Energy Generation and Distribution

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An Approach for Cost-Effectiveness Analysis and
Environmental Impact Analysis

Energy Generation and Distribution

The New South Wales Premier, Morris Iemma, outlined in a speech on Wednesday, 1st August 2007, the case for the New South Wales Government to move to natural gas to fuel the State's next base load power station which will operate 24 hours a day. Having substantial coal reserves New South Wales has previously relied upon coal as fuel for its base load power stations.

Following a move to natural gas to fuel base load power stations, three additional pieces of energy infrastructure become potentially useful:

- A synthetic natural gas plant
- A solar thermal concentrator array
- A natural gas to hydrogen conversion plant

Preliminary feasibility studies should aim to identify the circumstances in which these energy infrastructure components become financially attractive. The prices of natural gas, coal, and carbon dioxide emissions make up one set of variables to consider. The other variables – the costs of synthetic natural gas plants, solar thermal concentrator arrays, natural gas to hydrogen conversion plants, and carbon dioxide geosequestration – will provide for suppliers of these technologies clear targets for cost of manufacture and operation that must be achieved.

A synthetic natural gas plant converts coal into natural gas and removes 50% of the carbon for geosequestration in the form of carbon dioxide. This allows coal to be used in any application where natural gas is currently used - increasing the market-size and value of coal, reducing carbon dioxide emissions and boosting the supply of natural gas.

The move to gas and away from coal is likely to reduce confidence and optimism amongst investors, workers and communities dependent on the coal industry. This can influence people's current purchasing and investment decisions, with adverse economic consequences. Announcing a preliminary feasibility study into synthetic natural gas plants will help lift the confidence levels of people whose livelihoods are linked to the coal industry.

A solar thermal concentrator array, constructed alongside a base load power station and natural gas to hydrogen conversion plant allows solar thermal energy to be substituted for some of the natural gas that these would otherwise require, reducing carbon dioxide emissions and lowering the demand for natural gas.

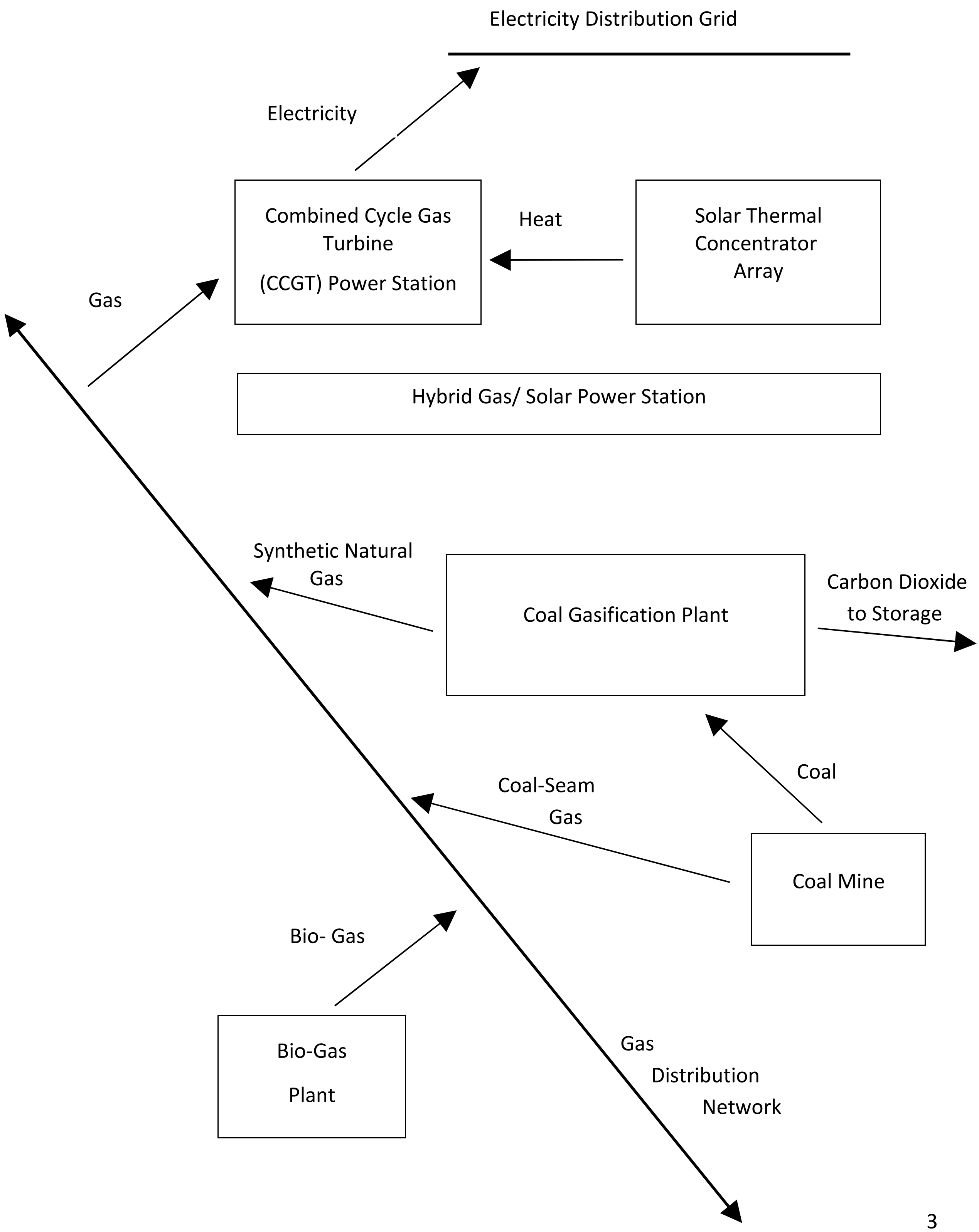
Site selection for a base load power station should consider integration with a solar thermal concentrator array at some stage in the future: availability of an adequate land area (avoiding productive agricultural land) and annual hours of sunlight should be taken into account.

A natural gas to hydrogen conversion plant converts natural gas into hydrogen and removes 100% of the carbon for geosequestration in the form of carbon dioxide. The hydrogen gas could then be used as fuel in a base load power station, producing only water vapour when it is burned – and no carbon dioxide emissions. Each cubic metre of natural gas is converted into 4 cubic metres of hydrogen gas (at the same temperature and pressure) with about the same energy value. This means a 4 times greater volume of gas needs to be supplied to a hydrogen fuelled power station to generate the same output as a natural gas fuelled power station. Also, many metals readily absorb hydrogen gas and become embrittled as a result.

Site selection and choice of materials for construction of a base load power station should consider the possibility of converting it from natural gas to hydrogen operation. It may be that the conversion would require the gas turbine to be replaced, with this cost being offset against the saving of reducing carbon dioxide emissions to zero. However, initial construction with fuel-supply lines and equipment suitable for either natural gas or hydrogen may add little to the original cost, and avoid down-time (and lost production) and expense for replacement of components during any future fuel conversion upgrade.

Investment decisions always involve some degree of uncertainty. An improved method of manufacturing hydrogen fuel cells for example may substantially lower their cost and at the same time render obsolete all thermal power stations – including gas, coal, nuclear and solar thermal power stations. However, as a direct consequence, investors with interests in synthetic natural gas plants, and natural gas to hydrogen conversion plants operated with solar thermal concentrator arrays, would see the value of these assets increase significantly – as hydrogen fuel cells became more widely used.

Energy Generation and Distribution Guidelines (1)



Coal Gasification Options

Option	Converting Coal/ Carbon to:	Percentage of Carbon Removed	Heat Energy Needed	Net Chemical Reaction
1	Water _ Gas	0%	175kj/mol	$C_{(S)} + H_2 0_{(l)} \rightarrow CO_{(g)} + H_{2(g)}$
2	Synthetic Natural Gas	50%	52kj/mol	$C_{(S)} + H_2 0_{(l)} \rightarrow \frac{1}{2}CO_{2\,(g)} + \frac{1}{2}CH_{4(g)}$
3	Hydrogen	100%	178kj/mol	$C_{(S)} + 2H_2 0_{(l)} \rightarrow CO_{2\,(g)} + 2H_{2(g)}$

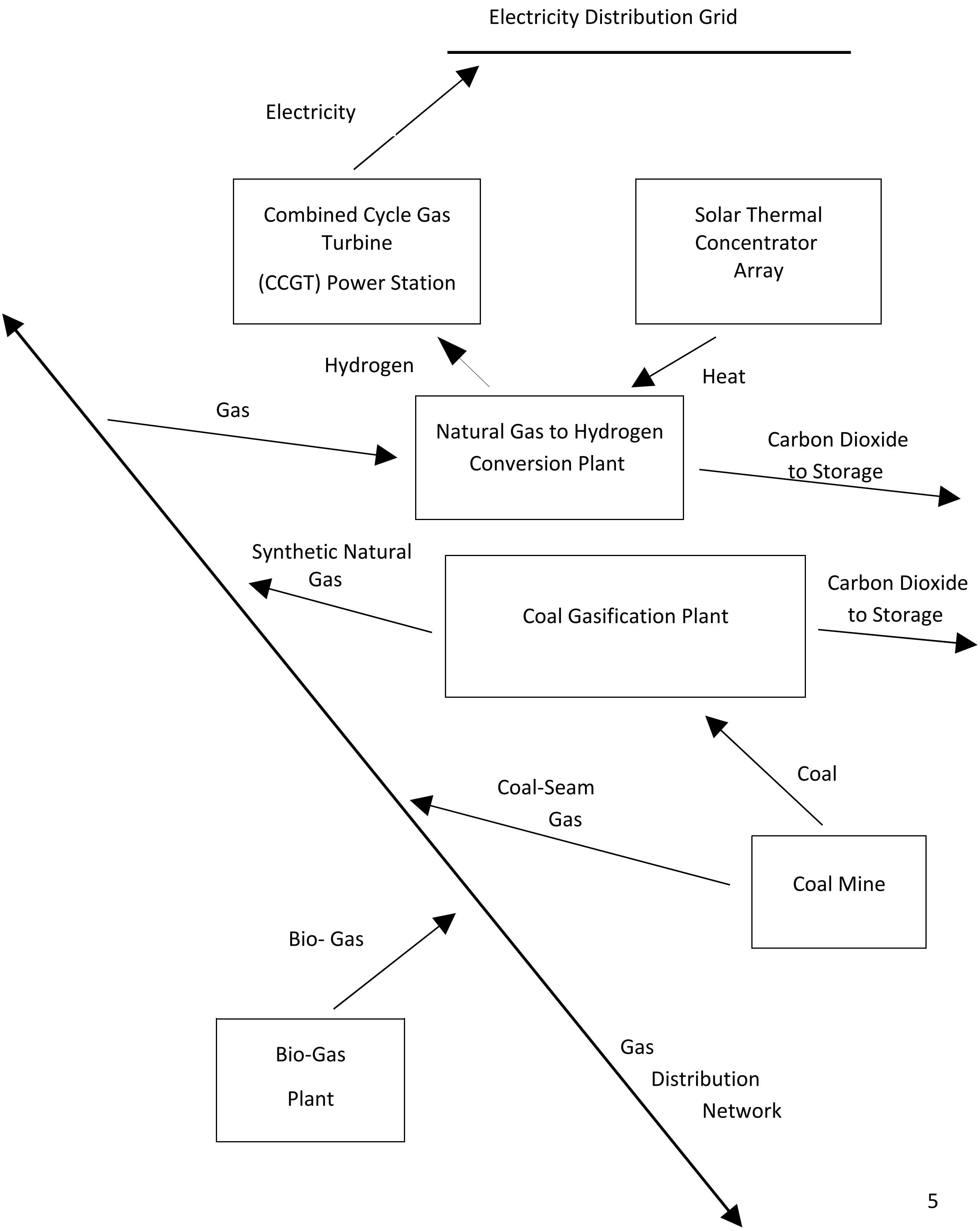
Option 2 – converting coal to Synthetic Natural Gas – removes 50% of carbon (in the form of carbon dioxide), produces gas that can be distributed in existing natural gas distribution networks, and requires relatively little energy, compared to options 1 and 3.

Note:

Option 2 often involves conversion to gas in two reaction stages. The first stage requires substantial heat energy. The second stage produces almost the same amount of heat energy. Only gasifiers designed to use the heat energy from the second stage as input into the first stage can deliver good energy efficiency. For example, some gasifiers that employ catalysts are capable of converting coal and water into methane and carbon dioxide within a single reaction vessel, and in doing so avoid the need to add substantial heat energy from some external source.

In each option, it is necessary to further consider the thermal energy available in the gas fuel produced. The amount of heat energy required to bring about the gasification reactions is only part of the evaluation of energy efficiency.

Energy Generation and Distribution Guidelines (2)



Synthetic Natural Gas Plant

An Approach for Cost Effectiveness Analysis and Environmental Impact Analysis

Ways to sell 1,000 tonnes of coal:

1. Burn it in a coal-fired power station, at 40% thermal efficiency, to produce electricity and 1,000 tonnes of carbon in the form of carbon dioxide mixed with combustion gases. Assume all the electricity produced is used in electric hot water systems.

2. Save 200 tonnes for later use. Of the remaining 800 tonnes, convert;

   - 400 tonnes into methane (that is, natural gas)
   - 400 tonnes into carbon dioxide, for geosequestration

   Then either:

   2.1 Burn this synthetic Natural Gas in a Combined-Cycle Gas Turbine (CCGT) power station, at 50% thermal efficiency, to produce electricity and 400 tonnes of carbon in the form of carbon dioxide mixed with combustion gases. Assume all the electricity produced is used in electric hot water systems.

Or:

2.2 Save 200 tonnes of carbon, in the form of methane, for later use, and sell 200 tonnes of carbon in methane (Synthetic Natural Gas) for customers to use in gas hot water systems – producing 200 tonnes of carbon in the form of carbon dioxide mixed with combustion gases.

Note:

1. The quantity and economic value of the useful end product (hot water) is identical in each of the 3 cases described at 1, 2.1 and 2.2

2. The quantity of carbon turned into carbon dioxide mixed with combustion gases is 1,000 tonnes, 400 tonnes or 200 tonnes – depending on the way the 1,000 tonnes of coal is used.

3. This means the potential earnings from coal can be 2 ½ times greater – using it as a raw material in a Synthetic Natural Gas Plant – instead of burning it as fuel in a coal-fired power station to produce electricity. With this option, CO2 emissions are cut by 80% - each 1,000 tonnes of CO2 from a coal-fired power station is reduced to just 200 tonnes from gas hot water heaters with no reduction in the end-product (the hot water produced), even though only 50% of the carbon has been separated for geosequestration.

Solar Thermal Concentrator Array

An Approach for Cost Effectiveness Analysis and Environmental Impact Analysis

Australian National University developers recently announced a commercial scale trial of a base-load solar thermal power station. It uses focusing parabolic mirrors and thermo-chemical storage to allow electricity to be generated overnight and on cloudy days from stored solar thermal energy.

Solar Thermal Concentrators, with or without solar energy storage, can be used in conjunction with a Combined-Cycle Gas Turbine (CCGT) power station. The benefits are:

1. Economic

   Increasing the area of Solar Thermal Concentrators will reduce the quantity, and hence cost of gas used per megaWatt-hour of electricity generated.

2. Environmental

   Carbon dioxide emissions at 400 kilograms per megaWatt-hour for periods of 100% gas-fuelled operation are eliminated for periods of 100% solar thermal energy operation.

Economic and environmental performance can be adjusted over the life of the Combined-Cycle Gas Turbine power station, in response to trends in the cost of-

1. Natural Gas
2. Carbon dioxide emissions
3. Solar Thermal Concentrators
4. Solar Thermal energy storage

Natural Gas to Hydrogen Conversion Plant

An Approach for Cost Effectiveness Analysis and Environmental Impact Analysis

Rio Tinto and BP announced a “cleaner energy” joint venture, Hydrogen Energy, in May this year (2007). A Combined Cycle Gas Turbine (CCGT) power station fuelled by hydrogen produces no carbon dioxide emissions.

Natural Gas to Hydrogen Conversion Plants require thermal energy to convert natural gas into hydrogen and carbon, in the form of carbon dioxide, for geosequestration. Solar Thermal Concentrators could be used to supply this energy requirement without any need for solar energy storage. For operation overnight, and on cloudy days, a relatively small quantity of natural gas burned to provide thermal energy is likely to be an acceptable solution.

To illustrate the scale of savings in the Solar Thermal Concentrators and carbon dioxide emissions (at the same time giving the option to “tune” the overall configuration - with offsetting increases in carbon dioxide geosequestration, and natural gas consumption) -

1. A 1000 MW power station at 100% output and 50% thermal efficiency would use 144 tonnes of natural gas per hour. This fuel contains 108 tonnes of carbon that is converted into 396 tonnes of carbon dioxide mixed with combustion gases (that is, about 400kg of carbon dioxide per MWh of electricity generated.)

2. Solar Thermal Concentrators intended to substitute all of the thermal energy supplied by 144 tonnes of natural gas - just for periods when solar energy is available – would be required to deliver 100% of the solar energy falling on an area of approximately 200 hectares (calculated on the basis of solar energy averaging 1000 watts per square metre for 6 hours a day).

   Note that this area of solar energy collection would allow a 100% substitution of 144 tonnes of natural gas an hour, but only for the expected 6 hours of solar energy available each day. To store solar energy for 24 hours operation would require 4 times more solar energy to be collected – the quantity expected to fall on 800 hectares on a clear, sunny day.

3. The 1000MW power station using hydrogen produced from natural gas as fuel would produce no carbon dioxide emissions. Also, a higher thermal energy content results in a reduced demand for natural gas. The hydrogen produced from 119 tonnes of natural gas will provide the same thermal energy available from 144 tonnes of natural gas.

4. Solar Thermal Concentrators intended to supply all of the thermal energy needed to convert 119 tonnes of natural gas an hour into hydrogen and carbon dioxide – just for periods when solar energy is available – would be required to deliver 100% of the solar energy falling on an area of approximately 52 hectares (calculated on the basis of solar energy averaging 1000 watts per square metre for 6 hours a day)

   Note:

   a. This is only about ¼ of the area if solar energy is to supply all of the thermal energy used in the power station during clear, sunny periods. This reduction is not "free". The balance of the thermal energy needed in the power station is provided by the hydrogen obtained from 119 tonnes of natural gas consumed each hour.

   b. Conversion of 119 tonnes of natural gas an hour into hydrogen, and carbon dioxide for geosequestration, can be carried out overnight and on cloudy days by burning 38 tonnes of natural gas an hour. This will create carbon dioxide emissions of 105 tonnes per hour during these periods of operation.

Comparing the power station operating with either natural gas, or hydrogen (and no Solar Thermal Concentrators) the most cost-effective configuration would depend on the cost of natural gas compared with the cost of carbon dioxide emissions and carbon dioxide geosequestration:

1. The natural gas power station generating 1000MW an hour-

   a. Consumes 144 tonnes of natural gas per hour

   b. Produces 396 tonnes of carbon dioxide emissions mixed with combustion gases an hour.

2. The hydrogen power station generating 1000MW an hour, in combination with a natural gas fuelled plant to convert natural gas to hydrogen

    a. Consumes a total of 157 tonnes of natural gas an hour (119 tonnes to hydrogen, 38 tonnes for thermal energy to drive the conversion process).

       (144 + 13 tonnes; increase)

    b. Produces 105 tonnes of carbon dioxide emissions mixed with combustion gases an hour.

       (396 - 291 tonnes; decrease)

    c. Produces 328 tonnes of carbon dioxide for geosequestration an hour.

       (0 + 328 tonnes; increase)

The addition of Solar Thermal Concentrators to collect the solar energy available on an area of 52 hectares for a period of 6 hours on clear, sunny days would save:

a. 38 tonnes of natural gas an hour, for 6 hours a day. This would otherwise be needed for thermal energy to drive the conversion of natural gas to hydrogen.
b. 105 tonnes of carbon dioxide emissions an hour, for 6 hours a day.