The Key Position of Solar Raw Materials for the Sustainable Manufacture of Goods and Agricultural Development

Contribution to the Eurosolar Convention 'The Farmer as Energy and Raw Materials Manager'
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by Dr. Hermann Fischer, Chairman AURO AG, Braunschweig

1 Introduction: 'Grüne Woche (Green Week)' at turning point

Since decades the 'Green Week' in Berlin is the leading convention for agriculture worldwide. But like never before at any of the 'Green Weeks' of past years, here and today the fact that agriculture is standing at a crossroads has become tangible. The despair of many of the women and men working in agriculture is great – many of them are facing the shattered remains of their existence.

As large as the crisis may be, it simultaneously offers an opportunity. Rarely has the willingness to think about alternatives in agriculture, to explore new paths and to try out even the unusual been as marked as during these weeks and months. The opportunity consists of the fact that due to the crisis, future-oriented concepts such as for example biological agriculture, the production of energy plants, the cultivation of renewable raw materials and others are now being accepted by ever increasing parts of society far beyond the circles of those pioneers who have opened up those areas. Only this increasing acceptance of the new, the turning away from tenacious aberrations and deformations can create the basis for agriculture to gain completely new tasks and positive prospects.

It are exactly the renewable sources of energy and the renewable materials, which are at the centre of today's conference, that offer agriculture new 'degrees of freedom', new options, a new variety of agricultural activity. Of course these new opportunities do not offer any patent remedy for the rehabilitation of agriculture. They are no universal remedy for agricultural structures that are diseased to the core and they are not yet the sole turning point of a muddled agricultural policy. But it is known from systems theory that additional degrees of freedom will stabilise a system and this aspect alone should be sufficient for agriculture to welcome the expansion of its range of activities and crops as something positive in every respect.

To put it more simply: variety is better than simplicity (in the sense of 'monopolistic structure'). It is not without reason that variety is the primary principle of everything biological. If simplicity were the more successful principle, today's world would merely consist of one or only just a few species. As we all know, the contrary is true: prior to the devastations that man has brought about, the biological cosmos was a stable, dynamic system and it gained this stability mostly from its variety, or, to put it in more scientific terms, from its biodiversity.

Nature does not know any monopolistic structures. The idea to derive power and influence from simplistic monopolies could only occur to humans who are completely estranged from nature. In agriculture in particular, there has always been knowledge of the importance of variety, up to the realization that only a varied sequence of crops will keep a cropland healthy in the long term. An enrichment of the diversity of agricultural activity, for example by means of energy plants and renewable raw materials is therefore in itself a true biological and ecological gain.

2 Parallelism of the energy and raw material problem

A wise conference management has introduced a dualism into the subject matter of this conference that addresses the farmer both as energy *and* as raw material manager. With this, a conspicuous signal has been set that points to the future. The previous separation – even in the heads of the most environmentally conscious people – of energy problems and material problems (or chemical problems) has not been the proper way to look at the matter, because these two areas are in fact inextricably linked: the problems have the same historic roots, the same material sources, the same structural reasons – and what they also have in common are the fundamental solutions. This has been reason enough for Eurosolar to name energy and material in one breath and to let the lectures by Hermann Scheer and my own contribution refer to each other as if they were reflections, so that it is possible to view both sides of the same medal simultaneously without having to turn the medal over.

2.1 Same source problems

The common ground already starts with the historic roots, which in turn are linked to the material sources of today's energy supply and materials supply. Where does the principal share of today's primary energy supply come from in all of the important industrial countries? From fossil sources: coal, crude oil, and natural gas. Where does a substantial part of the chemical-technical products we incessantly make use of every day from the moment we wake up to the time we go to bed come from? From petrochemistry, which is based on crude oil and to a smaller degree on natural gas and thus also on fossil sources.

We should keep reminding ourselves that this dependency on basically one source only for energy and materials has only been in existence for a short while. Only one hundred and fifty years ago, crude oil had no importance at all either for peoples' material or energy supply. Crude oil was an exotic and rare material that was scooped out of oil puddles that issued on the surface and was filled into chemist's bottles for the treatment of scabies. In fact, the scabies mite did not survive being tormented with this stinking, poisonous brew, which evolution very wisely preferred to store in low-lying geological 'landfills for hazardous waste', far away from the biosphere and far away from the delicate cell membranes of living things.

It has anyhow only been during the bat of an eyelid in human history that we have been dealing with crude oil in a big way, and this blink of human evolution will be over in no time at all – reason enough to urgently start looking around for workable alternatives. Oddly enough, this is what we have a problem with. There is a strange contradiction in the universal knowledge of the fact that the raw material crude oil will soon no longer be available and the audacious lack of concern with which most people ignore this fact, in particular those in responsible positions in industry and commerce, politics and culture who make decisions for the future of us all. I have elsewhere compared this behaviour with the compulsiveness of an addict, who is well aware of his dependence and the self-destructive effect of the drug, but who merely resolves every day anew that he will 'certainly tomorrow' start a cure for his addiction.

However, the problem has not yet been completely described with the insufficient permanent availability of the industrial fuel crude oil, but I will not get involved in the futile discussion whether the resources will last another 40 years or perhaps even another fabulous 60 years: this is a pseudo discussion which in the end only serves the purpose of distracting from the undeniable basic problem and the lead-in to its solution. During my lectures I keep meeting professors who proudly tell me that since their student days the availability horizon has always been specified as approximately 40 years, but in the process elegantly lie their way around the fact that since then, the time and money needed for exploration and extraction has assumed completely different dimensions. It is a little like the illusion that one will live for ever while one's hair is getting unmistakeably grey and thin.

An additional problem that equals the availability problem in every way is the incredible monopolization that has been created by crude oil as energetic and chemical raw material. On a global scale, the availability of resources and processing plants is lying in a few hands only. We realize this fact at most if petrol prizes change as if by magic, mostly following an upward trend and in reality hardly influenced by the dollar's exchange rate and ecological tax. This monopolization has no model in economic history and turns us all into hostages that can be blackmailed by oil conglomerates and petro-oligarchs. After a short while of startled dismay during the oil price crises in the seventies, most of us have in the mean time once more cosily settled down on the soft, warm lap of the conglomerates who lull us to sleep with lullabies of 'responsible care', though this sleep seems to be getting increasingly restless.

The growing restlessness has also something to do with the price of crude oil, i.e. with the uncertainty: what is in fact the 'real', the reasonable price of crude oil? The problem is, nobody is really able to answer this question. For logical reasons, there is no 'real' price for a non-renewable resource – such a fixing of prices is only possible on the basis of the costs for the regeneration of the resource. This is how in principle the prices of agricultural products are determined (if we disregard the preposterous consequences of subsidies): with his product, the farmer has to at least earn the costs for a renewed cultivation during the following year and a modest profit, or else he will not be able to continue his work in the long term. And this is exactly the issue we have a problem with when trying to fix the price of crude oil: regeneration is simply not possible - once extracted, forever lost - despite all the 'recycling' fuss.

Both energy suppliers and the chemical industry therefore have to live with the actually almost incredible problem that no one is able to provide them with a really reliable basis for their calculations. In practice, this only turns out to be of no consequence for these industries because they are able to pass on any conceivable price for crude oil to the product prices due to the already mentioned monopolistic structures – as explained, there is virtually no competition with producers who base their production on different raw materials. Although this will soon be changing, today's chairmen of Exxon, DuPont and BASF will by then be well-off pensioners for a long time already. One thing should at least be clear by now: with regard to the sources of their activity, energy suppliers and materials suppliers are in the same boat.

2.2 Similar sink problems

On the other side of the product line too, the problems in the area of energy and chemistry coincide to a large degree. In both cases, the identical basis – fossil carbon carriers – also causes an identical sink problem. But in this case too, people have only become aware of the energetic side to some degree. It is an almost compellingly logical consequence that in the case of a raw material we use as a fuel to heat, drive and create electricity 3 million times faster than it is regenerated, the secondary products of these energy conversion processes (in particular carbon dioxide) cause a continuous enrichment of the 'waste dump atmosphere' with climate-effective trace gases, an enrichment that it has been possible to measure without any problems for a long time already. The fact that this extreme enrichment cannot remain without consequence is also comprehensible to every clear-thinking human being. And it has also got about that even the most hard-baked appeasers are in the meantime no longer able to deny that these consequences lead to a global increase of the average temperature.

However, one thing has not yet got about: the consequences resulting from the material utilization of crude oil are absolutely identical to those of its energetic utilization. Even if crude oil is first processed into commodity chemicals in petrochemical factories and afterwards into synthetics in chemical retorts – some time in the future, even the most persistent and most difficult to degrade synthetic will start to rot or is burnt – in any case, the result of any petrochemical product line is at the end carbon dioxide – en'riched' by all sorts of halogenated hydrocarbons, nitro aromatic hydrocarbons and whatever other persistent secondary products remain.

What Hermann Scheer called 'conversion damages' may also not be omitted from this balance. These lead to a contamination of all environmental sinks (soil, air, water, organisms, human beings) long before the end of the product line. In the area of electricity generation these are above all heavy metal dusts, nitric oxides, sulphur compounds (even though the latter have clearly decreased, where has the sulphur actually disappeared toas it has still been in existence in the crude oil just as in the past?) and waste heat. In the area of chemical conversion of crude oil, the range of by-products and waste products that are inevitably generated if today's primitive methods of chemical synthesis are applied and that can only partially be filtered out is even considerably more extensive. But the verdict of Rainer Grieshammer (Öko-Institut), that the most important pollutant emissions of today's chemical industry are its products that enter our home in pretty packaging in the form of detergents, insecticides, lip sticks, ballpoint pen refills or micro fibre jackets, should also be taken into consideration.

One thing must at any rate be recorded: electricity generation and chemical production on the basis of crude oil lead to a dramatic overburdening of the absorption and processing capacities of our biosphere's material sinks. It is completely overtaxed with the quantity and type of emissions, for which it has not been able to 'train' sufficiently during the course of the evolution of life.

2.3 Same structural problems

Even from a structural point of view, the similarities between energy and chemical sector are amazing. In both areas, we are dealing with a marked spatial concentration of basic production. This is not surprising: electricity generation using fossil energy carriers with today's methods is all the more productive and economical the larger the installed capacity of the power station. The production of chemicals on a petrochemical basis following today's methods is all the more lucrative the larger the reactors used and the more successive synthesis phases of the chemical value-added chain are taking place on the same premises. To put it differently: in both cases productivity is heavily dependent on quantity.

These two closely related structural principles have brought us centralised large-scale power stations and the chemical molochs Bayer, BASF and Hoechst that occupy huge spaces. Both types of plants are not without reason built alongside the large rivers. But both manufacturing structures also mean: whole thickets of high tension lines that cut across the countryside to distribute the centrally produced electricity; whole fleets of petrol tankers and tank cars that distribute the base chemicals synthesized in the mega factories – as a rule hazardous materials – to the processing industry. In addition, the by-products and wastes occur in extreme local masses during the production of energy and base chemicals: plumes of smoke and condensate that darken the sun as well as freight trains loaded with flue gas desulphurisation gypsum at the power stations, contaminated effluents, odour emissions and occasional plumes resulting from hazardous incidents at the chemical sites.

Both of these complexes that are heavily orientated towards centralisation also form a high regional concentration of power: many a local politician and the media have already collapsed when faced with the job argument and the amount of trade tax generated, when it would actually have been their task to protect the citizen from damage to his health and the environment.

3 Parallelism of solar energy and solar materials

If what applies to the numerous parallels between fossil energy and material production is inverted, it also points to a high degree of relationship between renewable energy and renewable raw materials.

In both cases production leans on regenerative sources, which in the end may all be traced back to the constant stream of energy passing from the sun to the earth: on the one hand the solar energy stored in the wind, in bodies of flowing water and in the biomass or their direct conversion in photovoltaic plants, and on the other hand the photosynthesis in the plants that is exclusively driven by the energy contained in sunlight.

Instead of the principle of monopolistic structures, the principle of variety is inherent in both systems: just like only a sensible mix of all regenerative sources of energy on the spot makes perfect sense from an ecological and economical point of view, the desired and in themselves incredibly versatile plant components from colorants to aromatic substances, resins, oils, waxes, proteins to vegetable fibres are created in processes secondary to photosynthesis in hundreds or even thousands of different plant species.

In both cases, the basic principle functions all over the world: wherever the wind is blowing, rivers are flowing, tides are at work, the sun is shining and plants are growing it is also possible to create energy and materials on a solar basis. Fortunately these are also the regions where people who need the energy and materials prefer to live – for the few research scientists who live in the Antarctic it would be sufficient to create the energy and materials they require somewhere else and to transport them there.

Apart from the variety of sources, solar energies and materials also have in common that the sinks are problem-free: energy from wind, water, sun and biomass is created virtually emission-free, the most important 'waste product' generated during the cultivation of solar raw materials on arable land and in the forests is the oxygen that is vital for our life – other wastes, e.g. in the shape of other plant parts can either be processed to other products or can, if necessary, be composted and in this way form the basis for the next production cycle. Evolution has known how to prevent the persistence and accumulation of not readily degradable residual matter by means of an intelligent balance of building up of matter (photosynthesis) and decomposition of matter (degradation by microorganisms).

Both systems incidentally also possess the same structural advantages: in both cases, productivity simply does not depend on space. A small solar cell, related to the area it occupies, is just as effective as a large one. Ten plants simply produce ten times as many raw materials by means of photosynthesis as one single plant does. It is of no use, but rather creates additional problems, to extend the production of a certain vegetable raw material to dozens of square kilometres.

One of the positive consequences of this structural principle is that a decentralization of production is the obvious solution. In this way, heavy expenditure for the distribution of the amounts of energy or materials created is avoided – this means less traffic, less emissions and that pylons, high smoke stacks and overdimensioned development activities are no longer necessary. What is required on the spot is also created on the spot: right under the critical eyes, ears and noses of the consumers. In this manner, co-determination and co-shaping of the living space can be exercised to a completely different extent as is possible with the extreme separation of production and requirement customary today – not to mention the conveyance losses during the distribution of electricity that could be saved.

With the regional and local production of energy and raw materials, this production returns from the anonymity of 'somewhere', 'somehow', 'somebody' to full transparency and to the immediate responsibility of the people concerned.

But solar energy and solar raw materials still have a lot more in common. Only the fact that their sources are in principle inexhaustible makes sustainability possible. To put it differently: the demands of Rio 1992 for a 'sustainable development' will remain an illusion without the change to solar energy and material production, never mind how many colourful brochures and websites with continual reference to their efforts in the field of sustainability the multinational energy organizations and chemical associations will publish, these are and will always be empty phrases.

This is in particular true for the social field. The structures and consequential results of the fossil industry do not only hurt the life and soul of human beings – they have also destroyed millions of jobs as a result of globalisation and centralization. The satisfying and secure jobs of the future will not be generated here and in the long term also not in the made-up trendy crazes of an alleged 'New Economy', but there where the long-term safeguarding of basic human needs is dealt with in a manner that is both compatible with the environment and with human health – and such basic needs are the supply of energy and the supply of materials for everyday use.

As it is not only possible to organise the solar production of energy and materials in an environmentally compatible manner, but also in a manner that is compatible with human beings, the industries that will develop in this context will also be easily accepted by people. Large-scale demonstrations by Greenpeace in front of a field of flax like those held in front of the doors of a pesticide factory? Hardly conceivable. Hosts of policemen to protect a photovoltaic plant as is necessary to protect a Castor nuclear waste transport? Surely superfluous. It doesn't bear thinking about how many social costs alone could be saved and applied in a more sensible manner through these two effects alone!

4 Additional problems of the petrochemical industry

4.1 Crude oil: the most unsuitable chemical raw material conceivable

From a chemical point-of-view, a strange paradox is connected to the chemical raw material crude oil. In fact, there is hardly another conceivable raw material that is less suitable on the basis of its material properties to serve as material basis for the whole range of every-day chemicals. Whether paints, adhesives, detergents, fibres, fragrances, cosmetics – the molecular structure of crude oil's components is miles away from all these chemical functions. It is known that crude oil consists essentially of a mixture of inert, partly highly toxic and ecologically harmful hydrocarbons that have an unpleasant smell.

The result of this fact: an immense amount of chemical energy must be put into this inert and featureless mixture for it to result in the desired commodity. And the instruments today's chemists use to introduce a lot of energy into such an inert mass are still that violent, unspecific and undirected that a large part of the energy used does not even lead to the desired chemical reactions with the desired final products, but to a host of side reactions with unwelcome reaction products that often constitute nothing more than hazardous waste.

Still one of the most popular methods of chemists is to bring the inert crude oil hydrocarbons into a chemically reactive intermediate state by means of reactive chemicals such as chlorine and ozone, a state these raw materials would never voluntarily enter into. Even such seemingly harmless synthetics as polyurethane, a foam we use to pad the steering wheels of our cars, have a biography that contains a virtually complete genealogical tree of ultratoxins.

However, it is not only the structure of today's synthesis methods and the widely used aggressive and ecologically harmful intermediates that are questionable. Often, there is also a grotesque discrepancy between the amount of chemicals used and the finally resulting quantities of usable end product. One example is the manufacture of a customary azo dye. Editors of the magazine 'Öko-Test' have used the manufacturer's data to draw up a quantitative balance of only one of numerous synthesis steps during the chemical production of this dye. The result was that, apart from the desired end product, a sevenfold amount of toxic and ecologically harmful waste chemicals is created.

4.2 Chemical industry's dependency on crude oil greater than energy sector's

We quite rightly complain about our enormous dependency on the energy carrier crude oil in the context of today's energy and mobility generation. And yet this dependency is by far exceeded by the almost absolute bond of the chemical industry with the raw material crude oil. As much as crude oil as energy carrier is dominant: there is still nuclear power, coal, natural gas and a growing number of regenerative energy carriers that can no longer be ignored. The dependency is great, but it is not absolute.

Not so in the chemical industry: far more than 90% of all so-called organic-chemical products – from colorants to fibres, detergents, cleaning agents, cosmetics, floor coverings, interior design textiles, packaging, etc. are based on crude oil as sole raw material source. Strangely enough, the general public is far less aware of this much greater dependency than of the clearly smaller dependency on crude oil in the energy sector! This example also shows us how much more skilful the chemical industry is in concealing its sources and dependencies, compared to the large energy groups. Only very lately have these somewhat caught up as far as the cunning of their PR-work is concerned – not exactly an improvement the consumer has reason to celebrate.

5 The elementary process of the materials industry

5.1 The conditions of chemical conversion

For a more precise understanding of the radical difference between 'solar' and 'fossil' chemistry, we will below have a closer look at the elementary process on which every materials industry is based.

To start with, we will together think about the question why most substances in the world hardly change if they are not forced to do so by an external source. What does it actually mean that a material like cane sugar is called 'stable'? First of all it simply means that sugar crystals can remain in the sugar bowl for years without any change to their chemical properties. We can very easily test the fact that the sugar crystals have not changed with an analyser we constantly carry around with us, namely our tongue. The taste of the sugar that appears on our tongue precisely because of the chemical identity of the sugar molecules will remain exactly the same even years later.

But *why* do the sugar crystals actually not change? The answer seems trivial, but has a deep physical-chemical meaning: they do not change *because they do not have a reason to*. – To put it more scientifically: most materials remain 'stable' and thus chemically unchanged because they have adopted a *state of relatively low energy content* in their respective environment.

We know many such states of relatively low energy content from everyday life. Every ball that is lying somewhere without moving is in such a state. Just as this ball has come to rest on a slope in a small hollow and will not continue rolling down the slope without an external impetus, i.e. without the supply of new energy (or roll up the slope again if it is induced to do so with a sufficiently 'energetic' kick), the sugar crystals have arrived in an 'energetic hollow' where they will remain virtually permanently if they do not receive an external impetus. By the way, instead of the concept of the 'energetic hollow', chemists use the hardly less metaphorical concept of the 'potential pot'. Whether 'pot' or 'hollow' – there the stable materials in any case find a place of relative stability.

However, the world would be an extremely boring (and incidentally abiotic) place if materials would not continuously receive an impetus to transform or, to apply the 'hollow' metaphor, to leave their traditional energy hollow and to take up another position on the energy slope: further up, further down, to the side – the number of possibilities is great for most of the materials. And this brings us to the art chemists all over the world have mastered: many of them try nothing else the whole day long than edging the molecules of materials out of their relatively stable energetic position, in fact as far as possible such that they land exactly in that 'hollow' the chemists want them to reach. To put it differently: chemists force substances that would voluntarily (i.e. without external impetus) never change to carry out exactly the transformation they desire and for which their customers are prepared to pay.

Of course materials have also been changing in the past, long before any chemists, human beings or any living things at all existed on this earth. Those 'impetuses' that ensure that in nature, i.e. without human assistance, materials do change we will deal with in more detail later on. Because they will play a decisive role for the conception of a future chemistry. – But first of all we will remain with the work of those people we call chemists because they are able to force materials to leave their traditional 'place' not to simply move about in space (that would be the physicists' task), but also to change their material properties.

5.2 Energy supply as prerequisite for chemical synthesis

Now what is the trick chemists use to induce the materials in their laboratory to change into different materials? The secret is: energy supply. Because, if you supply the material that has just made itself comfortable in its energy hollow with that much external energy that it is just able to get over the rim of its hollow, it will virtually have the whole world at its feet – from an energetic point of view, the material will be able to reach numerous other energy hollows where it could come to rest again.

The energy that must be expended for a molecule to reach exactly the rim of its energy hollow or potential pot is incidentally called 'activation energy'. If you do not at least expend that amount of energy then everything will remain the same: although the molecule will take a 'run-up' for a chemical conversion, it will eventually roll back to its traditional hollow due to a lack of sufficient activation energy. Please remember: this 'hollow' is of course not really a natural depression in space, but only a mental image that is to make the energy relationships (or more precisely: relationships of potentials) during chemical conversions easier to understand – thus a 'model' of reality.

Let me give you a simple, practical example. Looked at from a chemical point of view, an ordinary household candle consists of paraffins. These are substances that merely contain carbon and hydrogen as atomic components. The paraffin hydrocarbons in the candle are chemical substances that have made themselves quite comfortable in their energy hollow. This is e.g. revealed by the fact that such paraffin candles can be stored for decades without any special precautions having to be taken and yet they do not in the least change from a chemical point of view. But if a sufficient supply of external energy is provided, e.g. in the form of the flame of a match, the molecules of the paraffin candle are able to leave their secure hollow high up on the slope and to change into different chemical substances in a matter of seconds.

Viewed from the outside, the transformation looks as follows: the candle's paraffin burns, the whitish substance of the candle apparently disappears into the void. During this process, a large amount of energy is released which is easy to notice as the light and heat of the candle flame. Looked at from the inside, i.e. from the point of view of the substances' chemistry, the paraffin's molecules combine with the oxygen in the air in a chemical reaction and in the process burn to carbon dioxide and water. Compared to paraffin, the reaction products carbon dioxide and water are very simple molecules with a much lower energy content. To put it simply: the difference in energy content between the original substances (paraffin and oxygen) and the end products (carbon dioxide and water) is released in the form of heat and light. To put it yet differently again: the fact that the candles' paraffin occupies an energy hollow that is situated relatively high-up on the slope turns the candle into a very effective energy reservoir because the stored energy can be easily released by simply lighting a candle.

Now you will also much better understand the match's function: it merely serves the purpose of applying the necessary 'activation energy' once only right at the beginning of the process so that some molecules of the candle wax will leave their secure energy hollow and plunge down the energy hill (i.e. burn). During this process, that much new energy is released that it is not necessary to hold the match permanently against the candle: the energy released at the beginning is ample to heave further molecules across the rim of the hollow, which in turn will plunge down and release new energy and so on until the wax is completely used up.

The burning of a candle is clearly a transformation of original substances into different end products and thus, according to the definition, a chemical reaction. It can be described by the simple reaction equation: „paraffin plus oxygen equals carbon dioxide plus water plus heat/light “. But this reaction does not require the competence of a chemist, it can be managed by every child without assistance and without any chemical knowledge, because it is a piece of cake to produce molecules that are relatively poor in energy from molecules that are relatively rich in energy. Almost every combustion, every decomposition is such an event where the substances merely have to plunge down an energy slope.

However, the art of chemists normally consists of something else: to produce from molecules that are relatively superior from an energetic point of view by means of chemical transformation different molecules that from an energetic point of view are either situated at the same level or even higher up. If we look at it from a structural instead of an energetic point of view: what matters in chemistry is to transform original substances of low or medium structural complexity into end products of medium or higher complexity. In this regard, a substance is by approximation regarded as all the more complex from a structural point of view the more single atoms and atomic groups are connected with each other in a molecule. Complex molecules are therefore as a rule larger and heavier (and more valuable) than less complex molecules.

If we return to the simple, energy-related contemplation we can approximately establish: chemists are jugglers who skilfully edge chemical substances from one potential pot to another while trying as much as possible to avoid that the substances – again only from an energetic and metaphoric point of view – drop into a potential pot at the wayside which they have not been supposed to reach. Because for a chemist, 'substance has landed in the wrong potential pot' is not very much different to saying 'instead of the desired product I have produced waste'.

5.3 The price of transformation: waste and by-products of chemical processes

This brings us to one of the central problems chemistry has not been able to do come to grips with or even substantially moderate in more than 150 years of scientific-industrial development: the huge-scale production of unwelcome waste and by-products during the course of a chemical reaction.

The reason for this dilemma is easy to recognize if we once more make use of the model of the 'potential pots' we have already discussed in more detail above. As we have seen, a substance is only able to react chemically if its molecules leave their traditional potential pots. On the other hand, they can only leave their potential pots if they are furnished with at least that much external (activation) energy that they are able to get over the rim of their potential pot. However, the dilemma is that today's methods of chemistry, which are as a rule still very rough, are not able to furnish the molecule with the necessary energy to 'escape' in such a well-dosed and economic manner that it is able to leave its potential pot without too much excess energy. In addition, these rough methods are not able to guide the molecule that gently after it has left its potential pot, that it is able to sail around undesirable neighbouring pots that should be avoided and that all the molecules of the same type land solely and completely in that target pot that represents the desired end product.

However, instead of using the desirable, gentle, optimised and controlled method, today the raw material for a chemical synthesis is mostly pushed out of its potential pot in a rather different, 'brutal' manner. A particularly popular means of such chemical-physical brutality is the chemical element chlorine. It is extremely aggressive and has not without reason been used as lethal toxic gas during World War I. By the way, this extreme chemical aggressiveness is also the reason why chlorine gas does not occur freely in nature. Everywhere it would arise it would immediately pounce on the surrounding molecules and fuse with them into 'chlorinated compounds'.

However, it is exactly this all-devouring property that has made chlorine that attractive as universal 'shake-up' in chemistry. The highly reactive element chlorine is able to get almost any of the many quite inert components of common crude oil moving – simply by forming a chemical compound with the material. This is because the chemical element chlorine, due to its very high energy content that forms the basis of its aggressiveness, can still give off such an amount of energy to its quite inert reactant that it will turn the tired crude oil hydrocarbon into a rather lively chlorinated hydrocarbon. Chemists say the inert hydrocarbon has been 'functionalised' by forming a compound with chlorine. This is because the hydrocarbons created in this manner can in turn be converted into numerous other products due to the strongly increased reactivity at their functionalised (in this case: chlorinated) molecule parts. To put it once more in a metaphor: this can be compared to the surfaces of a lot of smooth balls (these would be the little reactive crude oil substances) being equipped with countless small hooks (these would be the chlorine functions), which would put these balls in a position to stick to each other rather than to simply bounce off each other.

But where exactly does the free element chlorine take its high chemical aggressiveness (in physical-chemical terms: its high content of free energy) from that enables it to take up the position of a 'common lout' of chemistry? The answer is found very easily if we just take a closer look at the production process of chlorine. During this process, the rather sluggish substance sodium chloride is treated with one of the most concentrated forms of energy we know: with direct current. In huge plants for the 'chlorine alkali electrolysis', common salt is, like the name already indicates, turned both into chlorine gas and alkali - or to put it more accurately: caustic soda – by means of chemical decomposition with the aid of electric energy (electro-lysis). The large amounts of energy that have been pumped into the system by means of the electric current are partly preserved as reactivity in the derived products: both caustic soda and especially chlorine are very remote from the inertness of sodium chloride. It shall here only be mentioned in passing that the tremendous expenditure of energy that is necessary for the chlorine alkali electrolysis is in the end mostly derived from fossil or even nuclear energy carriers. We will later return to the additional problem concealed behind this fact.

Apart from chlorine, there are still some other 'chemical louts' that are able to get almost any inert organic raw material going with all their might: concentrated nitric acid, ozone, even direct current that directly impacts on certain raw materials. If these are used, the relatively inert original compounds do not result in chlorinated hydrocarbons as a first step, but e.g. simply in nitrified hydrocarbons if e.g. nitric acid is used instead of chlorine for the 'activation'. The original situation and the consequences remain the same: for the production of nitric acid too, huge amounts of energy are needed (in this case for the synthesis of ammonia from hydrogen and the very inert nitrogen; ammonia in turn is oxidized to nitric acid with the help of oxygen) and the nitrified compounds that are created in this first step (e.g. nitrotoluene) should be treated with similar caution from an ecological and health point of view as the chlorinated organic compounds.

But what is the chemical consequence of this enormous energy that is carried into the raw material molecules by means of the chlorine, nitric acid or one of the other common activator substances? The answer is as simple as it is disturbing: much more energy than the system is able to 'digest' is pumped into the system by means of these aggressive reactants. Or to use the metaphor of the potential pots: the original molecules are not supplied with just that much (activation) energy, that they are able to reach the rim of their energy hollows, but with incomparably more. With this huge excess of energy, the molecules of course do not roll out of their potential pots at a measured speed, but shoot out of these pots with virtually explosion-like force. To use another image: it is as if you do not pour your soup carefully across the rim of the tureen into your soup bowl (and even then some soup will always be spilled), but as if you throw a firecracker into the tureen hoping that as a result of the subsequent explosion some soup will land inside the bowl and not only next to it.

This is exactly what happens if materials such as chlorine are used to attack inert original molecules: although quite a few molecules land at the places (in the potential tops) you would like them to reach, many more just land somewhere else. But as 'somewhere else' has not been the target, these reaction products can at best be regarded as undesirable by-products, at worst as chemical waste. As part of the original excess of energy is now also retained by the first order reaction products, the subsequent reactions that are initiated with these activated intermediates are encumbered with a similar problem: scarcely or never will it be possible to produce the required materials with 100% accuracy. During the customary, multiple chaining of chemical reactions during which many single, successive chemical reactions gradually lead from the primary raw material to the final end product, huge amounts of waste and by-products thus remain behind virtually by the wayside. In the following chapters we will take a closer look at some of these reaction chains and also list exactly the extent of the waste quantities. It should anyhow be clear by now that with the methodology described, which is still by no means the exception but rather the rule, chemistry is lumbered with a problem. Now we have to ask the obvious question: must chemistry be this way? Is it not possible to produce valuable materials in a completely different manner? The answer: there are other methods and they have been functioning for an incredibly long time already completely without a hitch or problem.

5.4 The ingenious kind of chemical synthesis: 'Solar Chemistry'

For billions of years, chemistry without by-products that are detrimental to the environment and health has existed on our globe. (Here exceptions such as halogenated hydrocarbons in marine organisms prove the rule, because they have obviously not nearly as much impeded the evolution of life as have their alleged relatives pentachlorophenol, lindane or polychlorinated biphenyls within a few decades). Obviously Nature has discovered, tested and perfected a method in the course of evolution – whether by creation or by trial and error is not for us to decide at this point – that knows how to treat the substances of this world in a much more gentle way than our modern chemists are able to do.

The prototype of this gentle chemistry that takes place in nature – without human help as it has existed long before man made his appearance – is photosynthesis. That this has something to do with chemistry is already revealed by the word 'synthesis' that is contained in this expression – this is what chemists call the chemical building of complex substances from less complex ones. And that is exactly what happens during photosynthesis, again in a virtually prototype like manner. The original substances of this natural chemistry are among the most simple, least complex and structured substances we know: carbon dioxide and water.

Both these molecules only consist of three atoms with two different types of elements each: carbon and oxygen in the case of carbon dioxide; hydrogen and oxygen in the case of water. However, the end products of photosynthesis are the most complex, richly structured and valuable substances we know: cellulose in wood, colorants in blossoms, fragrants in leaves, proteins in fruits, oils in seeds, waxes on stalks, sugars in the sap of trees – thousands upon thousands of different precious products originate from these two simple original substances, occasionally supplemented by smallish amounts of other original substances such as nitrate or some trace elements.

But how is it possible that these simple original substances are turned into such complex end products? One thing has already become clear from our previous contemplations – here too, nothing much would happen without energy. The reason for this is already founded on the fact that the original materials are, considered from an energetic point of view, quite obviously at home in much lower potential pots as sugar, oil, protein & co. Thus, energy must be introduced into the chemical system from the outside – whether natural chemistry or not. But where does this energy come from? At any rate not from oil-fired power stations, coal-fired power stations, gas-fired power stations or nuclear reactors, because all these did not yet exist when 'photosynthesis' had been successful for a long time already.

The answer to this mystery is contained in the first part of the word 'photosynthesis', because the energy for this natural type of chemical synthesis is quite simply derived from – light. Of course yet again I do not mean the light of some halogen lamps, but the only source of light evolution had at its disposal before man appeared: the sun. Photosynthesis thus means nothing more than 'chemical synthesis with the aid of solar energy'. And the first step of this photosynthesis naturally takes place at the spot sunlight and plants preferably meet each other: in the green plant leaf.

But why is this type of chemical synthesis that much more gentle, environmentally benign and easy on life than the synthesis methods of today's chemists? It is much more difficult to find an answer to this question than you might think. The carriers of solar energy are light particles that are created on the surface of the sun in the course of gigantic nuclear reactions and that reach the plants and us on the surface of the earth through space and through the atmosphere. Looked at critically, these photons provide us with anything but tender loving care. In reality, the energy carriers of sunlight can quite definitely be seen as rather aggressive 'chemical louts', although they are not by a long chalk of such heavy calibre as chlorine, nitric acid & co. But these energy carriers are all the same able to severely change the chemical structure of our skin within a short period of time. If we are lucky, this chemical change only becomes apparent as tan. If we are unlucky, the protein in our skin is changed that severely that our body reacts with an inflammation to the foreign substances that have been created – this is what we call sunburn. And if we are very unlucky indeed, the energy carriers of sunlight will even change the material carriers of genetic information inside the nucleus of our skin cells in such a manner that these cells will degenerate – this is what we then call skin cancer.

But how is it possible that such potent energy carriers do not bring about such negative consequences with the photosynthesis they initiate as the aggressive primary molecules that are created during the chemical synthesis in a retort? The secret lies in the fact that an ingenious method is used to absorb and distribute the primary energy supplied by the light on the surface of the leaf in such a manner that no detrimental excess of energy is able act on the system. For this purpose, Evolution has developed a clever construction of biochemical reaction cycles that are chained and interlinked with each other, that we – particularly since we call ourselves modern chemists – can only contemplate with awe. During the course of these intertwined cycles (one example is the well-known 'citric acid cycle'), numerous different by-products are created, which in turn serve as intermediate deposits of parts of the energy that has been fed into the system at one point or as original substances for subsequent reactions.

At the final end of these interwoven material cycles are at any rate those plant components that are very precious to us and that can serve a large variety of purposes – from food, clothing, building materials, adornments and fuel to writing materials. And nowhere during the course of those interwoven processes does even the slightest amount of hazardous waste or health detrimental by-products arise. If one of these plant components is toxic to man, than this poisonousness is not the result of a hazardous chemical incident, but serves a very specific purpose e.g. the deterrence of predators.

And just as little as that do any products arise during photosynthesis that persistently refuse to be reintegrated into the cycle of materials. On the contrary: everything that has been built up in this natural manner can also be broken down into its original components in a natural manner by means of biological decomposition. What is even more: the material products of this biological decomposition (mostly by microorganisms that feed off this process) at the same time represent the most perfect original materials for the next production cycle by means of photosynthesis and thus the cycle has been perfectly closed. Only chemical engineering that takes these ingenious processes as an example is worth being called sustainable!

6 Chemical-technical products made of solar materials

6.1 The problem of subsequential costs

Already today, products made of solar raw materials can replace the relevant products of petrochemical origin in many areas, often even without any appreciable difference in price. Where petrochemical products are still considerably cheaper than those derived from renewable raw materials, this is mostly due to a form of distortion of competition: while regenerative raw materials already contain a large part of their social subsequential costs in their price due to their solar origin, this is not the case with petrochemical products.

To put it differently: if society would find a way to load all the ecological (example: climatic disaster), health (example: increasing allergies) and social (example: impoverishment of the native population in Nigeria) costs onto all the products made of crude oil, e.g. by means of a real ecological tax, than the products made of renewable raw materials would probably be by far the more economical ones.

6.2 Competitiveness and recoverability

Almost like a reflex, many people judge chemical-technical products made from regenerative raw materials in the following manner: 'it may be true that they are advantageous from an ecological point of view, but their technical disadvantages offset this again'. Where does such a prejudice come from? Mostly it originates from the fact that the perpetual publicity of the chemical industry has talked us that much into believing this fairy tale for more than a hundred years that we have meanwhile become unable to find another starting-point for a different type of thinking. By the way, this publicity has already commenced during the seventies of the 19th century, when the first coal-tar dyes were propagated with exactly this argument: they were said to be much more brilliant and to have much more beautiful colours than the customary plant dyes. Of course publicity left it unsaid that they were also much less light-resistant and often even carcinogenic and that whole rivers had been turned into biological mortuaries during their production. Thus, supported by the generally awakening faith in progress, it was able to develop its effect on the group consciousness unhindered.

In actual fact it is often exactly the other way around as far as the relation between the technical performance of natural materials and that of artificial products is concerned. A simple spider's thread has – applied to the same cross-section – many times the tenacity of a modern synthetic fibre. The adhesive certain mussels use to stick to ship walls possesses many times the tension strength of a modern two-component adhesive on the basis of a synthetic resin. Newly developed composite materials with plant fibres that have been imbedded in matrices of natural bonding agents attain the same or even improved mechanical properties at almost half the weight as do classic glass fibre reinforced synthetic materials (GRP) and manufacturers even report a considerably reduced tool wear.

However, a special advantage of these products manufactured on the basis of solar raw materials is their perfect integration in closed ecological cycles. In this manner, they are able to contribute to an equal balance between the formation of materials and the breakdown of materials and do not accumulate in the environment over longer periods of time. Even if, for logistic or organizational reasons, material recycling is not worthwhile for the production from regenerative raw materials, there is still the disposal path by means of composting or incineration. Both these processes in turn only lead back to those substances that constitute the basis for a new formation of materials: in essence carbon dioxide and water.

6.3 Examples of products made from solar raw materials

Examples of chemical-technical products made of renewable raw materials can meanwhile be found in many DIY stores, furniture shops, chemist's shops, textile shops, among toys and recreational articles and in the area of packaging. Insulating materials made of hemp, coconut fibre, waste paper cellulose and cork are very successfully replacing synthetic products made of polystyrene HRfoam, polyurethane or mineral fibres (the latter are wrongly regarded as purely mineral products: up to 20% of their weight may consist of bonding agents on the basis of artificial resin). Paints and varnishes made of linseed oil, plant resin and palm wax replace conventional products on the basis of petrochemically produced acrylate. Adhesives made of natural gum, plant protein and tree gum replace conventional synthetic resin adhesives on the basis of polyvinyl acetate.

Entire furniture series have been realised on the basis of solid wood with upholstery of plant fibres, covers of natural textiles and biological surfaces of natural paints. High-quality linoleum made of linseed oil, crushed cork and earthen pigments replaces environmentally harmful floor coverings made of polyvinyl chloride. A large variety of wall paints, varnishes and wood stains for the interior and exterior of the home is today offered on the basis of purely vegetable bonding agents and these are on top of that absolutely free of solvents, artificial resins, synthetic softening agents, monomeric residues, preservatives and wood preservation biocides.

Entire ranges of detergents and cleaning agents successfully do without synthetic, difficult to degrade surfactants on the basis of crude oil and instead rely on the gentle power of plant soaps, sugar based surfactants and biogenic emulsifiers. Complete series of toiletries and cosmetics do without petrochemical pigments, synthetic micro waxes, artificial aromatic substances and chemical preservatives. Even on the toy sector, soft plastics are on the retreat after scandals centring on plasticizers and heavy metals and are replaced by natural materials.

The range of natural substances that are ready to pounce and take over from synthetic products extends right up to packaging. If you have ever received a parcel, the precious content of which had been protected by a full load of polystyrene foam chips, which then stuck as if by magic to hands and objects while giving off an offending smell, facing your small household with undreamt-of waste disposal problems, you will appreciate modern packing material on the basis of special sausage-shaped corrugated fibreboard made from waste paper, which can be perfectly reused, has a pleasant feel and can, if necessary, be recycled as waste paper. – As you can see, the range of possibilities is enormous and these are by no means theoretical concepts but practical solutions that have been tried and tested for a long time already. If it was possible to shake up society in the same way as has already happened, at least partly, as far as energy matters are concerned, then the whole petrochemical fuss that has distracted us from important, sustainable innovations during the last 50 years, could be over in no time at all.

6.4 Necessary: an effective campaign for solar raw materials

In order to create the above-mentioned jerk it is first of all necessary to make solar raw materials much better known. From my own province, that of natural paints and coatings, I know that of those consumers who know of the bare existence of such alternatives, approximately half are also willing to make use of these. What is first of all necessary is a successful public relations work, as is already widely practised in the area of solar energy. It is not least this PR-work that has achieved that the number of people in the population who are sceptic about solar energy systems keeps on diminishing, while not only the number of supporters, but also the number of active users of solar energy is constantly on the increase.

It would perhaps be necessary, according to the model of the solar '100,000-roof-program' in Germany, to also launch an ambitious support program for the use of solar raw materials for building and renovation. My wish is thus a solar '100,000 living-spaces'-program by means of which the use of biological building and interior works materials for new buildings and reconstructions could be promoted. In this manner, it would be possible to provide the numerous small and medium-sized companies who are already today dealing with products made of solar raw materials with a new innovation thrust. What we need is a start-up climate, not for a new round of the Internet hype, but for solar products. Practice already shows that this a typical small and medium sized companies subject – and there is hardly another way the promotion of small and medium sized companies and environmental protection could be combined that perfectly.

6.5 What agriculture (& forestry) can do for solar raw materials

Everything that has been said here verifies the huge opportunities that solar raw materials constitute for a sustainable agriculture and forestry. After all the food scandals and debates about livestock epidemics, this is an area that could help farmers to develop a new type of self-confidence. Anyhow: they are in the true sense of the word the oil sheiks and chemicals bosses of the future. Quite soon, crude oil and fossil raw materials will have disappeared like a bad dream – but the agricultural production of materials will be possible as long as the sun is sending us heat and light and as long as we are able to keep the soil healthy.

Already today, farmers and foresters control by far the largest streams of energy and material on this planet – it is time that they eventually become aware of this fact. Compared with the potential of solar energy and solar materials, even the gigantic proportions of today's petrochemical industry and petrochemical energy sector seem ridiculously small. The hitch is however that we are on the verge of jeopardizing the entire basis of our existence with this mere passing comment in our biosphere's book of life. Let's erase this passing comment and turn back to the actual text of the book!

But one thing farmers should and must do to keep their demands for increased opportunities to plant solar raw materials credible: they should first of all start to use renewable raw materials to meet their own needs in house and home. I really know what I am talking about: I have quite often arrived at the farmyard of a farmer who had concluded a contract with our company for the cultivation of regenerative raw materials only to find him cheerfully painting the stable doors with a conventional synthetic resin varnish that had not only been produced from crude oil, but also smelled that way.

If we are jointly able to turn solar raw materials once more into the main source from which we satisfy our requirements of chemical-technical everyday products, then we are not only doing a lot for our environment, health and sustainability. We will also achieve something else, something wonderful, namely that the farmer in his capacity as food, energy and raw materials manager returns where he actually belongs: into the centre of society.

Dr. Hermann Fischer, AURO Pflanzenchemie AG, Alte Frankfurter Str. 211, D-38122 Braunschweig
Tel. +49 (531) 28141-0; Fax: +49 (531) 28141-62; e-mail: fischer@auro.de