Energy efficiency can be markedly improved

Optimization of energy conversion

by Constant Gras

Reducing CO_2 emissions and changing to renewable energy sources are the spearheads of the transition towards a sustainable energy supply. In this respect the efficiency of energy production and energy consumption leaves much to be desired, says Professor Gerard Hirs. "For the past forty years we have been converting natural gas into low quality heat while, on the other hand, we are still wasting residual heat of industrial production processes for the greater part", explains the Professor Emeritus of Engineering Technology. "

Irrespective of the fact that we use renewable energy sources, efficiency and saving energy are still prime and essential factors for a sustainable development." His plea at the beginning of the 1990s in favour of not taxing the industry for the volume of their energy consumption but rather for the inefficient use thereof, is therefore still of topical interest.

Along with many others, Hirs too thinks that the future energy supply will constitute hybrid energy. He foresees that, apart from using renewable energy sources and energy carriers such as sun, wind, water, and biomass, also fossil fuels and nuclear energy will remain in use for a long time to come. And that reinforces his plea in favour of stimulating energy efficiency even more.

Exergy

"In the meantime we are appreciative of the fact that the supply of fossil fuels is ultimately finite. Its conversion to usable forms of energy for human consumption as well as using that same energy is still a process that needs optimization", argues Hirs. "Our energy requirements consist on the one hand of heat and on the other hand of labour or power of which electricity is a special form. By fully converting fuels such as natural gas into heat, the recoverable labour thereof remains unused. That constitutes inefficient and low-grade use of energy."

According to Hirs, this practice is still far too abundant. "This is not only true for the built environment but also for the industry. It is much more efficient to start to convert fuels directly into labour and subsequently use the heat that inevitably is released for heating requirements." It follows that energy efficiency should not focus on energy saving, energy conserving and avoiding energy waste but also the quality of energy conversion; that is, optimising the amount of labour that can be harvested from an energy carrier. In the field of thermodynamics this process is referred to as 'exergy'.

Residual heat

"The industry uses fuels in different ways", explains Hirs. "Energy is used for powering machines or heating of produc-


Photo Danny Cornelissen

tion processes and also as raw material for chemical products. Chemical conversion of energy also requires performance of labour. In these cases the energy contained in fuels can be optimally utilized by using it in the first instance as raw material and for powering machines and subsequently convert the residual heat of production and powering processes for the purpose of heating requirements. The exergy of thermal energy conversion, and consequently also the quality or the yields thereof, can be calculated by means of the Carnot cycle. In practice, however, the maximum theoretical labour value of energy can never be achieved in terms of cost-effectiveness but it will go a long way towards covering the costs. Our first gas heated electricity generating stations achieved an electrical yield of forty percent, which is currently about sixty percent."

Cogeneration and the use of industrial residual heat for industrial heating requirements as well as heating of residential houses is referred to by Hirs as instances of efficient use of energy. "In order to satisfy our residential heating needs we should preferably utilize residual heat, stemming from industrial processes as much as waste incineration", he concludes. "In his capacity of manager and director of Comprimo Consulting Services he has demonstrated back in the 1980s that this very idea was feasible and performable, both from a thermodynamic and an economical viewpoint. "In the Netherlands, however, this is still only applied on a very small-scale.
In the process industry much heat is still lost through cooling towers, chimneys, and flaring off", says Hirs.

Technical preconditions

"In spite of government investment contributions and subsidies as well as other instigations of the government, the profitability of energy conversions has been found too low", he concluded in his inaugural lecture 'Nederland industrialiseert' ('the Industrialisation of the Netherlands'), at the occasion of the acceptance of the professorship Energy Technology at the University of Twente in 1992. "Prior to that, our industry was not yet organised properly", explains Hirs. "Many industrial installations were just too small to render energy efficiency economically feasible; that is, they were not geared to one another

in terms of energy transfer and in addition, operating hours in many companies were too short to be able to operate energy efficiently. Hence, concentration, integration, and intensivation of industrial production processes were preconditions for fundamentally improving the energy efficiency." Large-scale process installations, collective measures (such as cogeneration and the use of residual heat) as much as extending operating hours and process intensivation, as witnessed in the Rotterdam port and industrial area, have since led to significant improvements of the technical organisation of the industry. Having said that, we can always do better.

Taxing inefficiency

The energy consumption of the Dutch industry accounts for eighty percent of heat requirements in the shape of steam and heating of cooking stoves. The Dutch Institute for Energy *(Onderzoeksinstituut ECN)* estimated that the industrial heat requirements require 530 petajoule of energy annually, whilst heat stemming from production processes is actively cooled away by means of air and water coolers. If we continue like that, that means that in the chemical and refining sector one-hundred petajoule of residual heat above fifty degrees Celsius (as well as a capacity of more than 0.5 Megawatt per source) will be lost each year. According to ECN researchers, the non-actively cooled residual heat sources such as exhaust gasses, also in other industrial sectors, constitute an even larger potential in terms of energy efficiency. In the Dutch industry and the built environment this amounts to an annual total heat loss of approximately fifteen billion cubic metres of natural gas. Hence, in terms of efficient energy conversion and the use of residual heat there are many possibilities awaiting realization and what is more, the necessity thereof with regard to CO_2 emissions and climate change is increasing more and more.

IN 2012 EXCESS CO_2 EMISSIONS WILL BE TAXED ON EUROPEAN LEVEL, WHICH CONSTITUTE AN INCENTIVE TO THE INDUSTRY TO USE ITS RESIDUAL HEAT USEFULLY

Prof.dr.ir. Gerard Hirs, Professor Emeritus of Engineering Technology at the University of Twente.

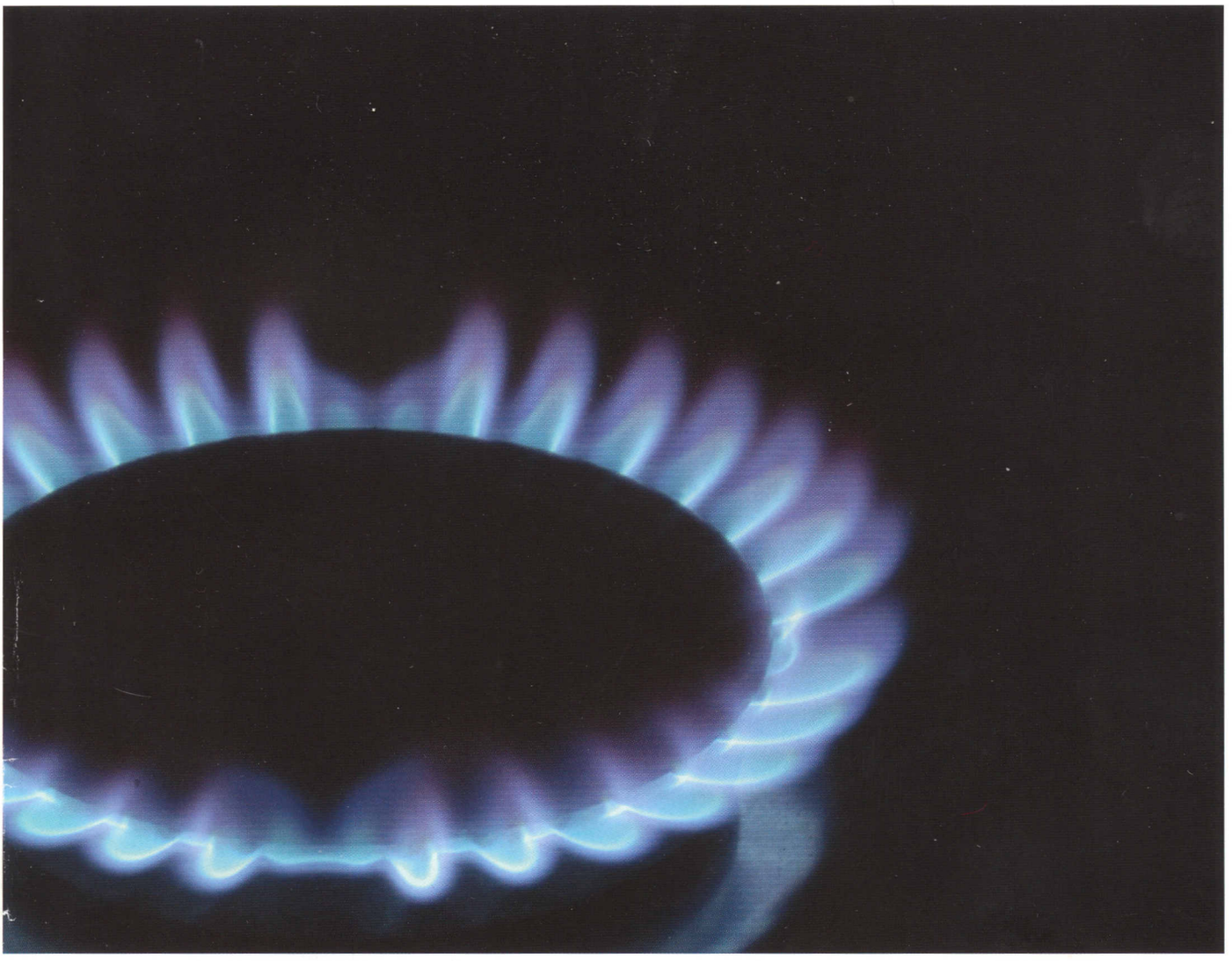
The fact that the energy efficiency of the Dutch industry has seen marked improvements over the course of the past fifteen years, although it still leaves much to be desired, is only partly due to abovementioned technical preconditions, according to Hirs. "Furthermore, there is an administrative-economical precondition that is still of current interest: the inefficiency of energy conversion and the use thereof is still not sufficiently taxed", he says. As early as 1991, Hirs has argued in favour of taxing the inefficient use of energy instead of the volume of energy consumption. However, the so-called 'Entropy Added Tax' (EAT) has never been carried through. "Entropy is a thermodynamic quantity with which we attempt to understand and quantify chaos in nature", explains Hirs. "According to thermodynamic theory the exergy loss of a system is proportional to the increase of the entropy thereof. Thus, simply stated, a tax imposed on the waste of energy content." The exergy of an energy carrier, the maximum recoverable labour and the ultimately utilized labour thereof, can thus be calculated.

Bricks

"I have seen it happen now three times; plans were made to use industrial residual heat from the Rotterdam port and industry area for the purpose of heat requirements of businesses and residential houses. In all these instances, it was owing to financial-economic factors that the plans failed to materialize", says Hirs. "On account of the fact that the use of residual heat generates insufficient financial rewards, such projects are likely to fail because of low energy prices or silly demands such as delivery guarantees. In the 1990s, owing to a steep decline of the gas price a number of similar projects were suddenly referred to as 'bricks'."

The latest development in this field constitutes the Warmtebedrijf (Heat Company), which was established in Rotterdam in 2005. This initiative of the Port of Rotterdam Authority, the municipality of Rotterdam, the Dutch *housing corporation* Woonbron, and the Province of Zuid-Holland failed about two years ago when Shell withdrew as a supplier of residual heat. Shell's Pernis refinery and the AVR Waste Incineration Plant in Rotterdam agreed to deliver residual heat for the purpose of heating residential houses in Rotterdam-South and the town of Hoogvliet. Shell indicated that it had underestimated the investments required for the delivery of residual heat. As from April this year, the Warmtebedrijf, from which also the Port of Rotterdam Authority has decided to withdraw, continues to operate with an altered business case and in much closer cooperation with AVR and the electricity companies Eon, Eneco, and Nuon.

Reduction of CO_2 emissions is one of the prime goals of this enterprise. In 2012 excess CO_2 emissions will be taxed on European level, which constitute an incentive to the industry to use its residual heat usefully. Energetically as well as from the point of view of sustainability this is a far better option than catching and storing CO_2. "As is the case with taxing the volume of energy consumption, a CO_2 tax is not an adequate incentive for companies to improve their energy efficiency',



'It is much more efficient to start to convert fuels directly into labour and subsequently use the heat that inevitably is released for heating requirements.'

states Hirs. "Furthermore, even if energy were to become cheaper, the decision will be easily made to cease or decrease energy efficiency investments. After all, inefficient energy use does not cost money; in addition, when energy prices are low it often becomes even more economically profitable than efficient energy use. Due to the large fluctuations of energy prices there is not a single project in this field that can make one's capital work. This way, the risk remains that history will repeat itself and investments in energy efficiency will turn into bricks. In fact, energy prices ought to be much more stable."

Returns

It seems that the efficiency issue and the CO_2 problem will be ultimately solved spontaneously on account of the transition to a sustainable energy supply. In fact, energy conversion from renewable sources provides nil or a neutral CO_2 emission and what is more, these sources are infinite. "Indeed, the sun will always be shine but solar energy is of course not free of charge", objects Hirs. "With the current solar panels it is possible to achieve an electrical return of less than fifteen percent. The returns of solar cells in terms of exergy are even lower, bearing in mind that the production thereof requires a lot of energy. Expressed in money, it looks even bleaker. With the current technical state of the art, the energy investment costs on a solar panel with an average life of twelve year can only be recovered after four years of electricity production. Hence, based on the present technique solar energy stands no chance whatsoever."

As a consequence, Hirs is opposed to subsidizing solar energy and other forms of energy, if that means that developers in this field are going to invest in existing and still immature technology. "In that case it constitutes a conservation measure", he concludes. "Both from an energetic and economic viewpoint we cannot allow ourselves to settle for an immature technology. What we can do, however, is subsidizing research institutions and companies that design and develop solar cells in order to encourage them to manufacture better cells." According to Hirs, thinking in terms of energy efficiency is also in the case of a sustainable energy supply both useful and necessary.