

## Gasification without Maxwell's Demons

Hans Grassmann<sup>(1,2)1</sup>, Fabiano Bet<sup>(3)</sup>, Daria Botsula<sup>(1)</sup>, Parsu Ram Sharma<sup>(1)</sup>

(1) University of Udine, (2) Isomorph srl, (3) Indesa GmbH

April 2026

### 1) Physics and renewable energies

It is generally known that the use of fossil fuels increases the CO<sub>2</sub> content of the atmosphere, which in turn increases the temperature of our planet. And in spite of many conferences and many billions of dollars spent, this increase augments each year. One should therefore conclude, that existing technologies are not sufficient to substitute fossil fuels.

This is not astonishing, fundamentally new problems – like global heating – may need fundamentally new techniques for solving them. Rather it is astonishing, that these new technologies do not emerge anywhere.

In this article we propose, that physics can be useful for developing new thoughts needed for the fight against the CO<sub>2</sub>, using the example of gasification.

### 2) Gasification

The use of natural gas got common only about 40 years ago. Before, gas was obtained from the gasification of coal (town gas). In particular during the second world war, also wood was gasified.

The gasification of biomass is CO<sub>2</sub> neutral, and might therefore offer an interesting contribution to solve the CO<sub>2</sub> problem, since in difference to photovoltaics and wind energy, gasifiers can be operated whenever needed, making use of easily stored biomass.

Over the last decades, many efforts to improve gasifiers were done in the field of engineering. But in spite of these progresses, even the most modern gasifiers are quite complex and expensive, and they can gasify only “high quality” biomass like for instance wood, but not for instance straw.

It seems worthwhile to study, whether a physics approach could overcome the limitations of state of the art technology, to provide a compact, simple and clean gasifier, able to operate with “waste” biomass (like straw).

Such a physics study should begin from the basics - from the fundamental working principles of gasifiers.

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1 [hans.grassmann@uniud.it](mailto:hans.grassmann@uniud.it), ORCID 0000-0002-8762-0127, Università di Udine, Via delle Scienze 206, I-33100 Udine

According to literature, gasification (in difference to combustion) is caused by a lack of primary air. For example “ If the oxygen supply is restricted, one can gasify the carbon into carbon monoxide ” [1].

Over the last years, gasification was studied also by means of computer simulation. Also these modern studies are still based on the old paradigm, for instance “ Gasification is a process in which incomplete combustion of the fuel or, using different terminologies, partial oxidation, occurs due to the insufficiency of a gasification agent ” [2].

This historical paradigm defines the way of gasifier construction until today: in a simple gasifier, a “small amount” of air is supplied to the gasifier, resulting in a low power density of the device and in a rather dirty gas (tar).

More modern gasifiers instead (being a result of the engineering effort) have a multi stage structure: a first “small quantity” of air is given to a first reaction zone, a second quantity of air is given to a spatially separated second reaction zone, since according to the paradigm, combustion would result, if these zones were not separated.

So the paradigm, according to which gasification is caused by a lack of oxygen, is not to be considered a merely academic or philosophical issue, rather it determines the way real gasifiers are constructed until today

From a physics point of view, one could understand the paradigm of a lack of oxygen, if the oxygen molecules where Maxwell Demons [3]: if they were able to see whether or not they are part of a lack of oxygen, and if they could accordingly react in one way or the other. But obviously, real oxygen atoms are not Maxwell Demons. It is therefore not clear, how they should decide on how to react, from a physics point of view.

### 3) Causality

The paradigm according to which gasification is a result of a lack of oxygen, is a causality argument: the lack of oxygen is the cause, gasification is the consequence.

Now, causality is an important part of human experience, and has always been an important part of philosophical study. While instead in state of the art physics causality seems to be less important, physics does not even have a measure for “causality”.

Seemingly, the scientific procedure regarding causality which is nearest to physics can be found in statistics, where Clive Granger has defined the “Granger causality” in 1969 [4]. He received a Nobel price for this work in 2003.

Since then, similar causality measures have been derived from the Granger method, always based on the same argumentative ground as Grangers work.

In 2020 a student has found, that the results of experiments with the nervous system of the worm “elegans” are in strong disagreement with the results of the Granger causality method applied to the nervous system of the worm [5]. The student has then tried to find the reason for this disagreement, and concluded, that the Granger causality in reality is not a causality measure at all, it is not scientific and in this sense is not even wrong.

Therefore it seems reasonable to question the causality argument, according to which gasification is caused by a lack of oxygen. This doubt, founded on theoretical grounds, can be explored by experiment:

the physics research company Isomorph srl has constructed a gasifier, which does not operate with a low flow of air, but which instead allows to provide small amounts of air as well as large amounts of air: the smallest amount of air is the one for which the gasifier stops operation and cools down. The largest amount of air is the one which mechanically blows the material out of the gasifier.

It was then found, that the gasifier works well, and it is not possible to change its operation from “gasification” to “combustion” or vice versa, by changing the flow of primary air [6] .

This opens the way for a new prospective on gasification, creating room for potential improvements, which are not possible under the old paradigm.

For this, a new explanation for the gasification process – substituting the old paradigm – would be useful. A very first explorative step towards such a new model is attempted in the next chapter.

#### 4) A new model for gasification

For a very simple explanation for the operation of a gasifier one might for instance assume, that the primary air with the solid material forms CO faster, as CO is oxidized to CO<sub>2</sub> - then the oxygen is consumed already, before CO<sub>2</sub> can form.

This qualitative argument can become a candidate theory, if one is able to associate it to a precise mathematical structure. For doing that, the following thought experiment is proposed:

We assume a tube filled with a mixture of an inflammable gas (like CO) and air. The tube may be oriented in parallel to the x-axis of a laboratory system, the left extremity of the tube may be at  $x=0$ .

If one ignites the gas mixture at  $t=0$  and  $x=0$ , a flame will propagate along the x-axis with a certain velocity, as shown in the figure.

An observer may travel at the same velocity with the flame. The observer can describe the flame in terms of some characteristic function, for instance this function may be the temperature, and since the observer travels at the same velocity as the flame, in his coordinate system (with axis  $x'$ ) the function will not depend on time, but only on space,  $f=f(x')$ .

In the laboratory system this becomes  $f(x-vt)$ , which is the mathematically precise description of a wave, so that all mathematical instruments available for waves apply.

If the gas in a small volume burns completely in a time  $T$ , this  $T$  is then the period of the wave and the wave length,  $\lambda$ , is linked to it through the velocity of the wave:  $v=\lambda/T$ .

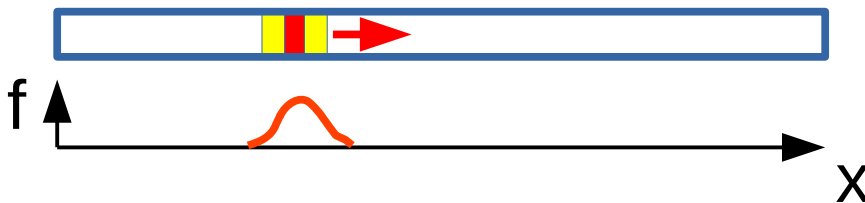


Figure 1: a flame travels along a tube in form of a wave.

If one fills the tube with carbon (instead of gas), and provides a steady flow of primary air (assuming of course, that the carbon does not block the air flow), the situation does not change: again there will be a

flame traveling at some characteristic speed, and a certain wave length, corresponding to the previous discussion.

The terms  $v_{\text{solid}}$  and  $\lambda_{\text{solid}}$  and  $v_{\text{gas}}$  and  $\lambda_{\text{gas}}$  may be chosen for the reaction  $\text{C} + \text{O} \rightarrow \text{CO}$  and  $2\text{CO} + \text{O}_2 \rightarrow 2\text{CO}_2$ , respectively.

Now we can give a mathematical requirement distinguishing gasification from combustion:

for  $\lambda_{\text{solid}} \ll \lambda_{\text{gas}}$  the first reaction (carbon to CO) consumes all oxygen, before  $\text{CO}_2$  can be formed – this is a gasification

If  $\lambda_{\text{gas}}$  is about as large as  $\lambda_{\text{solid}}$  or smaller, the CO formed is burned to  $\text{CO}_2$  – combustion.

$\lambda_{\text{gas}}$  is a material constant (depending on many parameters, like temperature and concentration)

$\lambda_{\text{solid}}$  depends on the density of carbon atoms  $dn/dx$  which are in contact with the gas flow. The higher this density, the faster oxygen molecules are consumed and the smaller  $\lambda_{\text{solid}}$ .

In a next step one can derive the operation of a real gasifier by supplying from the left carbon at the same speed as carbon is consumed. As a consequence, the wave of the carbon oxidation becomes now stationary.

In order to verify and to study in more detail this model, fluid dynamic simulation studies have been initiated, and will be reported in a separate article.

## 5) Physics context and Outlook

The results of this study support, what was found in a recent study on Granger causality [5], albeit in a totally different field: also in the case of the gasifier, the causality argument is not necessary as an explanation.

However, this seems to deepen further fore mentioned discrepancy between human experience and physics: how is it possible that in traditional physics causality is of little use, while instead it is present everywhere in human experience?

It is now precisely the study of the gasifier, which might shed light onto this seeming paradox: the causality argument for gasification could be made, if the oxygen molecules were Maxwell Demons. And Maxwell Demons were introduced by L. Szilard as intelligent beings [7].

This suggests that causality exists only in presence of intelligent beings: on the one hand, this would explain the “absence” of causality in classical physics – classical physics does not have intelligent beings as a subject of study.

On the other hand, it would support the evidence already given by L. Szilard for a new field of physics, which might be referred to as “physics of information” or similar.

## 6) Conclusion

Using the gasifier as an example, we have shown that physics can give an important contribution to the technologies of renewable energies:

In a first step, physics contributes - in this example – by showing that there is a problem, which otherwise does not get noted, namely the paradigm according to which gasification is caused by a lack of oxygen.

In a second step a physics experiment confirms, that indeed the classical paradigm must be wrong - it is possible to construct a gasifier which is not based on a lack of air.

In a third step, it is possible to create a connection between the gasification or combustion processes and a general mathematical structure, leading to a new theoretical approach for explaining gasification by means of a wave model.

(This new approach or model needs to be verified, and possibly extended and improved in future studies.)

On the one hand these results indicate, that to some extent global heating is related to a lack of physics in present society, the fight against CO<sub>2</sub> would profit from stronger physics efforts.

On the other hand, the progress of physics itself profits from these studies: the doubts about the validity of the classical causality paradigm are based on a new point of view of the Maxwell Demon. Thereby a connection between causality and Maxwell Demon is created, similar to the connection between the concept of information and the Maxwell Demon (proposed by L. Szilard). This suggests a connection between the concept of causality and the presence of intelligent beings – while in classical physics causality is not very important, and is not even mathematically defined, it is very important in the human world.

Like Szilard's studies of the Maxwell Demon, also the study of the gasification process indicates therefore the existence of a new field of physics, which might be referred to as "physics of information".

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