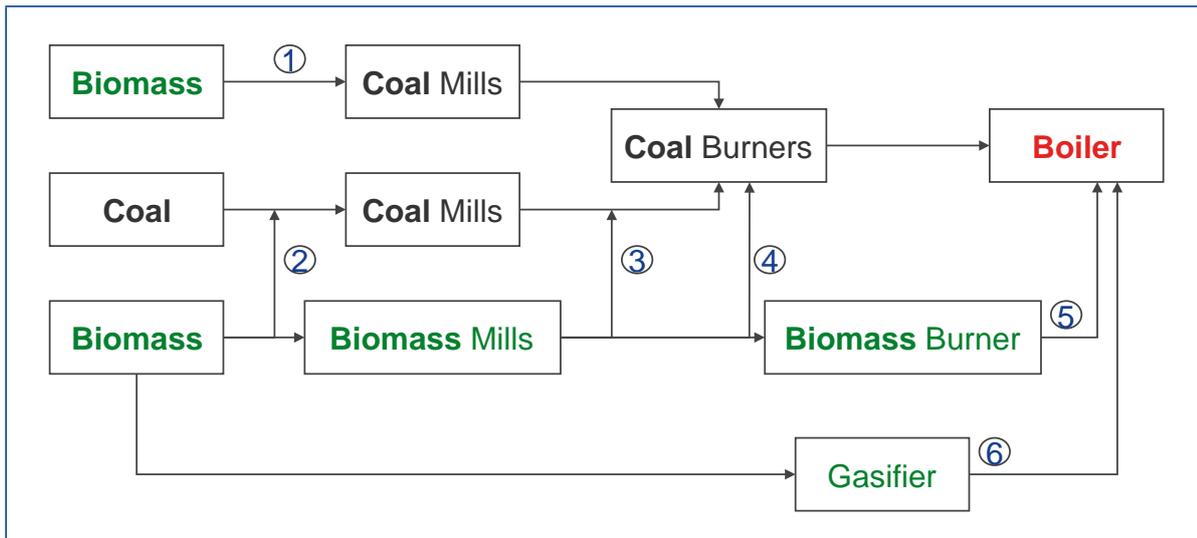


Figure 18: The principal direct and indirect biomass co-firing options

In Britain, the first initiatives to apply biomass firing and co-firing in pulverised coal boilers started in the early 2000s with the introduction of the Renewables Obligation, a British government policy instrument that provided a higher price for electricity generated from renewable sources, including biomass firing and co-firing. Initially, the biomass was co-fired at low co-firing ratios, generally less than 10% on a heat input basis. This was implemented in all of the large central pulverised coal power stations in Britain, at least on a trial basis. With increased experience, and after changes in the renewable energy subsidy rules, a number of stations increased the biomass co-firing ratio, and more recently the biomass firing activity has principally involved the conversion of a small number of the large coal boiler plants to 100% wood-pellet firing.

The options for the firing and co-firing of the biomass in a large coal-fired boiler are described in Figure 18:

1. Milling of biomass (pellets) through modified coal mills
2. Pre-mixing of the biomass with the coal, and the milling and firing of the mixed fuel through the coal firing system
3. Direct injection of pre-milled biomass into the pulverised coal pipework
4. Direct injection of pre-milled biomass into modified coal burners or directly into the furnace
5. Direct injection of the pre-milled biomass through dedicated biomass burners
6. Gasification of the biomass, with combustion of the product gas in the boiler

Initially, the focus was on the development of pre-mixing systems (option 2), followed by the direct injection of pre-milled biomass into the pulverised coal pipework (option 3). All of these options have now been demonstrated commercially in Britain or elsewhere in northern Europe. In most cases, the preferred biomass fuel has been wood pellets, for availability, quality control and transportation reasons, and to minimise the impacts on the boiler plant performance and integrity.

The milling of pelletised sawdust

Large coal mills are very robust and relatively resistant to the presence of tramp material, and have high availability and low maintenance requirements. Hammer mills are much more sensitive to tramp material and have a much higher maintenance requirement, depending on the fuel quality.

The conversion of large vertical spindle mills to the processing and firing of wood pellets has been demonstrated in several plants. The wood pellets behave differently from coal in the mill, but vertical spindle mills can be modified to provide mill product fineness at an appropriate throughput for firing through conventional coal burners.

In general terms, the mill has to be modified to operate with cold primary air, to provide appropriate product fineness and to maximise the fuel throughput. The grinding elements and the mill body generally don't need to be modified, but significant modification to the mill classifier and the mill internals are required. (The modifications that have been made to the Doosan Babcock ball and ring mills are marked in red in Fig. 19.)

After conversion to 100% wood pellets, the maximum heat input from the mill group may be reduced, commonly to around 60-80% of that with coal, depending on the mill type and configuration.

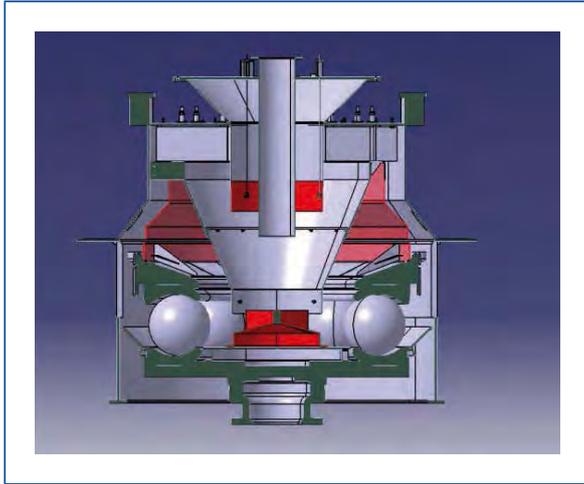


Figure 19: Ball and ring mill modified for processing wood pellets

Combustion systems

The modification of the Doosan Babcock Mark III low NO_x burners for the combustion of 100% milled biomass has been demonstrated successfully at a number of plants. It has been noted that there is a tendency for the flame produced by an unmodified coal burner, when firing milled biomass with a top size in the range 1-3 mm, to have the ignition plane located further out into the quarl than in a pulverised coal flame. This is considered to be a result of the longer heating times required for the larger biomass particles compared to pulverised coal. The result is that the flame monitor signal for the unmodified burners may be poorer than for a coal flame, particularly at reduced mill loads. There is no indication that the flames are unstable. At a number of power plants the burners have been successfully modified to bring the ignition plane back into the burner quarl, and improve the flame monitor signals.

Impacts on plant performance and integrity

The impacts of co-firing a wide range of biomass materials at low co-firing ratio, and of firing high-grade wood pellets at 100%, have generally been modest. The levels of bottom and fly ash generated with wood pellets are much lower than with coal. The risks of excessive ash deposition and corrosion of boiler surfaces are controlled by the fuel specification, i.e. ash content and ash composition, and with the use of fuel additives, in addition to the effective use of the installed online cleaning systems.

There can be an increased risk of high-temperature corrosion of superheaters and reheaters when firing 100% biomass materials, which have a much lower sulphur to chlorine mass ratio than do most coals. This should be monitored carefully and can be addressed by the use of fireside additives.

In general terms, the biomass materials have lower levels of the major pollutant species than have most coals, and the levels of emissions of sulphur and nitrogen oxides are lower than with coal.

Summary

It is clear that all of the more important technical options for the firing and co-firing of biomass materials in large pulverised coal boilers have been demonstrated successfully in northern Europe. The biomass materials can be milled to a suitable size for suspension firing, using either dedicated biomass mills or in modified vertical spindle coal mills. The existing pulverised coal burners can be used for co-firing a wide range of biomass materials at up to around 50% on a heat basis to a mill group of burners. Suitable modified burners are available for the firing of milled wood pellets at 100% on a heat input basis.

The impacts of biomass firing and co-firing on boiler plant performance and integrity are relatively well understood, and suitable diagnostic techniques and control measures are available to allow management of the key risk areas in most situations.

Session 4 – Discussion

AVAILABILITY OF BIOMASS FOR ENERGY

Most of the discussion points centred on the availability of biomass either on a worldwide or regional basis.

The planned high biomass provision for electricity in China, as indicated in IEA's medium-term report, was subject to particular doubt. Anselm Eisentraut of IEA Paris admitted that the report was based on a rather optimistic scenario, and emphasised that technology and supply chains had to be developed in parallel in order to achieve the target. The logistics of biomass transport was not a real problem when compared to coal, especially when energy density could be increased by torrefaction or pyrolysis.

Anselm Eisentraut noted that in reality a large part of the biomass would probably come from waste and therefore biogas would play a significant role there.

Apart from IEA figures for China, another Asian country, Korea, had set high goals for energy from biomass: more than 31% from purpose-grown biomass plus 33% from biowaste (including important shares of biowaste in MSW). Jinwon Park specified that, according to a Korean government white paper, pellets from Indonesia would have to be imported and would displace coal, which was also imported. The driver for the change was the quota system under which the power companies needed to increase the share of renewables on a mandatory basis.

The security of supply was also a major question for a large biomass-to-electricity plant (> 100 MW) in New Zealand. In the USA, in contrast, supply did not seem to be a concern. Bob Cleaves, president of the Biomass Power Association, mentioned that the plant operators would carry out very careful substrate evaluation before they would build a large plant.

Overall, an increase in the demand for sustainably produced bioenergy from 50 EJ to 150 EJ by 2050, as indicated in IEA's reports, was considered challenging. However, Anselm Eisentraut confirmed that this figure from the IEA was based on a rather conservative assumption. An additional question – whether the IEA models were aligned with the global energy assessment – could not be answered.

Economic considerations and policy measures

The IEA medium-term renewable energy report did not mention the cost factor. The reason was that in these reports, produced at short intervals, the focus was on the energy potential under the changing current and expected future policy framework. The cost of biomass production was considered in the long-term reports only. Policy measures were certainly as important as production cost. Anselm Eisentraut stressed that nothing would happen automatically. In the optimistic view of the medium-term report, it was assumed that the policy measures would be further developed up to 2018 in the same way as they had been over the past five to ten years. Carbon pricing could be a key driver in the longer run but it was not specifically addressed, unlike in the projections in IEA's Road Maps.¹⁶

In the US the construction of biomass power plants was supported by federal tax credits. It was still completely open what would happen when the credits came to an end in December 2013. Would projects fail then? Bob Cleaves was rather optimistic for large-scale plants, from 20 MW up. He believed that they still had a chance, at least in US states with additional support mechanisms. This was clearly different from PV and wind power, which might face serious problems. The economy of scale was a crucial factor. The question was raised as to whether this was also true for gasification plants? Christian Aichernig, Repotec-Renewable Power Systems could not answer this question because, over the last 10 years, the plants not only increased power output, which led to a price reduction, but were also further developed technically, which of course increased the price. The question as to which would be the economically most interesting usage – biomethane, power production or production of liquid fuel – did not have a clear answer in his opinion. More important was whether 100% of the co-produced heat was used. Without feed-in tariffs or any other support mechanism, the economic viability of a plant was questionable.

It was mentioned that Christian Aichernig's presentation gave the impression that gasification in Europe was a success story. If so, what was holding back the technology elsewhere? In the US, power companies considered that the technology had not been sufficiently developed. The planning period was too long; up to three years was far longer than for planning wind and PV installations. In addition, the raw biomass displayed extremely volatile prices; however, this was also true for conventional boilers. Another drawback in the US was that, years ago, the industry was over-optimistic about gasification, and it failed.

William Livingston of Doosan Babcock Power Systems noted that, in conversion of coal plants to biomass, the size of the plant was of high importance. A number of plants did not change the fuel for economic reasons, mostly because they were not large enough or because the transport cost was too high. But why would small-scale biomass burners not be profitable, given that due to shorter transportation distances they could use unprocessed wood? William Livingston replied that the type or form of wood used depended less on the size than on the age of the plant. Old systems would be difficult to convert and would accept pellets only.

¹⁶ Bioenergy for Heat and Power, <http://www.iea.org/publications/freepublications/publication/bioenergy.pdf>; Biofuels for Transport, <http://www.iea.org/newsroomandevents/pressreleases/2011/april/biofuels-can-provide-up-to-27-of-world-transportation-fuel-by-2050-iaa-report-.html>

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IEA Bioenergy

Further Information

IEA Bioenergy Website
www.ieabioenergy.com

Secretary
Pearse Buckley
ODB Technologies Limited
P.O. Box 12249
Dublin 9
IRELAND
Phone: +353 87 737 3652
Email: pbuckley@odtbioenergy.com

Technical Coordinator
Arthur Wellinger
Triple E&M
Châtelstrasse 21
AADORF, CH-8355
SWITZERLAND
Phone: +41 52 365 4385
Fax: +41 52 365 4320
Email: wellinger@triple-e-und-m.ch