EUROMOT

The European Association of Internal Combustion Engine Manufacturers

EUROMOT POSITION

Taxonomy – Technical Expert Group on Sustainable Finance Report of June 2019

Implications for stationary/large combustion engines

3 September 2019

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1. Introduction

The TEG (Technical Expert Group) mandated by the European Commission published the Taxonomy Technical Report /1/ in June 2019. Taxonomy is an EU classification system – to determine whether an economic activity is environmentally suitable. It forms parts of the implementation of the EU action plan on sustainable finance. The TEG´s recommendations on Taxonomy (and low-carbon benchmarks) will aid the Commission in the development of proposed future acts.

In December 2018, the TEG issued a call for feedback on the proposed criteria for the "first round" activities. In document /2/ part D are the sectors and activities included in the 1st round (Full list of 1st round climate mitigation activities, screening criteria and questions).

A call for feedback on the Technical Report /1/ is currently ongoing until September 13th 2019. In the Technical Report (page 17) is stated *"… **further refinement of the criteria may be required after feedback** from stakeholders. The TEG will **... Refine and further develop some incomplete aspects of the proposed technical screening criteria for substantial contributions ... Seek additional feedback on criteria that have not yet been subject to public consultation ... .** The TEG will not further expand the scope of climate change mitigation activities covered under the Taxonomy at this phase, nor will it seek detailed feedback on screening criteria which have already been reviewed*".

Note! Many sector activities included in the Taxonomy Technical Report such as "22.7 *Production of Electricity from Gas Combustion*" where **not included in the December 2018 "first round" revision package**.

EUROMOT has gone through the Taxonomy Technical Report. We support the target to work for *investments to become more sustainable and the system to promote truly sustainable development from an economic, social and environmental perspective*. However, this should be done in transition steps reflecting state of the art technologies. The target of adequate level of threshold (page 101 /1/): "... *Another challenge regarding the definition of* ***the screening criteria is setting the adequate level of thresholds****. Setting too low or too high thresholds, which do not reflect best market practices, would undermine the Taxonomy´s ultimate goal ... the selection of the* ***Taxonomy´s thresholds has been carefully considered based on existing standards ...***" is **not** fulfilled in e.g. in activity "22.7 *Production of Electricity from Gas Combustion*".

The electricity production activity is rather complex and consequently setting only one "solution works for all" for the screening criteria is not an adequate approach and will severely hamper the acceptance of Taxonomy. Below a brief discussion about the need to refine and develop further especially the "22.7 Electricity from Gas Combustion" activity, with counterproposals based on existing procedures and standards in order to make the activity technically feasible (representing the state of the art of research and technical progress). By this a robust unambiguous Taxonomy architecture is achieved for this activity. This BIG refinement & development need is emphasized further by the ambition to have taxonomy be applied globally.

2. Taxonomy eligible finance

Taxonomy economic activities may themselves be decarbonised, or they may enable decarbonisation in other sectors. TEG has therefore adopted following concepts which are considered Taxonomy eligible (/1/, page 29-30, 251):

- *"Green activities": "already low carbon"*
- *"Greening of activities": "activities contributing to a transition to net-zero emissions economy in 2050 but are not currently close to a net-zero carbon emission level; e.g. "22.7 Production of Electricity from Gas Combustion".*
- *"Greening by activities": "activities that enable low carbon performance or enable substantial emissions reductions; e****.g. installation of a highly efficient boiler in a building (boiler part considered Taxonomy eligible)****". (Note! Even the most efficient boiler fuelled by natural gas is not able to go below 205 g/kWh CO2 of heat produced).*

The above mentioned "efficient boiler" is part of the activity "21.1 Manufacture of low carbon technologies", part of Mitigation Criteria 3 (Annex 1A). It is of "greening by activities" type.

Other metrics of this activity (21.1) are shown in Annex 1A, e.g.

- "4. Manufacture of low carbon technologies that result in substantial GHG emissions in other sectors of the economy .... is eligible if they demonstrate substantial higher net GHG emission reductions compared to the best performing alternative technology/ product/solution available on the market on the basis of a product/solution available on the basis of a recognized *... cradle-to-cradle carbon footprint … validated by a third party".*

In the “21. Manufacturing” products/equipment/technologies are considered eligible if the overall benefits in terms of the GHG emissions reductions are proven by the life cycle carbon footprinting.

3. Gas Combustion Electricity supply sector

The “*22.7 Production of Electricity from Gas Combustion*” activity is rather complicated. Depending on the annual operating hours the electricity plant types can typically be grouped into following:

- ***Base load*** *plant operating more than 4000 hr/year*
- ***Mid-merit*** *plant operating between 1500 and 4000 hr/year*
- ***Peak-load*** *plant operating between 500 and 1500 hr/year*
- ***Emergency*** *plant operating below 500 hr/year*

The operational mode and annual operating hours will put frames for which types of technical solutions e.g. for secondary emission abatement are technically and economically feasible for the specific power plant type. E.g. the grid stabilisation/peak load plants used for e.g. enabling intermittent wind and solar based power will make many starts and stops and operate under variable loads which makes CCS (Carbon, Capture and Storage) extremely difficult.

“22.7 Production of Electricity from gas combustion” activity first criteria threshold is set to 100 g CO_2eq/kWh and it will be reduced every 5. year in line with trajectory to net-zero CO_2eq in year 2050. In below figure 1 some different prime mover CO_2 electricity intensity figures are shown, it can be concluded that the proposed threshold is not reachable without secondary CO_2 abatement measures. This is in line with quote (page 232 /1/) *“... unabated natural gas-fired power generation is not expected to meet the required threshold*.” Next to this, fuels from renewable origins are not available yet in the quantities and energy flows required for power generation. It is expected that this might take at least another decade.

I.e. the criteria threshold is largely based on the assumption that CCS (Carbon Capture Storage) is commercially available. There are many **theoretical** studies in the open literature that show the technical feasibility of CCS. **But:**

- *According to LCP BREF /3/ CCS is still at an emerging technology stage.*
- *Despite a European Commission plan for up to 12 CCS demonstration plants* ***by 2015, today there are no such plants, nor plans.*** */4/.*

Demonstrating CCS for a practical power plant still requires government co-ordination with a substantial amount of subsidies before it can be said to be an available commercial technology available for the power plant sector. In below chapter 4 CCS is further briefly discussed.

Conclusion

Thus set 1st technical screening criteria threshold for the activity (22.7) is not set at an adequate level considering the available feasible technology.

Alternative technical screening criteria thresholds, etc. reflecting the current commercially available technologies, state of the art research and progress on decarbonisation efforts are thus to be worked out ensuring topicality and market coherence.

3.1 Grid balancing/supporting plant

Quote page 294/1/ "... *CCS on dispatchable generation allows all aspects of the electricity supply system to be deeply decarbonised.* ***CCS provides a backstop*** *to the unabated operation of flexible electricity generation plants that are required to guarantee the operation and supply of year-around electricity. This is especially true in in more isolated grids with a high penetration of seasonable variable renewables (e.g. onshore and offshore wind) where the reliable operation of electricity networks requires on-demand electricity generation*".

Above statement is **not correct** due to the absence of a technical & economical feasible CCS technology currently. In addition, implementing CCS for installations having an intermittent character with variable loads and a relatively low utilisation factor will experience hugely negative economic consequences. Yet the power system cannot operate without the fossil fired (electricity) grid balancing/supporting (flexible) electricity generation plants. The taxonomy system should differentiate between large base load power plants and the facilitating smaller flexible plants that enable the renewables. For more information on CSS aspects see chapter 4 below.

Fast starting/stopping gas fired reciprocating engines are enabling a fast large penetration of sustainable intermittent energy sources as wind and solar into the power grid. The gas fired reciprocated engines are only operated (no need of a spinning capacity reserve) during periods when the intermittent renewable power generation capacity is not sufficient in order to keep the grid in balance and thus securing that functions of the society can continue to operate undisturbed while utilizing a highly decarbonised electricity. Depending on yearly weather fluctuations and installed power plant mix (existing intermittent renewable and fossil plant capacities), etc. connected to the electricity grid these grid supporting plants are of peak or mid-merit category. When the grid supporting gas fired reciprocating engines are enabling a fast and safe decarbonisation of the electrical grid this technology is qualifying for the 4th metric threshold mitigation criteria (see Annex 1A) of activity "*21.1. Manufacture of Low carbon technologies*".

Thus the gas fired reciprocating engine balancing plant could be part of activity 21.1. or be an own sub-activity of activity 22.7. If part of activity 21.1, the project developer could consider the grid supporting/balancing gas fired reciprocating plant expenditure and revenues as Taxonomy eligible. The in metric 4 of activity 21.1, specified cradle-to-cradle carbon footprint assessment to demonstrate the best performing available technology/product is alone without modifications too burdensome to be applied worldwide, instead or in combination with other existing EU legal framework should be used. Annex 1B text recommends usage of the LCP BREF /3/ (IED 2010/75/EU refers to LCP BREF) as the reference in order to get a threshold which is practical, worldwide applicable and based on

BAT. If a LCA/LCE is done in conjunction with LCP BREF it shall be for the operational phase only because a fossil fired plant has its biggest environmental impact during the operational phase (quote "Direct emissions from plant operation represented the majority of the life cycle emissions for fossil fuel technologies" ... /24/). For the grid balancing/supporting reciprocating engine plant the LCE boundaries shall be those of the actual plant.

The low and close to zero generating technologies (such as solar) are currently and in the near future only feasible with sufficient fuel-based balancing generation. **The performance of the integrated power sector should be considered for the taxonomy approach, not an individual generator that has a renewable enabling function**. In EU the grid average CO_2 intensity today is 296 g CO2/kWh (year 2016) /23/, in some EU countries the grid CO_2 intensity is much above (Poland about 700 g CO2eq/kWhe) and in some well below (France about 70 CO2eq/kWhe) /22/. **Thus by introduction of grid balancing gas fired reciprocating engines enabling a fast penetration of renewables such as wind and solar and a fast decarbonisation of the electric grid should be achieved.**

Below (see chapter 6) is a further discussion about the grid balancing/supporting gas fired reciprocating plant enabling a fast deep decarbonisation of the power grid already today with current available technologies in an economic affordable way. An alternative criteria threshold is also proposed.

3.2 Base load

A base load plant with high annual operational hours can usually afford to invest in e.g. more advanced secondary abatement techniques and have also more human & capital resources to operate these. In below figure 1 typical CO_2 intensities for some different electricity prime mover plants are shown. It can be concluded that electricity producing plants with a high electrical efficiency are **far above** the set CO2 criteria intensity threshold of 100 g CO_{2eq}/kWhe. **Note:** In figure 1 only the CO_2 compound has been considered, the CO_{2eq} figure is higher.

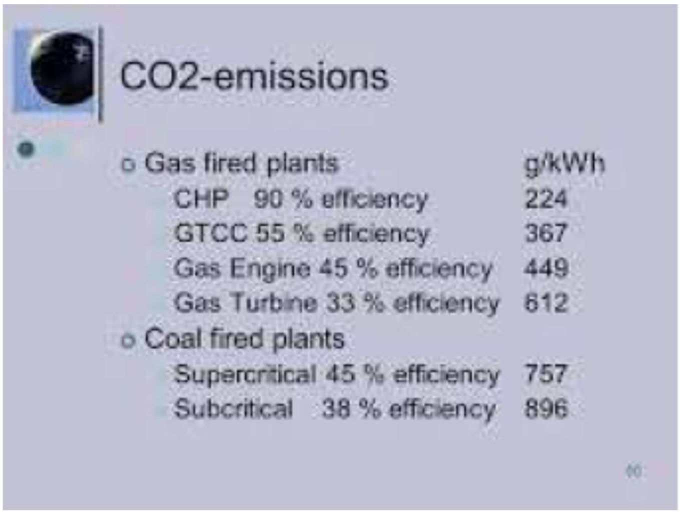

Figure 1: Typical CO_2 emissions from different prime movers /5/, page 50.

Further on according to the activity 22.7 page 251/1/ "... *an ISO 14044-compliant life cycle of emissions (LCE) assessment, that the life cycle impacts for producing 1 kWh of electricity are below the declining threshold*. ... *A full LCE shall be applied* ..." I.e. the **whole gas**

chain (page 232 /1/) from gas production in the field to the power generation to be considered in the set criteria threshold. This will decrease the share which can be allocated to the power production further.

CCS should thus in practise be a pre-requisite in order to cope with the set criteria threshold of 100 g CO_{2eq}/kWhe. As in above text stated (see also chapter 4) CCS is not an available commercial technique for many years to come and thus a revised technically feasible threshold criteria needs to be worked out. In below text (chapter 7) an alternative threshold for the base load gas fired electricity plants based on BAT is proposed.

4. CCS (Carbon Capture Storage)

Numerous public publications show clearly that CCS is **not yet a mature technology** for many years to come and a lot of R&D & testing work is to be done before the full CCS chain is fully technically proven.

In below text information from source /1/ (see Annex 2 "Quotes" of this paper) is compared to information available in the public domain. It can be seen that based on public domain available information *CCS is not a maturity commercially available technology today and a lot of R&D and tests still need to be made before it can be applied in the power plant sector.*

4.1 CC (Carbon Capturing) issues

Annex 2 text:

"... The availability of CCS means that no remaining segment of the electricity supply system will be capable of emitting CO_2 to the atmosphere. **Whilst some CO_2 capture technologies can incur an "Energy penalty" of 10-15 %, others not. For example the Allam cycle being developed ... does not incur an energy penalty** as supercritical CO_2 is integrated fully in the power system as a coolant. ... **It is therefore inaccurate to say that CCS is a highly energy-intensive technology. ...** "

Open Literature quotes:

- *" .... an European Commission plan for up to 12 CCS demonstration plants by 2015, today there are no such plants, nor plans. .... The Dutch government can still support* CCS for industrial facilities in the Port of Rotterdam (e.g. the Shell Pernis oil refinery and an Air Liquide hydrogen plant). Applying CCS might work on such a scale. Some factories and refineries emit more concentrated streams of CO2 than power plants, making carbon ***capture less costly****. "/4/.*

- *"The most notable feature of the Allam Cycle is that it employs carbon dioxide as its "working fluid," i.e., the substance whose flow over the blades of a turbine makes the rotor spin. The CO2 comes from an upstream combustor in which a **combination of pure oxygen and** methane or syngas is burnt at high pressure ..."/6/.*

- *CC (Carbon Capture) still an "emerging technique" for power plants (LCP BREF /3/).*
  - *CC plant requires additional energy consumption. CO_2 capture processes lead to an efficiency loss of typically about 8 – 12 % points (existing coal-fired plant case).*
  - *The flue gas to be "clean" before CO_2 abatement, in case of the Amine process e.g. NO_2 to be kept below 10 ppm-v to prevent Amina solution degradation.*

Conclusion 1

- *Allam: Oxygen instead of air as combustion media should mean that extensive R&D is to be done to most prime movers before applicable. Only for special applications when tested. This technology is still in a test stage. Such technological developments usually take at least 10 years of development and trials before they can be applied in practice.*

- *CO2 capture process is an energy intensive process with associated efficiency losses. Flue gas to be treated to be "clean" in order to avoid excess degradation of used media. E.g. in case of Amine reagent the NO_2 concentration has to be kept very low i.e. SCR need for some prime mover applications.*

- *No demonstration plants exist yet in the EU for a power plant, therefore CCS will not be a mature technology in years to come. The CO_2 concentration in the flue gas has a big impact on the operational cost, a coal fired plant typical CO_2 vol-% in the flue gas is typically 11 vol-% /10/ and for a gas fired reciprocating engine 5 vol-% CO_2. Thus CC has to be tested on different prime mover techniques in order to get the correct experience of the Carbon capture technique performance and resulting costs.*

4.2 Storage issues

Annex 2 text:

"... CO_2 transport and storage are established and proven processes with decades of operation and well-established regulation here in Europe ... "

"The IPCC estimates that over 99.9 % of CO_2 will remain underground. The EU has provided clear and extensive assessment and monitoring requirements through the 2009 CO_2 Storage Directive. CO_2 has already been safely stored in geological formations in Europe for over 20 years. Though decade-long CO_2 injection experiences in North America, and monitoring of CO_2 storage in Europe, the safe final disposal both in- and off-shore has already been established."

Open Literature quotes:

- *European Union experience of storage /7/*

  “Brussels also said the EU should have twelve "demonstration plants of sustainable fossil fuel technologies in commercial power generation" operating by 2015 ... But, as of 2017, the EU has zero CCS demonstration plants “/7/.

- *Norwegian storage experience*

  Source /9/ Quote:

  “The Sleipner CO2 project in the North Sea is one of only three large-scale CO_2 storage projects worldwide. The oldest in operation, Sleipner has been injecting about 1 million tonnes of CO2 into a sub-seabed saline aquifer **since 1996**. Carbon capture and storage (CCS) proponents point to Sleipner as proof that CO2 can be stored safely and permanently while heralding the Utsira formation, that it is a part of, as large enough to hold Europe’s emissions for years to come. **However,**

  - *A Statoil Hydro-operated project was abandoned in the spring of 2008 after leaked process-water from the Utsira formation revealed an incomplete understanding of the geology of the storage site.*

  - *A study by the Norwegian Petroleum Directorate has reversed previous estimates of CO2 storage capacity in the Utsira formation from “able to store all European emissions for hundreds* ***of years” to “not very suitable****”. ... that the Utsira events regarding* ***unpredicted leakages, unpredicted*** CO_2 ***movements inside the geological formation*** *and dramatically reduced storage estimates, underline how each field, each injection rate and each storage location is unique and would require detailed characterisation, management and monitoring. The occurrences described above show that CCS is neither a simple process nor a one-size fits-all solution to* CO_2 *pollution …* ***Alternative energy strategies, namely ones based on renewable energy and energy efficiency, are already available to deliver emission reductions. ...*** *“.*

  Source /8/ Quote:

  The Sleipner gas field in the North Sea has been used over the years as an example of safe storage of carbon dioxide, **but there is a crack ten metres wide and three kilometres** long not far from the present extent of stored carbon dioxide. This was shown by an investigation conducted on behalf of the EU several years after the start of the carbon storage project… Finding a large number of storage sites the same size as Sleipner or larger is therefore a very demanding task. A long-term storage site must have practically zero leakage**. Even very low leakage rates, as low as 0.1 percent (per year), could undermine the potential climatic benefits of geological storage on a time scale of a few centuries. The success of Sleipner’s carbon storage therefore depends on a low leakage rate. The problem is that it is impossible to detect carbon dioxide leakages in such small volumes. The fact that no leaks of carbon dioxide have been detected so far has been equated to no leaks**. To say that no leaks have been detected is not untrue, but this does not mean that there have not been any leaks. **We simply don't know!** … One may therefore conclude that the Sleipner carbon storage facility cannot be used as an example of a successful storage site. **The lack of technology to detect the very small leakage rates that will undermine the potential climate benefits of carbon storage is just one factor. The geological hazard of undetected cracks in the cap rock layer is another problem**. The general problem of scaling up the location and evaluation of storage sites in their thousands make the use of underground storage of carbon dioxide highly doubtful. ..."

Conclusion 2

The legislation for ensuring a proper supervising of CO_2 storage facilities and its connected responsibilities during many centuries to come is not available. It appears that the geological effects, both long term and short term, have insufficiently been investigated and cannot today predict the long-term performance of the storage. Theoretical studies have proved to be inadequate. Better tools are methods and tools are needed/to be worked out for better future predictabilities.

4.3 Transport issues

Annex 2 text:

"CCS provides a backstop to the unabated operation of flexible electricity generation plants that are required to guarantee the operation and supply of year-around electricity. This is especially true in in more isolated grids with a high penetration of seasonable variable renewables (e.g. onshore and offshore wind) where ... "

Open Literature quotes:

Source /4 / quote:

"… But the problems of upfront cost and scale remain. While building CCS into existing factories, refineries and waste facilities sounds modest and organic, it still requires pipeline and storage infrastructure at scale: **it would be prohibitively costly to build CO_2 compression and pipeline infrastructure for only a handful of factories**. … Ultimately, it would require ambitious, cross-border projects involving hub-and-spoke pipelines crisscrossing the North Sea, connecting multiple industrial installations and countries."

Conclusion 3

CCS in isolated grid areas will incur very high costs for the needed transport infrastructure.

Overall conclusion (summary of 1, 2, 3)

Demonstrating CCS for a practical power plant requires government co-ordination with a substantial amount of subsidies: a power plant operator does not have the financial means and the skills to design and build the infrastructure for CO_2 transportation; operation of the storage facility requires special skills and a long-term supervision obligation. **Billions of Euros are required for such a large-scale demonstration. This is the background that no project succeeded this far.**

The legislation for ensuring a proper supervising of CO_2 storage facilities and its connected responsibilities during many many centuries to come is not available. *The geological effects, both long term and short term, have insufficiently been investigated.* Proof of the inadequate knowledge is also found at the Groningen gas field in The Netherlands, where earthquakes resulting from gas production cause serious problems. Identical problems were experienced in Switzerland by drilling in aquifers.

Activities 23.10 ("*Capture of anthropogenic emissions*"), 23.11 ("*Transport of CO_2*"), 23.12 ("*Permanent sequestration of captured CO_2*") in document /1/ are only including to some ISO standards. *Theoretical studies often proved to be inadequate* and thus it is not enough to only refer to some standards.

Still a lot of R&D work, **long-term demonstration plant testing of the CCS is needed before it can be deemed to be proven, commercially available and safe enough** (see especially the "Norwegian storage experience" text above).

5. Hydrogen fuel option

The set "starting" CO_{2eq} intensity threshold for the "22.7 Production of electricity from gas combustion" activity is very ambitious. In below figure 2 (note! in the below figure only the CO_2 compound is for simplicity considered, other GHG compounds not included) is shown the ("**theoretical**") needed H_2 content of the natural gas in order to cope with the proposed criteria threshold.

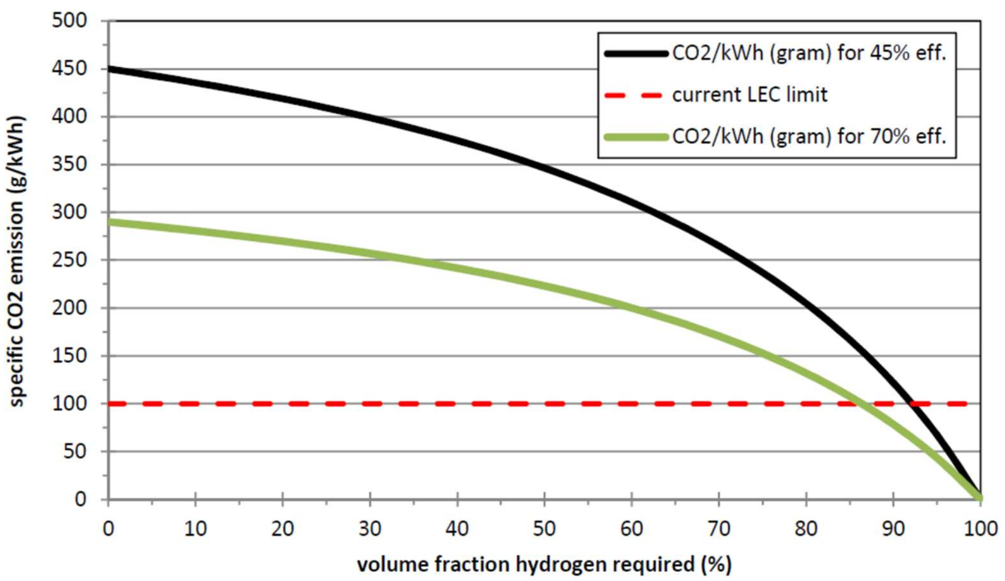

Figure 2: The "**theoretical**" reduction in specific CO_2 emission for a 45% efficiency and a 70% efficiency generator at various volume fraction of H_2 in average natural gas. The 45% efficiency prime mover would need 92% of hydrogen in natural gas to reach the 100 g/kWhe CO_2 target while the 70% efficiency prime mover would need 87%.

Not even the most efficient commercial available prime mover technology would fulfil the threshold without an almost 90 + % H_2 portion (or around 75 % of the energy provided by the hydrogen) in the used fuel gas. This amount of renewable hydrogen is not available in the coming decades.

Activity "*21.5 Manufacture of hydrogen*" page 205 /1/ proposes as one of the criteria threshold to be met:

"Average carbon intensity of the electricity produced that is used for hydrogen manufacturing is at or below 100 gCO_2e/kWh (Taxonomy threshold for electricity production, subject to periodical update)."

Electrolysis is one of the major processes to manufacture hydrogen. Electricity amounts fulfilling this criteria threshold will not be available in the near future in all EU countries, when fossil based electricity is by this threshold closed out. I.e. a "**chicken and egg" dilemma**, the needed huge amount of renewable hydrogen will not be available in many EU countries (see country specific average grid CO_2 intensity /22/).

Before injection of bigger H_2 quantities into the natural gas grid there are many aspects (technical, safety, etc.) which need to be solved - emissions (NOx might increase due to the fast combustion velocity of hydrogen), mixing of hydrogen in the grid (plug flow risk), material durability, etc. See document /20/ about consequences and hurdles to be overcome before a wide range use of hydrogen in power production.

Hydrogen has a fast combustion velocity and its´ wide explosion range compared with those of natural gas, thus the addition of hydrogen to natural gas has also consequences for the tuning and for safety measures for gas-fuelled equipment. The prime mover designed for natural gas is to be adjusted already when moderate high amounts of hydrogen is blended into the natural gas. To be noted is that H_2 has a much lower heat energy content than methane e.g. a 10 vol-% H_2 portion in the natural gas represents only 3 % of the total energy content in the natural gas pipeline. Some prime mover adjustments might have as a consequence a lower prime mover efficiency and thus have a detrimental impact on the CO_2 emissions. Future prime mover development will be needed to address this issue.

The energy flow in the pipeline will decrease drastically with a higher H_2-% of the gas blend, i.e. injection of H_2 in the natural gas might violate other EU ambitions such as to improve the energy efficiency further (by 2030) and energy security - **other EU ambitions than sole focus on decarbonisation are also to be considered!**

Instead of injecting hydrogen into the natural gas grid it should be preferable fed to the chemical industry which consumes it in big volumes, steel industry (a major CO_2 emitting sector in many EU countries) could be a big H_2 consumer in the future /21/. By this H_2-usage the decarbonisation could be done in a more effective way.

6. Grid Balancing/Supporting gas fired reciprocating engine plants

In chapter 4 above it has been concluded that CCS is not a viable option for a stand-alone gas fired reciprocating engine plant which is not near a larger hub for transporting the captured CO2 to a storage facility. and thus alternative criteria thresholds and a new approach is needed to make the Taxonomy meaningful, robust and accepted by stakeholders.

6.1 Gas fired reciprocating engine features

The gas fired reciprocating engine technique has several features which make it very suitable as a grid supporting plant:

a. *Fast start up and shut down*
b. *Good part load efficiency*
c. *Multifuel flexibility*

a. Fast Start-up and shutdown

Increasing penetration of renewable energy sources presents challenges for transmission grid operators to maintain electric reliability despite the intermittency of wind and solar power. This variability is managed **with redundant generating capacity that can quickly respond to fluctuations in demand,** and has predominately been served by coal and gas-fired units that are synchronized to the grid but operating at part load. Flexible power generation that can be rapidly brought online reduces the inefficiency of relying on part load operation. System operators, such as PJM, California ISO and ERCOT define such “quick-start” or “non-spinning” reserve as generation capacity that can be synchronized to the grid and ramped **to capacity within 10 minutes** /12/.

Whereas **conventional steam cycle generators (based on the Rankine cycle) can take more than 12 hours to reach full load, reciprocating internal combustion engines can be dispatched within minutes**. The two primary internal combustion engine technologies utilized for power generation are reciprocating engines and gas turbines. The differences between the two technologies affect start-up time and their suitability to provide flexible power. A reciprocating engine power plant can start and ramp to full load very quickly due to rapid ignition of fuel within the cylinders and the coordinated starting of multiple generating sets. /12/.

The single cycle **gas fired reciprocating engine power plant employing high efficiency lean-burn technology can reach full load in as little as 2 to 10 minutes (depending on engine type) under “hot start” conditions** (see Annex 4 Figures 1, 2). To meet “hot start” conditions, the cooling water preheated to a temperature above 70ºC, the engine bearings are continuously pre-lubricated, a jack up pump supplies pre-lubrication to the generator bearings, and the engine is turning slowly (cycling). **The shut down from 100 % to 0 % load is within less than 1 minute**. /11/, /12/. Although hot start conditions for CCGTs vary somewhat by manufacturer, maintaining energized electrical systems, purge credit, and steam temperature control enable CCGT (Combined Cycle Gas Turbine) start-up times of about 30 to 35 minutes from initiation of the start sequence. This is about half the time for conventional hot start that would require purge and gas turbine holds. In simple cycle, published start times for gas turbines are about 10 to 15 minutes /12/.

I.e. The gas fired reciprocating engine is fast enough to satisfy the grid demands and it can be shut down rapidly. There is no need for it to be left idling when it is not needed for electrical production. In case of **no idling operation no CO_2 or other emissions** are produced! See Figure 1 of Annex 3, the fast reacting reciprocating gas engine helps to secure the grid stability. ***Due to the frequent changing loads, many short running times with many start/stops the grid balancing/supporting plant is not an ideal place for the combined cycle power plant*** /19/ – single cycle plants are in focus**.**

b. Good Part load Efficiency

A multiunit gas fired reciprocating engine plant can be operated at high total efficiency at a wide power plant load range. The reciprocating engines that are on line are operating at their optimal loading area and at lower loads units not needed are gradually taken out of operation. See Annex 5 Figure 1, the multiunit gas fired reciprocating engine plant has a high efficiency down to a very low plant load. In Figure 2 of Annex 5 is shown the part load performance behaviour of different prime movers.

I.e. **Good part load efficiency** means also **less fuel consumption and associated CO_2 emission**.

c. Multifuel ability/flexibility

The main gas fired reciprocating engine types used today in power production are: SG – Spark Ignited Engine and DF – Dual Fuel (low pressure gas) engines.

SG engine type features /14/, /15/:
- *Unit size typically up to about 18 MWe.*
  Ignition of the fuel gas is initiated with a spark plug or some other device.
- *Only gaseous fuels such as: natural gas, biogas, landfill gas (some SG-types)*

DF engine type features /14/, /15/:
- *Unit size typically up to about 18 MWe*
- *Can operate on full load both in gas and liquid modes.*
  - *In gas mode the primary fuel is (low pressure) natural gas or other gaseous fuel such as biomethane with liquid pilot fuel (needed for ignition) share of 1 ... 2 % of heat input. Operation mode in gas mode is lean burn enabling low NOx emissions and a high engine efficiency.*
  - *In liquid mode fuel might be diesel oil, bio oil, methanol (in the future), etc.*

I.e. SG and DF engines will **not be “stranded assets”** in the future due to the **multifuel capability**, e.g. synthetic methane, liquid bio-oils, methanol or other synthetic fuels will be options when commercially available in big quantities.

6.2 Grid balancing/supporting gas fired reciprocating engine plant Taxonomy eligibility (Criteria metric and threshold proposal)

In above chapter 3.1 was proposed that the grid supporting gas fired reciprocating engine (plant) could be considered to be part of metric 4 of the activity "*21.1 Manufacture of Low carbon technologies*" or be a sub-activity of *"22.7 Production of Electricity from Gas Combustion*". The gas fired reciprocating engine grid balancing/supporting plant enables **already today** substantial GHG reductions in the power grid because of its ability to enable high fractions of wind and solar based power. An example is a case in the USA: decarbonisation of a grid including grid balancing gas fired reciprocating engines /17/ (See Annex 6 for more text) quotes:

"*Glendale: **Fastest energy transition ever**?*

…. Glendale's municipal utility quickly got comfortable with big batteries, distributed energy, efficiency and a few reciprocating engines ... The final portfolio, proposed in Glendale Water & Power's new integrated resource plan, would repower the Grayson Power Plant with a 75-megawatt/300-megawatt-hour Tesla battery installation and up to 93 megawatts of fast-ramping Wärtsilä engines ... GWP expects to be able to convert the engines to run on biogas, renewable natural gas or …, depending on the commercial maturation of those fuels. In the meantime, 18.5-megawatt units give the utility more precision to meet peaks than firing up much larger turbines. And if it's possible to reduce the number of engines and still meet reliability needs, Zurn said he's happy to do that ..."

In source /22/ the average carbon intensity of the electrical grid in different countries is given. Some EU countries (with a lot of nuclear or hydro power plants) already have a grid CO_2 intensity below 100 g CO_2/kWhe. Many EU countries are not far from this average grid CO_2 intensity level, by installation of efficient, fast reacting gas fired reciprocating engines into the grid the intermittent renewables penetration could be accelerated and the average grid 100 g/kWh CO_2 intensity achieved in many more EU countries in a short term frame. **An integrated approach for the power sector is needed instead of focussing on individual plants. The character and typical duty of the plant has to be taken into account.**

If thresholds need to be set for the grid balancing/supporting gas fired reciprocating engine (plant), the following could be the benchmarks:

- *LCP BREF /3/ chapter 10 has set BAT-AEELs for amongst all the net electrical efficiency of the (single cycle) reciprocating engine plant burning natural gas in table 10.23 (see also approved split view no 62 in chapter 12). Net electrical efficiencies are amongst all given for new plants. Efficiency is a proxy for the CO_2 emission for a given fuel. See Annex 7 for definition of the BAT AEELs.*

- *In table 10.26 is set BAT-AELs for the CH_4 emission for the lean burn gas reciprocating (SG) engine type. The maximum BAT-AELs span CH_4-limit value in the table (according to set conditions in the table) should be used as the BAT-level, this will enable amongst all following:*
  - *DF engine usage. A DF engine can operate on the liquid back-up fuel during gas grid supply interruptions and thus continue securing (balancing) the electrical grid stability also in emergency conditions.*
  - *Enhanced possibility to operate on varying natural gas compositions with e.g.*

different amounts of injected H_2 amounts into the fuel gas, natural gas qualities with varying Methane Numbers (MN), etc ... This will enable necessary tuning adjustments, etc. on the reciprocating engine due to the varying gas compositions at optimum fuel efficiency. I.e. enhanced fuel flexibility at optimized efficiency.

I.e. The N_2O emission is negligible from a lean burn gas engine and thus the (BAT) CO_2eq main components will get indirectly set by use of the BAT-AEEL efficiency and CH_4 BAT-AEL values.

The power plant owner is not in control of the gas quality & origin he/she will get to the plant, the power plant will have to accept what is delivered in the pipeline. A grid balancing/supporting gas fired reciprocating engine plant is only operated (no need of a spinning capacity reserve) during periods when the intermittent renewable power generation capacity is not sufficient in order to keep the grid in balance. If a LCA/LCE is done in conjunction with LCP BREF it shall be for the operational phase only because a fossil fired plant has its' biggest environmental impact during the operational phase (quote "*Direct emissions from plant operation represented the majority of the life cycle emissions for fossil fuel technologies"* ... /24/).
Thus the LCE (Life Cycle of Emissions)/LCA boundaries should be those of the actual power plant and made for the operational phase (see Annex 1B discussion (single cycle preference, etc.) and discussion in below chapter 7.3) for the grid balancing/supporting gas fired reciprocating engine plant.

We propose based on above text that the grid balancing/supporting gas fired reciprocating engine plant should belong to activity 21.1. or be an own sub-activity in activity 22.7. Due to the multifuel possibility the grid supporting gas fired reciprocating engine plant will not be a stranded asset in the future net zero carbon world.

7. Base load gas fired reciprocating engine plants

Taxonomy is a mechanism intended to be applied worldwide therefore the base load plant type is proposed to be included as a single electricity producing plant sub activity (in activity 22.7). In EU and other developed economies recent years trend has been that the existing base load plants have been operated less and less hours due to the penetration of the renewables energy production into the grid. Many big plants which in the past were built and operated as a base load case are today based on the granted annual operational in fact belong to the intermediate/peak plant categories. Even some very efficient natural gas fired plants have been closed down due to the recent years big change in the electricity power market, see e.g. news from Germany in source /19/. In contrast, the electricity consumption is growing fast in many emerging economies and it can be expected that gas fired electricity producing plants will be constructed and operated as base load plants still for many years around the world. This is despite the fact that the renewable energy production penetration into the grid is also growing.

In above chapter 4 has been concluded that CCS is not yet a viable option for an individual gas engine plant and thus alternative criteria thresholds and a new technical feasible approach is needed to make the Taxonomy meaningful, robust and accepted by stakeholders.

In above chapter 6 the gas fired reciprocating engine features have been described. In addition, the base load plant could in some cases be further optimized with e.g. CHP to further increase the total efficiency and reduce the carbon footprint.

7.1 CHP (Combined Heat and Power)

For base load power plants, the CHP (Combined Heat and Power) option for "useful heat should always be investigated", This means using the "heat produced in a cogeneration process to satisfy economically justifiable demand for heating or cooling".

In the LCP BREF table 10.23 a net total fuel utilization efficiency % is given for the gas fired reciprocating engine plant, but no combined cycle electrical efficiency is given for this category. Source /19/ quote "... ***you can either have high flexibility or high efficiency, not both simultaneously*** *...",* i.e. in power markets with a lot of intermittent renewable generation capacities connected to the grid the combined electricity production with a steam turbine is not a preference anymore. Single cycle electricity generation is preferred. *There is a risk that the installed steam turbine would become a stranded asset in the future when plant will start to operate more frequently on part loads with many start-stops with the further increased decarbonization (due to further penetration of intermittent solar, wind capacities installed) of the electrical grid*.

Efficiency level for the gas fired reciprocating engine case with steam turbine should be worked out separately for the gas fired reciprocating engine base load plant category, if of interest.

7.2 CCR (Carbon Capture Ready)

As shown in above chapter 4 CCS is **not a ready mature technology** for years to come. In EU big (> 300 MWth) power plants have already today to make the plant CCR ready (see text quote below).

Source /3/ quote of CCR readiness:

"Article 36 of the IED establishes the carbon capture readiness legal requirement for all plants of > 300MW$_e$ that meet the necessary conditions in terms of: availability of suitable storage sites; technical and economic feasibility of transport facilities; and technical and economic feasibility of retrofitting for CO_2 capture. A ***carbon capture ready (CCR) plant is a plant which can include CO_2 capture when the necessary regulatory or economic drivers are in place****. The aim of building plants that are capture ready is to reduce the risk of stranded assets and 'carbon lock-in'.* ***Developers of CCR plants should take responsibility for ensuring that all known factors in their control that would prevent installation and operation of CO_2 capture have been identified and eliminated. Space would need to be provided*** *for the CO_2 capture equipment (scrubbers, CO_2 compressors, oxygen production plant, etc.) and additional infrastructure including* ***cooling water and electrical systems, safety barrier zones, pipework and tie-ins to existing***

***equipment**. ...Further pre-investments can be made to reduce the cost and downtime for the retrofit of CO_2 capture. Some **potential CCR pre-investments apply to all technologies, including oversizing pipe-racks and making provision for expansion of the plant control system and on-site electrical distribution** ...*" .

This approach could be extended that all big base load plants should do a CCR plan as technically possible ready in the plant planning stage as part of the criteria threshold to be Taxonomy eligible. An alternative to this could be to show an alternative biogas, bioliquid etc. future sustainable fuel path.

7.3 Gas fuel chain carbon intensity

In activity 22.7 is stated that a full LCE (Life Cycle of Emissions) shall be applied, i.e. the fuel extraction (in the gas field) and transportation, etc. to the power plant are also to be considered besides the power plant emissions. See Annex 8 for the "gas chain" leakage activities. According to figure in Annex 8. methane intensity varies significantly by region from 0.1 to 1.7 tons of methane per kton of hydrocarbon production. Europe has a methane intensity of 0.36 which is less than half of the overall methane emission intensity of 0.75. There is a higher emission intensity from onshore (1.65) compared to offshore (0.23) /18/. The slip 0.1... 1.7 tons of CH4 per kton HC production corresponds to (assuming a net electricity production efficiency of 45%, GWP (100year) for CH_4 to 25) to roughly 0.33... 5.7 CO_{2eq} g/kWh of electric energy. To note is that the figures in Annex 8 are ***"very uncertain":*** ranging from 82 % known production in Europe ***to 10 % in Russia & Central Asia***.

*According to source /26/ estimated Russian gas production & transport natural gas (methane) losses figures are given as a total 1.... 2.5 % (see Annex 10). This is with above assumptions on net electricity production efficiency and GWP (100 year) for methane) equal **to about 30 ... 80 g CO_{2eq}/kWhe**.*

*Thus the gas production & transport CO2eq g/kWhe **seems to vary a lot around the world and is very uncertain for some regions**!*

Taxonomy is meant to be a worldwide tool, above have been shown that the natural gas production & distribution g CO_2eq/kWh varies greatly around the world. *The power plant owner is not in control of the gas quality & origin he will get to the plant, the power plant will have to accept what is delivered in the pipeline*. The gas importers/distributors have a much better control of the origin of the delivered natural gas and thus it shall be the obligation of the gas importer/distributor to supply a certificate containing the CO_2eq data (based on full LCE) of the delivered natural gas to the end consumer. This will make the process transparent and meaningful. Until such a process has been worked out we propose the power plant owner should restrict the LCE boundaries to those of the actual power plant.

7.4 Taxonomy eligibility (Criteria metric and threshold proposal)

An appropriate criteria threshold based on BAT for the base load gas fired reciprocating engine (plant) could be following benchmarks:

- *LCP BREF /3/ chapter 10 has set BAT-AEELs for amongst all the net electrical efficiency of the (single cycle) reciprocating engine plant burning natural gas in table 10.23 (see also approved split view no 62 in chapter 12). Net electrical efficiencies are amongst all given for new plants. Efficiency is a proxy for the CO_2 emission for a given fuel. See Annex 7 for definition of BAT AEELs.*

- *In table 10.26 is set BAT-AELs for the CH_4 emission for the lean burn gas reciprocating (SG) engine type. The maximum BAT-AELs span CH_4-limit value in the table (according to set conditions in the table) should be used as the BAT-level, this will enable amongst all following:*
  - *DF engine usage. A DF engine can operate on the liquid back-up fuel during gas grid supply interruptions and thus continue securing (balancing) the electrical grid stability also in emergency conditions.*
  - *Enhanced possibility to operate on varying natural gas compositions with e.g. different amounts of injected H_2 amounts into the fuel gas, natural gas qualities with varying Methane Numbers (MN), etc. ... This will enable necessary tuning adjustments, etc. on the reciprocating engine due to the varying gas compositions at optimum fuel efficiency. I.e. enhanced fuel flexibility at optimized efficiency.*

The same trend as seen in EU is expected to emerge also in the future in the emerging countries, i.e. base load fossil fuel based electricity production transfers into the intermittent/ peak categories with time when the electricity consumption growth is stabilized. As shown in above chapters 6.1 (Annex 5, figures1 and 2) different prime movers behave very differently when operating on part loads. *Importance of flexibilities such as fast start up/shut down ability, good part load efficiency will increase in the future.* As shown in previous chapter the gas fired reciprocating engine multiunit plant has a good efficiency also at very low loads (Annex 5, figure 1). Therefore, the approach when comparing BAT-AEELs efficiencies, etc. should be technique specific in order to be optimal (see discussion in Annex 1B). This in combination with the obligation to investigate/prepare for CCR or an alternative future sustainable fuel approach for the base load plant should make it taxonomy eligible based on best approach.

A fossil fired power plant has during its´ operational phase (typically up to 20 ... 30 years) the biggest environmental impact (including the GHG gases) /24/. See also discussion in Annex 1B. In above chapter 7.3 is explained why the LCE boundaries is to be those of the actual power plant until the gas importer/distributor can supply a certificate containing the CO_2eq data (based on full LCE) of the delivered natural gas to the end consumer (power plant).

I.e. The N_2O emission is negligible from a lean burn gas engine and thus the (BAT) CO_2eq main components will get indirectly set by use of the BAT-AEEL efficiency and CH_4 BAT-AEL values. Until gas importers/distributors cannot deliver CH4 intensity LCE data on the delivered gas to the power plant operator, the plant operator made LCE boundary is the power plant area.

8. Conclusions

EUROMOT supports the EU ambition for a net zero GHG emissions by 2050. In order to reach this ultimate target intermittent “criteria thresholds” for substantial GHG emissions reduction have been set for many sector activities in report /1/. In December 2018 TEG published a report with 1st round activities with proposed criteria thresholds for feedback. “*22.7 Production of electricity production from gas combustion”* activity was not in the first round package.

EUROMOT has studied the Taxonomy Technical Report /1/ in detail and unfortunately concluded that the set intermittent criteria threshold for e.g. activity 22.7 is too ambitious with the current commercially available techniques and R&D activities. The “*22.7 Production of Electricity from Gas Combustion*” activity is rather complicated and the approach “**one solution fits all” is not workable** – different sub activities are to be included with own metrics and thresholds.

The metric for e.g. activity 22.7 is amongst all requiring a full LCE to be applied including also the gas extraction, transport and storage systems. In chapter 7.3 is shown that the net greenhouse gas emissions of the natural gas & distribution are “very uncertain” with very big variations (*Note especially the high estimated CH_4 loss in Russia!*) around the world. The origin of the natural gas the power plant get via the pipe line might during the operational life of the plant vary greatly (the end consumer has to accept what is delivered in the pipeline) and thus an obligation is to be set on the gas importer/distributor to supply a certificate containing the CO_{2eg} data (based on full LCE until arrival to end consumer) in order to be meaningful. Until such a procedure is in place the boundary of the LCE, if done is to be restricted to the plant boundaries. See also Annex 1B.

Alternative technical feasible ambitious criteria thresholds are needed in order to enable Taxonomy to be widely accepted by stakeholders. By applying technical alternatives already available today a fast deep decarbonisation of the electrical sector can be achieved but these viable alternatives are unfortunately “locked out” from the market by the proposed **100 g CO2eq/kWh facility LCE threshold (in amongst all activity “*22.7 Production of Electricity from Gas Combustion*”)**.

In above texts (chapters 6, 7) alternative “sub activities” are briefly described (and proposed to be added with activity 22.7 (or also 21.1) in focus) and technical commercially available criteria thresholds for these “sub-activities” are proposed for the 22.7 (or 21.1) activity enabling a fast, efficient, economical deep decarbonisation of the overall electricity production. *These alternatives should also be doable worldwide.* **An integrated approach for the power sector is needed instead of focussing on individual plants. The character and typical duty of the plant have to be taken into account.**

DNSH (Do Not Significant Harm) criteria is referring to amongst all EU Environmental Directives/documents such as BREF (e.g. in activity 22.7). For power plants the IED 2010/75/EU or MCPD 2015/2193 are in focus, IED is referring to LCP BREF containing BAT-limits. Essential preconditions of compliance with of EU environmental Directives such as IED 2010/75/EU are a good existing infrastructure (fuel quality, reagent availabilities) and economy. In many areas around the world outside EU the existing infrastructure is very restricted and thus fulfilment of EU Environmental Directives will be very challenging/if even possible (lack of reagents, spare parts, suitable fuel qualities, lack of needed financial resources, etc.). Thus the worldwide GIIP (Good International Industry Practice) approach promoted by World Bank/IFC (International Finance Corporation) EHS (Environment, Health and Safety) Guidelines /25/ should be an alternative to EU Environmental Directives in areas with a restricted existing infrastructure in order to secure a truly sustainable development from an economic, social and environmental perspective. By this the acceptance of Taxonomy as a suitable global tool will be enhanced.

Beyond the environmental considerations, the economic and social pillars of sustainability are equally important, by above measures these aspects will also be in focus.

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ANNEX 1A: “21.1 Manufacture of Low carbon activities” page 187 – 189/1/

Mitigation criteria	
Principle	The manufacture of low carbon technologies that result in substantial GHG emission reductions in other sectors of the economy (including private households) is eligible.
Metric	1. **Manufacture of products, key components and machinery that are essential for eligible renewable energy technologies (Geothermal Power, Hydropower, Concentrated Solar Power (CSP), Solar Photovoltaic (PV), Wind energy, Ocean energy)** 2. **Manufacture of vehicles, fleets and vessels meeting the following criteria is eligible:** Passenger cars, light commercial and Category L vehicles: • Until 2025: vehicles with tailpipe emission intensity of max 50 g CO_2/km (WLTP). This also includes zero tailpipe emission vehicles (e.g. electric, hydrogen). • From 2026 onwards: only vehicles with emission intensity of 0g CO_2/km (WLTP). Heavy Duty Vehicles: N2 and N3 vehicles, as defined by REGULATION (EU) 2018/858: • Zero direct emission heavy-duty vehicles that emits less than 1g CO2/kWh (or 1g CO2/km for certain N2 vehicles); • low-emission heavy-duty vehicles with specific direct CO_2 emissions of less than 50% of the reference CO_2 emissions of all vehicles in the same sub-group (Heavy Duty CO_2 Regulation - Procedure 2018/0143(COD)). Rail Fleets: • Zero direct emissions trains Urban, suburban and interurban passenger land transport fleets
	Products for heat metering and thermostatic controls for individual homes connected to district heating systems and individual flats connected to central heating systems serving a whole building. 4. **The manufacture of low carbon technologies that result in substantial GHG emission reductions in other sectors of the economy (including private households) is eligible if they demonstrate substantial higher net GHG emission reductions compared to the best performing alternative technology/ product/ solution available on the market on the basis of a recognised/standardised cradle-to-cradle carbon footprint assessment (e.g. ISO 14067, 14040, EPD or PEF) validated by a third party.**
Threshold	No threshold applies, unless otherwise specified in the metrics.

- Zero direct emissions land transport fleets (e.g. light rail transit, metro, tram, trolleybus, bus and rail)

Water transport

- Zero direct emissions waterborne vessels.

3. Manufacture of the following products (with thresholds where appropriate) for energy efficient equipment for buildings and their key components is eligible:

- Installation of Building Management Systems (BMS)
- High efficiency windows (U-value better than 0.7 W/m^{2}K)
- High efficiency doors (U-value better than 1.2 W/m^{2}K)
- Insulation products with low thermal conductivity (lambda lower or equal to 0.045 W/mK), external cladding with U-value lower than 0.5 W/m^{2}K and roofing systems with U-value lower than 0.3 W/m^{2}K)
- Hot water fittings (e.g. taps, showers) that are rated in the top class (dark green) of the European Water Label Scheme (http://www.europeanwaterlabel.eu/)
- Household appliances (e.g. washing machines, dishwashers) rated in the top available class according to the EU Energy Label for each type of appliance
- High efficiency lighting appliances rated in the highest energy efficiency class that is significantly populated in the energy efficiency label (or higher classes) according to EU energy labelling regulations
- Presence and daylight controls for lighting systems
- Highly efficient space heating and domestic hot water systems rated in the highest energy efficiency class significantly populated in the energy efficiency label (or higher classes) according to EU energy labelling regulations
- Highly efficient cooling and ventilation systems rated in the highest energy efficiency class significantly populated in the energy efficiency label or higher classes according to EU energy labelling regulations
- Heat pumps compliant with the criteria for heat pumps given in the energy section of the taxonomy
- Façade and roofing elements with a solar shading or solar control function, including those that support the growing of vegetation
- Energy-efficient building automation and control systems for commercial buildings as defined according to the EN 15232 standard.
- Zoned thermostats and devices for the smart monitoring of the main electricity loads for residential buildings, and sensoring equipment, e.g. motion control.

Annex 1B: Taxonomy proposed standards

“Cradle-to-cradle carbon footprint”:

ISO 14040, link:
https://consequential-lca.org/clca/why-and-when/the-iso-14040-standards-for-consequential-lca/

“… *It is therefore obvious that also the* ***ISO 14040 series is concerned with improvements rather than measuring the status-quo.*** *This is also clear from the introduction to ISO 14040:2006 where all the listed applications of LCA are about improvements:*

“LCA can assist in:

- ***identifying opportunities to improve the environmental performance*** *of products at various points in their life cycle,*
- *informing decision-makers (…), e.g. for the purpose of strategic planning, priority setting, product or process* ***design or redesign****,*
- *the selection of relevant indicators of environmental performance,*
- *marketing (e.g. implementing an ecolabelling scheme, making an environmental claim, or producing an environmental product declaration).”*

PEF, link:
https://ec.europa.eu/environment/eussd/pdf/footprint/PEF%20methodology%20final%20draft.pdf

“Requirement of PEF studies:

All resource use and emissions associated with the life-cycle stages included in the defined system boundaries shall be included in the Resource Use and Emissions Profile. The following elements shall be considered for inclusion in the Resource Use and Emissions Profile:

- ***Raw*** *material acquisition and pre-processing;*
- *Capital goods: linear depreciation shall be used;*
- *Production;*
- *Product distribution and storage;*
- *Use stage;*
- *Logistics;*
- *End-of-life.”*

ISO 14067, link:
https://www.iso.org/obp/ui/#iso:std:iso:14067:ed-1:v1:en

“… *GHGs can be emitted and removed throughout the life cycle of a product which includes* ***acquisition of raw material****, design, production, transportation/delivery, use and the end-of-life treatment. Quantification of the carbon footprint of a product (CFP) will assist in the understanding and action to increase GHG removals and reduce GHG emissions throughout the life cycle of a product… . This document specifies principles, requirements and* *guidelines for the quantification* ***and reporting of the carbon footprint of a product (CFP),*** *in a manner consistent with International Standards on life cycle assessment (LCA) (ISO 14040 and ISO 14044).* ISO 14040 text above.

EPD, link
https://www.environdec.com/What-is-an-EPD/

"*An Environmental Product Declaration (EPD) is an independently verified and registered document that communicates transparent and comparable information about the life-cycle environmental impact of products. As a voluntary declaration of the life-cycle environmental impact,* ***having an EPD for a product does not imply that the declared product is environmentally superior to alternatives****.*"

The standards/methods proposed in the Taxonomy report on page 189 ("*21.1 Manufacture of Low Carbon Technologies*" activity) are very burdensome (covering the whole lifecycle "*cradle-to-cradle*") and ***not necessary declaring which product is environmentally superior to alternatives*** (e.g. see above case "EPD"). This is a rather theoretical and burdensome approach, there are more suitable existing EU legal framework available (see below text). Taxonomy is intended to be adoptable worldwide and thus a practical approach based on BAT is needed.

A fossil fired power plant has during its' operational phase (typically up to 20 ... 30 years) the biggest environmental impact (see source /24/). **Thus focus on the "operational phase" for the power plant is enough to judge criteria "** ... ***that result in substantial GHG emission reductions in other sectors of the economy..."*** especially when assessing the benefit of cogeneration or the grid balancing (peak) gas fired reciprocating engine plant environmental performance.

Existing legal framework such as EU Energy Efficiency Directive 2012/27/EU ("... *best practices for energy performance*"...), Harmonised Reference Values Regulation EU 2015/2402) **and LCP BREF 2017 /3/** are such suitable/practical ones to use for the purpose to determine "... ***low carbon technologies that result in substantial GHG emission reductions in other sectors of the economy***...".

In the EU 2015/2402 the reference value (in 2012/27/EU) for separate electrical energy from gas combustion efficiency has been updated (Annex I, to 53 %), preface text quote of 2015/2402: *" (2) The Commission has reviewed the harmonised efficiency reference values for the separate production of electricity and heat taking into account data* ***from operational use under realistic conditions****, provided by Member States and by stakeholders. As a result of developments in the* best available and economically justifiable *technology, observed during the review period 2011 to 2015)*".

This electrical efficiency of 53 % is achievable for a CCGT (Combined Cycle gas Turbine) at high (ideal) load conditions. In present power markets (e.g. in EU, USA) plants are operated at various loads and thus the actual efficiency is many times lower (see below figures 1, 2)) and thus ***the set separate electrical efficiency value in EU 2015/2402 is not representative "from operational use under realistic conditions*" of today** .... Note the good part load electrical efficiency performance of the multiunit gas fired reciprocating engine plant shown in figure 2. At lower plant loads reciprocating engines are gradually taken out of operation while remaining ones are operating at their optimal high load.

Article /19/ “***Energiewende shuts down most efficient gas turbine*** “ quote: “ ... *that this flexibility is only possible with the first turbine stage, not with the downstream steam turbine. And the first one runs not at 60 percent, but below 40 percent efficiency. In other words, with* ***CCGT you can either have high flexibility or high efficiency, not both simultaneously*** ... *...* “, i.e. CCGT is not anymore sufficient competitive in the flexible grid balancing power market, **thus the EU 2015/402 given efficiency level for the separate electrical production is not reflecting situation of today**! I.e. the preferable approach reflecting the current power market situation ***is to have specific prime mover reference values, in LCP BREF 2017 chapter 10 table 10.23 are BAT Associated Energy Efficiency levels (BAT AEELs) reflecting best the situation of today.***

For the natural gas fired reciprocating power plant the most important GHGs are CO_2, CH_4. N_2O is insignificant. The LCP BREF plant BAT-AAEL efficiency is a surrogate for the CO_2 emission (i.e. a high efficiency implies a low CO_2 emission), LCP BREF has set a BAT-AEL value for the CH_4 emission for the lean burn gas reciprocating engine (SG-type). By using these elements specified in the LCP BREF alone or in conjunction with a LCA/LCE method for the operational phase a BAT associated CO_{2eq} is achieved for the grid balancing (peak) gas fired reciprocating engine plant. At the same time other EU ambitions such as improving energy efficiency by 2030 are on the right track.

Conclusion

The latest LCP BREF BAT /3/ prime mover specific BAT-AEELs to be used when determining e.g. the BAT efficiency for separate electrical production. This in combination with the maximum CH_4 BAT-AEL is a surrogate for the CO2eq.

By using the elements specified in the LCP BREF alone or in conjunction with a LCA/LCE method (within actual plant boundaries) for the operational phase (“*Direct emissions from plant operation represented the majority of the life cycle emissions for fossil fuel technologies* ... /24/“) a BAT associated CO_{2eq} (footprint) is achieved for the grid balancing (peak) gas fired reciprocating engine plant. At the same time other EU ambitions such as improving energy efficiency by 2030 are on the right track

Beyond the environmental considerations, the economic and social pillars of sustainability are equally important and taxonomy should also consider these aspects and **not only focus on a low carbon economy**.

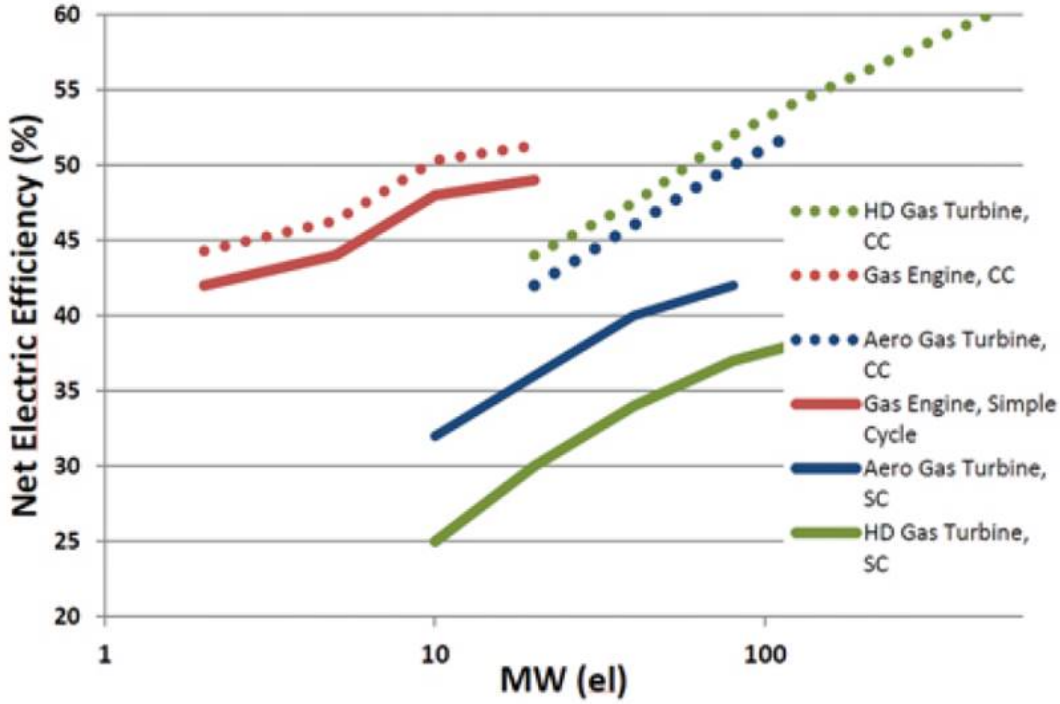
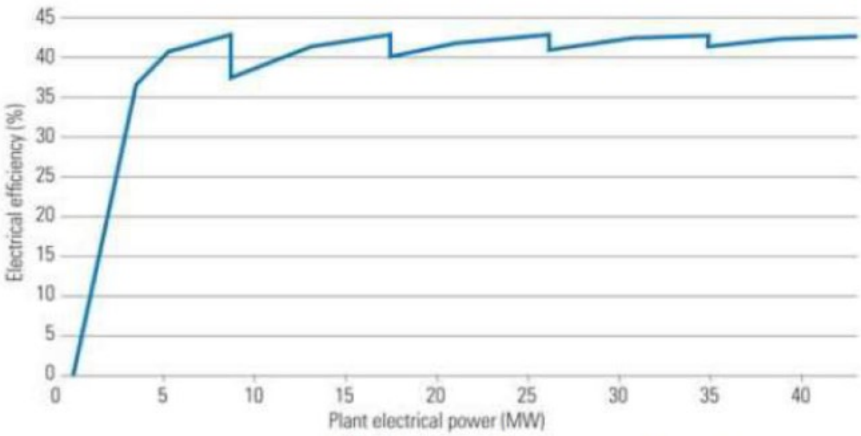


Figure 1: Typical El. Efficiencies v. load for some single unit prime movers/13/.



2. Even efficiency. The dispatch plan for the first five of the nine Wärtsilä 20V34SG engines at the Goodman Energy Center shows that very little efficiency is lost with part-load operation. *Source: Wärtsilä*

Figure 2: Multi-unit gas engine plant part load behaviour /11/

Annex 2 "CCS (Carbon Capture and Storage) Quotes page 293 – 294 /1/

"***Carbon capture and sequestration is a key technology*** *for the carbonisation of Europe… A typical CCS chain consists of three main stages:* ***capture, transport and storage. CO_2 transport and storage are established and proven processes with decades of operation and well-established regulation here in Europe*** *… CCS can be eligible in any sector if it enables that primary activity to operate in compliance with the threshold – for example, steel, cement or electricity production."*

Capture

... Time is a crucial factor, the later options for a deep carbonisation in an industry arise, the more costly they become … 2050 is only one investment cycle away for many industries. Thus decisions need to be made today. ... CCS on dispatchable generation allows all aspects of the electricity supply system to be deeply decarbonised. ***CCS provides a <u>backstop to the unabated operation of flexible electricity generation plants</u> that are required to guarantee the operation and supply of year-around electricity****. This is* ***<u>especially true in in more isolated grids</u>*** *with a high penetration of seasonable variable renewables (e.g. onshore and offshore wind) where the reliable operation of electricity networks requires on-demand electricity generation. The availability of CCS means that no remaining segment of the electricity supply system will be capable of emitting CO_2 to the atmosphere.* ***Whilst some CO_2 capture technologies can incur an "Energy penalty" of 10-15 %, others not. For example the Allam cycle being developed ... does not incur an energy penalty*** *as supercritical CO_2 is integrated fully in the power system as a coolant. ...* ***It is therefore inaccurate to say that CCS is a highly energy-intensive technology.***

Transport and Storage

*The transport and storage of CO_2 should be considered essential to the infrastructure of a modern sustainable society. It c****an aid electricity grid expansion, the integration of renewables and the deep decarbonisation...*** *Without CO_2 transport and storage infrastructure, Europe will not achieve its climate objectives. Chemically,* ***CO_2 bonds with surrounding minerals after injection... making CO_2 storage sites safe as time progresses****. The* ***IPCC estimates that over 99.9 % of CO_2 will remain underground****. The EU has provided clear and extensive assessment and monitoring requirements through the 2009 CO_2 Storage Directive.* ***CO_2 has already been safely stored in geological formations in Europe for over 20 years.*** *Though decade-long CO_2 injection experiences in North America, and monitoring of CO_2 storage in Europe,* ***the safe final disposal both in- and off-shore has already been established*****."**

Annex 3: Operational example of an 130 MWe gas reciprocating engine plant

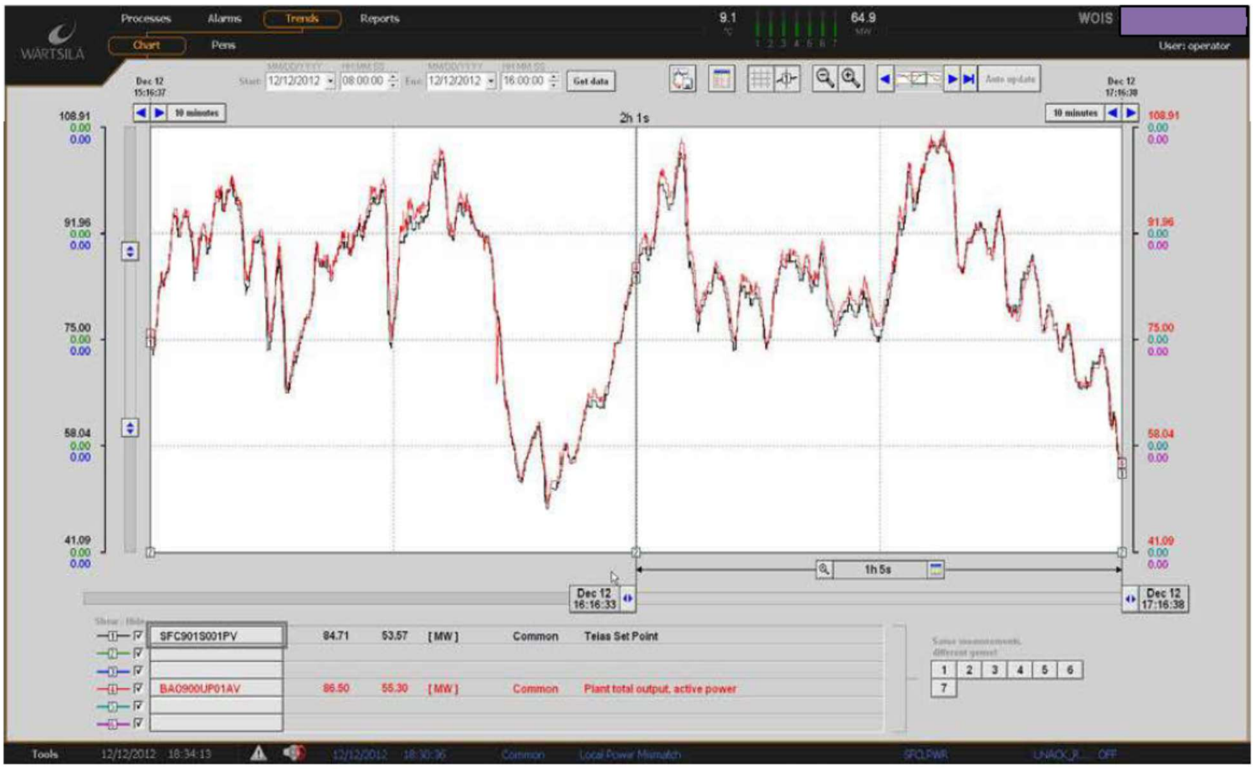


Figure 1: Gas Engine Plant consisting of 7 engine units, 130 MWe, 2 hour Scada trend. Plant set point signal from the grid TSO, is typically 40 -100 MWe in this case. /11/.

Annex 4: Start-up & loading examples

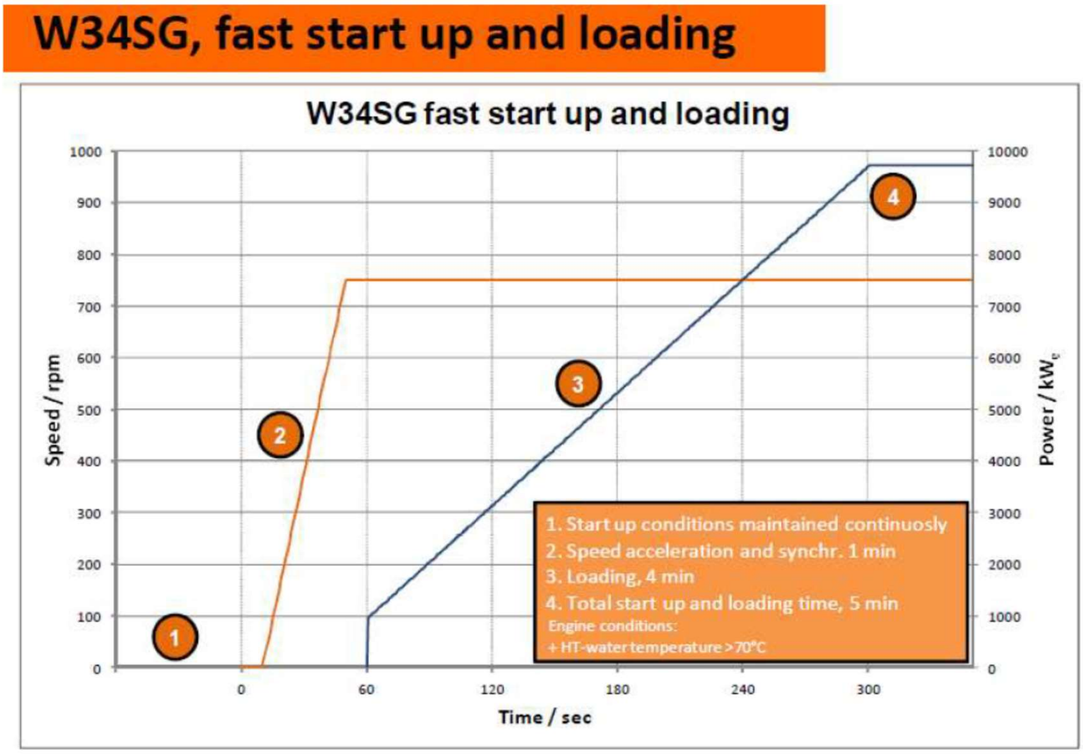


Figure 1: SG = Spark Ignited Gas Engine (source: Annex II, /11/)

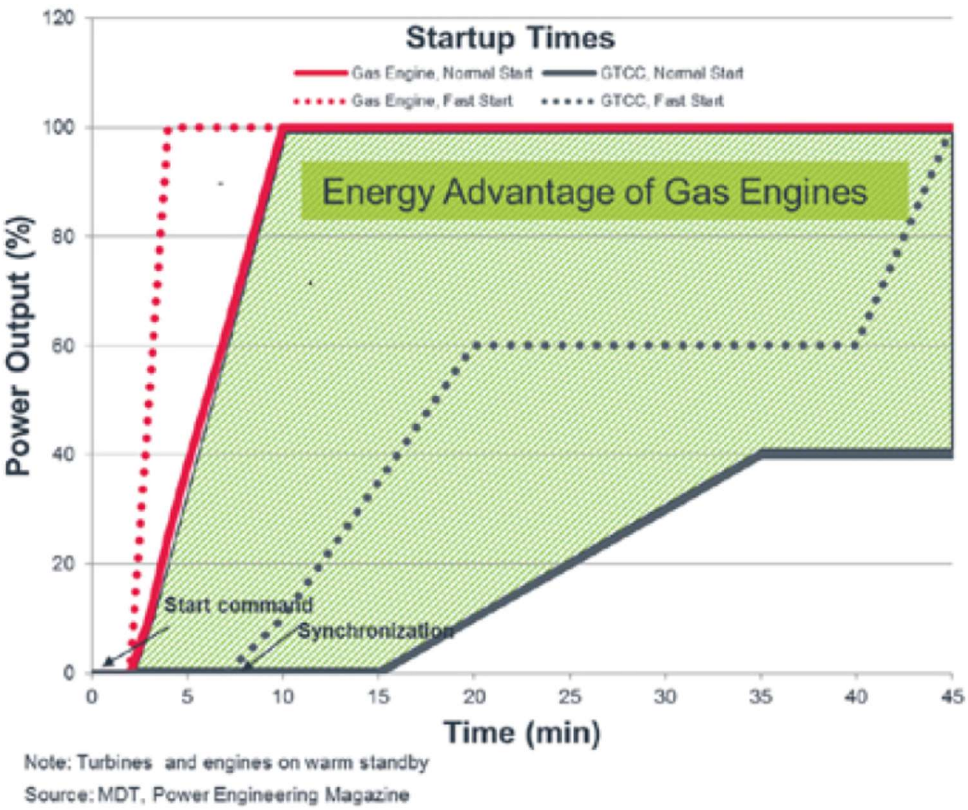
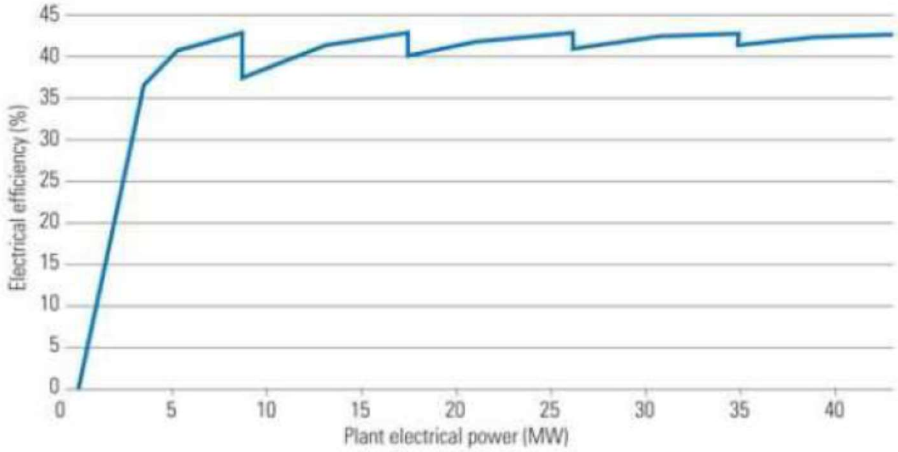


Figure 2: Start-up time comparison between CCGT and single cycle Gas engine/13/

Annex 5: Efficiency at different loadings



2. Even efficiency. The dispatch plan for the first five of the nine Wärtsilä 20V34SG engines at the Goodman Energy Center shows that very little efficiency is lost with part-load operation. *Source: Wärtsilä*

Figure 1: Multi-unit gas engine plant, source: Annex I /11/

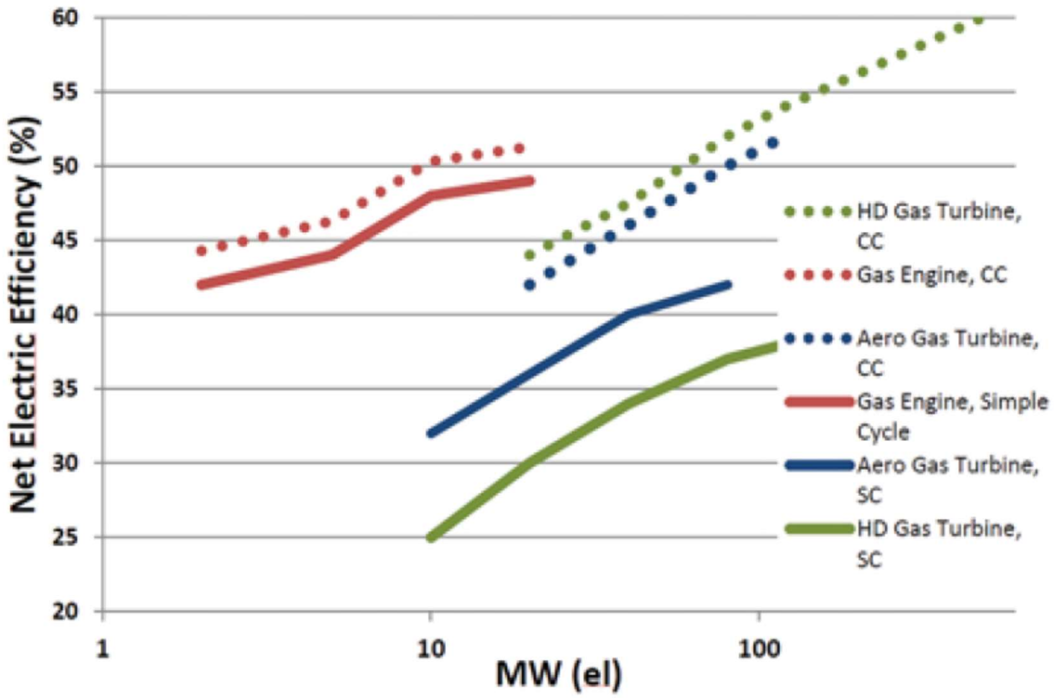


Figure 2: Typical El. Efficiencies v. load for some single unit prime movers /13/.

Annex 6: US-case: "*Glendale: Fastest energy transition ever?*" /17/ *quotes:*

"Glendale's municipal utility quickly got comfortable with big batteries, distributed energy, efficiency and a few reciprocating engines ... The final portfolio, proposed in Glendale Water & Power's new integrated resource plan, would repower the Grayson Power Plant with a 75-megawatt/300-megawatt-hour Tesla battery installation and up to 93 megawatts of fast-ramping Wärtsilä engines... . The final proposal does include some fossil fuel infrastructure, but the choice of Wärtsilä engines is notable. ... The company, a Finnish manufacturer of engines for ships and power production, has adopted a long-term decarbonization strategy that envisions running its equipment on synthetic biofuels one day ... Similarly, GWP expects to be able to convert the engines to run on biogas, renewable natural gas or…, depending on the commercial maturation of those fuels. In the meantime, 18.5-megawatt units give the utility more precision to meet peaks than firing up much larger turbines. And if it's possible to reduce the number of engines and still meet reliability needs, Zurn said he's happy to do that..."

Annex 7: Energy efficiency levels associated with the best available techniques (BAT-AEELs) /3/

"Energy efficiency levels associated with the best available techniques (BAT-AEELs)
An energy efficiency level associated with the best available techniques (BAT-AEEL) refers to the ratio between the combustion unit's net energy output(s) and the combustion unit's fuel/feedstock energy ***input at actual unit design****. The net energy output(s) is determined at the combustion, gasification, or IGCC unit boundaries, including auxiliary systems (e.g. flue-gas treatment systems), and for the unit operated at full load.*

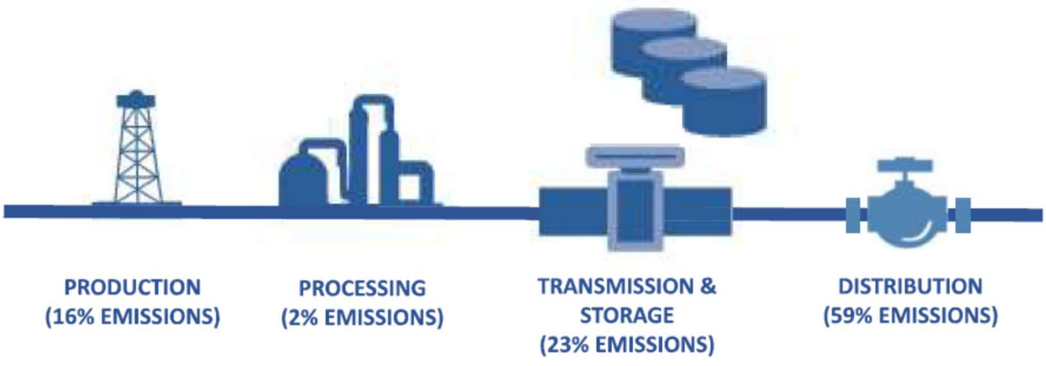
In the case of combined heat and power (CHP) plants:

- *the net total fuel utilisation BAT-AEEL refers to the combustion unit operated at full load and tuned to maximise primarily the heat supply and secondarily the remaining power that can be generated;*
- *the net electrical efficiency BAT-AEEL refers to the combustion unit generating only electricity at full load.*

BAT-AEELs are expressed as a percentage. The fuel/feedstock energy input is expressed as lower heating value (LHV)."

Annex 8: EU gas chain methane slip sources and contribution of delivery chain /18/

Figure 4: CH_4 emissions from natural gas operations[11] across the EU gas chain in 2016



Annex 9: Methane intensity per region /18/

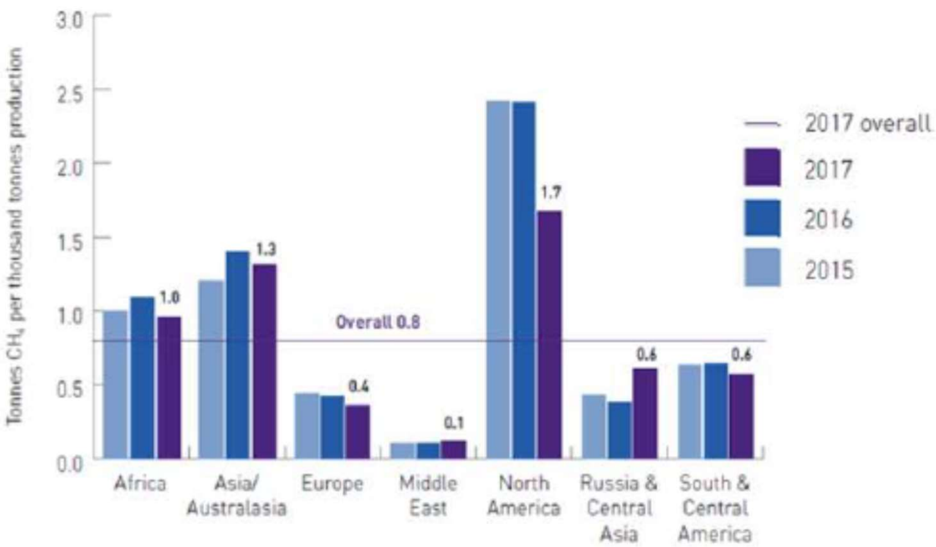


Figure 23: Methane emissions by hydrocarbon production by region

Annex 10: “Estimate of natural gas losses during transmission and distribution in Russia“

Source /26/

Table S5. Derivation of Lelieveld *et al.*[18] estimate of natural gas losses during transmission and distribution in Russia

Natural Gas Sector	Methane Loss (% of Total Throughput)	Data Source
Domestic Russian transmission	0.7% (0.4-1.6%)	Field measurements in Russia
Domestic Russian distribution	0.5 – 0.8%	Assumed the % of produced NG leaked in the Russian and U.S. distribution networks would be roughly equivalent
Domestic Russian gas spills at wells	0.1 ± 0.04%	Re-evaluation of data from Dedikov *et al.*[19]
Total	1.4% (1.0 - 2.5%)	