Solar Beyond Grid Parity Workshop

DESIGN GROUP BREAKOUT I

Thursday, April 12

Breakout Setup

- **Each breakout group contained a mixture of workshop participant expertise spread across the technology areas from the first breakout groups (i.e. Optics, Photovoltaics, System Engineering, Dispatchability/Portability)**

- **All breakout groups were set up to respond to a common hypothetical set of questions in the future from the New York Times about a revolutionary system design created by the team that converts and stores full spectrum solar energy. (see slides 2-6)**

- **Each breakout group was directed to use a slightly different approach in designing their hypothetical system:**
    - **Group 1 - store dispatchable electricity in a chemical form (slides 7-8)**
    - **Group 2 - store dispatchable electrcity using thermal/mechanical means (slides 9-11)**
    - **Group 3 - store dispatchable electricity using any approach (slides 12-15)**
    - **Group 4 - produce an energy dense transportation fuel (slides 16-17)**

Schedule for Breakout Session

- *10 mins – ARPA-E facilitator explains the exercise, participants study the materials, participants select a breakout Leader for the exercise. (ARPA-E facilitator retains responsibility for timekeeping, ensuring that the spirit of these guidelines is followed and making sure all elements are completed.)*
- *5 mins – Group brainstorming of key concepts that should be kept in mind (e.g. exergy efficiency, spectrum splitting). No critique or discussion of ideas at this point, just brainstorming of words that are written down so all can see. Group is collecting likely requirements to create the system (not solutions).*
- *10 mins – Each participant thinks and writes down several elements of the system solution they think could contribute. (include new technology advances here)*
- *10 mins – Groups of 3 participants discuss and agree on several things they think would be part of a good system to meet the requirements*
- *15 mins – The groups of 3 report back to the full group*
- *20 mins – Leader drives the group to decide final design elements that will be integrated into the system.*
- *30 mins – Finalize design by answering the NYTimes questions.*

Congratulations!

SETUP FOR GROUPS 1-3

Each member of your Technical Team has been invited to a ceremony at the White House. Your Team won a 2023 Presidential Medal of Honor for a breakthrough solar energy system you began to work on with 2013 ARPA-E funding. This system is so successful that nearly all the new solar systems installed in the world incorporate some of your innovations and most are entirely based upon the design you first fielded a few years ago. Development money is flowing freely and there are large technical teams all over the world working to improve the efficiency of the system and make the energy it produces even cheaper. In short, the future looks bright for widespread implementation.

These inexpensive new solar energy systems are able to collect solar energy when the sun shines and produce low-cost energy that can be used when clouds come over or even at night. The average cost of generating electricity with your system is falling below that of either PV or CSP electricity and is already at an **average price of 6 ¢/kWh**. It is thought that within a decade or two, as these important innovations spread, solar energy can provide a far higher proportion of our energy than previously thought possible. The carbon-induced climate change problem that has been on everyone's mind seems more manageable because of your new technology.

They said it couldn't be done, but you did it!

Congratulations!

SETUP FOR GROUP 4

Each member of your Technical Team has been invited to a ceremony at the White House. Your Team won a 2023 Presidential Medal of Honor for a breakthrough solar energy system **for making transportation fuel** that you began to work on with 2013 ARPA-E funding. This system is so successful that most of the new solar systems installed in the world incorporate some of the innovations you first fielded a few years ago. Development money is flowing freely and there are large technical teams all over the world working to improve the efficiency of the system and make the fuel it produces even cheaper. In short, the future looks bright for widespread implementation.

These inexpensive new solar energy systems are able to collect solar energy when the sun shines and store low-cost energy that can be used when clouds come over or even at night. It is thought that within a decade or two, as these important innovations spread, solar energy can provide a far higher proportion of our energy than previously thought possible. The carbon-induced climate change problem that has been on everyone's mind seems more manageable because of your new technology.

They said it couldn't be done, but you did it!

How did you do it?! The New York Times

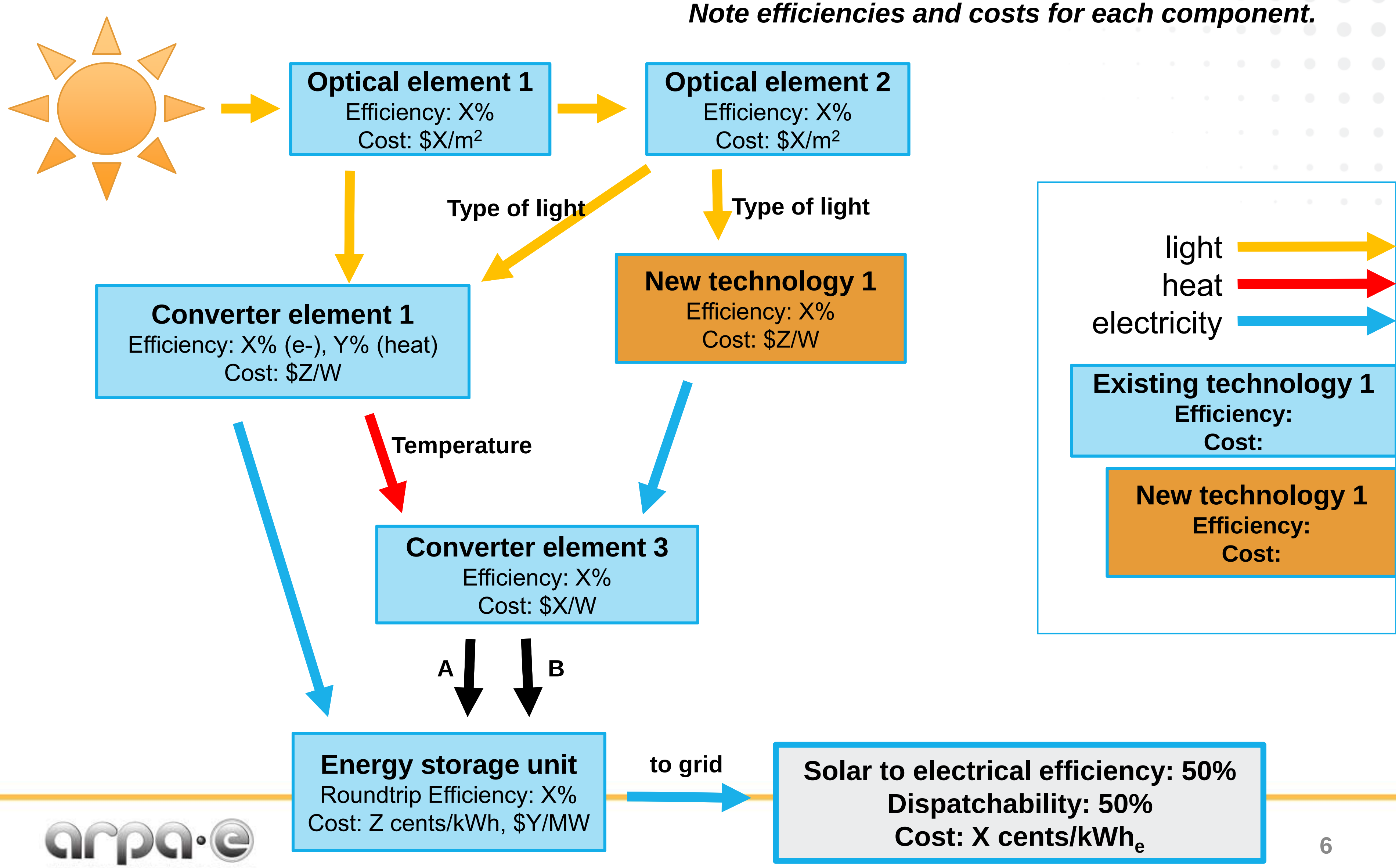
To prepare for a major article on your breakthrough in a special New York Times Technology Section, the Times Science Editor has just sent your Team some questions. After tomorrow's White House ceremony, members of your team will be interviewed for the article. It is important that you reach consensus on answers today, so you can speak with a common voice in the NY Times interview and in the many other interviews coming in the days to come.

The NY Times questions:

- What were the overall system design features that made your team successful?
  - New York Times readers don't want fine technical details, but they do want to understand the major energy flows and component efficiencies that make your solar system work. Please provide block diagrams of the entire system and of any critical components. We would also like to know the minimum or maximum size scale at which your system can be implemented while maintaining low cost and high solar conversion efficiency.
- What was the most crucial technology breakthrough that made your system a success? What other new technologies did you need to develop to make the system work?
- What mixture of expertise was critical to making your Team a success?
- How did you keep the costs of the produced energy so low?
- What setbacks, financial, technical or regulatory, did your Team face and how did you overcome them?
- What were the best ideas you tried that didn't make it into the final system design?

Block diagram template

Note efficiencies and costs for each component.



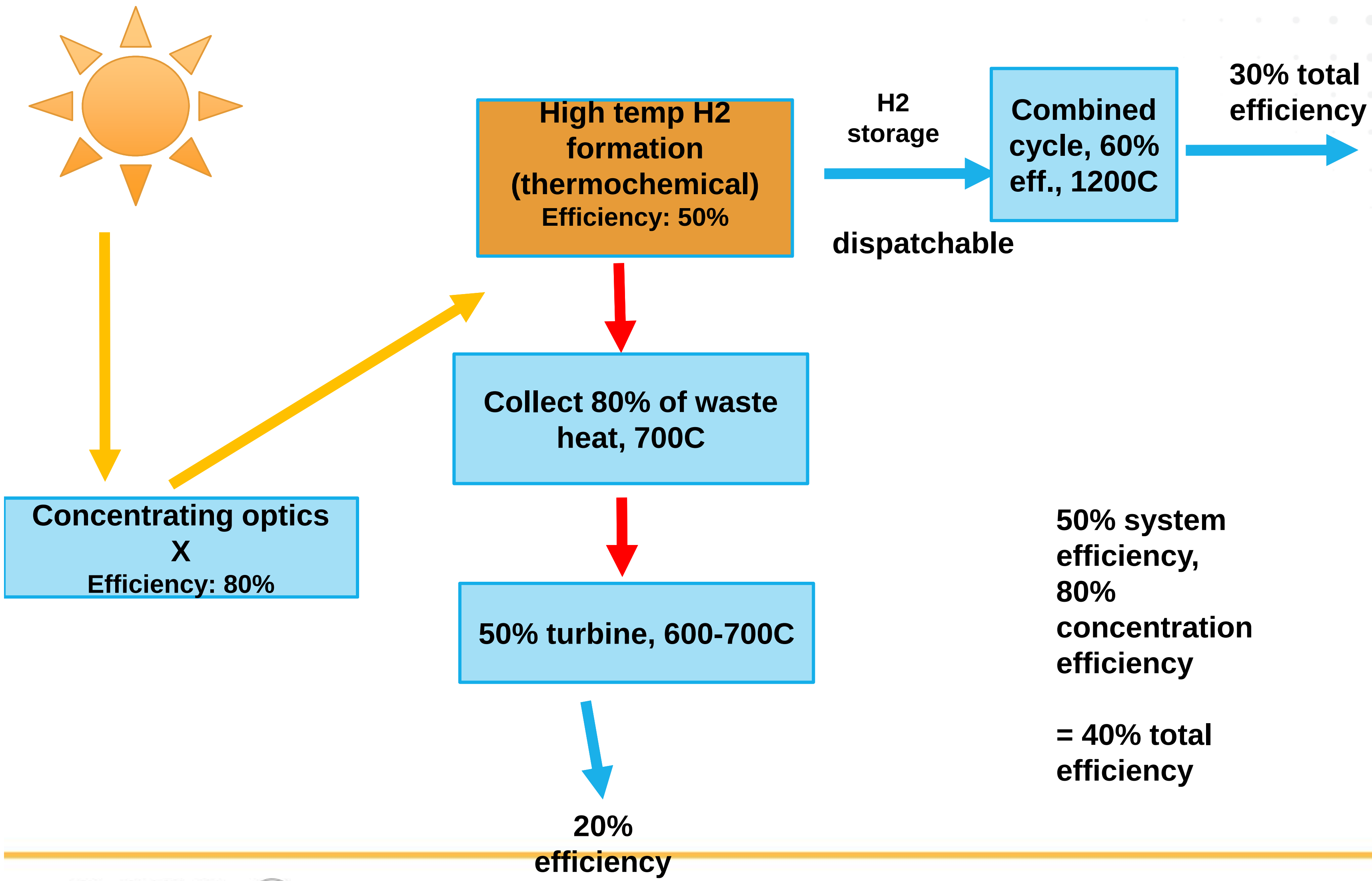
Setup for Design Group 1

The Presidential citation reads:

"For conceiving, designing, and prototyping an innovative solar system that produces electricity entirely from sunlight striking its optical aperture, at an **average conversion efficiency above 40%.** More than **half of the electricity fed onto the grid is dispatchable** whenever needed, by **releasing chemical energy** produced from solar energy. The average electricity cost from the prototype is already below the cost of either PV or CSP electricity today."

"This new solar system is highly competitive with more-polluting electricity generating systems using fossil fuels. The futuristic advances embodied in this solar energy system stand as prime examples of the continuing leadership by the United States in the world's scientific, technological and industrial communities."

Block diagram developed by Group 1



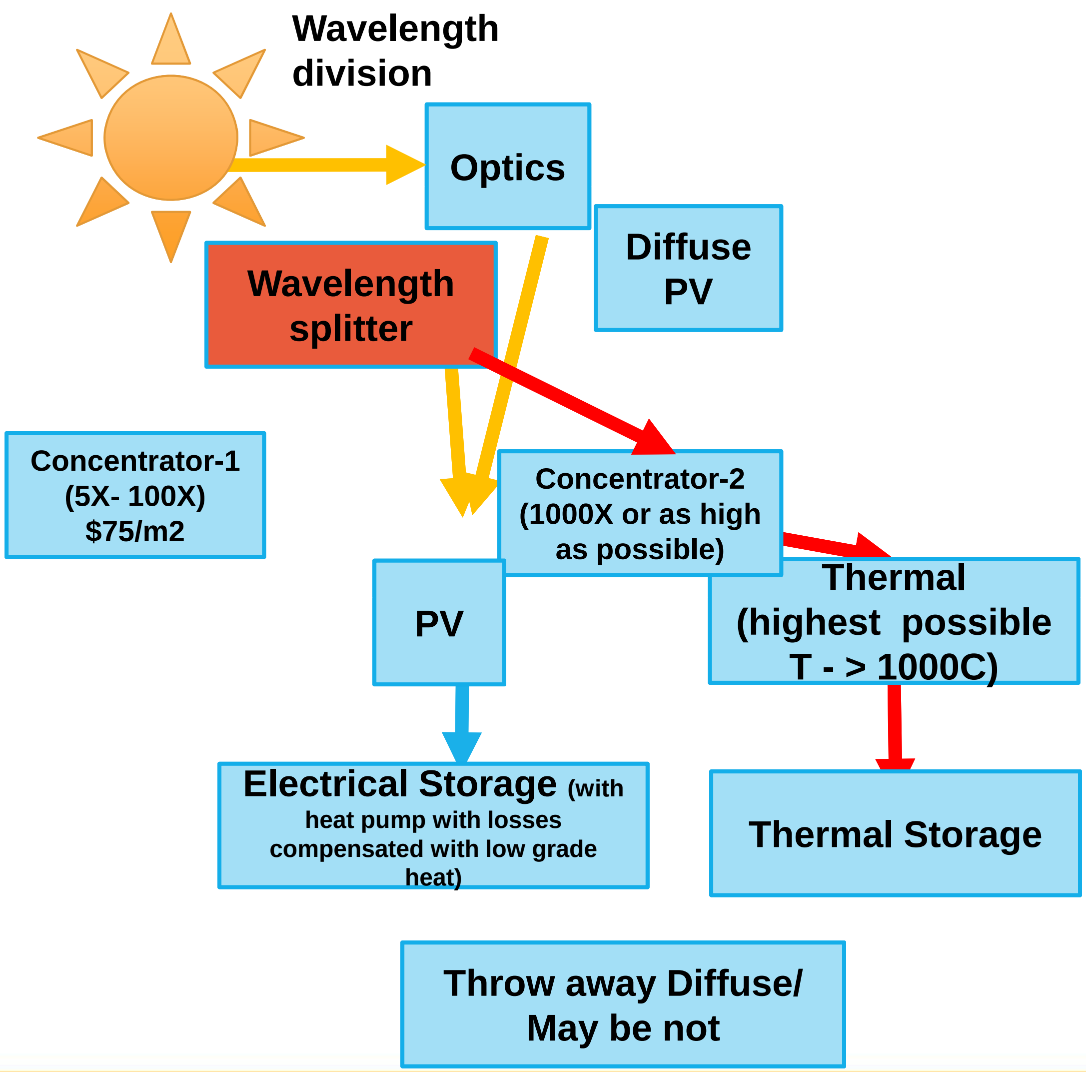
Setup for Design Group 2

The Presidential citation reads:

"For conceiving, designing, and prototyping an innovative solar system that produces electricity entirely from sunlight striking its optical aperture at an **average conversion efficiency of 40%**. More than **half of the electricity fed onto the grid is dispatchable** whenever needed, by releasing **solar energy stored using a thermal/mechanical system**. The average electricity cost from the prototype is already below the cost of either PV or CSP electricity today."

"This new solar system is highly competitive with more-polluting electricity generating systems using fossil fuels. The futuristic advances embodied in this solar energy system stand as prime examples of the continuing leadership by the United States in the world's scientific, technological and industrial communities."

Block diagram developed by Group 2



Group 2's responses to the NYT's questions

To prepare for a major article on your breakthrough in a special New York Times Technology Section, the Times Science Editor has just sent your Team some questions. After tomorrow's White House ceremony, members of your team will be interviewed for the article. It is important that you reach consensus on answers today, so you can speak with a common voice in the NY Times interview and in the many other interviews coming in the days to come.

The NY Times questions:

- What were the overall system design features that made your team successful?
  - Diverse set of individually simple solutions – PV + thermal, splitter, concentrator, thermal storage, electrical storage with heat pump to utilize waste heat or low grade heat to make-up for losses
- What was the most crucial technology breakthrough that made your system a success? What other new technologies did you need to develop to make the system work?
  - Wavelength splitter, concentrator
- What mixture of expertise was critical to making your Team a success?
  - Optics, materials, mechanical, thermal, system engineering, solar cell, large scale manufacturing
- How did you keep the costs of the produced energy so low?
  - Systems engineering, low cost materials,
- What setbacks, financial, technical or regulatory, did your Team face and how did you overcome them?
  - Exotic materials, cost of storage,
- What were the best ideas you tried that didn't make it into the final system design?
  - Para-Photonic crystals, high temperature PV (>300C),

Setup for Design Group 3

The Presidential citation reads:

The Presidential citation reads: "For conceiving, designing, and prototyping an innovative solar system that produces electricity entirely from sunlight striking its optical aperture at an **average conversion efficiency of 40%.** More than **half of the electricity fed onto the grid is dispatchable,** whenever needed, by releasing stored solar energy. The average electricity cost from the prototype is already below the cost of either PV or CSP electricity today."

"This new solar system is highly competitive with more-polluting electricity generating systems using fossil fuels. The futuristic advances embodied in this solar energy system stand as prime examples of the continuing leadership by the United States in the world's scientific, technological and industrial communities."

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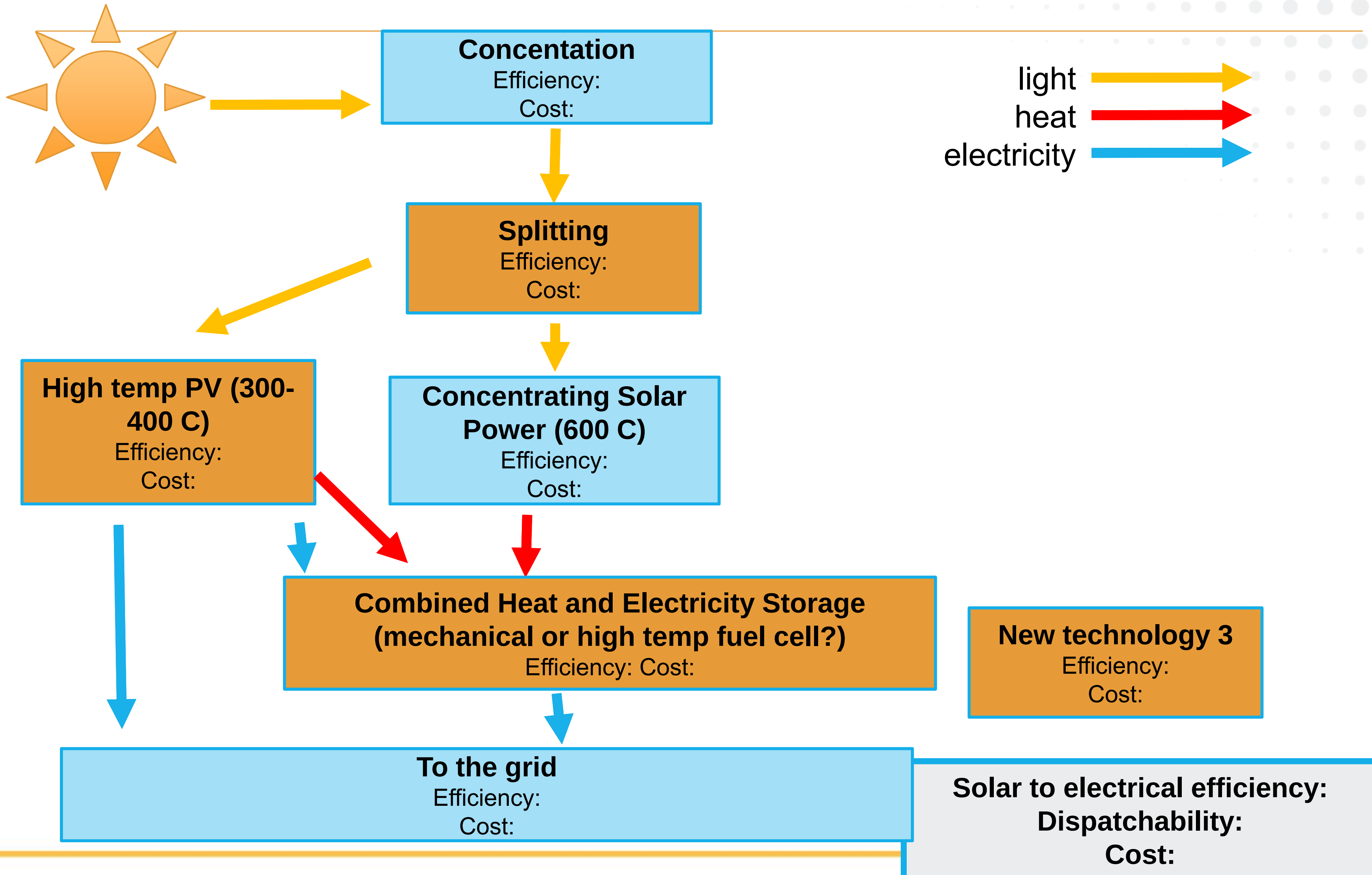
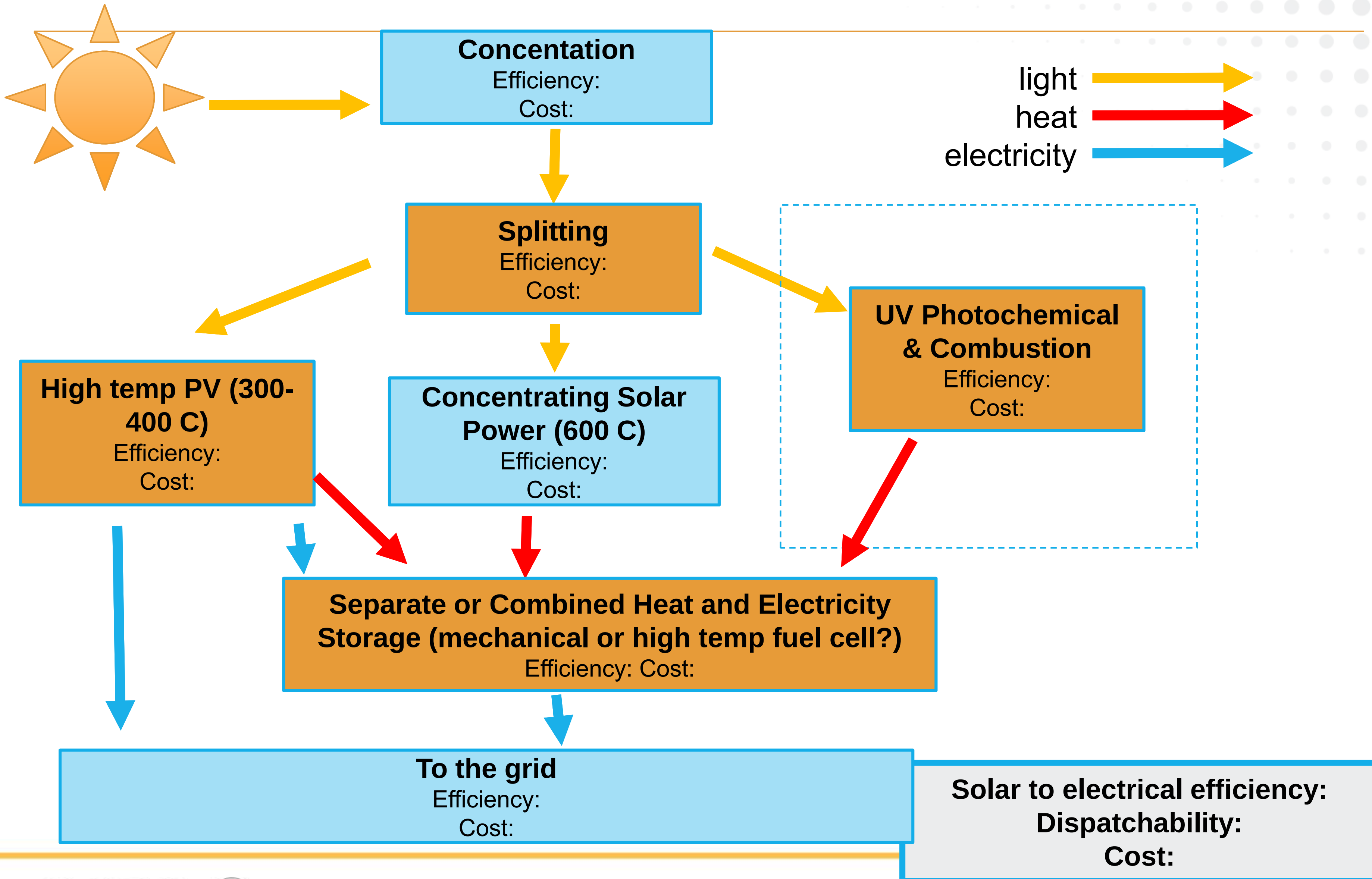
CHANGING WHAT'S POSSIBLE

Block diagram developed by Group 3 – Design A



Block diagram developed by Group 3 – Design B



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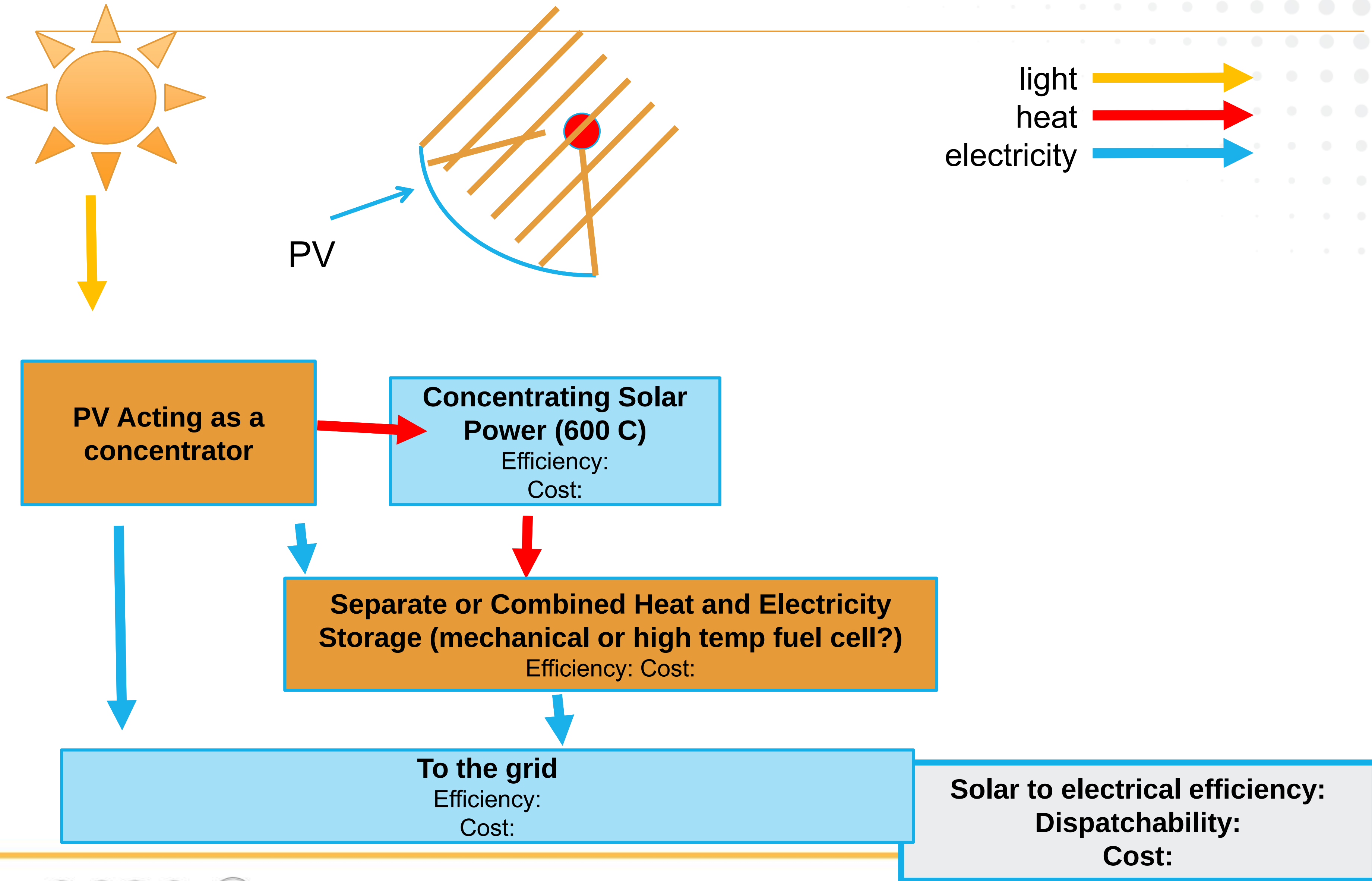
CHANGING WHAT'S POSSIBLE

Block diagram developed by Group 3 – Design C



Setup for Design Group 4

The Presidential citation reads:

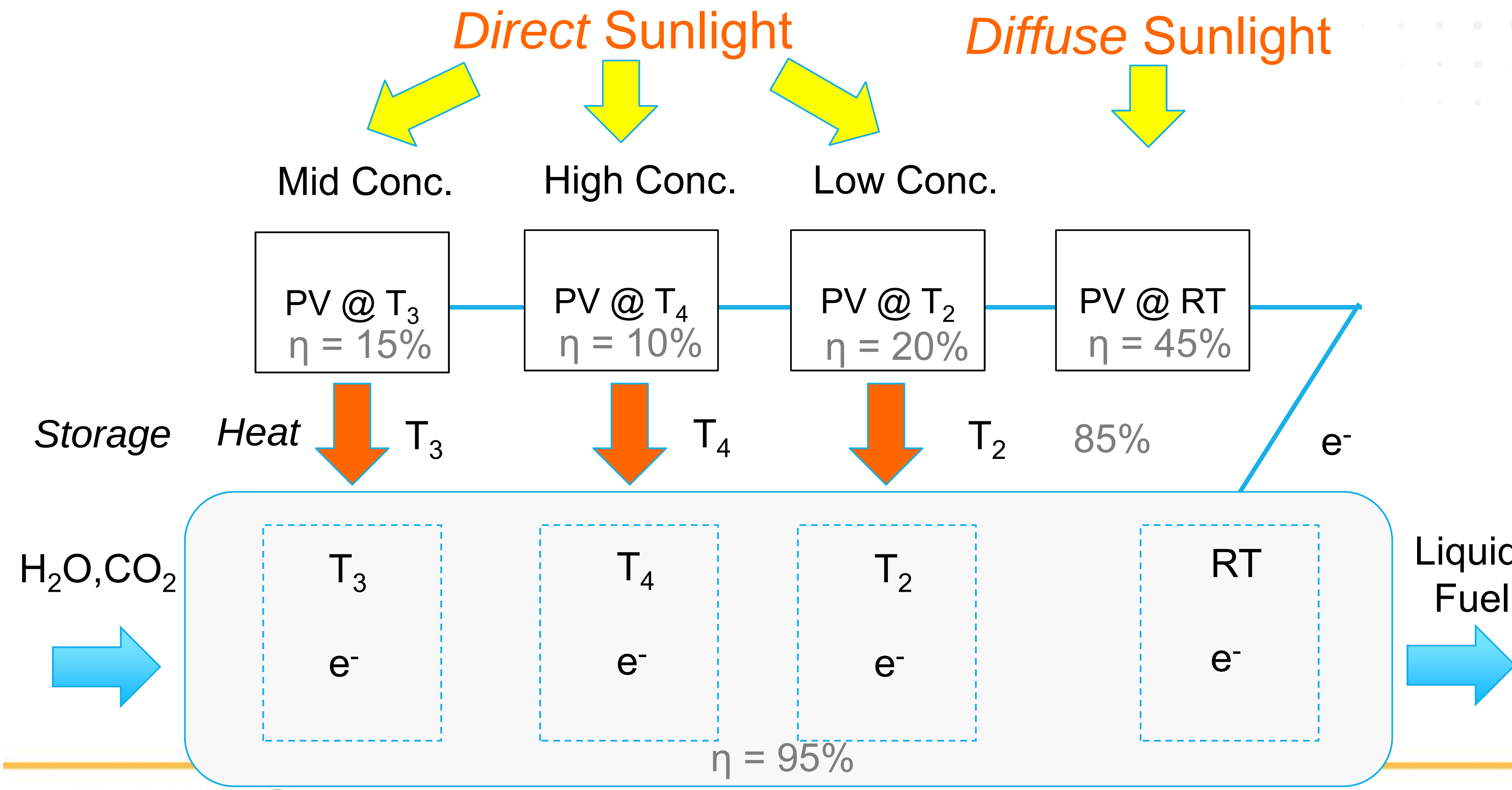
“For conceiving, designing, and prototyping an innovative solar system that produces an **energy dense transportation fuel** entirely from sunlight striking its optical aperture, with a **solar energy-to-fuel efficiency over 35%**. This solar fuel system uses no fossil fuels and instead **makes fuel from a combination of solar electricity, solar heat energy and sunlight itself**. The average **cost of fuel from the prototype is already equivalent to gasoline costing well below $3/gge**, making it highly competitive in the transportation sector.

The futuristic advances embodied in this solar energy system stand as prime examples of the continuing leadership by the United States in the world’s scientific, technological and industrial communities.”

Block diagram developed by Group 4

"Thermal Splitting" of Sunlight

Deliver the <u>right mix of heat and electricity</u> to processes in synthesizing liquid fuel



Heat/Electricity to Liquid Fuel Plant