A bridge to a hydrogen society

Giuseppe Spazzafumo

University of Cassino and Southern Lazio
Department of Civil and Mechanical Engineering

International Association for Hydrogen Energy
Hydrogen Energy Systems Division

Preamble

The aim of this meeting would be to outline a future for a region that should abandon its mining activity with a view to decarbonising the society.

But one week ago President Duda said that:

"*Using your own natural resources - in Poland's case, coal - in order to be able to ensure energy security is not in opposition to climate protection and progress in climate protection*".

I agree

In the near future, decarbonisation and coal mining are not in conflict. Not for your Region.

Unless you want to use nuclear energy, renewables energy sources are the core of decarbonisation process and hydrogen is the unique non-carbon fuel. However decarbonisation is a gradual process and eliminating coal could not be the best initial step.

Current energy situation in the Region

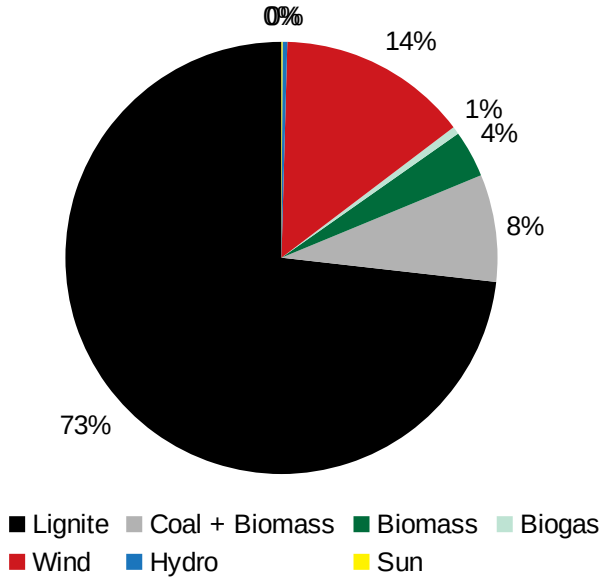
Electric power generation is dominated by lignite which is a regional source. However generation from renewable energy sources are increasing, especially from wind and biomass.

Another important sector is residential heating, which is mainly district heating based on lignite and natural gas (not a regional source).

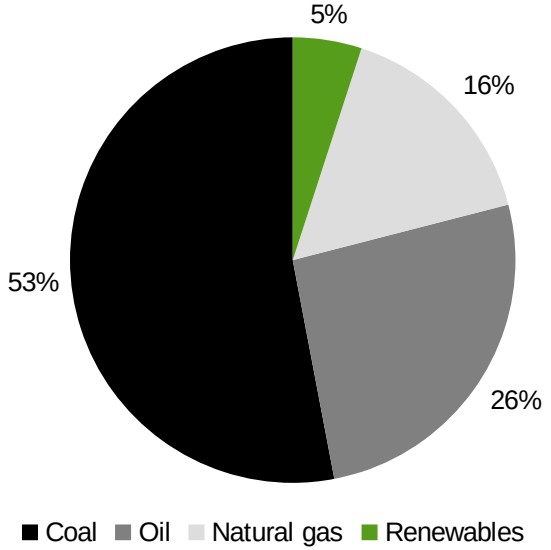
Finally, the transportation sector is mainly based on fuels which are not regional sources and which cover a significant share of the primary energy consumption.

I will focus my attention to hydrogen from wind, which seems the most promising.

Electric power generation (Wielkopolska, 2015)



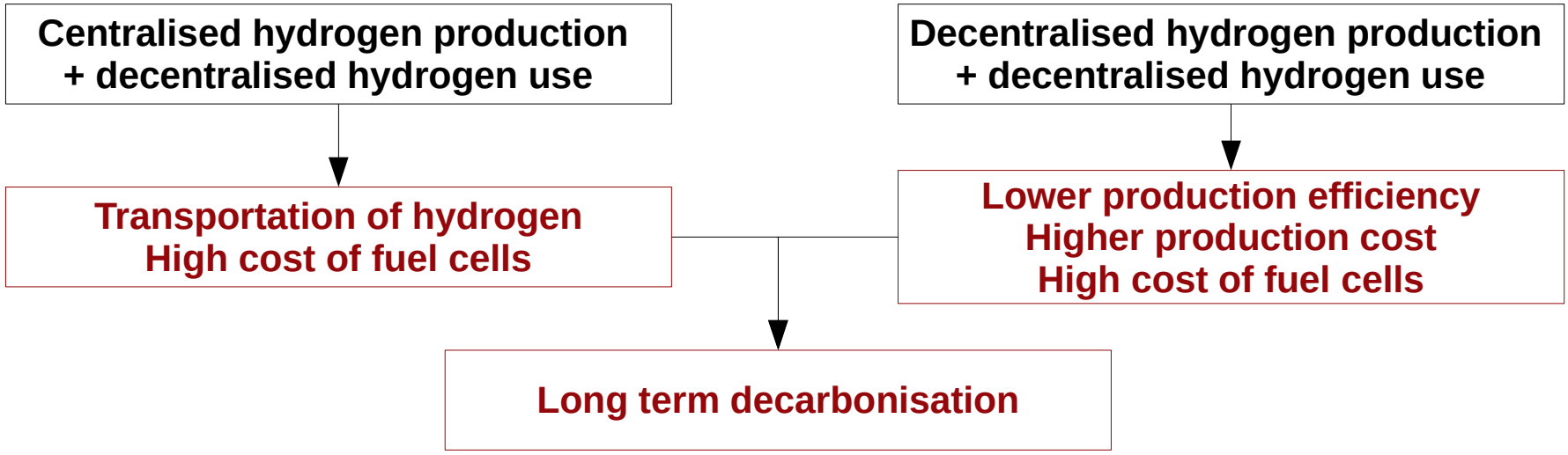
Primary energy consumption (Poland, 2015)



Hydrogen + Fuel cells

Replacing fossil fuels with renewable electric power and renewable hydrogen will require some decades. Until they will not cover the most of energy needs, the choice of how to use the available renewable hydrogen is fundamental.

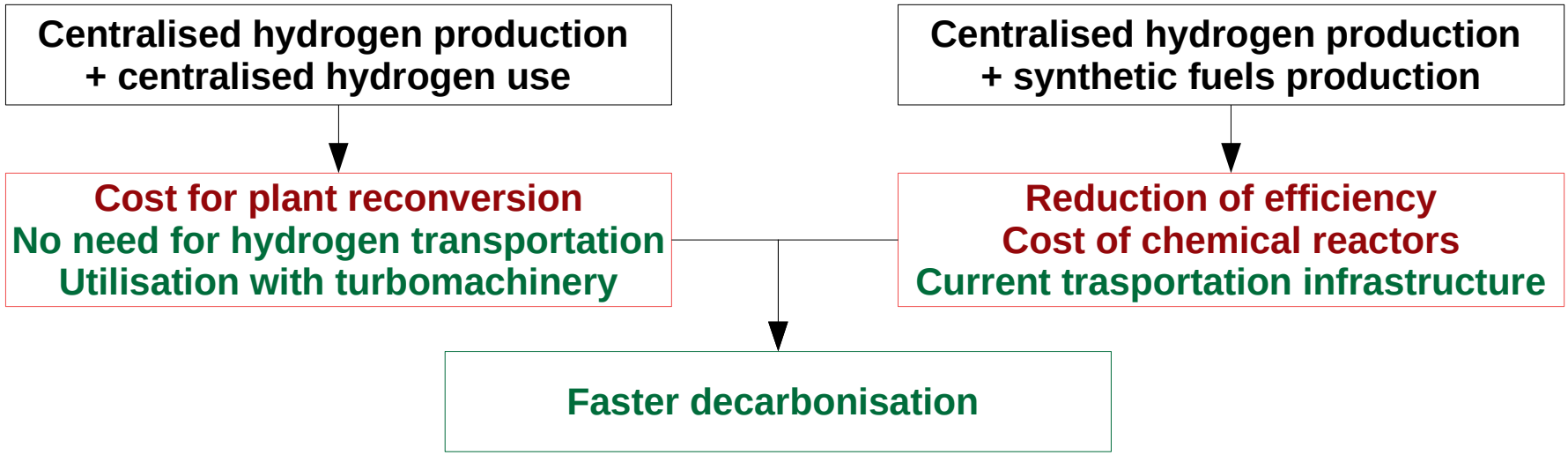
The hydrogen roadmaps proposed up to now are not really roadmaps for a fast development of a hydrogen society. They are rather roadmaps for the development of a society based on fuel cells. This is important, of course, since hydrogen and fuel cells are basic in our future energy systems. However these roadmaps are long term roadmaps which aim to a large replacement of fossil fuels only by 2050. This is because great investments are required for hydrogen production, distribution, storage and final use in fuel cells.



How to speed up decarbonisation

Concentrating infrastructure investments on hydrogen production will speed up the decarbonisation of our society.
Obviously we need also to continue to invest on research in the other technologies since this will probably allow to find solution to some issues still not solved.

The political decisions on which road to take should be taken on the basis of a Life Cycle Assessment extended to the entire system in order to guarantee the population the least impact on health.
LCA should be the watershed between technologies to invest industrially and technologies to be funded at the research level.
However economic evaluations are also important because a less expensive decarbonisation option could allow faster results.



Hydrogen use: transport vs power

Waiting for a full electric & hydrogen society, we have to decide which is the best use of renewable hydrogen.

From an environmental point of view the most critical sectors is transport, and eventually residential heating when not a district heating:
- emissions are generated especially in areas with a high population density;
- clean up of the exhaust gas is more difficult.

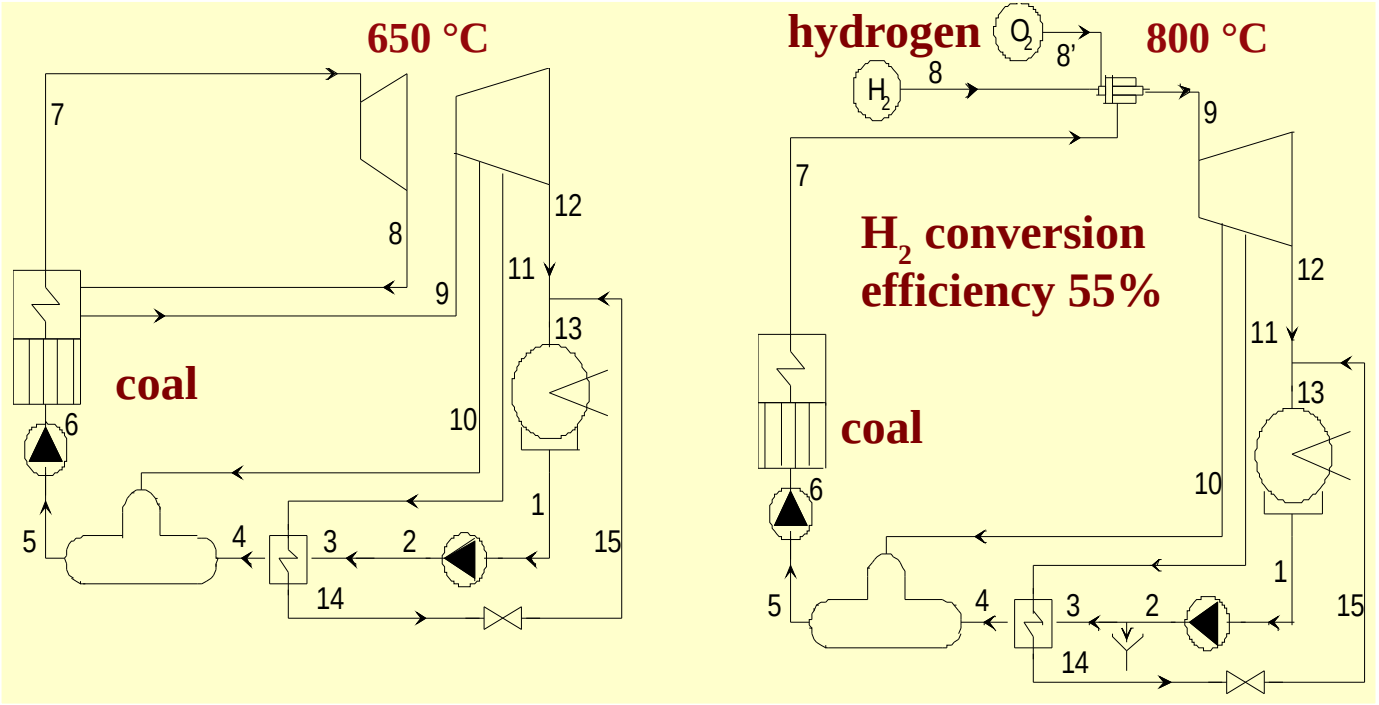
Replacing gasoline and diesel with hydrogen inside the vehicles engines would be the ideal solution, but it is far away due to distribution problems and cost of vehicles. Moreover the environmental impact of the construction of a PEMFC is still high.

On the other hand, replacing fossil fuels with hydrogen to generate power and heat is easier and more efficient, but maybe not the best solution from an environmental point of view, since carbon dioxide is not the unique harmful emission.

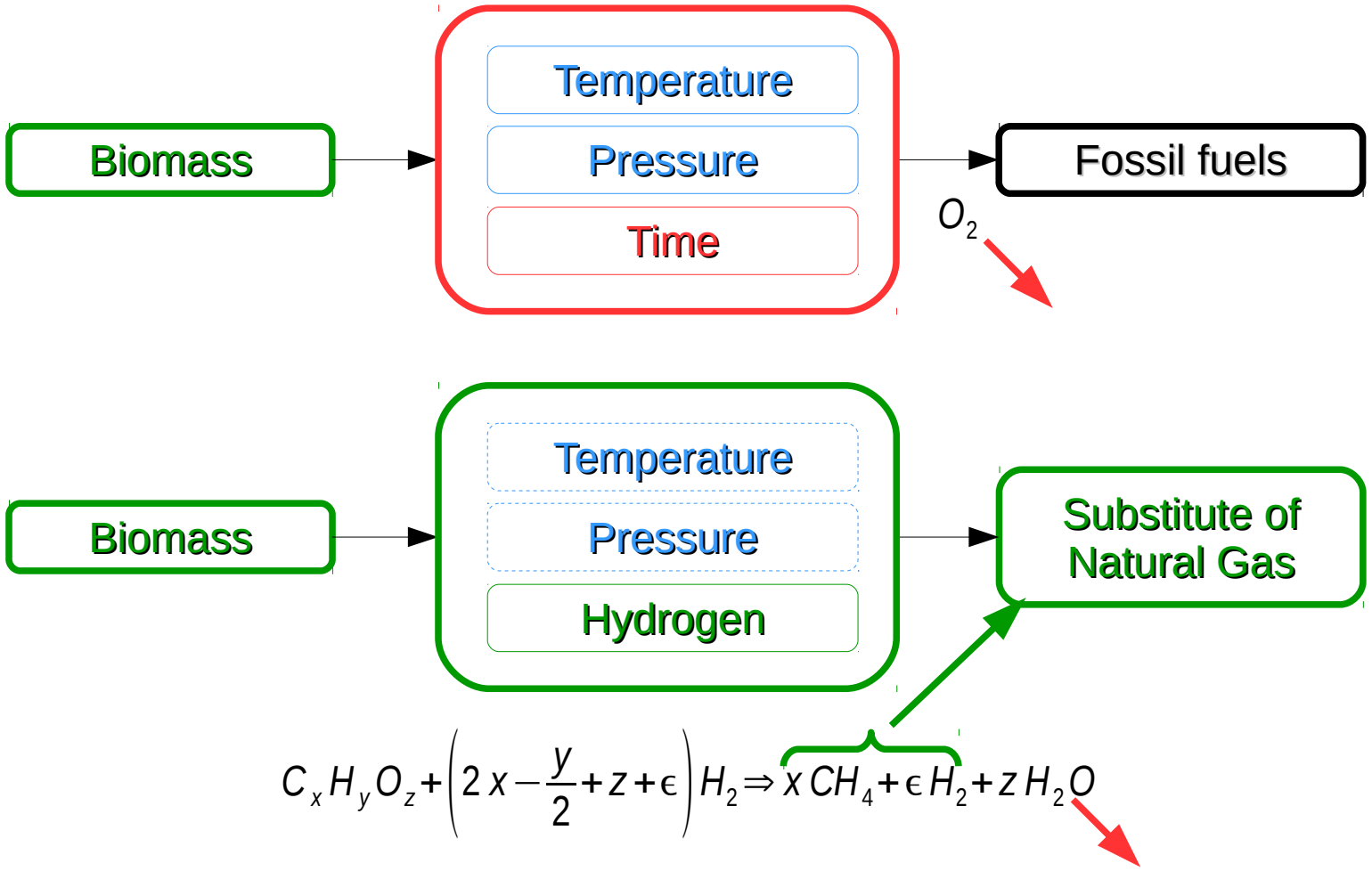
Finally, it is important to consider that in Konin Region power is mainly generated using a local primary resource and continuing to use such a resource in existing plants could make available money to be invested in hydrogen production.

A future efficient use of hydrogen

Maybe the most efficient way to convert hydrogen continuing to use coal is the so called "attached" cycle, that is ia a cycle in which hydrogen and oxygen are used inside a traditional steam system to improve its performance.
Being that hydrogen is used only in the hottest region of the Hirn cycle, its conversion (marginal efficiency) is very high: can easily reach 55% on HHV with a maximum temperature of 800 °C, but the temperature can be raised up to 1500 °C.
However this technology is not yet available: direct steam generators are at a laboratory level.



Hydrogen vs time



Power to fuel

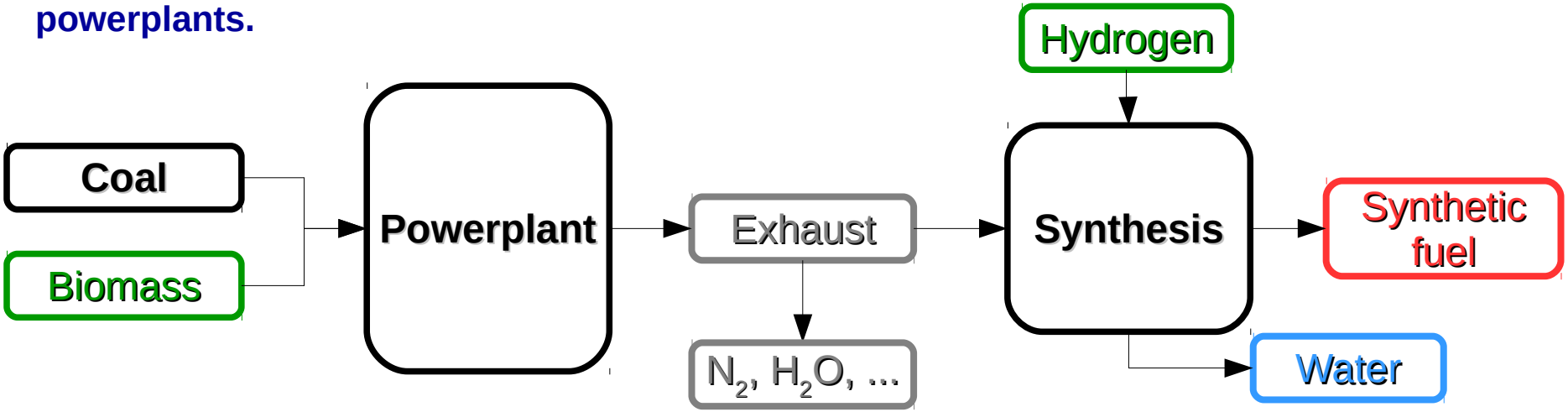
Although also coal can react with hydrogen to give a substitute of natural gas or gasoline or diesel fuel, coal hydrogasification and following treatment are not suggested unless there is the need to replace an obsolete coal plant.

Using biomass to produce a synthetic fuel is a good option, but currently there is a better source of carbon: carbon dioxide at high concentration into the gas leaving the chimneys of coal fired plants.

Such synthetic fuels, gaseous or liquid, are completely suitable to be distributed without changing the existing infrastructure and to be used in existing internal combustion engines: therefore, they could replace the imported fuels, with economic and environmental advantages.

The final carbon dioxide emissions are not avoided, but they are recycled, similarly to those absorbed by biomass, and do not contribute to new carbon dioxide emissions.

The same could be done with the carbon dioxide leaving the chimney of large biomass powerplants.



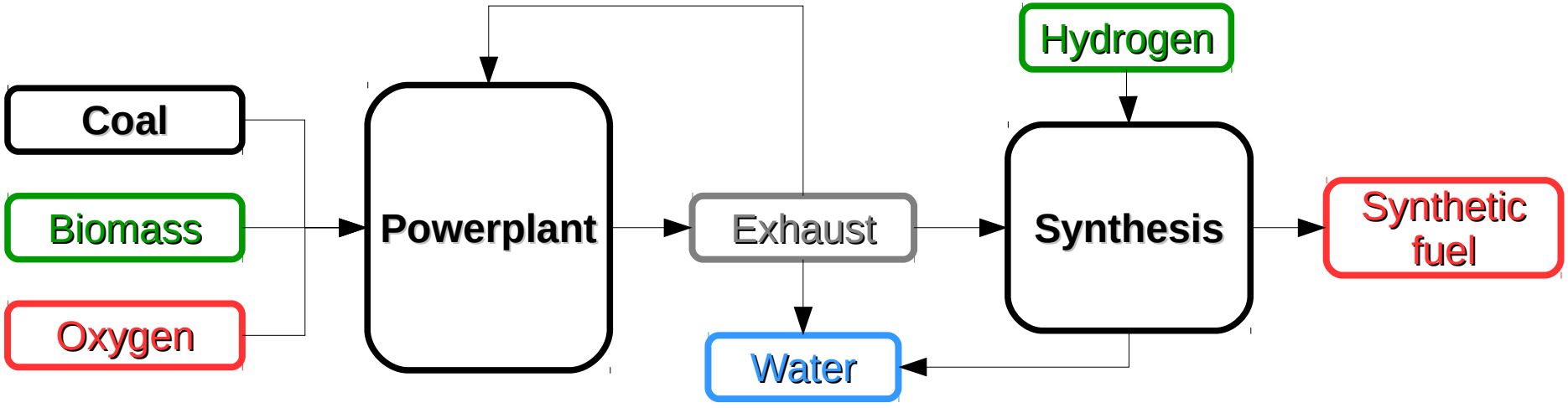
Carbon dioxide separation

Obviously current powerplants, or district heating plants, discharge into the atmosphere a gas containing not only carbon dioxide, but also water, nitrogen and other minor substances, whereas sulphur should be already removed.

Therefore separation of carbon dioxide from nitrogen could be a problem. Luckily electrolytic hydrogen comes together with oxygen. So that air for coal (or biomass) combustion can be replaced with pure oxygen, with the result of small amount of nitrogen in the exhaust gases from the chimney.

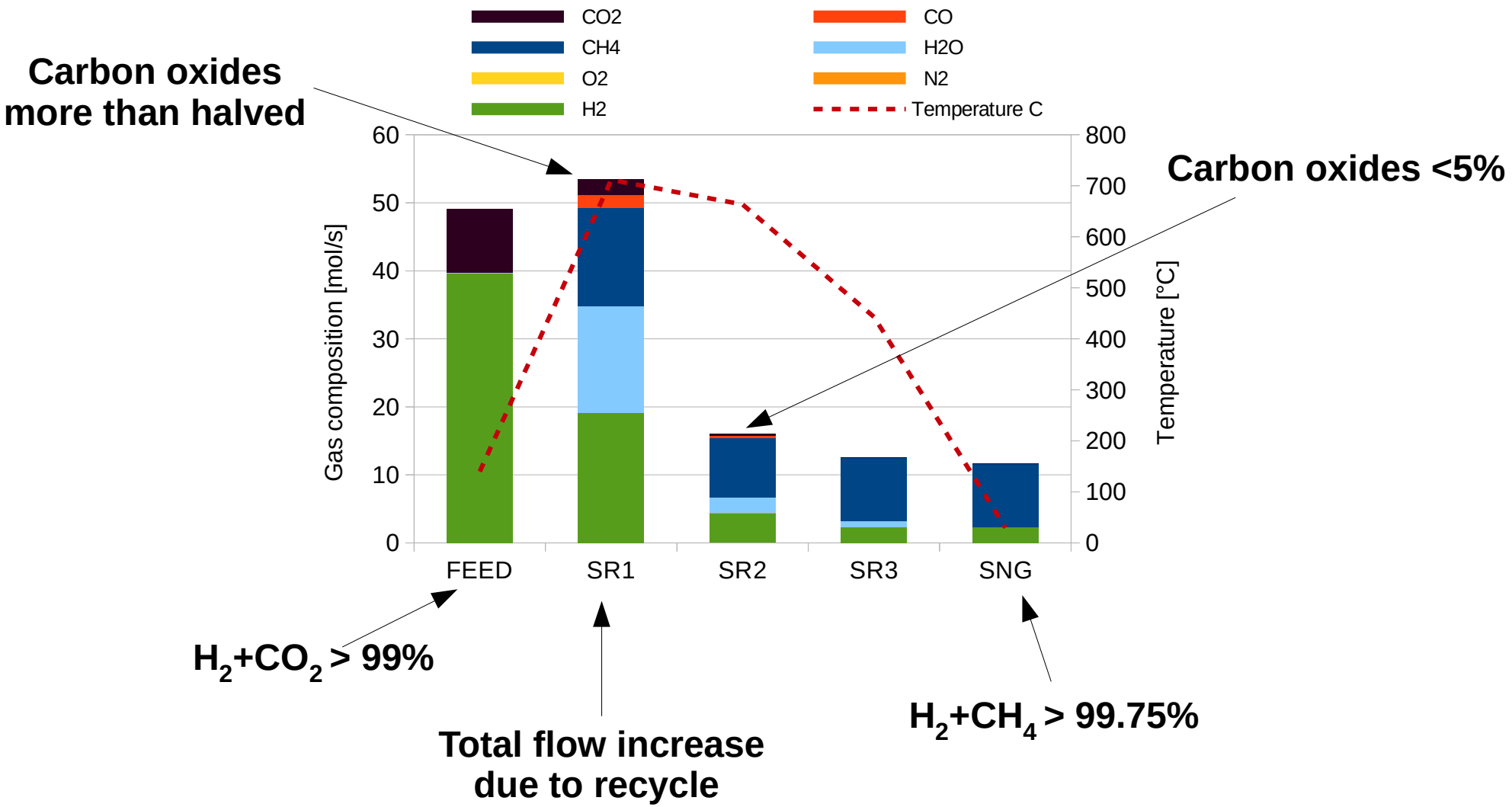
However this involves another problem: the significantly smaller flow of gas supplied to the heat exchangers of the plant. Such a problem could be solved by recycling a proper flow of exhaust gas.

In this way the gas recovered from the chimney is composed almost only by carbon dioxide and water vapour, which can be easily condensed and separated.



An example of composition changes

Methanation of carbon dioxide (Sabatier process) with three reactors.



Conclusions

Using hydrogen to produce a synthetic fuel is a solution at hand. It allows to eliminate carbon dioxide emissions without eliminating existing coal and biomass fired plants.

The distribution and the end use would have practically no additional costs.

If well coordinated, the best choice is the production of substitute of natural gas (SNG). This involve also the conversion of the existing gasoline and diesel vehicles to natural gas vehicles and, obviously, this will represent an additional end use cost. However, it could be made gradually when increasing the availability of SNG. This also allows to reduce harmful emissions inside the cities which involve lower health care costs.

So, my suggestion for a fast, although partial, decarbonisation of Konin Region are:

- concentrate your industrial investments in increasing renewable energy systems and in building power to fuel systems,

and at the same time:

- continue to invest in research on other hydrogen technologies (production, storage, distribution and fuel cells),

in order to be ready, when such technologies will be economically and environmentally mature, to move from the bridge to the full hydrogen society.

Thanks

Thank you for your kind attention ....