Subject:

Paulownia Plants Make GREAT Solar Collectors!

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The photosynthesis that takes place in the leaves of fast growing plants like Paulownia and Jatropha convert the suns radiant energy into biomass, which can then be converted into electricity. In this fashion they act just like 'natural' solar panels. Today's silicon solar panels are about 20-22% efficient at converting sunlight to electricity. It appears that Paulownia plants rival this efficiency, but also produce STORABLE fuel in the process – a much more valuable resource.

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How does nature compare against man's technology? This paper looks at using plants as natural solar collectors. The photosynthesis taking place in the leaves of fast growing plants like Paulownia and Jatropha convert the suns radiant energy into biomass. This biomass can then be converted into bio-oils, syngas and bio-char, all of which can then be converted into electricity through various generation processes. In this fashion they act just like 'natural' solar panels. How does this process compare with today's traditional silicon solar panels, which are about 20-22% efficient at converting sunlight to electricity? Quite favorably, it appears, with the added bonus that much of the natural process comes in the form of storable fuel - a much more valuable resource.

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The Study Process and Goals:

In this study we compare the potential energy collection and production from a tree known as 'Paulownia' (*Paulownia elongata* or *Paulownia fortune*) to that of traditional silicon solar panels, to see which process might be more efficient. Could an acre of Paulownia produce more electrical energy than an acre of solar collectors?

We begin by recognizing that the traditional solar panels produce DC electricity directly from their silicon junctions, while the Paulownia plant must be processed into constituent components in order to power an engine and run an electrical generator. The trees produce a bio-oil, a syngas, and bio-char, which are all the result of putting the plants through a pyrolysis process.

While there are any number of ways to convert those constituent components to electricity, we will look at using simple combustion engines and generators as the conversion process. Fuel cells and other techniques might be more or less efficient.

Energy Output from Solar Panels:

We start by examining traditional solar collectors. Over the past decade solar panel efficiencies have improved greatly. While a typical panel 6 or 7 years ago would produce about 250 watts of electric power, today's panels are often rated at 450 watts or more.

In a sunny region, **1 acre of solar panels** typically represents about 250kW of power and generates around **350,000 to 400,000 kWh per year** when arranged in rows that minimize external and self-shading. Depending on the solar insolation, this results in a Capacity Factor of between 15 and 20%.

According to many manufacturers and testing labs, solar panels used in these applications are about **21% efficient** at converting sunlight to electricity.

Energy Output from Paulownia Trees:

About the Pyrolysis Process:

Both **bio-oil** and **syngas** can be produced concurrently through the **pyrolysis process**. Pyrolysis is a thermal decomposition method that breaks down organic materials (such as Paulownia biomass) into multiple products, including:

- **Bio-oil** (a liquid),
- **Syngas** (a gaseous mixture),
- **Biochar** (a solid).

These products are produced simultaneously but in different proportions depending on the operating conditions, such as temperature, heating rate, and residence time. Typically, pyrolysis produces:

- **Bio-oil**: 50-75% of the total product yield.
- **Syngas**: 10-30%.
- **Biochar**: 10-20%.

The process works by heating the biomass in the absence of oxygen, which causes the volatile components to vaporize. These vapors are then condensed to produce bio-oil, while any gases that do not condense form syngas. The remaining solid material is biochar.

Applying the Pyrolysis Process to Paulownia:

An acre of Paulownia trees can yield about **50 to 150 tons (50,000 – 150,000 kg)** of dry biomass per year, depending on the growing conditions.

The biomass yield of Paulownia trees can vary significantly depending on factors such as climate, soil conditions, irrigation, and tree management practices. While 50 tons per acre per year is a conservative estimate based on average conditions, yields can reach much higher levels under optimal circumstances, including intensive cultivation practices.

Factors Affecting Biomass Yield:

1. **Climate and Growing Conditions:** Paulownia trees grow best in warm, temperate climates with adequate rainfall or irrigation.
2. **Soil Quality:** Fertile, well-drained soils lead to higher biomass yields, though Paulownia can also grow in degraded soils.

3. **Water Availability:** Irrigation or access to sufficient water can significantly boost growth rates, especially in arid or semi-arid regions.
4. **Tree Management:** Practices such as proper spacing, fertilization, and pruning can maximize biomass production.

High-End Yield Estimates:

Under **optimal conditions** with intensive cultivation, Paulownia plantations have been reported to produce up to **100 to 150 tons of biomass per acre per year**. This higher yield is more typical in regions with optimal water supply, temperature, and cultivation techniques (like in parts of China or highly managed agroforestry systems)

For the purpose of this study, a median value of 100 tons/acre will be used.

Processing:

Through the pyrolysis process, this biomass can then be converted into:

- **Bio-oil** (50% of biomass):
  - Bio-oil energy density: **18 MJ/kg**
  - Yield: **50%** of dry biomass → **50,000 kg** of bio-oil
  - Energy content: 50,000 kg × 18 MJ/kg=900,000 MJ
  - Converting to kilowatt-hours: 900,000 MJ × 0.2778 kWh/MJ = 250,020 kWh
- **Syngas** (30% of biomass):
  - Syngas energy density: **10 MJ/kg**
  - Yield: **30%** of dry biomass → **30,000 kg** of syngas
  - Energy content: 30,000 kg×10 MJ/kg=300,000 MJ
  - Converting to kilowatt-hours: 300,000 MJ × 0.2778 kWh/MJ = 83,340 kWh
- **Biochar** (20% of biomass):
  - Biochar energy density: **25 MJ/kg**
  - Yield: **20%** of dry biomass → **20,000 kg** of biochar
  - Energy content: 20,000 kg × 25 MJ/kg=500,000 MJ
  - Converting to kilowatt-hours: 500,000 MJ × 0.2778 kWh/MJ = 138,900 kWh

Total Energy from Paulownia per Acre:

- **Bio-oil**: 250,020 kWh
- **Syngas**: 83,340 kWh
- **Biochar**: 138,900 kWh

Gross Total energy per acre per year from Paulownia:

250,020 kWh + 83,340 kWh + 138,900 kWh = 472,260 kWh

Let us assume that the Syngas from the process is used to run the process itself (a 9.5kW/acre parasitic load***).*** *This results in a* ***Net Total energy per acre per year of:*** *472,260 kWh – 83,340kWh =* ***388,920 kWh/acre/year.***

Summary:

- **Paulownia trees (conservative growth)**: ~388,920 kWh per acre per year (from bio-oil and biochar, net of the syngas).
- **Solar panels**: ~350,000 to 400,000 kWh per acre per year (at 21% efficiency).

The two processes produce almost identical end results in terms of electrical energy production. Therefore the Paulownia Trees can be considered as converting sunlight to electricity at approximately *the same* equivalent 'efficiency' as the solar panels - 21%!

Conclusions:

1. Given a median growth environment, the Paulownia trees are just as effective at turning sunlight into electricity as today's solar panels.
2. The Paulownia trees are providing this energy through multiple STORED forms (bio-oil, syngas, biochar). These can be considered as FUELS. In this form the energy from the trees is MUCH more valuable than electricity supplied to the grid from solar panels, which must be used when it is available or else stored in more expensive batteries. This also opens up other markets such as transportation fuels.
3. While the Paulownia trees were collecting the sunlight and turning it into biomass, the photosynthesis process was also capturing and using Cardon Dioxide (CO2) from the atmosphere. This greenhouse gas is then 'sequestered' in the woody plant and forms the bulk of the leftover bio-char during the pyrolysis process. This char is then further sequestered by its use in soil remediation or as use in other products, such as graphene. This opens up the possibility of multiple forms of Carbon Credits and forms an active CO2 removal system from the atmosphere – at no additional cost!

Paulownia trees as an alternative energy source? Natural, Carbon Negative, and Efficient.

About the Author

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