Workshop on Implementation of BAT Conclusions for Waste Incineration

Puzzle piece 3: calculation of energy efficiency

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Puzzle piece 3: calculation of energy efficiency

- Energy efficiency in WI BREF – the three cases
- Performance test and nominal design values
- Boundaries of the calculation
- WI BREF energy efficiency formulas
- Example of calculation
- Difference with R1 formula

Energy efficiency - difference with R1 formula

BREF Energy efficiency calculation

- **Assess the ABILITY of the installation to recover energy efficiently**
- To be performed only once, or after any modification that could significantly affect the energy efficiency
- Two kinds of formula depending on the type of plant (heat only, electricity only, CHP-based on the turbine)
- Based on the performance test levels or the design values of the plant (or part of it)
- Heat and electricity are summed up together only in the case of a CHP plant equipped with a backpressure turbine
- No multiplicative factor to take into account the reference efficiency of other plants
- Benchmark value to be checked with BATAEELS of BAT 20

***R1 value** is a benchmark value set by the WFD. If met, the plant is considered a recovery operation (non disposal)*

R1 value calculation

- **Assess the EFFECTIVE energy recovery over a year (which depends on the demand)**
- To be performed periodically (e.g. Every 3 years)
- Same calculation for all waste incineration plants, indipendently from the setup
- Based on the ratio between the overall production of energy and the total amount of energy provided in input in the given year
- Heat and electricity are summed up together
- Multiplicative factors applied to electricity produced (2.6, based on the average European efficiency of coal plants) and to heat produced (1.1, average heat efficiency of heat plants)
- Benchmark value to be compared with a threshold to get the R1 status

Energy Efficiency in Waste Incineration BREF Final Draft

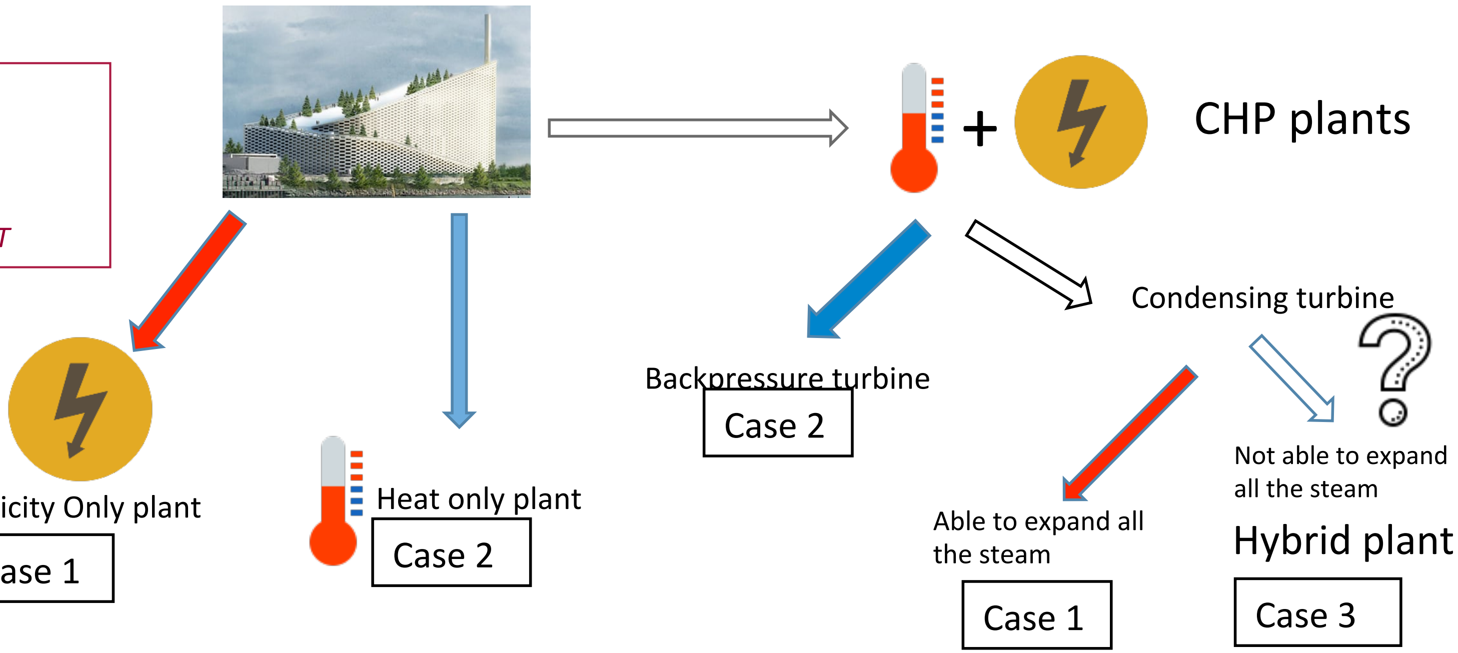
“The BAT-AEELs given in these BAT conclusions for the incineration of non-hazardous waste other than sewage sludge and of hazardous wood waste are expressed as:

- ***gross electrical efficiency** in the case of an incineration plant or part of an incineration plant that produces electricity using a condensing turbine;*
- ***gross energy efficiency** in the case of an incineration plant or part of an incineration plant that:*
  - *produces only heat, or*
  - *produces electricity using a back-pressure turbine and heat with the steam leaving the turbine.”*

Case 1 – for electricity oriented plants

Case 2 – for heat oriented plants

- ***BAT:** Best Available Technique*
- ***BATAEEL:** Energy efficiency LEVEL Associated with BAT*



Energy Efficiency – BAT 2: monitoring

“BAT 2. BAT is to determine either the gross electrical efficiency, the gross energy efficiency, or the boiler efficiency of the incineration plant as a whole or of all the relevant parts of the incineration plant.

Description

*In the case of a **new incineration plant**, or after each modification of an existing incineration plant that could significantly affect the energy efficiency, the gross electrical efficiency, the gross energy efficiency, or the boiler **efficiency is determined by carrying out a performance test at full load.***

*In the case of an **existing incineration plant** that has not carried out a performance test, or where a performance test at full load cannot be carried out for technical reasons, the gross electrical efficiency, the gross energy efficiency, or the boiler **efficiency can be determined taking into account the design values at performance test conditions**. For the performance test, no EN standard is available for the determination of the boiler efficiency of incineration plants. For grate fired incineration plants, the FDBR guideline RL 7 may be used.”*

Performance test – Waste incineration plant

Performance test is usually performed on:

- **boiler(s)** (eg. with FDBR RL 7, which adapts DIN EN 12952-15 to the incineration of waste)
- **the turbine generator set(s)**,(e.g. with the IEC 60953-1/2 or the DIN 1943)

And verifies that the equipment can achieve its guaranteed parameters and function as intended, and is usually carried out after the commissioning period or retrofit of a plant.

Usually no performance test on:

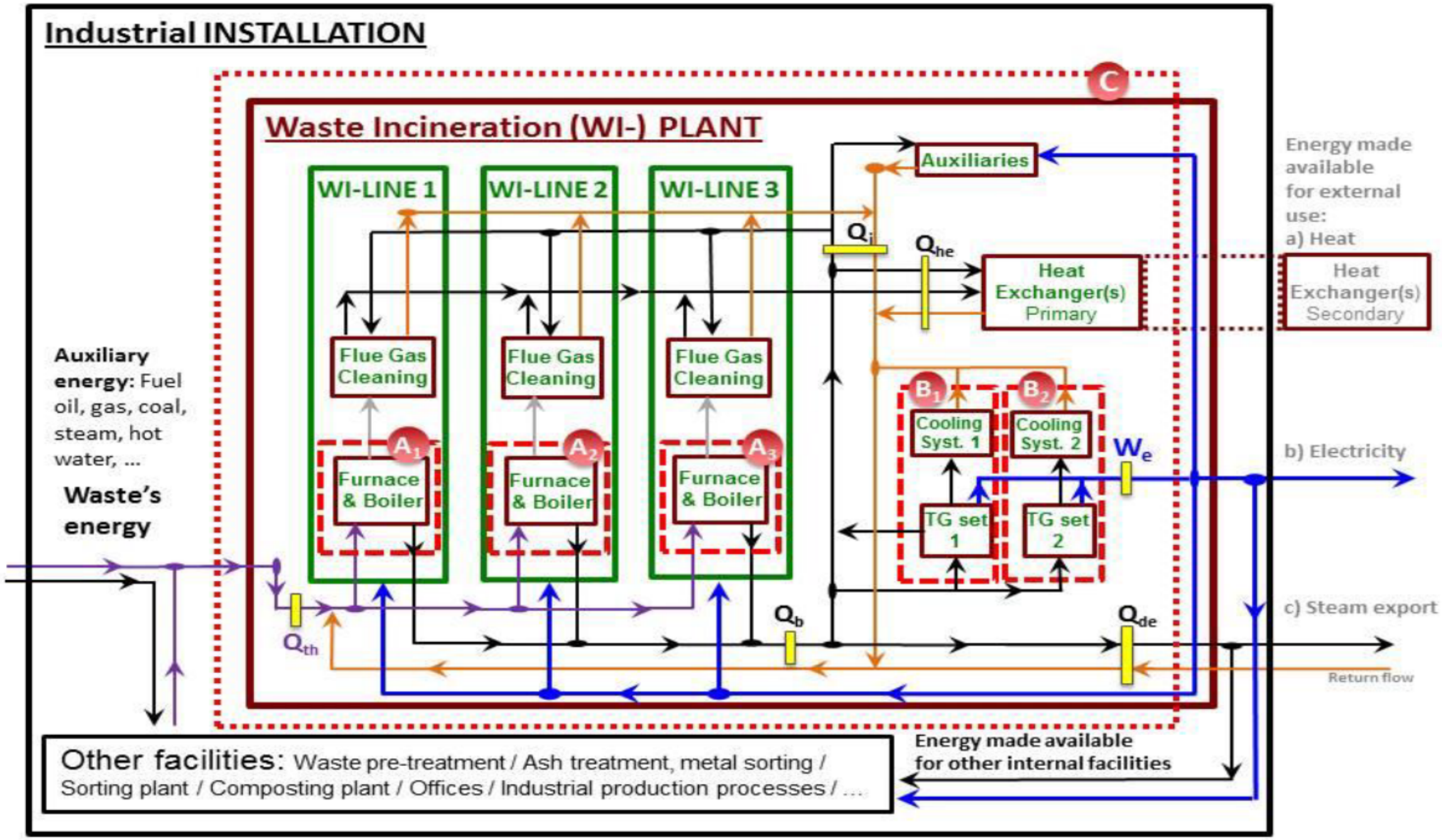
- ***heat exchangers for district heating***
- ***steam direct export system***

For these parts, <u>nominal design values are used instead</u>

Implementation of WI BREF: possible situations

	New plant	Existing plant with modification (as in BAT2)	Existing plant without modification (as in BAT2)
Definition	*A plant first permitted following the publication of these BAT conclusions or a complete replacement of a plant following the publication of these BAT conclusions.*	*Not a new plant.* Modifications that could significantly affect the energy efficiency	*Not a new plant.* No modification that could significantly affect the energy efficiency
Before getting/ updating the permit	To apply for the permit, design values of equipment able to comply with BATAEELs	Design values of new equipment able to comply with BATAEELs	-
On boiler(s) and turbine generator set(s)	Carry a Performance test, if possible	Carry a Performance test on new equipment, if possible – use existing performance test on old equipment, if available. Otherwise use design values	Use existing performance test (if available), otherwise use design values
On heat exchanger and turbine steam direct export system	Use design values	Use design values	Use design values

Boundaries of the calculation according to WI BREF, Chapter



Part of an incineration plant:

- *an incineration line and its steam system in isolation;*
- *a part of the steam system, connected to one or more boilers, routed to a condensing turbine;*
- *the rest of the same steam system that is used for a different purpose, e.g. it is directly exported.*

The energy efficiency may be assessed at the level of the waste incineration plant, with the system boundary shown in Figure, or at the level of a part of the waste incineration plant in cases where the amounts of energy recovered by different parts of the plant cannot be appropriately summed together for example.

Gross Electrical Efficiency – Formula case 1

Power output to thermal input ratio

Correction factor to take into account the internal use of heat

: electrical power generated, in MW;

: thermal input to the thermal treatment units (e.g. furnaces), including the waste and auxiliary fuels that are used continuously (excluding for example for start-up), in MWth expressed as the lower heating value.

: thermal power produced by the boiler, in MW;

: thermal power (as steam or hot water) that is used internally (e.g. for flue-gas reheating), in MW;

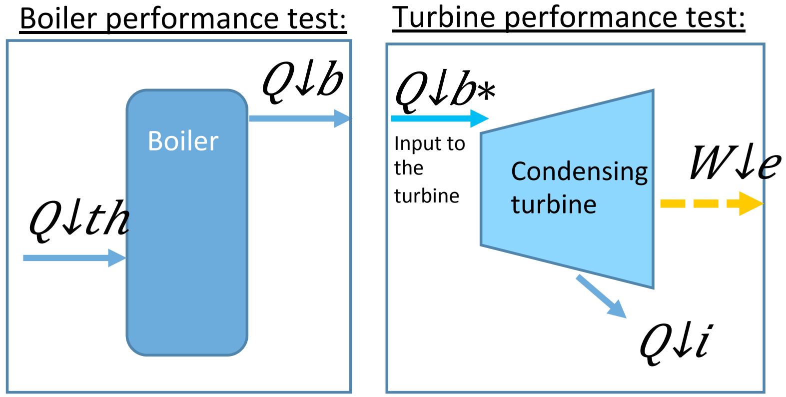
Applies to electricity oriented plants:

- Electricity only plant
- CHP plants able to expand all the steam in the condensing turbine

Q_i should not take into account the heat that is used internally when it result in an energy used in the production of steam/hot water by the boilers

Other correction factors can be used eg.:

- For ambient temperature and pressure
- Ageing



* If turbine input ≠ boiler output (e.g. because the performance test has been performed during different days) the two values should be matched

Gross Energy Efficiency – Formula case 2

: electrical power generated, in MW;

: directly exported thermal power (as steam or hot water) less the thermal power of the return flow, in MW;

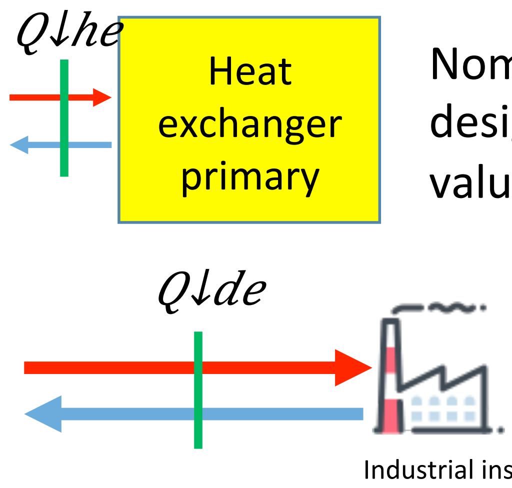
: thermal power supplied to the heat exchangers on the primary side, in MW;

: thermal power (as steam or hot water) that is used internally (e.g. for flue-gas reheating), in MW;

: thermal input to the thermal treatment units (e.g. furnaces), including the waste and auxiliary fuels that are used continuously (excluding for example for start-up), in MWth expressed as the lower heating value.

Applies to heat oriented plants:

- Heat only plant
- CHP plants equipped with a backpressure turbine



Nominal design values

Qde and Qhe should be corrected to the part of the nominal thermal power supplied when connected turbine is operated at nominal load

Internal consumption of heat

$(Q_b / (Q_b - Q_i))$

When the Q_i is equal to 0, this factor is equal to 1, and therefore has no impact,

If Q_i >0, the factor is >1 and increase the number resulting from the formula.

Examples of Qi are the following:

- Steam used for reheating the flue gas
- Heat for flue gas cleaning system
- Soot blowers
- Steam driven devices such as pumps, compressors, vacuum pumps
- Heating, cooling and warm water of buildings, instruments, apparatus silos, greenhouses
- Energy used for steam trace heating
- Heat recovered from flue gas condensation[1]

[1]The energy recovered in this way could also be used outside the WtE plant, but since it cannot be accounted elsewhere in the calculation, it should be added to the internal use.

BREF Waste Incineration - BATAEELs

Plant	BAT-AEEL (%)			
	Municipal solid waste, other non-hazardous waste and hazardous wood waste		*Hazardous waste other than hazardous wood waste* [(1)]	*Sewage sludge*
	Gross electrical efficiency [(2)] [(3)]	*Gross energy efficiency* [(4)]	*Boiler efficiency*	
New Plant	25-35	72–91[(5)]	60–80	60–70 [(6)]
Existing plant	20-35			

(1) The BAT-AEEL only applies where a heat recovery boiler is applicable.
(2) The BAT-AEELs for gross electrical efficiency only apply to plants or parts of plants producing electricity using a condensing turbine.
(3) The higher end of the BAT-AEEL range can be achieved when using BAT 20 f.
(4) The BAT-AEELs for gross energy efficiency only apply to plants or parts of plants producing only heat or producing electricity using a back-pressure turbine and heat with the steam leaving the turbine.
(5) A gross energy efficiency exceeding the higher end of the BAT-AEEL range (even above 100 %) can be achieved where a flue-gas condenser is used.
(6) For the incineration of sewage sludge, the boiler efficiency is highly dependent on the water content of the sewage sludge as fed into the furnace.

Energy efficiency: possible issues

1)BATAEELs cannot be met in the plant without a major retrofit

BATAEELs do not have the same legal status of BATAELs (which are mentioned explicitly in IED Chapter 2).

Achieving the levels might be out of the control of the operator. (measures listed in BAT 20 could not be sufficient, or applicable)

2) What if a plant does not fit into neither case 1 nor case 2?

See next slides..

Special cases: hybrid plants – case 3

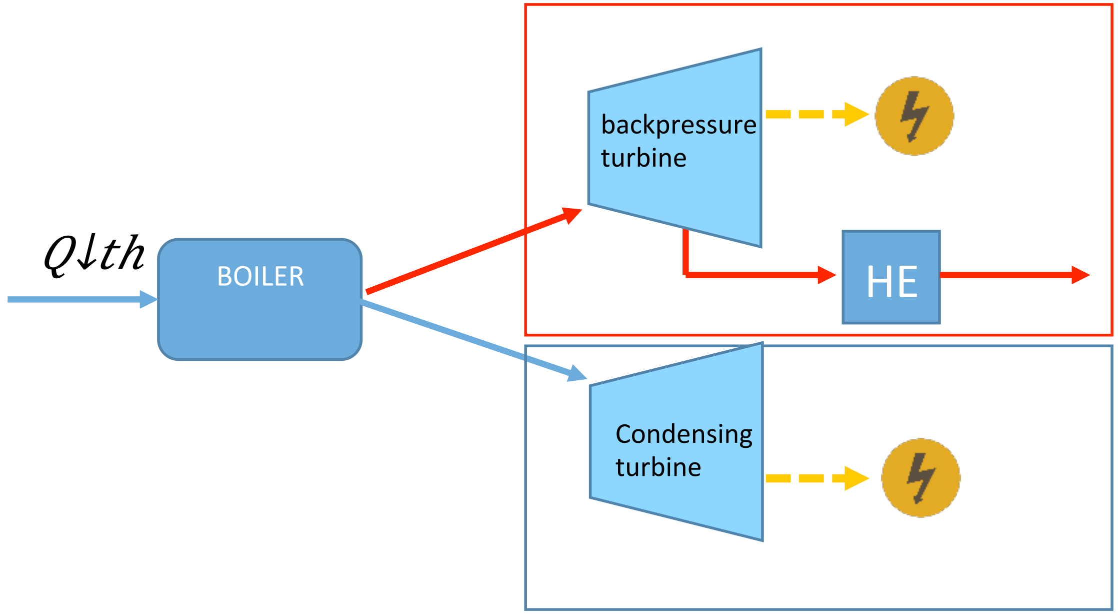
Special cases exist, in which neither one nor the other formula can completely apply to the plant.

Examples of special cases are:

- A plant which **is able to expand only part of** the steam in the condensing turbine
- A plant which has both a condensing turbine and a backpressure turbine, in parallel.

What to do?

A solution may be to divide the plant into «parts», and calculate efficiency separately



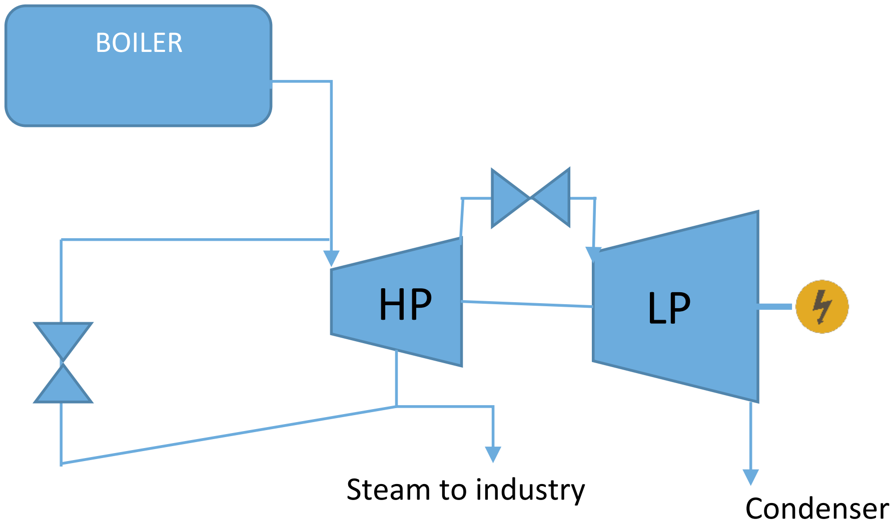
Case 2

Case 1

Example of two turbines in parallel.

Qth should be split depending on the input to the turbine

Example of calculation of energy efficiency for a hybrid case



SETUP:

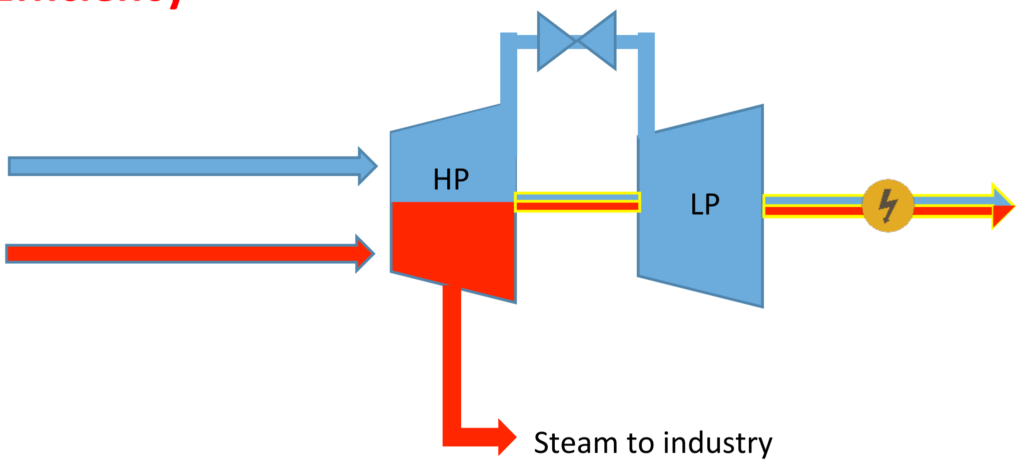
- One condensing turbine – divided in HP and LP
- LP turbine only able to expand part of the steam
- The rest of the steam is delivered to a nearby industry

It is not possible to calculate the efficiency of this **entire** plant through either the formula of Gross electrical efficiency or the Gross energy efficiency.

Example of calculation of energy efficiency for a special case

A solution is to split the steam flow in two parts:

- **steam that can go through the whole turbine**, and will correspond to the capacity of steam that the LP turbine can expand. Gross Electrical Efficiency
- **steam that is then exported to the industry**, and **pass only through the HP turbine, The HP turbine will be considered as a virtual backpressure turbine. Gross Energy Efficiency**



The electricity produced should be divided according to the delta enthalpy of the steam in HP turbine, then going to industry, and the one that fully expand also in the LP turbine

The draft explanatory and guidance document includes one detailed example with thermodynamics parameters

Energy efficiency - difference with R1 formula

BREF Energy efficiency calculation

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***R1 value** is a benchmark value set by the WFD. If met, the plant is considered a recovery operation (non disposal)*

R1 value calculation

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- To be performed every year
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Thank you!

Questions?