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Energy Planning:
the process and the issues

with solar energy as example

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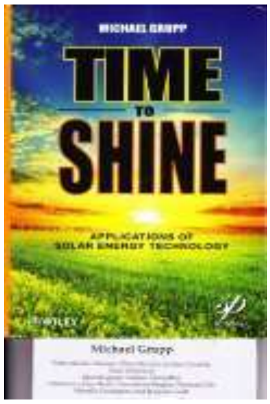

ENERGY PLANNING - WITH SOLAR AS AN EXAMPLE

Conventional energy planning still tends to be very much about supply; indeed in some countries this sector is still called the "Department of Power" or similar. Quite often planners still go straight to energy supply options before really considering *how much* energy is needed and *for what*. This may be due to the old view that energy supplies necessarily have to grow and grow – that "more" is always good – or it may be due to a fascination with new supply technologies. We need to remember that energy in itself is not the goal: the goal is *welfare*, achieved in part through the *services* (warmth, cooked food, light) which energy provides. The obvious priority is always to see how much we can achieve with as little as possible.

There is also a recognized disconnect between energy planning on the one hand, and urban planning on the other. The two must be seen together and integrated. Decisions made by the planner will to a very large extent, favourise or restrict the potential for energy efficiency in a city area.

Hence, energy planning involves both the supply and the demand side. At the "downstream" end, it will always be a general priority to minimize needs (Demand Side Management) before one considers supply. This is not least because no energy supply, not with renewables either, is completely "clean" and all involve technology, costs, natural resources, distribution systems, administration, and risks.

It should be noted that the following applies in the main to *stationary* energy, not transports; though naturally transport energy needs and solutions are also closely related to physical planning and the overall energy supply system.

ENERGY AND URBAN PLANNING

To summarise very briefly, the urban plan will affect the resultant energy needs in the following ways:

- Location: a new urban development may be in a climatically favourable area or unfavourable such as a windy zone, a north facing slope with no solar access, or a poorly ventilated valley,
- Location again: if located far from shops, schools and workplaces it will result in higher transport energy use and emissions,
- Orientation: the basic street layout should enable buildings to use solar energy and be oriented to use local breezes (in hot climates) or protect from wind in cold climates,

- Overall urban structure and layout can be shaped so that building district scale energy systems will be economical,
- Typology: type and height of buildings will provide various densities, more or less favourable for energy efficiency,
- Detail: whilst the above only ensure a potential for energy efficiency, they only provide the framework; they must be followed up in the detailed design; this is where building regulations, energy efficiency standards, and good design, will play their part.

The urban plan should also consider available local sources of energy, including for example, the potential for using waste heat from nearby industries. Further, there should be guidelines and standards to ensure low carbon designs, including selection of low embodied carbon materials, requirements for renewable energy and heat recovery, etc.

SELECTING THE CONTEXT

Although it is largely valid to say that "the best kind of energy is the energy we don't need", there will always be advantages in having plentiful supplies of clean energy. And whilst energy efficiency and reduced consumption should be top priorities, our future energy supplies, hopefully reduced in quantity, must be renewable. The perceived weaknesses of renewables, including solar energy – its intermittent nature and low energy density – are not a problem provided that one selects the most appropriate and economical applications. There is also the key issue of considering one's energy supply system as a whole.

Some applications make most sense on a large and fairly centralized scale; others make equally good sense applied on a local, even individual basis. Wind power is a typical case where there are huge economies of scale due to "the physics". With thermal solar panels and photovoltaics, there is less apparent difference between a small or a large array. In cities, district energy supplies rather than individual systems can provide very large economies of scale and far superior technical efficiency. Energy choices also include many non-technical parameters – such as logistics, aesthetic impacts and cultural appropriateness – this is where the purely engineering view has to be balanced with the larger picture.

What energy sources are best for an energy supply system seen as a whole? System considerations include to what extent the available flows of renewable energy at a given locality match the end use demand, and the load profile of the overall network. An energy system must provide for a fairly constant base load as well as providing for "spikes" or times of peak demand, such as especially cold days, or the TV intermission during the evening news. when everyone turns on their coffee machines. For example, wind power in northern Europe (as well as wave power) usually offers a fairly good match to demand since there is most wind in the heating season. Solar on the other hand is often most abundant when we least need it. Geothermal and biomass energy are in principle available at any time, and "storable" - giving them one of the same big advantages that fossil fuels have.

Our major energy needs are of several kinds: specific electricity, motive power, high temperature heat and low temperature heat (or cooling). The first two of these are high quality (high exergy) energy. A typical national energy system in industrialized countries comprises around one third each to transports, electricity-specific uses, and heat.

In general, future energy supplies should preferably not be transported over long distances as today (oil, gas and coal as well as electricity), with more supplies being provided by local and regional sources. Hot water is a suitable energy carrier for solar heat over short distances. Solar energy can only be transported over long distances if transformed to electricity or synthetic fuels – both of which processes imply considerable losses.

WHAT PLACE FOR SOLAR?

Due to its intermittent nature, solar energy cannot as a rule provide the base load needs in an energy supply system. However, there are exceptions even to this. We also need to be open to future technical developments that may surprise us. A possible route to solving the availability/storage weakness of solar is the solar-to-fuel option; another is seasonal storage of solar heat (and cooling), which was investigated during the 1980s, then largely abandoned, but is now being applied in interesting large scale projects in several countries.

Technically speaking many solar technologies are now fairly mature. On the other hand we should remember that high technical *efficiency* of systems is not a prime goal in itself: *low-cost, low efficiency* solutions such as passive solar heating, or simple types of solar cooker, may be equally interesting in the real world. Because that world is always contextual, it comprises specific people and needs at a specific locality within a specific economic and cultural setting.

It may be remembered that solar water heaters were introduced in the 1890's, the first solar power station was under construction in Egypt in 1911, and photovoltaic cells have been around since the 1950's. However, it does seem as if renewables really are taking off now. It is therefore all the more important to identify the right priorities. In the following section we shall review briefly some of the guiding principles behind appropriate choices; as the above introductory remarks indicate, these decisions are complex and very dependent on specific context.

A simple way to assess solar choices can be to ask the basic questions: who, why, where, and how. This reflects the approach of Appropriate Technology developed by pioneers such as E.F.Schumacher and Hassan Fathy. Their focus was the appropriateness of small scale solutions for people in developing countries: whilst large-scale solutions are appropriate in other contexts. The question of appropriateness applies to all three parts of environment, economy, and society – the triple bottom line of sustainable development.

A highly technical house may be appropriate for an engineer client but not for a disabled couple. A centralized electricity power station may be appropriate where there is a high population density and a particular need for *electric* applications. Nuclear power can only be base load power. A district heating system will not be economical in a sprawling suburb since the cost of long stretches of underground piping will be prohibitive. The energy planner has to approach decisions from many angles; there can be no linear decision making process.

COORDINATING SUPPLY AND DEMAND

Energy planning should, in general, start by looking at the demand side. The following is a necessarily very simplified illustration of steps in the process. The energy planner's first question is therefore:

1: How much energy do we really need, and for what?
Choice of appropriate energy supply depends also largely on *what kind* of energy is needed: is it cooling, low temperature heat, medium temperature heat, or is it power-specific requiring electricity? This is the issue of energy quality. The energy planner's second question is therefore:

2: What kinds of energy, and how much of each kind?
Flat plate solar collectors produce more energy per square meter than photovoltaics (PVs), so if the need is for low temperature heat, the, they are a better choice than PVs. If there is as much need for space heating as for electricity, as in a typical cold climate, it might seem logical to have both kinds of solar but it could be more rational to provide electricity by photovoltaics and heat from another source, such as a district heating system. The first priority should be to see how much of this demand can be covered – one might say *avoided* - by good planning, passive design, efficiency measures and load management. The energy planner's third question is therefore:

3: How much can the demand be reduced?
One now looks at specific state-of-the-art processes, designs and technologies that are in use. But at this point the overall planning framework has to be considered; for it has a large effect on the energy needs.

We have to look beyond individual cases alone; this concerns the urban or regional scale. The energy planner's fourth question is therefore:

4: Is the overall planning energy efficient?

Decisions on the level of the physical planning have a great effect on energy needs. Energy authorities have often overlooked this because they are not urban planners. Energy planning has been a specialized field; city and regional planners have not been concerned with energy planning. Authorities are now stressing the need for an integrated approach. Locating residential areas far from workplaces is decisive for transport energy needs; scattered suburban layouts make public transport uneconomical; many streets have buildings pointing in all directions, making future use of solar almost impossible. Of course many such planning decisions are made on the basis of other criteria, such as available land, or views, leading to solutions which are not optimal. If large savings in transport energy are achieved by placing a housing estate near the city center, even if it is on a north-facing hillside where solar energy will be impossible, one might discard the solar solutions. The application or not of solar technology must be subordinated to the overall picture.

The next task – closer to the drawing boards of the planners and architects, but equally important to integrate – concerns the specific requirements for buildings and other facilities. The energy planner's fifth question is therefore:

5: What are appropriate requirements for buildings' energy efficiency and renewable energy?

Note that we are not yet at the stage of considering supply: our focus is still on the downstream side - reducing the energy end-use needs through requirements for energy performance, space needs, infrastructures and building technology. This includes for example, building regulations and efficiency standards for heating, lighting, electrical equipment and so on. But the solar considerations start to emerge at this stage: street layouts, building orientation and roof slopes need to maximize the potential for using solar energy. "Green" planning guidelines are focusing on this, to ensure that solar technology can be incorporated into roofs and facades either now or in the future. Similarly, the choice of a dense building layout will both be more efficient in itself, and also make it more likely that a good district heating solution can be applied.

The next task is to look at the supply end to see what options are available – with the overall goal of maximizing renewable energy. Fossil fuel solutions such as bottled gas or diesel generators for emergency or peak supplies will be included only if unavoidable. The energy planner's sixth question is therefore:

6: What are the available local flows of renewable energy?

This will include an analysis of the energy quality and quantities, diurnal or seasonal availability, location, technical and economic feasibility. Included should be an assessment of whether there are any nearby sources of waste heat such as industries which might provide useful energy. In Norway, for example, several towns are now almost entirely supplied by bio-energy from the waste products of local forestry industries; others receive waste heat from smelting industries.

One can now see both "ends" of the picture and begin to assess alternatives. The energy planner's seventh question will thus be to address the overall picture:

7: What are the best supply solutions in the light of these factors?

There are technical-economic options: even the preference, stated above, for efficiency and reduced demand has exceptions. It may be *cheaper* to provide renewable energy supply than to reduce demand. For example, in an area with extremely good wind, is it cheaper to superinsulate all buildings, or to put up a large wind turbine? Or, if solar electricity becomes very *cheap*, what's the point of expensive CFL's? On the other hand, there is the general "upstream" imperative that all energy supplies should be as renewable and environmentally benign as possible. But here again there are tradeoffs; it takes a lot of resources, renewable or not, to make a solar power station.

Selection of supply technologies will, at this point, also need to be considered in the light of knowhow, existing infrastructures, and cultural appropriateness. Various impact studies and risk assessments will be carried out relating to environment and even national security. As well as resilience to possible future climate change! Cost evaluations should be on a lifecycle basis as opposed to short-term payback. There are also qualitative considerations of a purely sociological and political kind. One may prefer local renewables for strategic reasons even though imported supplies would be cheaper; one may prefer solutions that are decentralized and individually owned rather than large systems dependent on control by big public or private corporations.

In this way the energy planner considers both the demand side and the supply together in order to arrive at the optimal solution. The relevance of various solar applications lies within a specific context – geographical, social and functional. Solar will certainly have its part to play, and in our view it is likely be quite a large part in future energy systems.

ENERGY AND PEOPLE

There are, equally, issues that are not technical but managerial or sociological. Solar supply may be feasible but it might be cheaper (remembering that a kilowatt of power saved is as good as if not better than a kilowatt produced) to spend the money on energy information campaigns. Here too the whole picture must balance the engineering viewpoint.

Energy use in *identical* buildings varies with a factor of four to five times depending solely on the energy awareness and consumption habits of the occupants. There is growing awareness that energy is not a *technical* issue but *a socio-technical* one. Are passive houses with controlled mechanical ventilation systems appropriate in Norway, where people like sleeping with their windows open? Parabolic solar cookers certainly aren't appropriate in places where cooking traditionally is only done after sundown. And are PVs a good idea in some far away jungle where there isn't an electrician to be found?

There is a growing need for "energy anthropology". Energy decisions are in the last resort very much determined by human factors. It is being increasingly shown that technological changes for energy efficiency may achieve far less results than expected, due to sociological, cultural and behavioural factors. Choices have social and cultural, not only technical and economic determinants. Solar energy applications are no exception. They must be politically favourable, culturally appropriate as well as user friendly. With solar as elsewhere we need to remind ourselves of the adage that we as architects, planners or engineers cannot in fact deliver *sustainability*; we can only provide solutions that a) will be sustainable *if used sensibly*, and b) make sustainability *more likely* by providing well designed solutions that people find easy to understand and use.

ECO-MINIMALISM

My colleague, late Howard Liddell of GAIA Scotland has written a book advocating "eco-minimalism". Our ultimate goal is not renewable energy, but *a sustainable world*. There is the well known irony that a solar collector is much more "efficient" if installed on an energy guzzling house, since it will need every joule the collector can produce, whereas on a low energy house it will not be needed (hence useful) for much of the year. Many early solar collectors seemed to be quite efficient, but when placed on today's low energy buildings, they deliver far less useful energy!

Ecominimalism says that as a rule the best solution is that which requires as little technology as possible – of whatever type, renewable or not. For solar collectors and wind turbines also require resources, contain harmful components, produce wastes – and follow Murphy's Law by failing now and again.

Yes, for all technology, with or without sales guarantees, can and does fail now and then. So how much, solar or not, do we really need? Another of my GAIA colleagues, architect Rolf Jacobsen, developed the phrase: "I will give you a lifetime guarantee on every piece of technology that I don't need to install".

Hence, before we roll out our solar credentials, we should ask if we can find a solution where *even solar* would not be needed. This is partly a question of design, partly a question of people, behaviour and needs. In today's superinsulated passive buildings in cold climates, for example, the heat of the occupants and the lights is enough to maintain a good indoor temperature, without the need for almost any energy technology - neither solar nor fossil. Even more so if the occupants lead fairly energy conscious lifestyles. Similarly, in hot climates bioclimatic design with natural ventilation can largely replace the need for mechanical cooling.

FUNCTIONAL ISSUES: THE RIGHT MATCH

Solar technology applications are in many cases relevant for local uses and individual buildings. Here again there are choices regarding application and scale. The question of "where?" includes the huge issue of appropriate scale: should we require every building to provide its own solar hot water - the kind of renewable energy requirement now being introduced by law in countries like the UK? Does this make sense when some buildings are on the shady side of the hill, and a large-scale power supply from outside the town would be far cheaper per unit delivered?

The Western Harbour district in Malmo, Sweden, is one of the first large urban areas to be supplied 100% by renewable energy. There are solar panels, and biogas production from wastes, but the main part of the energy comes from one very large windmill placed on the coast a few kilometers away. Not a small windmill on every building – which is a dubious idea, even though a few designers fantasize about it.

Are solar panels appropriate on old historical buildings? Retrofitting existing buildings to a low energy standard is extremely important; but it can require extensive changes to their appearance. In the case of historical buildings, to safeguard their appearance it makes more sense (and can be far cheaper) to grant them "exception" status and address *the supply end instead*. Providing renewable energy from outside the city might do this. One can see this as a kind of micro scale trading mechanism analogous to CDM …

Certain types of buildings, such as the functionalist style, are relatively easy to retrofit and to install solar panels on facades and roof. Other types are very difficult. Solar applications will always be cheaper if they can be integrated into the building fabric or roof; or given some additional function. Examples are PV canopies as shading on hot climate roofs, as covered walkways or bicycle shelters. A less fortunate idea was the installation of solar collectors doubling as noise barriers along (Swiss) highways. The dust thrown up by the vehicles means that they require constant cleaning!

PROCESSES AND DELIVERY ISSUES

Delivery is a big issue. Many renewable technologies have suffered years of difficulties due to poor organization, delivery and follow up. Delivery is also very much a question of how ownership, financing and maintenance can be organized. Experience has often been that it is not the technology in itself that has been the problem hindering broader acceptance and growth, but such factors.

In most cases, production of solar applications will be industrialized, but there are still quite a few situations where self-help or at least, small-scale local production has benefits. Not least if we think of how local production sustains local economies. This may also argue for less high-tech applications in some situations – including rural areas of developing countries. But local economic production networks such as BALLE in the USA are delivering a similar message.
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The above are just a few examples of the complexity of energy decision making. When we are confronted with the real world then the technical side becomes only part of a larger whole. The most appropriate technology may be far from the most efficient or exciting one. In other cases, the most expensive solution may be best, not the cheapest. Those PVs in the jungle come to mind: if you really insist on doing that, better be sure you install the expensive, upmarket ones with a 30 year guarantee!

STAKEHOLDERS AND DECISION MAKERS

Energy decisions need to be taken at the right level. There is a need for more understanding about energy amongst politicians. Placing the onus on individual homeowners or companies to solve their own energy supplies satisfies the idea of the free market, as well as individual freedom of choice. It has the advantage of involving users, thus fostering both better awareness and responsibility. Setting up a centralized energy system may optimize the environmental and economic results but be seen as socialism or technocratic arrogance. The typical North American Energy Utility is in theory somewhere in between, since the public good, not private profit, is at the core of its mandate. These choices inevitably have a political side too.

There is no doubt that it makes sense in many cases to choose larger scale solutions. However, some technologies including solar are also readily amenable to small scale application: this gives advantages of individual freedom as well as flexibility, in addition to enabling people to understand, interact and participate meaningfully in their environmental footprint.

The question of stakeholders is receiving increased attention. One problem is the so-called “split incentives” issue. Those who invest in buildings, for example, are often property developers and not the same people as those who are going to have to pay the energy bills. So they have little incentive to build low energy buildings. Those who invest in renewable energy options are often not going to reap the benefits of reduced pollution – though carbon taxes are helping to overcome this disincentive.

DISTRICT HEATING SYSTEMS

The preceding paragraph touches again on the issue of identifying appropriate scale. An example of this dilemma is that of district heating systems (DHS). The same applies to District Coolign systems, which are less well known. DHS has become widespread in recent years, however without the issue of appropriate scale being discussed.

In brief, district heating systems usually deliver piped hot water (from a big and economically efficient energy plant) to a large area, and usually have a monopoly of supply to that area, since no company would make such investments at the risk of being upstaged. There is often also an obligation for all users in the area to connect to this supply. This is because the system would make a loss if every second building did not connect: the costly underground pipes would be delivering far less energy per kilometer.
A problem is that obligatory connection to DHS systems largely removes the incentive for individuals to build zero energy buildings. It thus reduces freedom of choice. It does not shift our priorities away from supply towards demand either. There is also the issue that any monopolistic system needs a regulator.

On the other hand, in purely technical or economic terms, district heating often makes a lot of sense. There is no simple answer. As a very general - oversimplified! - rule however one might say that DHS makes most sense in *dense* urban areas, whereas in spread suburban areas it would be better for buildings to be self sufficient with their own renewable energy.

A major advantage of district heating systems is that they can supply energy from combined heat and power producing facilities (CHP). In conventional power plants, fossil fuels as well as nuclear and biofuels generate electricity through the steam cycle with heat as a byproduct which, in former years, was simply discharged into air or the nearest river (hence the cooling towers). This type of electricity generation is at most around 45% efficient, meaning that more than half of the energy is lost as waste heat. Today, instead it is increasingly being piped to nearby housing estates or other users. To be able to use this waste heat, however, means that CHP plants have to be located quite near the end users. Small to medium scale local CHP plants are now widespread, and their production of approximately half heat and half electricity corresponds with the end use needs - at least in cold countries that have a large space heating need.

Another major argument for solutions using piped hot water as the energy carrier is that the energy source can be switched; it could be gas today but bio-energy or solar in future. There is a downside to this however. What if zero energy buildings become economical? Or if it becomes cheap to use photovoltaics, even if that electricity is used for heating? Constructing urban pipe networks is hugely expensive; nobody will be willing to abandon them after a few years. DHS may therefore be locking us into solutions such as gas for many decades, instead of providing the flexibility, which was the main argument.

In the following paragraphs we take a brief look at some of the issues and overall questions of appropriate scale and type of technology as they concern *solar applications*.

SOLAR CONCENTRATION

In general, it makes sense to use solar for low temperature applications – such as passive solar architecture and domestic hot water. This keeps it simple. Concentration is an extra cost factor and should be used only where higher temperatures really are required.

SOLAR AVAILABILITY

Solar energy is available during the daytime and mostly in summer. This is a major limitation for some applications but not for all. Many people do not realize that although incoming radiation is less in the far north, this is not necessarily a limitation either; the crucial point being that the solar contribution will be most useful at *different times* of the year in Spain than in north Norway.

A solar panel will naturally deliver more at sunny latitudes. Where there is a large need for space heating as in the far north, there is no sun at all in mid winter and the panel will produce nothing; but on the other hand, as late as May and June, when the sun is up for 20 hours or more, there is still a need for space heating! In other words, where a Spanish solar collector will provide useful heat mainly in the midwinter months, the arctic collector may provide almost as much useful heat in the spring and autumn – in the four months May, June, September and October. And although the collector in Spain will also produce lots of energy in the summer months, that heat is not needed; the *annual* heat produced per square meter by that technology will be much higher - but the *useful* heat delivered may be quite similar.

FLAT PLATE THERMAL COLLECTORS

These come in several varieties which are in many cases economically viable today. Naturally they are particularly applicable where there is a large need for hot water, but can also cover a part of space heating needs in cold climates. One of the main advances has been to develop collectors that can be integrated into roofs or walls, as opposed to being added extras; this greatly reduces costs – since the collector itself is the roof sheeting or wall cladding panels.

There are without doubt also some useful applications of air based, as opposed to water based, collectors. These include solar drying and space heating, the main advantages being simplicity and the ease with which one can deal with air, as opposed to water or other fluids.

Flat plate thermal applications are almost always on a local and fairly small scale, with no grid connections. Only low temperature heat is involved. Hence, implications for the overall energy system are limited to a reduction of (mainly) summer energy demand that can be achieved if most or all buildings cover part of their heat needs in this way. In some countries, such as Israel and Spain, this kind of individual solar water heating is already obligatory.

There is an important implication for city planning: if we are to use solar energy then streets must be laid out so that most roofs are more or less south facing (in our north hemisphere!), and heights must be zoned so that neighbouring buildings do not shade each other. Consideration for solar energy should therefore be included in urban design. The EU has recently highlighted the need for attention to this in future city planning, not least since it seems likely that both thermal solar and photovoltaics will become competitive. This has seldom been done in practice yet, although the municipality of Davis in California was a very early example of solar zoning with the intention of ensuring "solar access" to all properties. In many recent planning concepts highlighting sustainability, one can also see a tendency for the designers to point most buildings towards the sun. (Traditional settlements knew this of course!)

As an applications planner, however, it's important not to be unnecessarily rigid. The physics of solar tells us that there is only a small loss of efficiency if a roof slope is not quite the ideal angle, or if a building is oriented 20 or 30 degrees off south.

THERMAL FOCUSING COLLECTORS

These are enjoying revived interest; they are a fairly "high tech" application, which however has the advantage of higher efficiency and hence greater output for a given number of units (and other factors such as the area of land required).

The nature of the technology helps us to identify appropriate uses: these collectors, usually vacuum tubes, are almost impossible to integrate into building fabric – and are thus not very appropriate for individual installations except as added bits of technology beside the buildings; fine on a farm maybe, but not ideal in a suburban garden or the forecourt of an office block.

High tech focusing collectors often require tracking mechanisms. This may be fairly cheap given today's electronics but requires a high degree of precision and maintenance and gives higher susceptibility to errors and failures. Concentrating collectors deliver higher temperature heat, up to several hundred degrees. There are many end uses for this type of heat; cooking and laundries are examples; or else up scaling towards higher temperatures for steam generation and the conventional power cycle.

SOLAR COOKERS

In addition to high tech collectors there are useful low tech applications, often useful in developing country applications. Solar cookers are an example. One might remember that they can also be used for heating pots of water when one is not cooking – enough to do the washing up, then the laundry …

SOLAR POWER STATIONS

These are large arrays of tracking collectors, heliostats, where a high degree of precision is required. This enables one to achieve temperatures of over 1,000 degrees at the focal point, making it possible to create the normal steam cycle to drive a turbine and produce electricity. But why produce high quality exergy, when much of the demand at the other end of the transmission line is for low temperature heat? As noted elsewhere, heliostats demand a high level of technology, directionality and maintenance. The economically viable scale is quite big. The energy source is free but it would seem an unlikely candidate as a cheap renewable solution of the future, except perhaps in a desert city with no wind, waves or biomass.

SOLAR SEASONAL STORAGE

One way to describe this might be as "artificial geothermal energy"; summer heat produced by solar collectors is pumped underground, forming a heat store in large volumes of rock or soil. This heat is then pumped up to heat buildings in winter. The technology is simple, requiring little more than pumps and heat exchangers. This application relies on economies of scale. When large volumes are involved, the small surface to volume ratio means that heat losses from the store area to the surrounding ground are low. As an extension of this, in some cases another part of the underground is cooled down by cold water in winter, providing a "cold store" as well, that is used for summer cooling. In the Spree River district in central Berlin the system provides both winter heating and summer cooling to a large city area. Interest in large scale district energy systems of this kind is growing rapidly, both for cold climate and hot climate cities.

The first seasonal storage of solar heat was in fact in an experimental house at MIT (USA) in 1939. However, the heat store was as big as the house itself and required insulation more than a meter thick. In an original solution in a 1980's pilot project in Sweden, heat storage was in a large water pool, where the solar collectors were placed on a thick cover made of floating (and revolving) polystyrene insulation.

Air conditioning represents a growing load in hot countries. Given global warming, future cooling needs are also estimated to increase in colder climates too. Solutions such as seasonal storage, at a large scale such as for entire cities, may be interesting for coastal cities in hot climates where it may be possible to use ground cooling, or to fetch cold water from deep in the sea. With GAIA International we briefly investigated this option when designing the Master Plan for a new Ecocity in Taiwan.

PHOTOVOLTAIC APPLICATIONS

Advances in photovoltaic technology were slow for some decades, largely due to low oil prices, but PV is now an industry expanding at a rate of over 20% per annum. As it becomes more economical it has some big advantages, not least that it can be applied on any scale, from a single unit on a street light or isolated holiday cottage to a large power plant. And electricity is still often the easiest and cleanest energy carrier.

There are now PV panels that replace normal roof sheets, and even systems that can be rolled out on top of existing flat roofs on industrial and other buildings. PV arrays have also been applied as balcony rails or semi-transparent roofing. Applications are therefore potentially almost universal; this, for any marketing industry, is a big advantage.

However once again we need to remember the big picture. PVs do not produce very much energy per square meter (around 150 kWh/m2.year in France). To supply a *normal* house with PV energy, one would pretty much need to cover the whole garden with PVs. But in extremely *low energy* houses, then the picture becomes really interesting; because the south facing roof area is then enough. In rounded figures, in a moderate climate such a roof will provide around 7,000 kWh per year, which is more than the house needs. Hence the appellation "plus energy houses" - see Rolf Disch in Freiburg, Germany - these buildings, including both houses and offices, sell a surplus to the grid. One has an energy income, not an energy bill. This should be the future of all sensible architecture!

These buildings produce a surplus in the summer. This surplus might be particularly useful for air conditioning, in many inland climates such as the American Midwest for example where the summer cooling peak load is as high as the winter heating peak. Here again, we see the need for integrated energy planning where the individual system and the overall energy system can work in synergy; the energy supply system, as a whole must be brought into the picture and cater for this. In addition – the question of effective delivery again – policies and tariff systems must be designed to send out the right signals to manufacturers and users. In Germany for example, small producers receive a high price for green energy they deliver to the grid, this has aided the products to become widespread.

This last point raises other essential issues in energy planning: ownership, legislation and even rights. Large power companies were not interested in buying tiny amounts of renewable energy from individual consumers. Battles had to be fought - first by the grassroots supporters of wind energy in Denmark. On the other hand, it is not really very difficult in technical terms to integrate small suppliers into the grid.

SOLAR FOR EXISTING SETTLEMENTS

It is often stated that most of tomorrow's buildings are already built. This is mainly true in developed countries where population growth is small and the rate of renewal of the building stock is typically 1% or less per year; the existing settlements and cities thus pose the major energy problem for the future. Solar energy applications have a considerable potential here. Much of the solution again lies in *first* reducing demand - through energy saving retrofitting. However, many existing roofs can be solarized with both thermal and PV applications. Some facades will be available too although many, in towns, will not receive much sun. In the case of fairly low-rise traditional urban buildings, solar roofs may in the future typically provide 50% of the energy needs once these have been reduced through energy saving measures.

Typical old urban apartment blocks have been retrofitted to extremely low (passive standard) energy needs, for example by architect Karl Viriden, Zurich. By insulation and other measures, the energy demand has been greatly reduced, at which point the roof, including both thermal solar for hot water and solar photovoltaic electricity, is large enough to cover all the needs.

In the case of existing settlements, a primary task will be to make cost analyses showing whether it is better to retrofit and solarize the individual buildings, or to choose solutions at the larger urban scale and provide renewable energy supplies from outside the "system boundary" of the town itself.

Here again we see the need to consider the urban planning together with the energy question. One of the main difficulties in improving existing settlements lies in their structure. One may change or replace individual buildings, but the overall layout to a large extent determines energy use, in particular for transport. It has often been said for example that the typical sprawling American suburb is designed "on the assumption of cheap gasoline forever" (Clark Bullard) - it is almost impossible to get around without a car. Sprawl is typical in other countries too. This lies outside the scope of this paper, but is important to remember. On the other hand, suburbs do present an easy opportunity for individual solar installations.

CONCLUSIONS ON ENERGY PLANNING

It seems likely that in the not very distant future, solar energy will be standard for most buildings, so that roofs are not only providers of shelter from the weather, but energy producers – including thermal solar panels and photovoltaic. The planning of national energy supply systems needs to take this into account. Amongst other things this scenario does lessen the advantages of some alternatives such as biofuels-based district heating systems – since everybody needs a roof anyway.

On the other hand, it also to some extent turns energy policy focus back in the direction of electricity. This would be a significant policy shift; in recent years the accent has been on getting off electricity, since this was primarily produced in fossil fuel power stations.

It can thus serve a final example in this brief discussion of how applications of technologies such as solar, are interwoven with urban planning, energy system planning, broader social considerations and policy decisions on several levels.

The first conclusion is that it is not useful to evaluate a technology, solar or other, in isolation from its context of application. Another conclusion is that decisions on future energy priorities are very complex. This in itself represents a risk - which again argues in favor of giving top priority to the energy saving end of the question. The only technology that can't be a bad investment, or go wrong, is the one you don't need.

The solar age is nevertheless our future. Having good applications and abundant supplies of solar energy can only be an advantage.

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