Small-scale Concentrated Solar Power

A review of current activity and potential to accelerate deployment

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Contents

The views expressed in this report are those of the authors, and do not necessarily reflect those of the Department of Energy and Climate Change or the Department for International Development.

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1 Executive summary

Introduction

This report investigates the potential to accelerate the deployment of small-scale concentrated solar power (CSP) in various developing countries, with a focus on industrial process heat and rural on/off-grid applications.

It was undertaken by the Carbon Trust for the Department of Energy and Climate Change and the Department for International Development, to inform the design of a possible intervention.

The report sets out the need for an intervention by identifying the main barriers and market failures; it reviews relevant previous experience of demonstration and deployment of small-scale CSP; and it assesses delivery mechanisms for an intervention to scale-up deployment of these CSP applications.

The project covered a number of low carbon development priority countries across three regions: India, Latin America and Sub-Saharan Africa. Within those regions, India, Kenya and Chile were chosen for detailed research. For the purposes of this research, small-scale was defined as 100kW up to 2MW, and all relevant CSP technology types were included.

This study was conducted from November 2012 to January 2013 using desk-based research and interviews with experts and stakeholders. Experts from 28 organisations were interviewed, including technology suppliers, academic experts, NGOs, and government advisors, across 9 countries.

The need for an intervention

There is substantial growth potential in the use of small-scale CSP for industrial process heat, with a potential increase in global deployment from c. 25MW today to 63GW in 2050 – growth by a factor of 2,500 – and growth potential in Africa and Latin America of as much as a factor of 4,600 from now to 2050. Small-scale CSP can be deployed in a wide range of potential industrial applications and sectors.

CSP systems are generally used to complement existing industrial process heat systems, such as coal or oil fired boilers, and reduce the consumption of fossil fuels rather than displacing them entirely.

The case for CSP will vary in strength depending upon the fuel being displaced. In certain sectors and countries, CSP may offer reduced benefits, for example where sustainable biomass can be used, but in many industries biomass is not a practical option and CSP systems will displace expensive and carbon intensive fossil fuels, and accelerating deployment will offer significant carbon abatement and cost saving benefits.

In addition to these benefits, using CSP to generate industrial process heat offers other important benefits, both to system users and to the host country, including: increased energy security, reduced deforestation and land degradation, local health benefits, and potential local job creation and economic growth.

At present, critical barriers are holding back the deployment of small-scale CSP in both industrial and rural / off-grid applications. These will need to be addressed if the benefits are to be realised. The key barriers for industrial applications are low awareness that CSP is a potential energy source for industrial process heat, lack of confidence that the technology works in local conditions and applications, and payback periods that are considered unattractive by potential customers. For rural / off-grid applications the critical barrier is the lack of an optimised and proven technology solution.

These barriers need to be overcome now to access the full range of benefits available from deployment of small-scale CSP. Other barriers, such as low availability of finance, will become more important as the markets for these applications develop.

Experience to date

These are relatively new applications and markets vary considerably in development state. India is the world's leading market for CSP in industrial applications with 70 installed systems, a range of domestic manufacturers and massive potential demand. Kenya and Chile are much less developed markets but both have good solar resources, appropriate industries and some small-scale CSP activity. All three countries show strong national interest in renewable energy, but only India has put in place an ambitious support programme for concentrated solar power, in the form of its National Solar Mission.

There is a small but growing number of international support programmes focussed on industrial CSP. These programmes all support national policies, and feature substantial funding from the host governments and the private sector. In India UNDP, UNIDO and GIZ are implementing or developing well-resourced programmes that target or include the scaling up of solar energy in industrial contexts; the most relevant of these is the recently launched UNDP programme focussed entirely on small-scale CSP in industrial applications, which includes the creation of 30 demonstration projects as well as awareness raising, capital grants and capacity building.

The picture is quite different for rural and off-grid and on-grid applications. Energy access is a priority for many countries and multi-lateral development organisations, with numerous projects aimed at improving energy access using renewable technologies. However there are no major programmes devoting significant attention to applications of CSP technology in rural or off-grid settings. We have found only two examples of pilot or demonstration projects for small-scale CSP in rural applications, one in India and one in Thailand. Similarly, there is very little activity focussed on small-scale CSP for on-grid power generation. The vast majority of on-grid CSP projects are of much greater capacity than the 2MW limit of this project.

Conclusions

As outlined above the critical barriers to deployment of CSP in industrial applications are low awareness, lack of confidence, and unattractive payback periods. An intervention focussed on demonstration of plants would most directly address these critical barriers. There was a broad consensus in our interviews that demonstration projects were needed to stimulate demand growth in new markets.

Because there are several large (USD 20m plus) programmes either active or planned in India focussed on scaling up small-scale CSP, a new intervention should focus on other developing countries for maximum additionality.

An intervention based around a programme of demonstration projects, operating across a group of 3-4 countries, could leverage Indian experience and best practice and have a transformational effect on the uptake of small-scale CSP technologies. Significant stakeholder engagement and general awareness raising would be required alongside the demonstration activity.

Rural / off-grid applications are at a far earlier stage of development, calling for a different type of intervention. The main barrier for rural applications is the lack of an optimised small-scale CSP technology solution, which has led to CSP being excluded from previous energy access projects. This issue could be addressed through a competition to develop an optimised technology solution followed by field trials to prove it in real-world conditions.

We do not see any need for an intervention in small-scale CSP for on-grid power generation, as on-grid applications seem better served by medium and large-scale systems.

2 Introduction and context

This study investigates the potential for UK intervention to accelerate the deployment of small-scale concentrated solar power (CSP) in various developing countries, with a focus on industrial process heat applications, and rural or on-grid or off-grid power or combined heat and power applications.

It has been carried out by the Carbon Trust on behalf of and with input from the UK's Department of Energy and Climate Change (DECC) and the Department for International Development (DFID). It will feed into evidence being gathered for a possible intervention by the International Climate Fund, a £2.9bn fund that is managed jointly by DFID, DECC, the Department for Environment, Food and Rural Affairs (Defra) and the Foreign and Commonwealth Office (FCO).

Specifically, this report sets out the need for an intervention by:

- identifying the barriers and market failures that are hindering demonstration and deployment, and estimating the potential benefits that could be unlocked by addressing them;
- reviewing and capturing the lessons learned from existing experience of demonstration and deployment of small-scale CSP;
- assessing delivery mechanisms for an intervention to support and scale-up deployment of the relevant small-scale CSP applications.

The study was conducted between November 2012 and January 2013.

To undertake this study, the Carbon Trust partnered with Dr Christopher Sansom – CSP Team Leader and Senior Lecturer in Ultra Precision Engineering at Cranfield University and a specialist in small-scale CSP technologies – to provide additional experience and expertise specific to the industry. We are very grateful to Dr Sansom for his contributions.

3 Methodology

Scope

Technology overview

Concentrated solar power covers a wide range of possible scales, technologies and applications. This study covers:

- Only small-scale systems, defined for the purposes of this study as ranging from c. 10kW up to 1-2MW energy production capacity – large-scale systems for on-grid electricity generation are excluded;
- Two different types of application – use of CSP technology to produce industrial process heat, especially in the range of 200-300^{o}C; and use of CSP in rural and on-grid or off-grid situations to produce heat, electricity or combined heat and power (CHP);
- Any CSP technologies that can meet the requirements above – these typically include parabolic troughs, parabolic dishes (both flat and curved glass) and Fresnel concentrators (see Box 1).

Country selection

The ICF prioritises a number of countries for potential low carbon development projects. Included in the scope of this study are India, Mexico, Brazil, Chile, Peru, Uruguay, Ethiopia, Kenya, Malawi, Mozambique, Rwanda and Tanzania.

Following a high level review in which all twelve countries were profiled, three countries were selected for detailed research. The short timescale for the project made it impractical to research all twelve countries to the level of detail required to understand the critical barriers, level of current activity and optimal potential intervention, given the paucity of published material and need to gather information through primary research.

The high level review profiled the countries using the following metrics:

- good solar resource, measured by the level of Direct Normal Irradiance (DNI);
- the presence of existing large-scale CSP projects or activity;
- the existence of small-scale CSP applications or activity;
- the degree to which national policy prioritises or has a focus on CSP;
- the presence of good market conditions, including industrial sectors well suited to industrial process heat CSP;
- the need for off-grid energy solutions (based on % of the population with access to the electricity grid.

In addition to the above metrics, we included a subjective assessment of whether we felt it would be easy to identify and contact suppliers, academics / experts and government officials, and whether they would be likely to have informed or useful perspectives on small-scale CSP.

Based on the results of this high-level analysis we selected India, Kenya and Chile as focus countries. This was agreed with DECC and DFID following the project kick-off meeting. A summary of the high level review is shown in Figure 1.

Figure 1 - Summary of high level country review

	India	Brazil	Chile	Mexico	Peru	Uruguay	Ethiopia	Kenya	Malawi	Mozambique	Rwanda	Tanzania
DNI[1]	✓✓	✓	✓✓	✓✓	✓✓	✓	✓✓	✓	✓	✓	×	✓
Large-scale CSP activity	✓✓	✓	✓✓	✓✓	×	×	×	✓✓	×	×	×	×
Small-scale CSP activity	✓✓	✓	✓	✓	×	×	×	✓	×	×	×	×
Government policy focus on CSP	✓✓	×	✓	✓	×	×	×	×	×	×	×	×
Relevant Industries	✓✓	✓✓	✓	✓✓	✓	✓	✓	✓	✓	✓	✓	✓
Off grid need (% access to grid)[2]	66 ✓✓	98 ×	98 ×	98 ×	86 ✓	98 ×	17 ✓✓	16 ✓✓	9 ✓✓	12 ✓✓	~10 ✓✓	14 ✓✓

Box 1 - Overview of solar concentrators

Parabolic dish – non tracking

Non-tracking parabolic dishes focus sunlight onto a single point in front of the dish. This example is an array of Scheffler reflectors developed by Wolfgang Scheffler, which uses flat mirrors.

Parabolic dish – tracking

Tracking parabolic dishes also focus sunlight onto a single point, but track the sun as it moves across the sky. This example is the ARUN reflector developed by Clique Solar in India, which also uses flat mirrors.

Parabolic trough

A parabolic trough uses curved glass to focus sunlight along the focal line of the trough. This example is made by Italian company Soltigua.

Fresnel reflector

Fresnel reflectors use flat mirrors mounted on the ground at varying angles to concentrate light along the focal line of the system. This example is made by Soltigua.

[1] National Renewable Energy Laboratory - http://www.nrel.gov/gis/mapsearch/
[2] World Bank data

Research and analysis

This study has been conducted using desk-based research, with data and insights gathered from published materials and from interviews with experts and stakeholders in various countries. Compared to more established renewable technologies, there is quite a limited amount of relevant published material on CSP and the majority of this is focussed on large-scale CSP for on-grid electricity generation. Small-scale CSP (for any application) is not covered in detail in many published documents. As a result, interviewing relevant individuals was the main research activity, and considerable time was spent identifying and contacting interviewees.

In total, we interviewed experts from 28 organisations, including technology suppliers, academic experts and NGOs, and government advisors, across 9 countries (we spoke to a number of relevant experts or technology suppliers outside of the three focus countries).

A summary of the distribution of interviewees is shown in Figure 2.

Figure 2 - Summary of the distribution of interviewees

	India	Chile	Kenya	Other	Total
Technology supplier	3	0	2[3]	5	10
Expert	3	2	5	4	14
Government	1	2	1	0	4
Total	7	4	8	9	28

[3] One of these suppliers, Kyoto Energy, manufactures concentrating PV systems for rural heat and power

4 The need for an intervention

There is substantial growth potential in the deployment of small-scale CSP for industrial process heat, offering significant benefits

- **Potential growth in global deployment from c. 25MW today to 63GW in 2050 – a factor of 2,500**
- **Even greater growth potential in Africa and Latin America – by as much as a factor of 4,600 by 2050**
- **Wide range of potential applications and sectors. Industries currently using fossil fuels offer the most compelling case for deployment of CSP**
- **Significant benefits including climate change mitigation, enhanced energy security and local environmental benefits**

Industrial process heat

Potential deployment

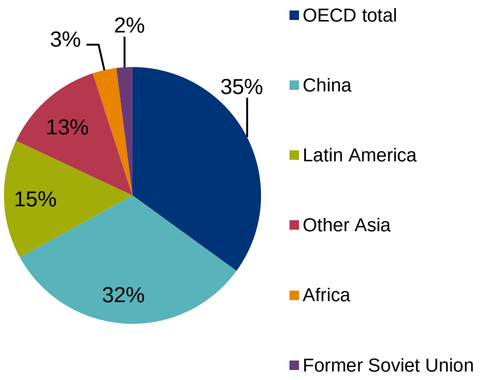
In a 2011 report on the potential for renewable energy in industrial applications, the United Nations Industrial Development Organization (UNIDO) estimates that the potential for solar thermal production of industrial process heat in 2050 is 5.6EJ. However, according to the report "only 8% (0.5 EJ/yr) of the estimated 5.6 EJ/yr of solar thermal energy in 2050 will require the use of CSP technologies; the rest can be achieved using flat pane collectors and evacuated tube collectors."[4]

This is equivalent to approximately 139 TWh of heat output in 2050, which would require approximately 63 GW of installed capacity[5]. UNIDO's report includes a regional breakdown of the 2050 potential (shown in Figure 3); using the same breakdown across regions, the potential installed capacity of small-scale CSP for industrial process heat in 2050 is approximately 1.9 GW in Africa and 9.5 GW across Latin America[6]. For comparison, in 2011 the global installed capacity of PV was 70GW[7].

It is estimated that there are 100 small-scale CSP plants currently in operation worldwide[8]. Assuming an average capacity of 250kW per plant (based on case studies – see following section and Annex A), the global deployment estimate for 2050 is a factor of 2,500 larger than current deployment of c. 25MW.

UNIDO's estimates of potential in 2050 equate to 7,600 250kW plants across Africa and 38,000 250kW plants across Latin America. Based on our research we estimate that there are currently no more than 10 installations of small-scale CSP for industrial process heat across Africa and Latin America, so there is potential for enormous growth in these regions – as much as by a factor of 4,600 from now to 2050.

Figure 3 – Regional breakdown of solar thermal potential for process heat in industry[9]



In a separate estimate, included in the concept note for a programme under development in India, UNIDO estimates that "for meeting heat requirements in the textile finishing processes, about 20,000 solar dishes of the ARUN-160 type could be deployed across the industry, leading to an

[4] Renewable Energy in Industrial Applications: An assessment of the 2050 potential, UNIDO (2011). Note: "including the chemical sector could potentially increase the contribution of solar thermal to 8EJ per year"
[5] Assuming a capacity factor of 0.25 – see discussion on page 10
[6] Not including Chile, which is a member of the OECD
[7] REN21 Global Status Report - http://www.ren21.net/Portals/0/documents/Resources/GSR2012_low%20res_FINAL.pdf
[8] UNDP India project document
[9] Adapted from Renewable Energy in Industrial Applications: An assessment of the 2050 potential, UNIDO (2011)

estimated reduction in CO2 emissions of the order of 2.7 million tonnes."[10]

The ARUN-160 dish can generate between 80-100 kW of thermal output[11], so 20,000 dishes would equate to an installed capacity of 1.6 – 2 GW for the textile industry in India. We do not have access to the assumptions underpinning either this estimate or the estimates of 2050 global potential, so it is hard to compare these different projections, but an estimate of c. 2GW potential in a single sector in India (as above) is hard to reconcile with the UNIDO report's estimate of potential capacity in 2050 of c. 3.4GW for 'Other Asia' (which we assume includes India).

Potential applications

Most small-scale CSP systems generate heat output in the range of 150-300^{o}C, which makes it appropriate in a wide range of industries, many of which are found in all but the least developed countries. Some of these industries, and the temperatures required by the main processes, are shown in Figure 6.

Industrial heat applications of CSP would generally complement established forms of heat generation, such as oil or coal fired boilers, and would not replace them entirely. Industrial users would use the CSP systems to reduce their fossil fuel consumption and to reduce their exposure to expensive fuels with volatile prices. Variable output due to varying solar irradiance, and space constraints, make it impractical to completely replace existing baseload heat generation with a CSP system. The proportion of total process heat requirement met by a CSP system will vary from site to site, but it is unlikely to be much more than 30%[12].

The existing fuel that a small-scale CSP system may displace would also vary significantly by country and by industrial process, depending on price and availability of fuels. For example, in the Kenyan tea industry, wood is the preferred fuel for heat processes, though some factories use fuel oil due to limited availability of biomass.

Figure 4 shows the primary energy mix of the three focus countries – India[13], Chile[14] and Kenya[15] – which gives an indication of the kinds of fuels that would be displaced.

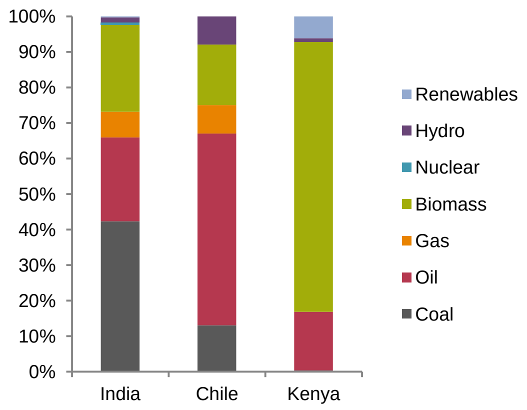
In Chile, the majority of the primary energy supply is derived from fossil fuels, much of which is imported.[16] Many other Latin American countries have a similar energy mix.

In Kenya, the predominant fuel is biomass, of which as much as 57% comes from unsustainable sources[17]. Biomass plays a similarly important role in other countries in Sub-Saharan Africa.

India is heavily reliant on coal, but much of this is used for electricity generation.

Ultimately, individual industrial sectors (and sites) will use the energy sources most practical and affordable to them, and this may vary within single countries. Further research into fuel consumption in specific industries is needed to identify the fuels most likely to be displaced and the best sectors to target with small-scale CSP.

Figure 4 - Primary energy mix of focus countries



Storage

One of the distinctive attributes of CSP at any scale is its ability to store energy relatively efficiently and cheaply. Excess energy generated by the system during the day can be stored in various storage media (for example molten salt, though many materials can be used including concrete) and this heat can be used after sunset when the system is not capturing solar energy. In applications where CSP systems are used to drive chillers for air-conditioning or other uses, storage can also be

[10] Promoting business models for increasing penetration and scaling up of solar energy, UNIDO
[11] Interview: Clique Solar
[12] Email communication with Sopogy
[13] http://www.iea.org/stats/pdf_graphs/INTPESPI.pdf
[14] http://www.iea.org/publications/freepublications/publication/Chile_2012.pdf
[15] http://www.reegle.info/countries/kenya-energy-profile/KE

[16] IEA Chile Energy Policy Review 2009 http://www.iea.org/publications/freepublications/publication/chile2009.pdf
[17] [17] Biomass Energy use in Kenya, Practical Action - http://pubs.iied.org/pdfs/G02985.pdf

used to create a cold reservoir which can be drawn upon when needed.

This attribute is a considerable advantage over solar PV when CSP is used for electricity generation, because a large-scale on-grid CSP plant can use the stored thermal energy to run its turbines and feed electricity into the grid for several hours after sunset (in many countries this may be a period of high demand).

While it offers potential benefits in extending the time during which a system can provide heat, storage is not yet a common feature of industrial process heat applications of CSP. The degree to which storage would be useful will vary from sector to sector and from site to site depending on the operating practices of individual facilities and processes. Storage is more expensive at small-scale than large scale[18], and the economics will only be compelling where heat demand is high at times when the sun is not shining (e.g. after sunset).

As CSP systems generally complement rather than completely replace existing baseload heat systems, the requirement for thermal storage to meet heat demand outside of hours of high solar irradiance is reduced, because fossil fuel powered baseload capacity can meet the demand at that time[19]. This applies to both temporary lulls in solar energy received (e.g. cloudy periods) and post-sunset operation. As storage for small-scale systems becomes cheaper, it will become more attractive as a means to further displace fossil fuel consumption.

While several of the leading international small-scale CSP technology suppliers offer storage as a potential component in their systems, it is generally not prominently featured in their websites and case studies / reference projects.

Benefits of deployment

Deployment of CSP to generate industrial process heat has a number of key benefits, both to system users and to the country itself[20]:

- **Climate change mitigation:** CSP can offer sizeable reductions in carbon emissions by displacing the use of fossil fuels or unsustainably sourced biomass. The potential energy and carbon savings are quantified in the following section
- **Energy security:** in regions where there are limited indigenous natural resources, fuels are often imported at high cost. Switching to CSP can improve energy security and reduce pressures on international energy markets;
- **On-going cost saving**: over the life of a system, the levelised cost of heat from a CSP system could be much lower than existing fuels (e.g. diesel or fuel oil). These cost savings can be re-invested in growth and jobs;
- **Reduced deforestation or land degradation**: in countries where CSP would displace biomass, increased deployment of this technology could help protect ecosystems;
- **Health benefits:** switching to CSP could reduce consumption of fossil fuels or biomass, improving local air quality and reducing adverse health impacts;
- **More reliable processes**: CSP systems can offer improved temperature control and more reliable processes than traditional biomass based systems, e.g. in pottery firing;
- **Local job creation / economic growth**: some CSP systems can be easily manufactured locally in developing countries (especially Scheffler dishes which were designed to be manufactured anywhere[21]). This technology offers greater potential for local supply than most renewables (e.g. PV).

Quantifying the energy and carbon benefits

There are a number of existing small-scale CSP plants currently being demonstrated (or in commercial operation) around the world. Details for 7 of these plants are provided as case studies in Annex A. In general, aside from the 2MW on-grid system operated by Sopogy in Hawaii, these vary in size from between 100 – 300kW, supplying process heat for industrial applications or providing space cooling.

The demonstration projects planned by the UNDP programme in India (see section 5) anticipate 15,000 m^2 of reflector across 30 systems. Since small-scale CSP systems in India are often of the 'ARUN' parabolic dish design, this equates to 500 m^2 per system, or 170 – 250 kW installed capacity per system.

[18] Interview: Archimede Solar & Elianto
[19] Email communication with Sopogy
[20] IEA CSP Roadmap 2010
[21] Interview: Wolfgang Scheffler

Given these points of reference, we define a 'standard' small-scale CSP plant to be of the order of 250kW and use this to estimate the potential benefits.

The output of any CSP system is heavily dependent on its capacity factor (the ratio of actual output over a period of time (e.g. a year) to theoretical maximum output if a system operated at full nameplate capacity, expressed as a percentage) which can vary significantly by region. As noted elsewhere in this report, performance monitoring for the small-scale CSP systems deployed around the world has been quite weak, so there is limited data on actual system performance. Several technology suppliers do include actual performance data for their reference projects which enable capacity factors to be calculated. Figure 5 contains the capacity factors for 8 projects around the world. Based on these figures and other inputs including our interviews we have used a capacity factor of 25% to model the potential output and deployment of small-scale CSP systems.

Assuming a capacity factor of 25%, a 250kW system without storage could generate approximately 0.55 GWh of energy per year. If fuel oil is being displaced[23], and assuming an efficiency of 76% for fuel oil boilers[24], one 250 kW CSP plant would save approximately 60,000 litres of fuel oil and 240 tCO_2 per year. If one system has an economic lifetime of 20 years, it would save approximately 4.8 $ktCO_2$ in total. These figures are very sensitive to capacity factor. To illustrate this sensitivity, total lifetime CO_2 saving ranges from 3.9 $ktCO_2$ to 5.8$ktCO_2$ with capacity factors of 20% and 30% respectively.

This is broadly in line with Sopogy's 291 kW system in Mexico (see Annex A), which has a claimed lifetime carbon saving of 3.45 $ktCO_2$. It is likely that any differences are due to variations in capacity factor around the world and the carbon intensity of the fuel being displaced.

Expanding this to a larger scale, 30 small-scale CSP systems at 250 kW each would save approximately 1.8 million litres of fuel oil and 7.2 $ktCO_2$ per year. The following section explores the potential deployment in the Kenyan tea industry to provide some context for these figures.

Figure 5 - Capacity factors of existing systems[22]

Location	Capacity (kW)	Application	Capacity Factor
Mexico	291	Cooling	29%
Arizona	700	Cooling	28%
Texas	219	Cooling	21%
Arizona	180	Cooling	21%
UAE	130	Cooling	20%
India	600	Process heat	16%
California	24	Cooling	15%
Japan	100	Process heat	4%

[22] System capacity and actual output figures taken from reference project case studies available on company websites and used to calculate capacity factors

[23] With a carbon emissions factor of 3.75tCO2/t – UNDP project document

[24] Average of 72 – 80% from http://cibo.org/pubs/whitepaper1.pdf

Assessing the potential for CSP in the Kenyan tea industry

In 2011, the tea industry in Kenya generated USD 1.09bn (KES 109bn) in export value, up 12.4% on the previous year, while local consumption was valued at USD 0.11bn (KES 1.1bn)[25]. As one of the largest industries in Kenya, with significant need for process heat in the temperature range accessible to small-scale CSP, the Kenyan tea industry is an interesting case study and could provide valuable insights into the deployment potential of developing countries. Tea is one of the industries currently being targeted by the sole supply of small-scale CSP technology in Kenya.

The Kenya Tea Development Agency (KTDA) manages 55 of the largest Kenyan tea companies, with each providing detailed financial and company data to the KTDA[26]. In 2011, 36 of these companies mentioned rising fuel costs as a major challenge to their business.

Many of these companies use biomass as their primary fuel for heat. However, due to dwindling supplies and associated increased prices, 34 of these factories have announced plans to grow eucalyptus trees on their own land, with the intention of being self-reliant for sustainably sourced biomass by 2015. Whether this is feasible given the amount of land required to for such production to be fully sustainable is not clear[27]. At this stage it does not seem likely that CSP would be a compelling option for these sites.

However, 17 of the factories still rely on fuel oil, and due to rising prices, have expressed intent to change their primary fuel. These factories used 3.6 million litres of fuel oil in 2011, resulting in CO_2 of approximately 14 ktCO_2 in 2011.

Assuming a 250kW CSP plant abates 60,000 litres of fuel oil per year, 60 plants would be required to displace all the fuel oil demand of these tea factories. However, as only 30% of this demand would likely be displaced by CSP[28], the total amount of fuel oil that could be displaced would be 1.1 million litres, requiring approximately 18 plants. Space and other constraints may mean that not all of this demand can feasibly (or cost-effectively) be met by CSP, but it illustrates the potential deployment within just one industry.

Assuming other industries present similar opportunities for deployment of CSP (many industries would not have the land to grow biomass for own use, increasing their potential use of CSP), it is possible that a country like Kenya could deploy several hundred systems across a number of industrial sectors. Deployment of this magnitude would place Kenya firmly among the leading countries for small-scale CSP (indeed today, it would make Kenya the country with most deployed capacity). In order to achieve this, a number of substantial barriers to deployment would need to be overcome. These are described later in this section.

A comprehensive assessment of the potential deployment in other industries (and countries) is beyond the scope of this report but would be a very valuable next step (and should be conducted as part of the design of any intervention in Kenya or indeed other developing countries).

Comparison with other technologies

CSP is one of a number potential energy sources for the generation of industrial process heat. The most commonly used alternatives today are boilers fuelled by coal, liquid fuels, gas or biomass. Electricity (locally generated or taken from grid supply) is used in certain applications. Heat pumps can be used for lower temperatures. Waste heat from other on-site heat-intensive processes can also be used.

Figure 7 compares CSP to some of these alternatives across several important metrics to illustrate some of the advantages of using CSP over other sources. The metrics are:

- **Suitability for process heat:** whether or not a technology or energy source is suitable for the generation of on-site process heat;
- **Cost of energy:** assessment of the levelised cost of energy over the lifetime of the system, including the cost of equipment, installation, maintenance and fuel;
- **Price volatility:** assessment of how volatile the price of the fuel source is. Oil and grid electricity have been especially volatile in many developing countries;

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[25] http://www.kilimo.go.ke/index.php?option=com_content&view=article&id=448:-tea-industry-performance&catid=149:news&Itemid=46

[26] http://www.ktdateas.com/index.php?option=com_content&view=category&id=38&Itemid=247

[27] Interview: Altener

[28] Email communication with Sopogy

- **Carbon intensity:** assessment of the carbon intensity of the energy derived from the fuel or technology. Normally measured in tonnes of CO_2 per unit of energy (e.g. MWh);
- **24 hour availability:** whether the energy output (in this case process heat) is available on a 24 hour basis to serve constant production processes. Boilers using fossil of biomass fuels can be run constantly. Solar energy is limited to daylight hours but CSP systems with storage can produce heat for several hours after sunset;
- **Scalability:** an assessment of how easily a system could be scaled up if heat demand at an industrial facility increased significantly. Boilers can easily be upgraded, or additional ones added as they do require a large amount of space. Adding to a CSP or PV system could be constrained by available space;
- **Local component supply:** being able to replace system components easily is important to industrial users and more complex components may need to be imported. PV panels for example are not made in many developing countries. This may lead to supply issues, and limits local job creation opportunities;
- **Ease of maintenance:** it is advantageous for industrial users to be able to maintain all parts of their process heat systems. Those with complex components may be difficult or expensive to maintain.

Figure 6 - Industries and processes relevant to small-scale heat from CSP

Industrial sector	Process	Temperature range (°C)	Chile[29]	India[30]	Kenya[31]
Food and beverages	Boiling	95 – 105		✓	
	Canning	60 – 120	✓		
	Drying	30 – 90		✓	
	Fish (salmon)	25 – 150	✓		
	Heat treatment	40 – 60		✓	
	Pasteurising	80 – 110		✓	
	Sterilising	140 – 150		✓	
	Sugar milling	60 – 105			✓
	Tea/coffee	60 – 80	✓		✓
	Washing	20 – 46		✓	
	Wheat	40 – 80	✓		✓
Metal treatment (galvanising, anodising, and painting)	Cleaning	60 – 90		✓	
Textile industry	Bleaching	60 – 100	✓	✓	✓
	Drying and degreasing	100 - 130			✓
	Dyeing	100 – 160		✓	✓
	Fixing	160 – 180			✓
	Pressing	80 – 100			✓
	Washing	40 – 80		✓	
Chemical industry	Boiling	95 – 105		✓	
	Distilling	110 – 300		✓	
	Plastics	120 – 220	✓		
	Soap	200 – 260			✓
	Synthetic rubber	150 – 200	✓		
Rubber industry	Vulcanisation	170		✓	
Timber	Paper	65 – 150	✓		
	Wood pulp	120 – 170	✓		
Mining	Smelting	1260 (out of scope)	(✓)		

[29] Independent research carried out by Dr C. Sansom
[30] UNDP India project document – tick marks are not exhaustive of all relevant industries in India but reflect those highlighted by the UNDP
[31] Independent research carried out by Dr C. Sansom

Figure 7 – Comparison of CSP against other relevant energy sources for industrial process heat[40]

	CSP	PV	Biomass	Coal	Fuel oil	Grid power	Comments
Suitability for process heat							CSP and boilers generate heat and are well suited to process heat applications. Grid electricity is used to generate process heat in some applications but PV is not well suited to heat generation
Cost of energy	USD 14 /GJ[32]		USD 2.5-7 / GJ[33]	USD 2 /GJ	USD 16 - 22 / GJ[34]	USD 16 /GJ[35]	CSP is more expensive than biomass and coal but can be competitive against oil and grid power over full lifetime. Figures for biomass, coal and fuel oil do not include capital cost of boilers
Price volatility							Once installed, solar technologies are not subject to fuel price volatility. Biomass price influenced by diversity of supply
Carbon intensity	0	0	17 kg/GJ[36]	116 kg/GJ[37]	122 kg/GJ[38]	109 kg/GJ[39]	Some biomass is not sustainably sourced. Grid carbon intensity depends on grid mix
24 hour availability							CSP with storage can produce heat after sunset. Grid power is not 100% reliable in many countries
Scalability							If site energy demand grows, CSP and PV are less easily scalable than other sources due to space constraints
Local component suppliers							In less developed countries certain PV components will need to be imported
Ease of maintenance							If PV panels develop faults it may be difficult to repair them locally. Grid supply problems can only be solved by the grid operator

High
Medium
Low

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32 Assuming that a 250kW system costs $400,000 and has a 20 year life, with 2% annual opex costs and a capacity factor of 0.25.
33 Figures for Africa; lower end is for residues, higher is for energy crops. From UNIDO report 'Renewable Energy in Industrial Applications'
34 Charles Oloo, a small-scale CSP supplier in Kenya – 62-82 KES per litre of fuel oil; UNDP India project document – 36 INR per litre.
35 Assuming 5 KES (0.06USD) per unit, after monthly charge
36 Based on Defra/DECC GHG conversion factors, assuming system efficiency of 60-70% (from http://cibo.org/pubs/whitepaper1.pdf). This estimate does not include whether the biomass is sustainable or not
37 Based on Defra/DECC GHG conversion factors, assuming system efficiency of 75-85% (from http://cibo.org/pubs/whitepaper1.pdf)
38 Based on 3.75 tCO_2/tonne from UNDP project document – India, assuming system efficiency of 72-80% (from http://cibo.org/pubs/whitepaper1.pdf)
39 Kenyan electricity grid intensity – based on 0.393 $kgCO_2$/kWh - US Department of Energy: http://www.eia.gov/oiaf/1605/pdf/Appendix%20F_r071023.pdf
40 Dr C Sansom

Rural / off-grid applications

As outlined in the previous section, there are various estimates of the potential deployment of CSP technologies in industrial process applications. In contrast, we are not aware of any estimates of the potential deployment of small-scale CSP in rural or off-grid applications.

There is no doubt that the market for renewable energy technologies in rural / off-grid contexts is huge. In 2012, nearly 1.3 billion people had no access to electricity, and 2.6 billion had no access to clean cooking facilities[41], many of these in ICF priority countries. In India alone, based on electrification data from Figure 1, as many as 540 million people lack access to electricity.

Advocates of CSP technology believe it is well suited to meeting the energy needs of rural or energy poor communities. In its CSP Roadmap, the IEA states that "in countries where electrification of households is not complete, small-scale or mid-scale CSP plants offer co-generation of electricity for remote or weakly interconnected grids, and process heat for some local manufacturing".[42]

This view is echoed by some small-scale CSP technology suppliers, for example the CEO of German manufacturer Solarlite (partner in the TRESERT project): "The future of CSP is not the large-scale project of 150 MW or more but the individual customized solution to supply energy to industries and rural regions."[43]

For rural applications, there is particular interest in CSP-biomass hybrid systems. The IEA's roadmap says: "Where DNI is good but not excellent, and large amounts of biomass (notably animal residues) are available for gasification, these [small or mid-scale] CSP plants are often hybridised with biogas. While the main driver is the availability of the resource in Africa, Brazil, China, India and other developing economies, these plants entail no CO2 emissions at all." This is consistent with the fact that both of the rural CSP pilots we identified are CSP-biomass hybrid systems.

Box 2 below contains a view from our expert collaborator Dr Sansom on the potential of CSP in off-grid applications.

For reasons explored in later sections, it is not currently considered a viable solution and the various published reports that assess the potential for renewable energy technologies in off-grid settings do not cover CSP in detail.

On-grid applications

On-grid applications of small-scale CSP were also included in the scope of this project, however our interviews and research revealed very little activity in small-scale on-grid power generation.

Above 2MW capacity, the vast majority of CSP plants operating, or under construction, around the world are for on-grid electricity generation, and there are a number of large and well-known corporate players focussed on this market, including Abengoa, E.ON, Areva, and GDF Suez. A number of countries including India, Spain, Saudi Arabia, and South Africa have introduced or plan to introduce incentive schemes designed to add CSP generating capacity into their electricity portfolios.

Very few of these projects are less than 10MW in size and a significant number are in excess of 100MW. At these scales the economics of the plants are more attractive to project developers and the electricity output makes a more meaningful contribution to the grid.

The response to Spain's CSP feed in tariff illustrates this point. The CSP feed in tariff for CSP included projects from 100kW up to 50MW, but of the 50 CSP plants built in Spain, 44 are 50MW capacity systems, and there are only 2 below 5MW. Both of the sub 5MW systems are demonstration projects for innovative technologies (a new tower type and a Fresnel system), rather than standard operational plants.[44] Despite the availability of a generous incentive available for plants as small as 1-5MW, no developers built standard (non-demonstration) plants of this scale.

A few small-scale CSP technology suppliers do list power generation as one of their applications. Sopogy have a 2MW on-grid electricity generating project in Hawaii (see case study in Annex A), but in our interview they described themselves as focussed on industrial heat and did not mention on-

[41] IEA World Energy Outlook 2012
[42] IEA CSP Roadmap

[43] http://www.evwind.es/2012/05/20/the-future-of-concentrated-solar-power-is-the-individual-customized-solution/18613/

[44] http://www.nrel.gov/csp/solarpaces/by_country_detail.cfm/country=ES

grid power generation at all (nor did they mention the Hawaii project). [45]

Small-scale CSP in on-grid power generation applications could be a valuable option for mini-grids or island grids where overall demand is limited (and where waste heat from the CSP system could usefully be used). In these cases a 1-2MW system could be the right size to serve local grid demand, with heat storage and generation after sunset providing an additional benefit (e.g. over a PV system).

Because on-grid CSP at small-scales is attracting such limited interest among developers and customers at present, it is not explored any further in this report which focuses instead on industrial heat and rural or off-grid applications.

[45] Interview: Sopogy

Box 2: Off-grid rural power generation using CSP - an expert view

In conducting this research, the Carbon Trust collaborated with Dr Christopher Sansom, CSP Team Leader and Senior Lecturer in Ultra Precision Engineering at Cranfield University.

"Any intervention in off-grid power generation for rural communities only makes sense in sub-Saharan countries, and not in South America, given the large rural population in countries such as Kenya which have no grid support – a situation not found in countries such as Chile.

Approximately 50% of the rural population in Sub-Saharan Africa (SSA), i.e. 500 million people, are using biomass for cooking and/or heating. In Kenya, only 50% of this biomass is from sustainable sources. An intervention to replace unsustainable biomass (and kerosene) with small-scale CSP would have significant implications for CO2 reduction. If replicated across rural SSA, the impact on climate change would be significant and positive. We should also remember that 1.5 million people die prematurely each year from inefficient biomass stoves.

These are the communities that would benefit from small-scale CSP. They only need domestic electrical power for lighting, charging radios and mobile phones. PV can only supply power during the day, but cannot provide the heating/cooling/cooking/lighting/ at the peak cooking times and at night. It doesn't matter how cheap the power from PV is, it is being generated at the low-point in domestic demand and cannot be stored efficiently.

The basic human needs are 0.1MWh of electricity and 1MWh of heat per year. A 500kW CSP system in the centre of a Kenyan rural community would provide electrical power for schools and industry and allow charging of batteries during the day, plus heat for industry and thermal storage. In the evening, at night, and in the early morning, the stored heat is released for community or domestic cooking, heating, and perhaps lighting as well.

From a technical perspective the solution would be similar to the parabolic trough installation for industrial process heat, but I would recommend three differences.

- Firstly, the installation would be smaller in size and lower in power output. This is because I would recommend lower cost components and manual tracking, reducing cost.
- Secondly, the installation would have thermal energy storage – the most significant advantage that CSP has over other power generation sources, namely the ability to store energy.
- Thirdly, the system would need to be maintained and repaired by the local community, so the knowledge transfer process would need to have an additional dimension. This would involve training Kenyan academics and engineers as in the case of industrial process heat, but would then additionally involve a training programme for community-based technicians.

The intervention in rural Kenya, for example, would involve a number of small-scale parabolic trough installations in selected communities across the country – preferably communities with both agricultural and some small-scale industry (such as food processing or textiles). These would be demonstrator plants for the technology, but also should be flagship demonstrators for positive impacts on climate change in rural Africa as a whole – and linked to national and international climate change strategies."

- Dr Chris Sansom

Critical barriers are holding back the deployment of small-scale CSP in both industrial and rural / off-grid applications. These will need to be addressed if the benefits are to be realised

- **The key barriers for industrial applications are low awareness, lack of confidence, and unattractive payback periods**
- **For rural / off-grid applications the critical barrier is the lack of an optimised and proven technology solution**
- **These barriers need to be overcome now to access the full range of benefits available from deployment of small-scale CSP. Other barriers, such as low availability of finance, will become more important as the markets for these applications develop**

Critical barriers in industrial process heat applications

There are three critical barriers that are currently holding back deployment of small-scale CSP in industrial applications. These need to be addressed in the near-term to scale up this technology and realise the available benefits. The barriers are described as follows:

- **Low awareness** is a critical barrier to wider deployment of small-scale CSP. Most interviewees referred to the problem of low awareness among potential customers (users of industrial process heat), and a number of interviewees also referred to a lack of awareness among government, engineers and financiers[46]. These awareness issues mean that CSP is not considered as a potential source of process heat.
- **Lack of confidence** is a critical barrier where stakeholders are aware of the availability of small-scale CSP for heat generation but are not confident that it can operate reliably to deliver the energy required and the predicted savings. International examples are not sufficient to provide confidence: potential customers require local examples in relevant industries.
- **Unattractive payback periods** are a critical barrier, especially in the Indian market, where awareness and confidence barriers have been partially addressed. Even though industrial CSP systems can pay back in as little as 5 years (including subsidy in India) this can be longer than potential customers are willing to bear[47]. In less developed markets, this is likely to become a more important barrier once awareness grows and customers are confident that CSP is a viable option from a technological point of view.

It was notable that very few interviewees mentioned the low availability of finance as a barrier to industrial applications of CSP. For most comparable technologies (i.e. relatively new technologies or applications) this is a substantial barrier, usually addressed by dedicated or concessional loan facilities. It is likely that this did not come up because in most markets, this application of CSP is so nascent that other barriers (those described above) are more critical.

Critical barriers in rural / off-grid applications

For rural or off-grid applications there is one pre-eminent barrier that needs to be addressed in the immediate term. Once addressed (and depending upon the outcome) other barriers that are not currently critical will become the key obstacles to deployment of CSP in rural and off-grid contexts.

The **lack of an optimised technology solution** is the most critical barrier for rural or off-grid applications of CSP. While CSP technology has been optimised for industrial process heat generation, and there are an ever increasing number of deployed systems around the world, CSP has not been proven in rural or off-grid contexts. It is thus not being considered in energy access programmes where more well-known technologies are being trialled or implemented. In a sense, there is currently not a technology solution to be aware of or confident in, which is why these barriers, critical for industrial applications, are not particularly important for rural or off-grid contexts.

Once (or perhaps 'if') CSP can be optimised for and proven in rural and off-grid applications, **access to finance** is likely to become a critical barrier. This is a common barrier for renewable energy projects in rural communities, which often have limited access to financing to pay for the capital cost of systems. In this case the general difficulty of accessing finance for renewable energy projects at this scale is

[46] Interviews: Chilean Ministry of Energy; PSE

[47] Interviews: Clique Solar

compounded by a lack of awareness (and confidence) on the part of financiers[48]. This is not yet a major barrier as there is no evidence of attempts (unsuccessful or otherwise) to raise finance for rural small-scale CSP projects.

Other barriers

Though not currently critical in preventing the deployment of small-scale CSP in comparison with those discussed above, there are two more barriers that are relevant to both industrial process heat and rural / off-grid applications, and which will become more important once the market develops:

- **Operational barriers:** While some small-scale CSP systems are designed to be as easy as possible to install, operate and maintain[49], CSP systems are often perceived to be more complex to design, integrate and maintain than commonly available alternatives, including biomass burners and PV systems. Industrial customers are fearful of disruption to production capacity and this perceived complexity may combine with unattractive payback periods to weigh against the decision to install CSP. There are further constraints such as space limitations – for many customers (e.g. those located in areas where land is highly valuable) only rooftops are suitable for installation of CSP systems, and this can limit the percentage of a site's process heat energy demand that can be met by a CSP system. Below a certain materiality threshold, customers may see a CSP system as worth investing time and resources in.

- **Shortage of required skills:** These applications of CSP are relatively (or very) new, so there is not yet a large established pool of qualified designers, installers and maintenance engineers. If demand grows quickly then the shortage of these skills in local supply chains may become a constraint. Very few interviewees considered this to be a major barrier at present, and generally interviewees felt it would be straightforward to overcome. One international manufacturer designs its systems to be easy to install and operate and not reliant on highly skilled local labour.[50]

A summary of these barriers and their relative importance is shown in Figure 8.

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[48] Interviews: Camco Kenya; Abengoa Solar
[49] Interview: Sopogy
[50] *Ibid.*

Figure 8 - Summary of barriers identified

Barrier	Issues	Industrial process heat	Rural / off-grid	Comment
Availability of optimised technologies	The optimal technology solution is either not proven or available locally	x	xxx	The lack of an optimised technology solution is the critical barrier for rural or off-grid applications
Low awareness	Low level of knowledge / awareness about potential applications of CSP	xxx	xx	Awareness of industrial applications is low among both customers and governments; this is less of an issue for rural applications at this stage
Lack of confidence	Lack of robust / comparable evidence that CSP works at small-scale and in local conditions	xxx	xx	Lack of confidence that CSP is a viable option is a major barrier for industrial applications; this is also a barrier in rural / off-grid uses
Long payback	Payback period considered too long by potential customers and financiers	xxx	xx	Even with available subsidy paybacks are considered unattractive in India for industrial use. This is not yet a barrier in rural / off-grid
Access to finance	Limited access to capital to finance installation	xx	xxx	Access to finance will be a major barrier for rural applications, but is less critical until the technology and business model are proven
Shortage of necessary skills	Lack of skilled and experienced technicians and engineers to install and maintain systems	x	x	A second-order barrier in both applications that could hold back supply once demand grows
Operational complexity	Complex system to design and install; space requirements also a constraint	x	x	Integration / installation can be complex but this is not a major barrier. Space constraints may limit the potential benefits

x Weak barrier

xx Medium barrier

xxx Strong barrier

Each focus country presents unique challenges and opportunities

- **India is the world's leading market for CSP in industrial applications with 70 installed systems, a range of domestic manufacturers and massive potential demand**
- **Kenya and Chile are much less developed markets but both have good solar resources, appropriate industries and some small-scale CSP activity**

India

The Indian market for small-scale CSP is already the most developed in the world with 70 systems installed, of approximately 100 worldwide. These are predominantly parabolic dishes, with two designs dominating the market: arrays of Scheffler concentrators and the larger 'ARUN' concentrators.

According to research undertaken by UNDP, around 50 of those systems are used to produce steam for very high volume cooking, for example at religious institutions. Other industrial sectors where CSP has been deployed include dairy, baking, and laundries.

The existing installations in India have almost exclusively been installed by local companies, which are able to provide systems more cheaply than international firms (see Figure 9). The low price points favoured by the Indian market have made the Indian market unappealing to some international manufacturers, despite its size. In addition, foreign firms can find it difficult to penetrate the Indian market.[51]

The Indian Ministry of New and Renewable Energy provides a capital subsidy worth up to 30% of the cost of CSP systems, as part of the JNN National Solar Mission. This is a key reason for the pre-eminence of the Indian market and is discussed in more detail in Section 5. During our research several interviewees identified other reasons why the Indian market is so far ahead of other markets[52]:

- Good solar resource;
- Large demand for industrial process heat often met by on-site consumption of fossil fuels;
- High cost of diesel;
- Well-established capabilities in the use of steam (important for easy acceptance and integration);
- Many companies of the optimal size (where a standard size CSP system can make a meaningful contribution against the energy demand, without them being over-exposed). [UNDP India have identified a related issue: companies with a steam requirement greater than 5 tons per hour are likely to use less expensive solid fuels (e.g. coal) which makes the economics less attractive. In India there are lots of smaller companies using liquid fuels against which CSP can compare favourably.]

Kenya

While there are at least two suppliers of small-scale concentrated solar energy systems (one concentrated solar thermal, one concentrated PV) in Kenya[53], there is no evidence of any operational small-scale CSP systems for either industrial process heat or for rural/off-grid applications. The sole supplier of small-scale thermal CSP systems was not aware of any existing systems in Kenya and has spent several years trying to gain acceptance for CSP in industrial applications, with limited success so far.

Kenya has a number of industries that would have potentially relevant applications, including[54]:

- Salt processing;
- Food and beverages;
- Dairy;
- Pharmaceutical and cosmetics;
- Textiles;
- Commercial laundries;
- Steam cooking for large catering establishments.

Another potential application of industrial heat in Kenya could be to provide cooling through absorption chillers, in particular for the cut flower, dairy and fishing industries[55].

[51] Interviews: Abgenoa Solar; PSE; Soltigua; Sopogy, UNDP India
[52] Interviews: Sopogy; IIT Mumbai; Clique Solar
[53] Interviews: Altener Solar Industrial Process Energy Ltd and Kyoto Energy
[54] Altener.co.ke – products page
[55] Interview: Access Energy

Kenya has a significant problem from deforestation, with forest cover decreasing at 0.09% per year. In 2000 Kenya used 34 million tonnes of biomass, of which 57% came from unsustainable supplies, and as much as 16.5 million tonnes of biomass were used in charcoal kilns with only 10% efficiency. Kenya's emissions from deforestation are estimated to be c. 14m tonnes CO_2 per year[56]. Switching from biomass to CSP in industries currently using unsustainable supplies could reduce emissions and deforestation.

The majority of the Kenyan population is not connected to the grid. If the technology barrier described above can be overcome then small-scale CSP could be an important energy source for rural Kenyan communities.

Chile

Chile has some of the highest direct irradiance levels in the world, reaching 3100 kWh/m^2/year in its northern region. As a result it has recently become a focus for international suppliers of utility-scale CSP – with a 360MW plant currently in development[57] – and has attracted international finance for large-scale CSP from the Clean Technology Fund.

Chile has few indigenous energy sources, so it imports fossil fuels at high cost. Given the quality of the solar resource, CSP offers attractive benefits at both large on-grid scale and small-scale.

Chile does not have a very diversified economy and industrial activity is concentrated in a few sectors. Nevertheless there are some potential industrial applications of small-scale CSP in Chile, in particular in[58]:

- Mining;
- Timber – e.g. for drying wood pulp;
- Food processing – e.g. for canning food and smoking salmon;
- Textiles;
- Chemicals – e.g. plastics and synthetic rubbers.

Of these industries, mining facilities are often located in regions of very high solar irradiance, where grid electricity is not always 100% reliable. These mining operations consume huge amounts of electricity and process heat, and could be well suited to CSP systems. Much of their energy demand is 24 hour, so CSP systems with storage could offer advantages over PV based systems.

There is currently no subsidy scheme that would be applicable to small-scale CSP. The Chilean electricity market is very liberalised, and the government is generally unwilling to intervene[59].

Manufacturing is not a major sector in Chile, which typically imports equipment rather than make it locally. CSP systems would likely therefore need to be imported from overseas in the short-term, although if Scheffler dishes can be made in Kenya, presumably they can be made in Chile as well. The Clean Technology Fund does not anticipate local supply chain constraints for its planned CSP projects in Chile: its Investment Plan notes that "the [50 MW CSP] project will source 70% of its supplies from local firms by 2030, providing broad economic stimulus for Chile's low carbon development objectives".[60]

The vast majority of Chilean population is connected to the grid, so there is less urgency in prioritising rural community projects. If Chile looks to decentralise its electricity grid in the future, however, then small-scale CSP could be an ideal technology solution.

[56] Biomass Energy use in Kenya, Practical Action - http://pubs.iied.org/pdfs/G02985.pdf
[57] http://www.nrel.gov/csp/solarpaces/project_detail.cfm/projectID=252
[58] Dr Christopher Sansom, Cranfield University
[59] Interview: Pontificia Universidad Católica de Chile
[60] http://www.climateinvestmentfunds.org/cif/sites/climateinvestmentfunds.org/files/Approval_by_mail_CTF_funding_for_Chile_Concentrated_Solar_Power_Project_PID.pdf

5 Experience to date

India, Chile and Kenya all have deep national interest in renewable energy, but only India has put in place an ambitious support programme for concentrated solar power

- **India has ambitious plans for CSP at all scales, and is providing strong support through the National Solar Mission**
- **In Chile the Clean Technology Fund is financing CSP but there are no government programmes supporting small-scale CSP**
- **The Kenyan solar market is growing, and there is evidence that the government may be willing to support CSP in future**

Jawaharlal Nehru National Solar Mission (India)

The Government of India has ambitious plans to accelerate the deployment of solar power in India by 2022. Its flagship programme for enabling this is the National Solar Mission which was launched in January 2010.

Specific targets of the Mission include[61]:

- Creating policy that will enable the deployment of 20 GW of grid connected solar power by 2022;
- Improving conditions for solar manufacturing capability in India, particularly in the local supply chain;
- Promoting programmes for off-grid systems, deploying up to 2 GW by 2022[62], and
- Achieving 20 million square metres of thermal collectors by 2022.
- There are no specific targets for concentrated solar thermal but there are 'tentative' targets of 25,000 m^2 by 2013, 50,000 m^2 by 2017 and 75,000 m^2 by 2022. As of 2007 the total installed area was c. 5,000 m^2, and UNDP estimated the total installed area in 2012 to be 20,000 m^2.[63]

The Solar Mission offers a capital subsidy for small-scale CSP projects on the basis of collector area installed. This provides up to 30% of the cost, and underpins the 'near commercial' status of the technology in India. Because the subsidy is based on collector area installed, rather than system performance, there are concerns that it is not incentivising installation of the most appropriate or efficient systems or technologies.

Another criticism of the subsidy scheme is that it can be very bureaucratic, and it can take a long time for beneficiaries to access the subsidy payments.[64] This has been partly addressed through the creation of a Channel Partner scheme, whereby approved manufacturers can get the subsidy directly from the Government, which allows them to offer a cheaper product to their customers and save them the hassle of dealing directly with the subsidy scheme.

Because of the Government's commitment to solar energy of all forms, and in particular to CSP, the Ministry of New and Renewable Energy is aware of the potential of small-scale CSP, and is supportive of domestic and international efforts to scale up the deployment of this technology.

Clean Technology Fund activities in Chile

The Clean Technology Fund (CTF) is financing a CSP project in Chile alongside the Chilean Ministry of Energy and the Inter-American Development Bank (IDB), with a particular emphasis on demonstrating a large-scale plant with thermal energy storage[65].

This project is funded through loans and grants from international bodies, up to a maximum of USD 450m. This will include provision for the construction of demonstration plants, knowledge sharing and capacity building.

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[61] JNN Solar Mission – "Towards Building SOLAR India" http://www.mnre.gov.in/file-manager/UserFiles/mission_document_JNNSM.pdf

[62] The Solar Mission does not make a distinction between solar technologies

[63] UNDP – Market Development and Promotion of Solar Concentrator based Process Heat Applications in India

[64] Interviews with Indian suppliers

[65] http://www.climateinvestmentfunds.org/cif/sites/climateinvestmentfunds.org/files/Approval_by_mail_CTF_funding_for_Chile_Concentrated_Solar_Power_Project_PID.pdf

The CTF has also allocated USD 50m for a project demonstrating off-grid and self-supply projects. This will have no technology or application restrictions, so small-scale CSP applications could be considered.[66]

Chile currently has a tax exemption scheme for solar collectors (e.g. for residential hot water) that will run until 2020. It could be possible to put an incentive scheme for small-scale CSP in place in the short to medium-term, but low awareness and a risk averse, non-interventionist approach among policy makers would need to be overcome first - these are the main barriers to implementing policies favourable to small-scale CSP.[67]

Kenya

There appears to be a general lack of awareness and policy support for small-scale CSP in the Kenyan government – other renewables, especially geothermal power, are currently receiving far more attention and support[68]. There are currently feed in tariffs for small-scale (sub 10 MW) renewables including solar, covering both PV and solar thermal and concentrated solar thermal[69], but these are for electricity generation only. There is no subsidy for CSP in process heat applications.

However, we have learned from interviews that the Kenyan Government is becoming aware of the potential for CSP, and are open to supporting renewables in general[70]. There is very little regulatory burden for setting up new projects in Kenya, which significantly reduces the resources required to complete the planning and approval process, and could make Kenya attractive for an intervention[71].

Given the policy environment, small-scale CSP could potentially be incorporated into existing support mechanisms, including the feed-in tariff (for electricity generation)[72].

Kenyan demand for solar products is also projected to grow significantly in the coming years[73]:

- Demand for domestic PV generation could reach 22 GWh per year by 2020
- Installed capacity of solar water heating is projected to nearly triple from 140,000 units to 400,000 units

Kenya Climate Innovation Center

Supported by the World Bank, DANIDA, Denmark's governmental development agency and UK Aid, the Climate Innovation Centre (CIC) aims to support the development of climate technologies relevant to Kenya[74]. The location of the first CIC (of a planned network of CICs around the world) in Kenya indicates real interest in stimulating local innovation in climate technologies. Small-scale CSP is well suited to exactly this sort of local innovation.

The CIC provides advisory services, financing and facilities to help incubate Kenyan start-ups. Both Kenyan suppliers interviewed were aware of and involved in CIC activities.

Industrial applications of CSP are becoming the focus of international support programmes. India has several well-resourced programmes being implemented or developed

- **UNDP, UNIDO and GIZ are implementing or developing well-resourced programmes that target or include the scaling up of solar energy in industrial contexts**
- **The most relevant is the recently launched UNDP programme focussed entirely on small-scale CSP in industrial applications in India**
- **UNIDO are also developing a comprehensive small-scale CSP and energy efficiency programme in Malaysia**
- **These programmes all support national policies, and feature substantial funding from the host governments and the private sector**

When we asked the project manager of the UNDP India project (described below) what projects they had been able to refer to and learn from in designing their project, he replied that they had not been able to find any other examples of comprehensive small-scale CSP projects as

[66] Interview: Chilean Ministry of Energy
[67] Interviews: Chilean Ministry of Energy; Pontificia Universidad Catolica de Chile
[68] Interview with African Energy Policy Research Network
[69] Feed in Tariff policy, Dec 2012. http://www.erc.go.ke/erc/fitpolicy.pdf
[70] Interview: Kenyan Government
[71] Interview: Kyoto Energy
[72] Interview: Kenyan Government
[73] http://www.wto.org/english/tratop_e/envir_e/wksp_goods_sept09_e/ikiara_e.pdf
[74] http://kenyacic.org/

references.[75] Since they began that process a number of other programmes have either been launched or are under development, but there are still only a very limited number of relevant programmes around the world.

UNDP India

The United Nations Development Programme (UNDP) is running a programme in India, in partnership with the Global Environment Facility (GEF) and the Indian Ministry of New and Renewable Energy (MNRE). This programme, which runs from January 2012 until July 2016, aims to help to scale-up deployment of CSP systems for industrial applications.

The project has a total budget of USD 23.75m which comes from a range of organisations:

- GEF – USD 4.4m
- MNRE – USD 6m grant subsidy, USD 1.35m in kind
- Industries – USD 6m in cash
- Financial institutions – USD 6m

Its key activities would include[76]:

- Supporting the deployment of 30 demonstration plants (15,000 m^2 of collector area), and a further 60 replication plants (30,000 m^2 of collector area).[77]
- Providing an additional subsidy of up to 10% of costs (on top of the subsidy provided by the Solar Mission) and then raising awareness, promoting knowledge sharing, capacity building and setting of standards.
- Encouraging foreign suppliers to move into the Indian market to provide a broader diversity of technologies. Currently, the only small-scale CSP technologies widely available in India are of the domestic Scheffler or ARUN designs. However, the UNDP note that this aim may be in conflict with the Indian Government, which appears to favour Indian companies[78].
- Building capacity and developing skills by providing 25 university fellowships and PhDs for researchers.

These activities aim to bring down the payback time enough for potential users to invest. According to the UNDP the current payback time for industrial process CSP systems without any subsidy is nine years. With the Solar Mission subsidy this comes down to six years, and with the additional support from this programme, the payback time falls to five years. Beyond this, the UNDP believe that payback time needs to fall to three years in order to be commercially viable and competitive with other technologies.[79]

UNIDO/GEF India

Where the UNDP India project focuses specifically on solar thermal power for industrial heat applications, there are other internationally funded programmes that aim to scale up the solar market in general.

The United Nationals Industrial Development Organisation (UNIDO) is developing a concept for a project working with GEF, MNRE and the Indian Renewable Energy Development Agency (IREDA) to promote business models to increase penetration and scaling-up of solar energy[80].

The project concept note states that it is designed to support the National Solar Mission and the National Action Plan on Climate Change.

The project is planned to run for five years, and has a budget of approximately USD 22m from various funders, including:

- GEF – USD 75k grant, USD 75k in kind
- MNRE and the Ministry of Small and Medium Enterprises (MSME) – USD 5.9m grant/in kind
- IREDA through the Asian Development Bank (ADB) – USD 10m loan
- Undefined private investors – USD 5.8m cash/in kind

[75] Interview: UNDP
[76] More detail is available in Annex B
[77] UNDP – Market Development and Promotion of Solar Concentrator based Process Heat Applications in India
[78] Interview: UNDP
[79] *Ibid.*
[80] http://www.thegef.org/gef/sites/thegef.org/files/gef_prj_docs/GEFProjectDocuments/Climate%20Change/India%20-%20(4788)%20-%20Promoting%20Business%20Models%20for%20Increasing%20Penetrati/PIF%20India%20Solar%20v6.0_for%20re-submission%20to%20GEF%205Jan12%20FINAL.pdf

Its key activities would include[81]:

- Developing a set of recommendations and guidelines for policy makers to catalyse deployment of solar technology in industrial thermal and cooling applications;
- Providing detailed technical specifications, technology application information packages and between 15-25 pilot projects to demonstrate the technical and financial viability of projects, and to enhance local manufacturing capacity;
- Scaling up industrial applications through replication by identifying suitable technologies, developing business models and financial support mechanisms, and by developing standards and quality control frameworks;
- Raising awareness and building capacity through training, workshops, institutional knowledge sharing, documentation, and industry-academic partnerships.

There is potentially some overlap between the UNDP and UNIDO projects in India. The UNIDO project will include cooling applications which are not covered by the UNDP project, and UNIDO normally focus on the larger industrial sectors where UNDP typically focuses on less industrial sectors. The leadership and co-ordination role played by MNRE will be important in ensuring that these and other projects in India are complementary.[82]

UNIDO/GEF Malaysia

UNIDO and GEF are also developing a project in Malaysia, currently at the concept stage, which aims to promote and demonstrate sector specific energy efficiency improvements and solar thermal technology in industry[83].

The project is planned to run for five years with a budget of USD 20m, from various sources:

- GEF – USD 60k grant
- Malaysian Government – USD 2.44m in kind
- Undefined private sector – USD 17.4m grant/in kind
- Other financials – USD 100k

The project will have three main components[84]:

- Strengthening institutional capacity and knowledge sharing; monitoring and evaluating the impact of previous and existing policies and programmes, and the provision of support mechanisms (incentives, technical assistance, certification and financing);
- Raising awareness and capacity building, by strengthening the skills and competency of service providers, consultants and industry, as well as raising awareness among industry management and financial institutions;
- Demonstration and scaling up of sector specific energy efficiency and solar thermal systems in specific industrial subsectors. This includes support for energy efficiency measures in 40 factories, of which ten will implement solar thermal demonstration projects.

ComSolar

The German Organisation for International Co-operation (GIZ) and MNRE are currently implementing a project “Commercialisation of Solar Energy in Urban and Industrial Areas” (ComSolar), which aims to develop and demonstrate innovative business models for solar energy applications in urban and industrial sectors / areas85 ComSolar comes under the International Climate Initiative (ICI) of the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU).

Its activities include[86]:

- Urban and industrial pilot projects to demonstrate technical and financial feasibility;
- Technology transfer through Public-Private Partnerships;
- Monitoring of projects and dissemination of leanings to raise awareness;
- Capacity building;

[81] *Ibid.*
[82] Interview: UNDP
[83] http://www.thegef.org/gef/sites/thegef.org/files/gef_prj_docs/GEFProjectDocuments/Climate%20Change/Malaysia%20-%20(4878)%20-%20GHG%20Emissions%20Reductions%20In%20Targeted%20Industrial%20Su/4-11-12%20%20ID4878%20%20PIF%20GEF5%20on%20EE%20and%20Solar%20Energy%20Revised%20after%20GEFSec%20Comments%2010%20Apr2012x.pdf

[84] *Ibid.*
[85] http://www.comsolar.in/
[86] *Ibid*

- Strategies to encourage replication.

In 2011 ComSolar commissioned and published a study to identify promising industrial sectors for solar technologies. The study analysed industrial sectors on various dimensions including their overall energy consumption; their heating and cooling requirement; and their previous solar experience. The study was conducted by PwC India and found that:

"The most promising sectors were identified as - Textile (Finishing), Pulp & Paper, Food Processing, Pharmaceuticals, and Electroplating / Galvanizing) - suggesting the use of primarily solar thermal technologies for various applications which are commercially attractive in terms of internal rate of returns (IRR) and payback-times. The commercial viability of solar technologies is much higher for industries using fuels sources such as furnace oil, coke or diesel."[87]

The only global activity focussed on small-scale industrial CSP is an IEA knowledge sharing programme

- **The IEA's Solar Heating and Cooling Programme aims to raise awareness and connect researchers from relevant projects around the world**
- **There are no global or multi-country programmes with dedicated funding for technology demonstration or awareness raising**

IEA-SHC Tasks 33 and 49

The IEA Solar Heating and Cooling (SHC) programme runs a number of subtasks, including Tasks 33 – Solar Heat for Industrial Process – and 49 – Solar Heat Integration in Industrial Processes – which are relevant to industrial process heat applications of CSP technology.

Though the programme is affiliated with the IEA, it receives no direct funding from the IEA and instead acts to encourage knowledge sharing and dissemination between existing projects and resources.[88]

The scope of Task 33 – which ran from 2003 to 2007 – was industrial heat up to 250°C, with no limits on technology or heat transfer medium (though it did not include concentrating systems due to the low temperature range). Task 33 focused on EU countries.

Its activities included four areas of focus:

- Solar process heat survey and dissemination of task results
- Investigation of industrial energy systems
- Collectors and components
- System integration and demonstration

Task 49 is more relevant to the scope of this project because the temperature range in scope extends up to 400°C, meaning that CSP technologies are included. The relevant sub-objectives of Task 49, which runs from 2012 to 2015, are to[89]:

- Identify new applications for solar thermal energy in several production processes through the combination of process intensification technologies;
- Develop planning tools, calculation tools for solar yields in large scale plants;
- Install and monitor large-scale demonstration systems;
- Develop guidelines for solar process heat;
- Lower the barriers for market deployment.

Task 49 has participants from across the EU, as well as a number of other countries including the US, Australia, China, India and Mexico. Participants are mostly research institutes (such as the Fraunhofer Institute in Germany), but solar technology companies are also involved.[90]

Beyond the IEA's SHC programme we are not aware of any other global or multi-country programmes that are focussed on small-scale CSP.

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[87] http://www.comsolar.in/images/PDF/Identification%20of%20Industrial%20Sectors%20Promising%20for%20Commercialisation%20of%20Solar%20Energy_ComSolar_GIZ.pdf

[88] Interview: IEA SHC Task 49
[89] http://task49.iea-shc.org/objectives
[90] Interview: IEA SHC Task 49

There are no large-scale programmes focussed on small-scale CSP for rural or off-grid applications

- **Energy access is a priority for many countries and multi-lateral development organisations, and there are numerous projects aimed at improving energy access using renewable technologies**
- **While many of these programmes are technology neutral, none have devoted significant attention to applications of CSP technology, so we have not profiled them**
- **We have found two examples of pilot or demonstration projects for small-scale CSP in rural applications. Both are CSP-biomass hybrids**

Pilot CSP-biomass hybrid plant in India

Indian technology firm Thermax[91] have piloted a 256kW electrical CSP and biomass hybrid plant in Shive village, near Pune, India. The system is off-grid, produces heat at up to 220°C and has thermal storage capacity. The biomass boiler uses local agricultural waste and is used as a backup at times when there is cloud cover[92].

The project was partially funded by the Department of Science and Technology (DST) under the Public-Private-Community Partnership model and was commissioned in December 2011.

On the project, Thermax have worked with several national technology institutes including IIT Mumbai and IIT Madras to develop the technology, including using the pilot as a testing site for new and improved component designs. DST intends that the performance data generated at this site can be used to assess the viability of setting up similar plants in other off-grid communities.[93]

Despite having support and involvement from the Government, Thermax faced a number of barriers in setting up this project which might hinder future off-grid CSP projects in India. The main barriers were:

- Navigating the approvals process;
- Financing the project, despite a government capital subsidy of up to 90% for rural electrification projects;
- A lack of experience in solar and biomass hybrid projects made operation and management challenging.[94]

TRESERT, Thailand

TRESERT is a combined solar thermal energy-biomass power plant for electricity, refrigeration and heat generation, located in the energy park of Naresuan University in Thailand. The plant produces 500kW of thermal outputs, and up to 50kW of electrical output.

The TRESERT project ran from 2008 to 2012. Its objective was to demonstrate an innovative technology for the decentralised provision of electrical energy, heat and air conditioning from solar energy and biomass and to introduce it to potential cooperation partners in the region of Southeast Asia[95].

TRESERT is a partnership between the Institute for Solar Research at the German Aerospace Center and the School of Renewable Energy Technology at Naresuan University.

Other relevant experience

- Sopogy have a 291kW parabolic trough system installed in Hermosillo, Mexico. This system drives a chiller to provide air conditioning to a cement plant operated by Holcim Apasco[96].
- Aora energy have piloted an innovative small-scale hybrid solar tower system in Samar, Israel. The modular system can also generate electricity which can be solar to the grid.[97]
- The EU is funding research in CSP for industrial process heat, for example the InSun research project which is being co-funded through the 7th Framework Programme.[98]

There is a more extensive range of case studies available in Annex A.

[91] http://thermaxindia.com/Solar-Power-Business-Solutions.aspx
[92] http://www.eai.in/reaction2012/solar-csp-and-solar-thermal/solar-biomass-distributed-power-generation-project-mr-venkat-subramaniam-thermax/
[93] http://www.dst.gov.in/about_us/ar11-12/PDF/ch4-Solar.pdf
[94] http://www.powermin.nic.in/bharatnirman/bharatnirman.asp
[95] http://www.solarlite.de/en/project_phitsanulok.cfm
[96] http://sopogy.com/projects/index.php?id=56
[97] http://aora-solar.com/active-sites/
[98] http://www.fp7-insun.eu/

Cost of small-scale CSP systems for industrial process heat

As part of the interview process, we asked technology suppliers to estimate the cost of a 500kW thermal system using their technology.

Capital cost varies by technology, manufacturer location and complexity. The cost range for the different technologies was as follows[99]:

- Parabolic trough: 1,300-2,000 USD per kW
- Parabolic dish: 650-900 USD per kW
- Scheffler dish: 900-1,900 USD per kW

On-going operation and management costs were given as an annual percentage of capital costs, and tend to range from 1 – 5%.

The UNDP have also conducted a review of costs for small-scale CSP systems, the results of which are shown in Figure 9, and are broadly in line with the results of the interviews.

Note that cost estimates tend not to include thermal storage, as relatively few suppliers include storage in their systems due to the additional complexity; however one estimate put the cost of a system with storage at $9000[100].

Our interviews suggested that for a standard system, 50-70% of the total cost is accounted for by the solar field equipment, with the remainder being installation and integration cost.

Monitoring and performance data

One of the reasons low confidence remains a substantial barrier in India, despite an installed base of 70 systems, is that there has been very little performance monitoring of the installed systems, so there is a shortage of robust evidence about how different systems have performed in different settings and conditions.

This gap has been recognised by the UNDP project, which aims to build an evidence base of performance data, collected from both specific technology assessments and also from the demonstration systems that the project will fund.

There are a range of project outputs that could be monitored to allow robust performance monitoring and analysis, including:

- energy performance data (e.g. steam production or electricity output)
- energy usage data from the industrial plant, including staff behaviours;
- local environmental data, e.g. DNI or wind speed;
- system downtime, including the reason (e.g. fault or scheduled maintenance);
- on-going costs and resource needs (including staffing and specialist assistance, e.g. for repairs)
- any unexpected obstacles arising during the system installation process;

Measuring the thermal and electrical output of CSP systems is not complicated and can be done using widely available measurement equipment.[101]

Given the relatively already high capital cost of CSP systems, monitoring equipment would need to be low-cost and easy to integrate. An example of this is the 3G enabled *BitHarvester* monitor being developed by Access Energy for use in off-grid systems in Kenya[102]. Such devices could feasibly allow for remote operation of systems, reducing the need for on-site staff.

[99] Interviews with technology suppliers
[100] Interview
[101] Source: C. Sansom
[102] Interview: Access Energy

Figure 9- UNDP India cost estimates of small-scale CSP systems

	Collector temperature (°C)	Specific thermal power (kW/m^2)	Cost (USD/m^2)	Cost (USD/kW)
Compound Parabolic Concentrator (CPC) vacuum tube	90 – 130	0.60 – 0.65	130 (China) 450 – 900 (Europe)	200 – 220 690 – 1500
Parabolic dish with fixed focus (e.g. Scheffler)	100 – 150	0.21 – 0.31	250 – 300 (India)	800 - 1430
Parabolic dish with moving focus (e.g. ARUN)	150 – 250	0.34 – 0.50	500 – 600 (India)	1000 - 1760
Parabolic trough	120 – 250	0.50 – 0.56	650 (Europe)	1160 – 1300
Linear Fresnel	100 - 200	0.50 – 0.56	650 – 900 (Europe)	1160 – 1800

Skills and training

Small-scale CSP, in either industrial or rural applications, is a new technology with limited deployment today but substantial potential for growth. If the critical barriers described in Section 4 are addressed, there could be rapid growth in demand for these technologies. In order to service that demand, the supply chain – including designers, engineers and installers as well as technology manufacturers - will need to grow and each country with substantial CSP demand will need a local workforce with the required skills.

We asked our interviewees whether they felt that the supply of an appropriately skilled workforce was likely to be a major constraint. There was less of a consensus on this question than on other areas (e.g. there was a fairly high degree of commonality to the answers about critical barriers).
Some interviewees did feel that a shortage of the right skills could be a barrier, and that training is an important activity. Specific viewpoints included the following:

- Training is important but should be provided as part of a wider demonstration programme;[103]
- Research productivity in CSP is very low (in Chile) – there are very few university research groups looking at the area;[104]

A number of interviewees, on the other hand, felt that training and skills were not critical issues for the growth of the small-scale CSP market. Specific viewpoints included:

- The maintenance of a small-scale CSP system does not require advanced skills;[105]
- Some systems are designed to not be reliant on local skills, even at the installation stage;[106]
- It is too soon to think about training – instead the focus should be on raising awareness. Similarly, a lack of market demand for skills might result in trained technicians finding jobs in other sectors, so demand must lead training provision.[107]

There are already several planned training activities focussed on capacity building and skills development in small-scale CSP. The UNDP India programme, UNIDO India and UNIDO Malaysia all include training, in the case of India this may be because the markets is more advanced, whereas in other markets other more critical barriers need to be addressed before skill shortages could be become a critical issue. The UNDP India project is providing 25 university fellowships and PhD positions to promote research into small-scale CSP.[108]

In general, the prevailing view from interviews was that it is too soon to be promoting training, before there is widespread awareness of small-scale CSP technologies. Once there is more awareness and market demand, local specialists would use their existing skills to move into the sector, however at this point targetted training programmes could be valuable

[103]Interview: Soltigua
[104]Interview: Pontifica Universidad Catolica de Chile
[105] Interview: PSE
[106] Interview: Sopogy
[107] Interview: PSE; Practical Action
[108] Interview: UNDP India

6 Conclusions

An intervention focussed on demonstration of plants would most directly address the critical barriers to the deployment of small-scale CSP in industrial process heat applications in developing countries

- **Markets outside of India are very nascent and the main barriers to address are low awareness, lack of confidence, and unattractive payback periods**
- **The most relevant programmes are new and have not yet yielded useful lessons**
- **All the major programmes studied are comprised of a package of activities, addressing multiple barriers, with demonstration at their core**
- **Because there are several large (USD 20m plus) programmes either active or planned in India focussed on scaling up small-scale CSP, a new intervention should focus on other developing countries for maximum additionality**
- **An intervention focussed on demonstration projects, operating across a group of 3-4 countries could leverage Indian experience and best practice and have a transformational effect on the uptake of small-scale CSP technologies**

Market development

As described in section 4 the Indian market is considerably more developed than other developing countries. The main barriers are common across the countries, but are likely to vary in relative importance.

In India, for example, unappealing payback periods are a critical challenge. In less developed markets awareness and confidence may be more critical barriers, as potential customers are unlikely to be put off by payback periods until they are aware of the relevance of small-scale CSP systems to their business.

Key barriers to address

Small-scale CSP for industrial process applications is at a very early stage in all developing countries outside India.

As detailed in section 4 the key barriers to address are:

- Low awareness among potential customers, designers and engineers, and government ministries;
- Lack of confidence that CSP systems will offer a reliable source of energy in the relevant country and industry contexts;
- Unattractive payback periods (especially in the absence of government subsidies or grants).

Summary of lessons learned from previous experience

The most relevant programmes are those focussed on scaling up small-scale CSP in India and Malaysia, as described in Section 5. Of the three comprehensive programmes (UNDP India, UNIDO India and UNIDO Malaysia) only the UNDP India programme has commenced, formally launching in May 2012. The other two are still at the concept or pre-approval stages.

While these programmes may not yet provide useful lessons learned during implementation, they are the result of in-depth studies of the Indian and Malaysian markets and their design can offer valuable insights.

All three programmes are comprised of a package of activities, together addressing multiple barriers. Figure 10 shows which activities are included in these programmes. Awareness raising, demonstration projects, and capacity building are included in all three projects, and all seek to reduce the payback period by offering capital grants. In the case of the Indian programmes these grants

Figure 10 - Summary of existing programmes

	UNDP /GEF India	UNIDO / GEF India	Com Solar India	UNIDO / GEF Malaysia	IEA – SHC Task 49
Innovator support		✓			(✓)
Knowledge sharing	✓	✓		✓	✓
Awareness raising	✓	✓	✓	✓	✓
Demonstration	✓	✓	✓	✓	(✓)
Capacity building/training	✓	✓	✓	✓	
Capital grant/subsidy	✓	✓		✓	
Finance/soft loans					
Standards and certification	✓	✓		✓	✓

complement the subsidy available under the National Solar Mission.

It is worth noting that these are substantial, five-year programmes that have the resources to tackle a number of barriers, and the time to schedule these activities as appropriate. We assume that an ICF funded programme would need to be largely complete by March 2015 and thus it may be advisable to focus on a smaller set of the most critical barriers.

The two large Indian projects both feature significant involvement and funding from the Indian government. Strong government support is highly likely to increase the chances of overall project success, and lack of support can make projects challenging to implement. Both these projects specifically refer to support of the National Solar Mission in their objectives. Linking project outcomes to existing government priorities and policies will help bolster local support for international projects.

Possible interventions

The barriers faced by small-scale CSP in industrial process applications are common to many other new technology solutions and can be overcome by a number of interventions.

Figure 11 lists a selection of relevant interventions, along with a few example activities, and an explanation of why this intervention could be relevant in this case. This is not an exhaustive list of all possible interventions, but a ‘menu’ of the interventions considered most relevant during this project, based on our research into market status and main barriers faced.

Each of these interventions directly addresses one or more barriers hindering the deployment of small-scale CSP in industrial applications, and several also indirectly or partially address other barriers. For example capital grants directly address the payback barrier by reducing the initial investment outlay required (and thus the payback), and may also address the access to finance barrier by making it easier to obtain finance (either because less is required in total, or because a grant is evidence of government or industry confidence).

Figure 12 aligns the interventions listed in Figure 11 with the barriers listed in Section 4, showing which barriers are directly and indirectly or partially addressed by which interventions. The critical barriers of awareness, confidence and payback are highlighted.

Figure 11 - Summary of potential interventions

Intervention	Example activities	Rationale for consideration
Innovator support	Prize funding; Single entity grants; R&D grant calls; Incubation activities	To stimulate innovation activity to identify and develop the right technologies and business models
Knowledge sharing	Network creation; conferences	To share and maximise learnings from projects
Awareness raising	Campaigns; events	To raise awareness of the potential of small-scale CSP
Demonstration	Pilot projects; case studies; test centres	To build confidence among customers, governments and financiers that the technology works in diverse applications
Capacity building	Creation of training courses; university courses and fellowships; sponsorship	To develop the necessary skills in the supply chain and associated workforce (designers, technicians, engineers)
Finance	Soft loans	To improve access to finance for projects
Capital grants	Grants; subsidies	To reduce initial investment costs and improve paybacks
Standards & certification	Developing standards; certification; accreditation; verification	To build confidence and trust in the marketplace

Figure 12 - Possible interventions and barriers addressed

	Technology	Awareness	Confidence	Payback	Access to finance	Skills	Operational
Innovator support	✓✓			✓		✓	✓
Knowledge sharing	✓	✓	✓				✓
Awareness raising		✓✓	✓				
Demonstration	✓	✓✓	✓✓		✓	✓	✓
Capacity building			✓			✓✓	✓
Finance					✓✓		
Capital grants				✓✓	✓		
Standards and certification			✓✓		✓		

Key barrier	✓✓= directly addresses	✓= Indirectly / partially addresses

As the table shows, each of the critical barriers is addressed by a different activity or intervention:

- **Low awareness** is addressed by awareness-raising activity such as media campaigns, case study dissemination, and events
- **Lack of confidence** that the technology works is addressed by demonstration projects and pilots proving that small-scale CSP is a viable solution in relevant industrial contexts
- **Unattractive payback periods** can be reduced by capital grants or subsidies (and over time, by cost reduction through innovation or economies of scale)

Based on our research and specific input from technology suppliers in both developed and developing countries, these three activities are felt to be most appropriate in order to support and accelerate the deployment of small-scale CSP for industrial applications. In particular, demonstration projects were felt to be the single most needed intervention in the relevant markets.

Lack of confidence in the technology, or in specific systems can also be addressed by standards and certification. This is likely to arise when market demand has been successfully stimulated and new suppliers enter the market, not all of which will meet best practice standards. However, this is not a critical activity in most countries due to the very nascent state of the market and supply chain.

Country selection: building on activity in India

As outlined above, India is the leading global market for small-scale CSP in industrial applications, with c. 70 out of c. 100 systems deployed. The Indian market is substantially more advanced than any of the other countries in-scope, and as described in Section 5, has several large-scale and comprehensive programmes focussed on small-scale CSP for industry.

Our initial hypothesis at the start of this project was that India would be a good place to focus an ICF funded intervention because of its status as a leading market, but one with huge potential for growth. At that stage we were not aware of the existence of the specific programmes being implemented or planned by agencies such as UNDP and UNIDO.

The presence of several large, comprehensive programmes makes it harder to be additional in the Indian market – an important consideration for the ICF. The programme manager of the UNDP project felt that there was room in India for additional projects – especially any that could help address the core challenge of reducing payback of CSP systems from 5 to 3 years – but as these projects are in their initial stages or are yet to launch, it is difficult to be sure of what additional project activities would be most complementary[109].

The planned projects are focussed on driving demand for CSP in industry in India and in enabling that demand to grow. Once demand has been successfully stimulated there may be supply chain challenges that can slow growth or undermine confidence in the technology:

- New, lower quality technologies may enter the market
- Poor installation by some installers can undermine confidence in the systems
- Manufacturing may be not right-sized to the new, bigger market, meaning economies of scale are not exploited and costs remain high

A number of these issues were encountered in the UK in the biomass heat market (a proven technology with mature markets in regions such as Austria and Scandinavia). As a result the Carbon Trust designed the Biomass Heat Accelerator programme to address these issues[110]. This programme is summarised in Box 3.

Our conclusion is that while there may be potential to design a programme in India that complements or builds on the existing (and planned) activity in India, at this stage it would be hard to ensure additionality or that a programme would have transformational impact beyond what is already happening.

Country selection: targeting other developing countries

As outlined above, other developing countries lag India considerably in market development.

[109] Interview: UNDP

[110] http://www.carbontrust.com/media/147632/ctc809-biomass-heat-accelerator-overview.pdf

These markets have considerable potential because of the wide applicability of small-scale CSP in industry – most countries have (or are developing) the industries that need process heat in the temperature range served by small-scale CSP. In many cases these industries are currently served by unsustainable energy sources such as expensive, imported liquid fuels, coal or unsustainably sourced biomass.

An intervention focussed on these countries would be highly additional, because there are no programmes of which we (or our interviewees) are aware that are focussed on supporting the deployment of small-scale CSP in any application or context (industrial or rural / off-grid).

Any new intervention could be designed to learn from and leverage the experience and best practice being developed in India, both through the international programmes and in the wider marketplace.

The in-scope countries (excluding India) fall into two broad categories in terms of market development:

- Those countries where there is evidence of some small-scale CSP activity, either in the form or existing or planned pilot or demonstration projects, or in the form of active domestic suppliers raising awareness and trying to sell systems to industrial customers. This group includes Mexico, Chile, Brazil and Kenya.
- Those countries where there is no evidence of any specific activity focussed on small-scale CSP and no evidence of any domestic supply base. These countries have varied market and solar resource conditions. This group includes Ethiopia, Tanzania, Malawi, Mozambique, Rwanda, Peru, and Uruguay.

Box 3 – Case study: Carbon Trust Biomass Heat Accelerator

The Biomass Heat Accelerator (BHA) was a Carbon Trust technology transfer programme that set out to identify and stimulate the potential market for Biomass Heat - a proven technology already with mature markets in other countries such as Austria an Scandinavia - to the UK

By working to support and stimulate both the market and the supply chain at the same time, BHA partially de-risked the expansion of biomass heat in the UK

The following activities made up the Accelerator:

- **Workstream 1: Data gathering and benchmarking** – investigating existing biomass installations: costs, common operational and engineering issues.
- **Workstream 2: Installers' cost-base reduction interventions** – engaging with the supply chain and installers to increase capacity and reduce cost.
- **Workstream 3: Refining of market potential and demonstration of best practice** – Finding most promising sites, following through development process on a number of sites, analysing cost.
- **Workstream 4: Fuel supply-chain activities** – Preparation of a suite of guides and tools to assist in fuel procurement.
- **Worksteam 5: Knowledge transfer** – Sharing best practice, producing a set of guides, case studies, tools and templates.

Focussing on 3-4 countries

Creating a new intervention in a single country in either of these categories would be relatively high risk, because at this stage not enough is known about the market potential (both demand and supply), critical barriers, and likely level of government support in the potential countries. Currently unseen factors affecting any of these could make achievement of an intervention's objectives difficult.

Because of this we suggest that the intervention cover a group of 3-4 countries. Focussing on many more than this would risk the intervention becoming difficult to manage, and funds would be spread too thinly to achieve the desired impact.

To exploit programme management efficiencies, maximise useful learnings, and maximise replication potential, the countries could be selected to form a regional cluster – e.g. Kenya, Tanzania, and Ethiopia or Brazil, Mexico and Chile. This could also create a critical mass of addressable market demand sufficient to attract new suppliers (both domestic and international).

An assessment of the level of government support and further research into the addressable market (number and size of relevant industry sectors; fuels expected to be displaced) should be carried out to inform country selection – this is beyond the scope of this project.

Delivery model

Whatever countries are chosen, our research suggests that the core element should be the creation of demonstration plants. This addresses the critical confidence barrier and was most commonly cited as the single most essential intervention by technology suppliers (we did not speak to potential customers, but would expect they would also want to see evidence that it works, in the form of demonstration or pilot projects).

A programme of demonstration activity should be accompanied by awareness raising activity – targeting potential customers, designers and engineers, and the national government.

Substantial additional engagement and consultation with key stakeholders and actors in the target countries would need to be undertaken to better understand the potential applications, key barriers, and other relevant factors that would inform the design of an intervention.

The following section describes two demonstration programmes run by the Car bon Trust in the UK and outlines some of the key lessons learnt. These lessons could be relevant to the design of a demonstration programme for small-scale CSP.

Lessons from Carbon Trust demonstration programmes

The Carbon Trust has designed and run a number of demonstration projects in the UK, for example the Advanced Metering Field Trial, and the Micro-CHP field trail. Brief details of these programmes are provided below.

The **Advanced Metering Field Trial** ran from 2004 to 2006, and was the first trial of advanced metering for the SME community in the UK, covering 582 sites[111]. The objectives of the programme included the following:

- Stimulate market demand by demonstrating that advanced metering can reduce energy consumption and costs;
- Identify the nature of advanced metering services that yield the best savings;
- Develop case studies, highlighting the advantages of advanced metering;
- Quantify the potential UK-wide carbon savings attributable to advanced metering in the SME community.

The **Micro-CHP Accelerator** ran from 2005 to 2008 and was the first large-scale, independent field trial of micro-CHP (combined heat and power) systems in domestic and small commercial applications in the UK, together with a complementary field trial of condensing boilers[112]. It had the following objectives:

- Install a range of Micro-CHP units in real operating environments representative of the likely UK installations; and to obtain robust, independently monitored performance data;
- Assess the carbon performance of the Micro-CHP units relative to alternative heating technologies, in particular condensing boilers;

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111 http://www.carbontrust.com/media/77244/ctc713_advanced_metering_for_smes.pdf

112 http://www.carbontrust.com/media/77260/ctc788_micro-chp_accelerator.pdf

- Provide general insights to inform future technology development and policy decisions relating to Micro-CHP.

Based on our experience of running demonstration programmes (including the two described above) we have identified the following considerations and lessons to take into account when designing programmes:

- **Define clear objectives**. Demonstration projects are designed to prove (or otherwise) uncertainties around a system or technology. From the outset it is important to know what you are trying to prove and design the project accordingly. For example this may be to better understand the economics or energy yield of a system in a particular environment, to create a high profile project to demonstrate technical feasibility, or to gather a robust and compelling evidence base to inform policy change.
- **Focus on overcoming one challenge at a time**, not taking on multiple challenges in parallel. Though multiple challenges / barriers can be overcome, it is generally more practical to tackle these sequentially. For example if a technology has not yet been shown to work in a country, do not attempt to demonstrate a novel technology at the same time, but focus on tried and tested systems that have been proven elsewhere.
- **Scale the programme appropriately.** Make sure that there are sufficient installations to isolate erroneous results. Doing this requires a critical mass of common elements across a number of demonstrations – for example, at least three systems using the same technology in the same application and environment at the same scale. Demonstrating three installations of different technologies in different applications at different scales would make it challenging to isolate any common problems. If there are 10 or 20 installations then different combinations of technologies, applications and scales of operation become possible. In other words, consider carefully the number of installations and match this to the number of variables.
- **Consider the whole system**. Care should be taken to ensure that the entire technology system is properly engineered. We have had examples where local fitters or installers have created issues in a demonstration project that have not been related to the core technology being evaluated, but have materially impacted the results. It may be possible to include a training element to help transfer best practice from experienced technicians to a would-be workforce.
- **Seek to learn and continually evolve** the programme as new developments come to light. Though a certain degree of analysis can be carried out ex-ante to optimise the design of any intervention, in the process of implementing the intervention, lessons will be learnt that help to refine the structure of future interventions.
- **Stakeholder engagement** and dissemination of results in multiple, appropriate fora over the course of the programme and beyond are required for success. Without these there is a risk of a small number of ‘white elephant’ projects being installed that do not lead to further action. For example our Industrial Energy Efficiency Accelerator programme focuses on engagement with trade associations in each sector to share lessons learnt.

Meeting ICF criteria

An intervention focussed around a programme of demonstration projects, with associated activity to address other barriers, would meet a number of ICF criteria:

- It would have high **additionality** if implemented in any of the in-scope countries outside of India, because there are currently no programmes aimed at supporting the deployment of small-scale CSP in industrial applications in these countries. In any of the sub-Saharan countries, this programme would likely lead to the very first installations of these technologies in the country.
- It could be highly **transformational** because a successful intervention could move a country from having no deployment of these technologies at all to being among the leading countries in terms of deployed capacity / number of working systems.
- It would **leverage private sector investment** by encouraging industrial companies to invest in renewable energy technologies (in the first instance by matching their investment with grant funding for demonstration projects).
- It would offer good **value for money**, especially by sharing programme management costs and

best practice and project lessons across 3 similar countries.

Supporting or expanding existing programmes

In most of the in-scope countries we have not found existing or planned programmes that could be supported, expanded, or built upon using ICF funds.

As outlined above there are several very relevant programmes in India, either current or planned. These programmes are comprehensive packages of activity designed to address the main barriers and to support the National Solar Mission. In the case of the UNDP project they are the product of in-depth programme design activity and were designed to fill all the critical gaps in the market landscape as perceived at the time of design.

Given that there are other large programmes planned for India (e.g. the UNIDO programme) we do not feel that looking to expand these (already large) programmes in India is the most sensible option for the ICF in the short term. It may be that there is an opportunity to expand or scale up these interventions in the future, once the projects are further underway.

There are other opportunities that could be built on or expanded with ICF funding:

- The Climate Innovation Centre in Kenya is a potential source of grant funding for local suppliers to run demonstration projects. We have not spoken to the Centre so do not have information about the resources at their disposal to finance these projects but additional funding ring-fenced for CSP might enable them to scale up this activity (and potentially attract new suppliers – which would be well aligned with the Centre's mission).
- Climate Innovation Centres are also planned in a number of other countries, including Ethiopia, and once these are established they could have specific streams of activity focussed on stimulating small-scale CSP activity among the local innovator community.
- The IEA's Solar Heating and Cooling Programme Task 49 (described in Section 5) is a knowledge sharing platform with involvement from a number of developing countries (although the programme is managed in the EU and most activity seems to be take place within the EU). There are currently participants from Mexico and India. Because the programme has limited funding, participants need their own funding to take part in the project. Making funding available to relevant participants from countries such as Kenya or Chile (or other in-scope countries should they be the focus on an ICF intervention) would enable them to share in and benefit from the best practice and knowledge being developed around the world.

Rural / off-grid applications are at a far earlier stage of development, calling for a different type of intervention

- **The main barrier / challenge for rural applications is the lack of an optimised small-scale CSP technology solution**
- **As a result CSP has been excluded from previous energy access projects and there are only a few pilot projects worldwide**
- **This issue could be addressed by a competition and field trials to develop an optimised technology solution and prove it in real-world conditions**

Market development

The market for small-scale CSP in rural or off-grid applications is at a considerably earlier stage. We found only one example of a pilot project in the in-scope countries (the DST-Thermax CSP-biomass hybrid project in India) and one in another developing country (the TRESERT project in Thailand).

However, unlike the industrial process heat market for CSP technologies, where there are incumbent technologies or alternative fuels serving the energy needs of the market, there are hundreds of millions of people in the in-scope countries who do not have access to modern energy services, so potential demand for the energy output of small-scale CSP (and other technologies) is already a focus for governments, NGOs and development organisations.

As outlined in Section 4, a number of experts and technology suppliers believe small-scale CSP has a potential role to play in rural or off-grid settings.

Key barriers to address

The main challenge facing small-scale CSP in rural or off-grid applications is that the technology has not yet been optimised to work in these contexts. Unlike industrial applications, where there are numerous different providers of small-scale CSP technology and around 100 installations across the globe, the use of CSP in rural or off-grid situations remains unproven.

As a result, the ‘market’ (non-governmental organisations, Government, and development agencies) does not consider CSP as a suitable technology for rural applications, and it has been excluded from the scope of the many rural energy access projects (for example where PV, biogas, micro-hydro have all been piloted) that have been implemented in energy poor communities and regions, probably because the technology lacks track record and project designers and implementers favour the lower risk approach of focussing on ‘proven’ technologies.

Lack of an optimised technology solution is the critical barrier obstructing progress in these applications at the moment, but once addressed, other barriers will become critical.

Availability of funding to finance renewable energy projects is a major barrier for the energy poor communities that could benefit from small-scale CSP systems, and is likely to be a significant barrier when / if the technology can be optimised and proven.[113]

Possible interventions

As outlined above, the main issue facing the development of this market / application is the lack of an optimised technology solution. This is best addressed by working with innovators and technology developers to refine and prove the technology in the required contexts.

Due to the much earlier state of development of this market, a number of interventions that are appropriate in the industrial market are not suitable at this time. These include capacity building, provision of finance, capital grants or other forms of subsidy, and standards and certification. These interventions may all be appropriate as the rural market develops and other barriers (such as the lack of the necessary skills in the local community) become more important.

Delivery model

A phased intervention could be used to optimise small-scale CSP technologies for rural and off-grid contexts.

The first phase would be to understand the potential for CSP in this application. This would involve a desk-based study to benchmark CSP against other suitable technologies, looking at market state and growth, industry analysis, technology performance (and alignment with energy needs of target communities), and timeframe for cost reduction.

This phase would include detailed study of the existing pilot projects in India and Thailand.

If this first phase confirmed that CSP has potential in these applications, a competition or challenge could be run to encourage technology suppliers to develop concepts for appropriate CSP technology solutions. This would involve putting out a call inviting suppliers to submit solutions against a defined scope outlining the requirements (e.g. eligible technology types, system capacity and cost range).

A field trial would then be run installing the successful project concepts in various situations to assess their real world performance. The results of these trials could be benchmarked against the results from previous trials of alternative technologies (e.g. PV, biogas, micro-hydro).

Engagement of key stakeholders – government officials, NGOs, development partners, community representatives – would be important throughout the project to raise awareness and ensure buy-in and confidence in the project results.

Such a project would transform the evidence base for the potential of small-scale CSP in rural and off-grid applications. A successful project with encouraging results would lead to small-scale CSP being included in the scope of future rural energy projects, because it would no longer be seen as unproven or inappropriate for these contexts.

A technology neutral competition or challenge, with the same parameters (except the focus on CSP technologies) could also be appropriate, except there is a risk that the majority of applications would be from other technologies. Such a challenge might be less additional (we have not reviewed

[113] Interview: Practical Action

technology neutral or non-CSP projects aimed at addressing energy access issues).

Meeting ICF criteria

An intervention focussed on small-scale CSP in rural or off-grid applications would meet several ICF criteria:

- It would be extremely **additional**. While we have identified two pilots of small-scale CSP for rural contexts, we have not found any comprehensive programmes focussed on this application. A new programme
- It could have a **transformational** effect on the seemingly widely held perception that CSP is not suitable for small-scale off-grid applications. The creation of a robust evidence base demonstrating that small-scale rural CSP works in real world conditions, based on a field trial, accompanied by appropriate stakeholder engagement and awareness raising, could ensure that CSP is included in major rural energy access programmes. Until that happens, it seems unlikely that CSP will be seriously considered as a viable solution for these applications.
- Use of a challenge or competition to source concepts from technology suppliers could deliver good **value for money** and **leverage private sector investment** in the development of solutions to match the specifications of the challenge.

Supporting or expanding current activity

We are only aware of the two rural small-scale CSP projects described above (DST-Thermax in India and TRESERT in Thailand). We have not spoken to the implementers of either project and do not know if there is an opportunity to support or expand these projects.

We would expect both projects to offer significant lessons to any new initiatives focussed on this area and the technology suppliers involved – Thermax (India) and Solarlite (Germany) – may be interested in participating in a new competition based intervention.

As increasing energy access for energy poor communities is a global priority, there are many programmes aimed at increasing the deployment of appropriate technology solutions. As noted elsewhere in this report, these projects do not currently include CSP in their scope, probably because the project implementers favour 'tried-and-tested' technologies. It may be possible to use ICF funding to expand the scope of one of these projects to specifically include small-scale CSP. This would mean that the CSP results could be included in and compared to other results from the project, and the programme management resources of an existing programme could be leveraged rather than replicated.

7 Annex A – case studies

Sopogy – MicroCSP Power Generation at Holaniku, Hawaii[114]

Developer	Sopogy
Location	Holaniku, Hawaii
Date commissioned	December 2009
Application	Electricity generation
Technology	Parabolic trough
Installed capacity	2MW
Temperature range	93 – 176 °C
Estimated CO_2 reduction	31 ktCO_2 over life

"Located at the Natural Energy Laboratories of Hawaii, Holaniku at Keahole Point is the world's first Concentrating Solar Power project using MicroCSP technologies. Holaniku also incorporates thermal energy storage which solves the volatility challenges typical to renewable energy technologies, such as wind and photovoltaic systems." -Sopogy

Sopogy – MicroCSP Solar Cooling at Holcim cement plant, Mexico[115]

"Sopogy's MicroCSP technology will be used to drive a 75 ton single-effect chiller and provide a renewable source of cooling for the new Hermosillo cement plant, which was inaugurated on March 10, 2011.

As the first solar powered air-conditioning system in Latin America, installation of the MicroCSP parabolic troughs have been assembled and mounted on the roof and ground in front of the cement production facility." -Sopogy

Developer	Sopogy
Location	Hermosillo, Mexico
Date commissioned	March 2011
Application	Cooling
Technology	Parabolic trough
Industry	Cement
Installed capacity	291 kW
Temperature range	74 - 95 °C
Estimated CO_2 reduction	3.45 ktCO_2 over life

Sopogy – MicroCSP Solar Cooling at Masdar[116]

Developer	Sopogy
Location	Abu Dhabi, UAE
Date commissioned	July 2011
Application	Cooling
Technology	Parabolic trough
Installed capacity	130 kW
Temperature range	133 – 171 °C
Estimated CO_2 reduction	1.83 ktCO_2 over life

"Sopogy's proprietary solar thermal solution has been designed to demonstrate the cost-effectiveness and smaller collector footprint of high-temperature solar thermal cooling compared to a conventional electric chiller plant powered by solar-generated electricity. The successful outcome of the project will enable solar thermal air conditioning to be a major source of cooling for other buildings within Masdar City." -Sopogy

[114] http://sopogy.com/projects/index.php?id=39
[115] http://sopogy.com/projects/index.php?id=56
[116] http://sopogy.com/projects/index.php?id=40

Waltow Germany – heat for fish farming[117]

"At Woltow, Mecklenburg-Western Pomerania, Solarlite has developed and built a solar thermal energy pilot plant in combination with a biomass plant. The plant generates the heat required to provide a constant temperature of 26 °C in the fish breeding tanks. The African catfish needs this high water temperature for successful breeding." -Solarlite

Developer	Solarlite
Location	Woltow, Germany
Date commissioned	April 2007
Application	Process heat
Technology	Parabolic trough
Industry	Fish farm
Installed capacity	220kW
Temperature range	250 °C max

Clique Solar – Chitale Dairy, India[118]

Developer	Clique Solar
Location	Sangli, India
Date commissioned	October 2009[119]
Application	Process heat
Technology	Parabolic dish
Industry	Dairy
Installed capacity	320 kW (2 dishes)
Temperature range	152 °C
Estimated CO_2 reduction	110 – 130 tCO_2 per annum
Fuel oil displaced	40,000 – 60,000 litres per annum

"The two-dish ARUN system generates steam which is used for Pasteurization, Can Washing, Cleaning in Place and Crate washing. Both these ARUN dishes are installed on the terrace of its 3-storeyed building. The footprint area is less than 3m x 3m per dish. The ARUN dish tracks the sun on two axes. Water circulates through the receiver coil which is placed at the focus of dish transferring the thermal energy from the sun to the circulating water and converting it to pressurized steam at 152°C at 5 bar." -Clique Solar

Aora Israel – combination fuel solar tower[120]

"Located 34 km north of Eilat, Kibutz Samar is the site of AORA's first CSP prototype module, which has been in operation since 2009, injecting thousands of kW of utility-grade power into the Israeli national power grid every year. This prototype unit has been the testing ground and upgrading proof facility for this versatile 100kW micro plant design." -Aora

Developer	Aora
Location	Samar, Israel
Application	Heat and power
Technology	Tower + hybrid fuels
Installed capacity	100 kW_{th}

Thermax India – cooling demonstrator[121]

Developer	Thermax
Location	Solar Energy Centre Gurgaon, Haryana, India
Date commissioned	October 2009
Application	Cooling
Installed capacity	100 kW
Temperature range	140 – 210 °C

"In this innovative installation, for the first time in the world, Thermax has integrated a triple effect chiller and solar parabolic concentrators (collectors), both indigenously developed by the company. While conventional solar systems take up a large area for limited cooling output, the Thermax project through in-house R&D has achieved a significant space reduction of nearly 30% and a 20% increase in cooling efficiency. This has brought down cost and moved the project closer to commercialisation." -Thermax

117 http://www.solarlite.de/en/project_woltow.cfm
118 http://www.cliquesolar.com/DairyIndustry.aspx
119 http://mnre.gov.in/file-manager/UserFiles/solar_steam_system_for_process_heat.pdf
120 http://aora-solar.com/active-sites/
121 http://www.thermaxindia.com/Packaged-Boilers/Thermax-Solar-Cooling-Center.aspx

8 Annex B – programme details

UNDP India[122]

- **Project title:** "Market Development and Promotion of Solar Concentrator based Process Heat Applications in India (India CSH)"
- **Duration**
  - Start date: August 2011
  - End date: July 2016
- **Project cost:** USD 23.75m
- **Expected results**
  - 32.9 ktCO_2 saving over 5 year period;
  - 315 ktCO_2 saving over 20 year economic lifetime for supported projects, including replication
- **Project components**
  - **Technical capacity development**
    - Enhanced understanding of CSH (concentrated solar heating – project term for CSP used for heat) technologies, applications and markets;
    - Adoption of standards and specifications for guidance of manufacturers and users for assurance of CSH quality, safety and performance;
    - Testing laboratories for verification of manufacturer claims and guidance of CSH users to enable informed decisions.
  - **Awareness enhancement and capacity building**
    - Strengthened technical capacity and awareness of stakeholders of CSH systems for industrial / institutional process heat applications;
    - CSH project activities facilitate and / or influence the widespread replication of CSH technology applications in India.
  - **Pilot demonstration of CSH technologies for various applications**
    - Increased number of commercial and near-commercial CSH technologies for a diversity of applications;
    - Improved technical and economic performance of commercial and near-commercial CSH technologies in an increased diversity of applications.
  - **Sustainable financial approach in the adoption of CSH technologies and applications in India**
    - Enhanced understanding of the financial viability of CSH technologies and measures to mitigate investment risks;

[122] http://www.undp.org/content/dam/india/docs/market_development_and_promotion_of_solar_concentrators_based_project_document.pdf

        - Promulgation of favourable financial policies that promote increased use and promotion of CSH for low and medium temperature process heat applications.

- **Key outputs**
    - 30 demonstration projects and 60 replication projects totalling to 45,000 m^2 of solar collector area directly supported by the project, installed and monitored during the 5-year project duration.
    - 10 CSH technology application information packages developed, utilised and available for further CSH market development support at the end of the project implementation period.
    - Commercial availability of all 5 CSH solar concentrator technologies in the Indian market by end of project. It is expected that about thirty technology package suppliers will be available to market CSH technologies in India by end of project.
    - Annual sales of CSH to increase from around 2,000 m^2 /year in 2010 to 15,000 m^2 /year in 2016.
    - Demonstration projects (30):
        - Will focus on industries with high potential for replication: dairy, hotels, hospitals, textile, pharmaceutical, chemical, metal treatment, food processing, institutional cooking;
        - USD2,000 is available from the project for a feasibility study, and USD8,000 available for Detailed Project Report preparation;
        - Technical training of 2 people per site is included;
        - Include technical support through project execution;
        - An additional 10% of project cost (up to USD 20,000) to cover cost of monitoring equipment and other obligations – this is in addition to MNRE subsidy of 30%.
    - Replication projects (60):
        - USD 2,000 to fund project feasibility study;
        - Technical training of 2 people per site;
        - Up to USD 6,000 for monitoring equipment.
- **Estimated replication:** a factor of 3 – described as ‘conservative’.

UNIDO India[123]

- **Project title**: "Promoting business models for increasing penetration and scaling up of solar energy"
- **Duration**: 60 months (dates not yet confirmed as project is still at concept stage)
- **Project cost**: USD 21.8m
- **Expected results**: Direct global environmental benefits 84-98 ktCO_2 over 20 year life of technologies.
- **Project components:**
  - **Strengthening of policy and institutional framework**
    - Detailed set of recommendations and guidelines for policy makers to catalyse deployment of solar technology in industrial thermal and cooling applications.
  - **Technology investment and application**
    - Detailed technical specifications pertaining to technologies identified for deployment;
    - Developed technology application information packages and characterised technologies, applications;
    - Pilot demonstration of solar technologies for various industrial applications – indicatively 15 – 25 in number, across most promising industries.
  - **Scaling up of solar technologies in industrial applications**
    - Identified technologies most suitable for replication across target industries;
    - Developed business models and financing facility, including non-grant instrument(s), for effective scaling up of different technologies;
    - Supply of quality system components for solar energy technologies secured through developing standards, quality control, performance guidelines and a certification framework.
  - **Awareness raising and capacity building**
    - Trained manufacturers, vendors and installers;
    - Targeted workshops to raise awareness among the business community;
    - Institution of information sharing platform;
    - Documentation of project outputs, case studies, best practices and lessons learnt disseminated to ensure larger replication;
    - Technical capacity building including through industry and academia.
- **Estimated replication**: 3 – 5 (described as conservative), resulting in emissions savings of 252 – 490 ktCO_2.

[123] http://www.thegef.org/gef/sites/thegef.org/files/gef_prj_docs/GEFProjectDocuments/Climate%20Change/India%20-%20(4788)%20-%20Promoting%20Business%20Models%20for%20Increasing%20Penetrati/PIF%20India%20Solar%20v6.0_for%20re-submission%20to%20GEF%205Jan12%20FINAL.pdf

UNIDO Malaysia[124]

- **Project title:** "GHG Emissions Reductions in Targeted Industrial Sub-Sectors Through EE and Application Of Solar Thermal Systems"
- **Duration**: 60 months (dates not yet confirmed as project is still at concept stage)
- **Project cost**: USD 20m
- **Project components:**
  - **Development of regulatory framework, support programme and financial incentive mechanism to facilitate solar thermal energy utilization**
    - Institutional capacity strengthened, including international experiences shared with government stakeholders;
    - Monitoring, evaluation and impact assessment of previous and existing policies, programmes and also of this new project;
    - Support programmes and mechanisms (e.g., financial incentives, non-grant instruments, technical assistance, certification and financing schemes) developed and approved.
  - **Awareness raising and capacity building program relating to process optimization and solar thermal energy utilization in targeted industrial sub-sectors**
    - Strengthened skills and competency of service providers, consultants and industry in the implementation of energy saving based on process optimization and process heating and cooling, in selected sub-sectors;
    - Improved skills and competency of service providers, consultants and industry in solar thermal technology;
    - Enhanced awareness among industry management and financial institutions to take decisions on investments in energy saving and solar thermal applications.
  - **Demonstration and scaling up of sector-specific energy efficiency and solar thermal energy utilisation in targeted industrial subsectors**
    - Energy saving measures and investment projects implemented in 40 factories;
    - Out of these 40 factories, at least 10 will implement solar thermal demo projects;
    - Case studies prepared and presented to raise more investment in energy efficiency and solar thermal integration using the new capacity and financing mechanisms.

[124] http://www.thegef.org/gef/sites/thegef.org/files/gef_prj_docs/GEFProjectDocuments/Climate%20Change/Malaysia%20-%20(4878)%20-%20GHG%20Emissions%20Reductions%20In%20Targeted%20Industrial%20Su/4-11-12%20%20ID4878%20%20PIF%20GEF5%20on%20EE%20and%20Solar%20Energy%20Revised%20after%20GEFSec%20Comments%2010%20Apr2012x.pdf

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