A Comparison of the Environmental Consequences of Power from Biomass, Coal, and Natural Gas

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Outline of Presentation

Short discussion of life cycle assessment (LCA)

Purpose of LCAs conducted

System descriptions
- Biomass IGCC
- Average coal
- Coal/biomass cofiring
- Natural gas combined cycle

Comparative Results
- Air emissions
- Greenhouse gases
- Energy

Life Cycle Assessment: Definition

LCA is:

- a systematic analytical method
- used to quantify the environmental benefits and drawbacks of a process
- performed on all processes, cradle-to-grave, resource extraction to final disposal
- ideal for comparing new technologies to the status quo
- helps to pinpoint areas that deserve special attention
- reveals unexpected environmental impacts (no show-stopping surprises)

Systems Examined

Biomass IGCC	Indirectly-heated gasification Dedicated hybrid poplar feedstock Zero carbon sequestration in base case
Average coal	Pulverized coal / steam cycle Illinois #6 coal - moderate sulfur, bituminous Surface mining
Biomass / coal cofiring	15% cofiring by heat input Biomass residue (urban, mostly) into PC boiler 0.9 percentage point efficiency derating Credit taken for avoided operations including decomposition (i.e., no biomass growth)
Direct-fired biomass	Biomass residue Avoided emissions credit as with cofiring
Natural gas	Combined cycle Upstream natural gas losses = 1.4% of gross

Purpose of Studies

Biomass LCA was conducted to answer common questions:

- What are the net CO_2 emissions?
- What is the net energy production?
- Which substances are emitted at the highest rate?
- What parts of the system are responsible for the greatest impacts?
- What should biomass R&D focus on?

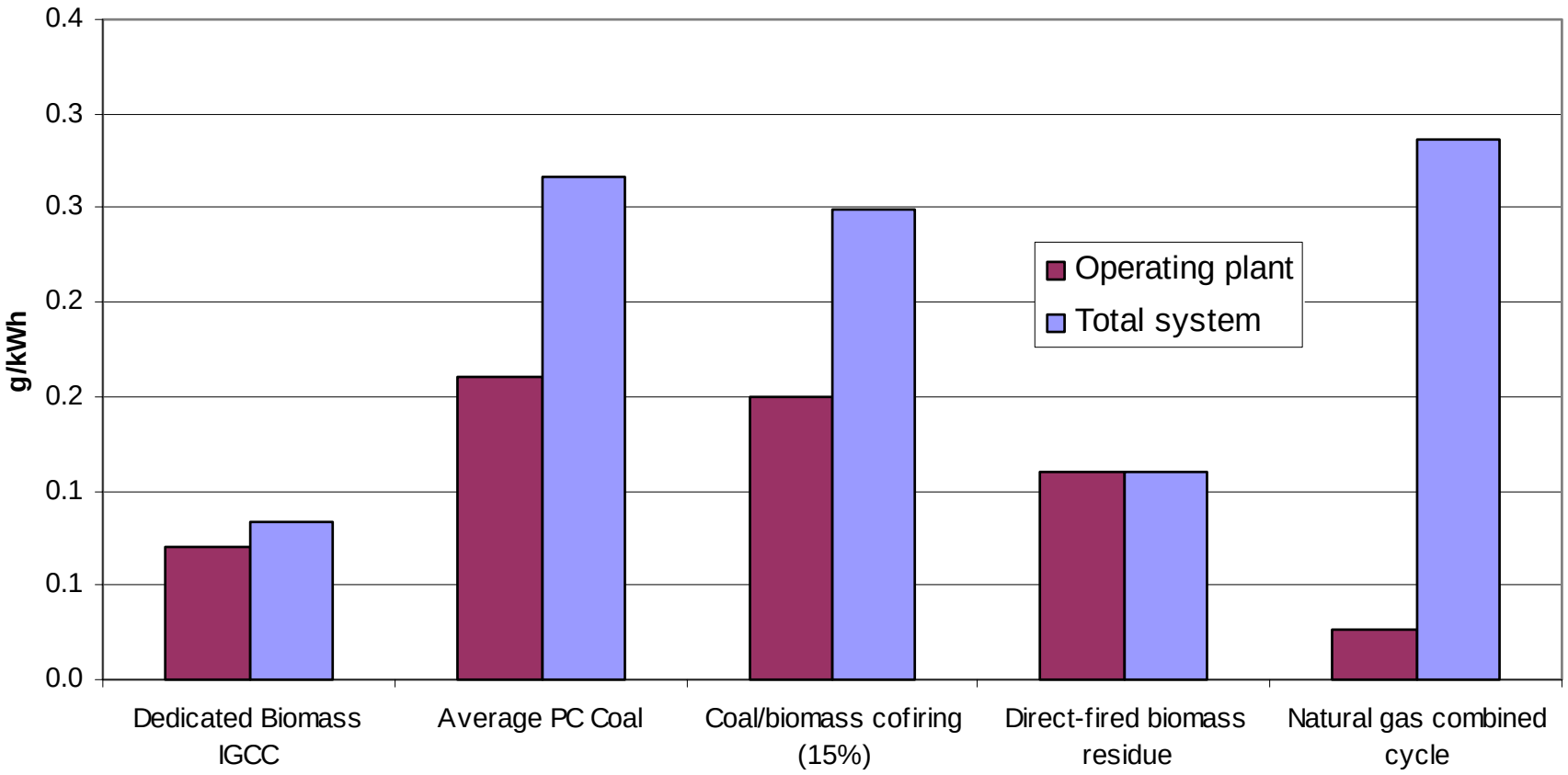
Coal and natural gas LCAs the foundation for quantifying the benefits of biomass power.

Direct-fired biomass system describes current biomass power industry.

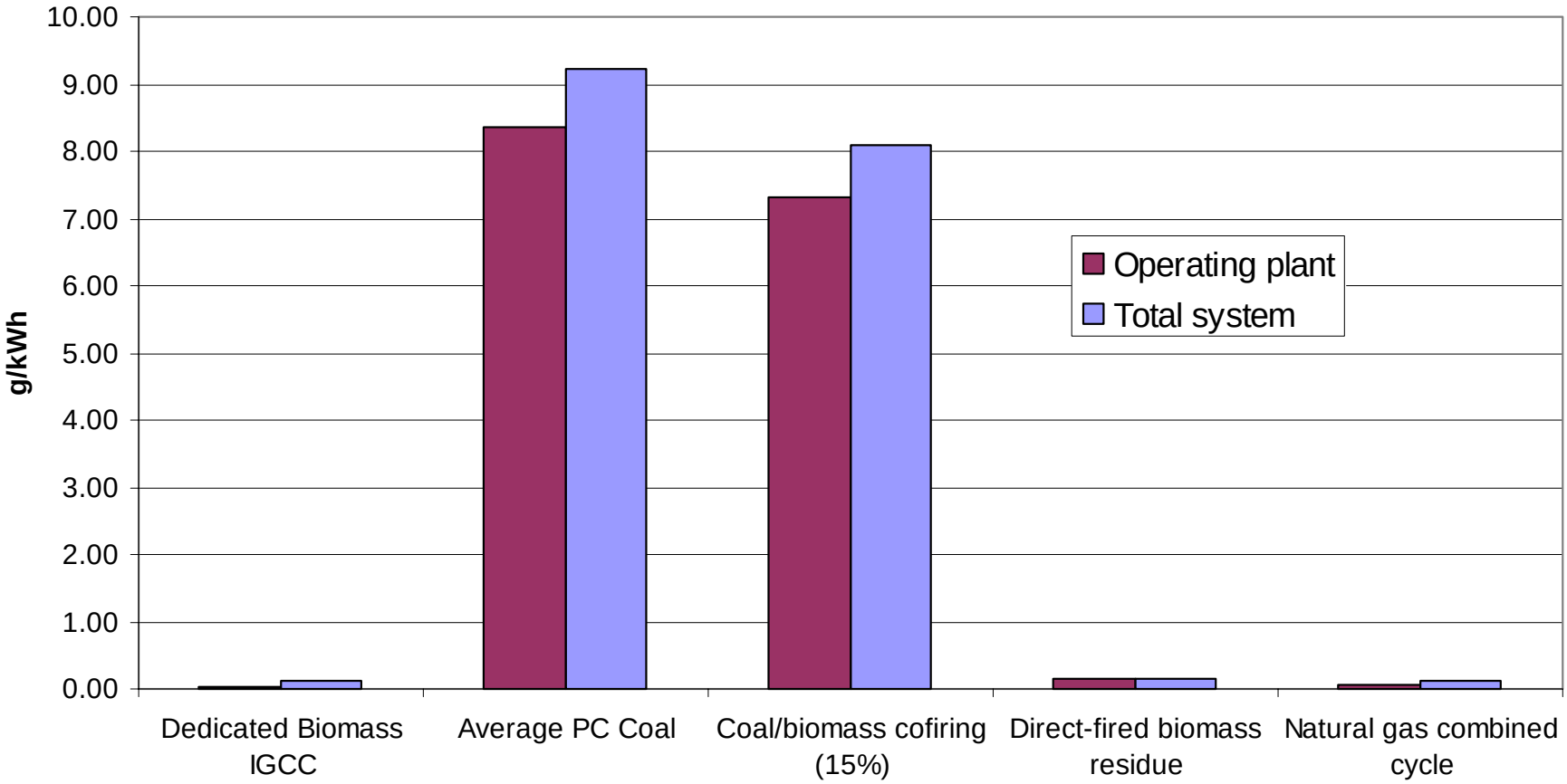
Cofiring LCA examined near-term option for biomass utilization.

Each assessment conducted separately - common systems not excluded.

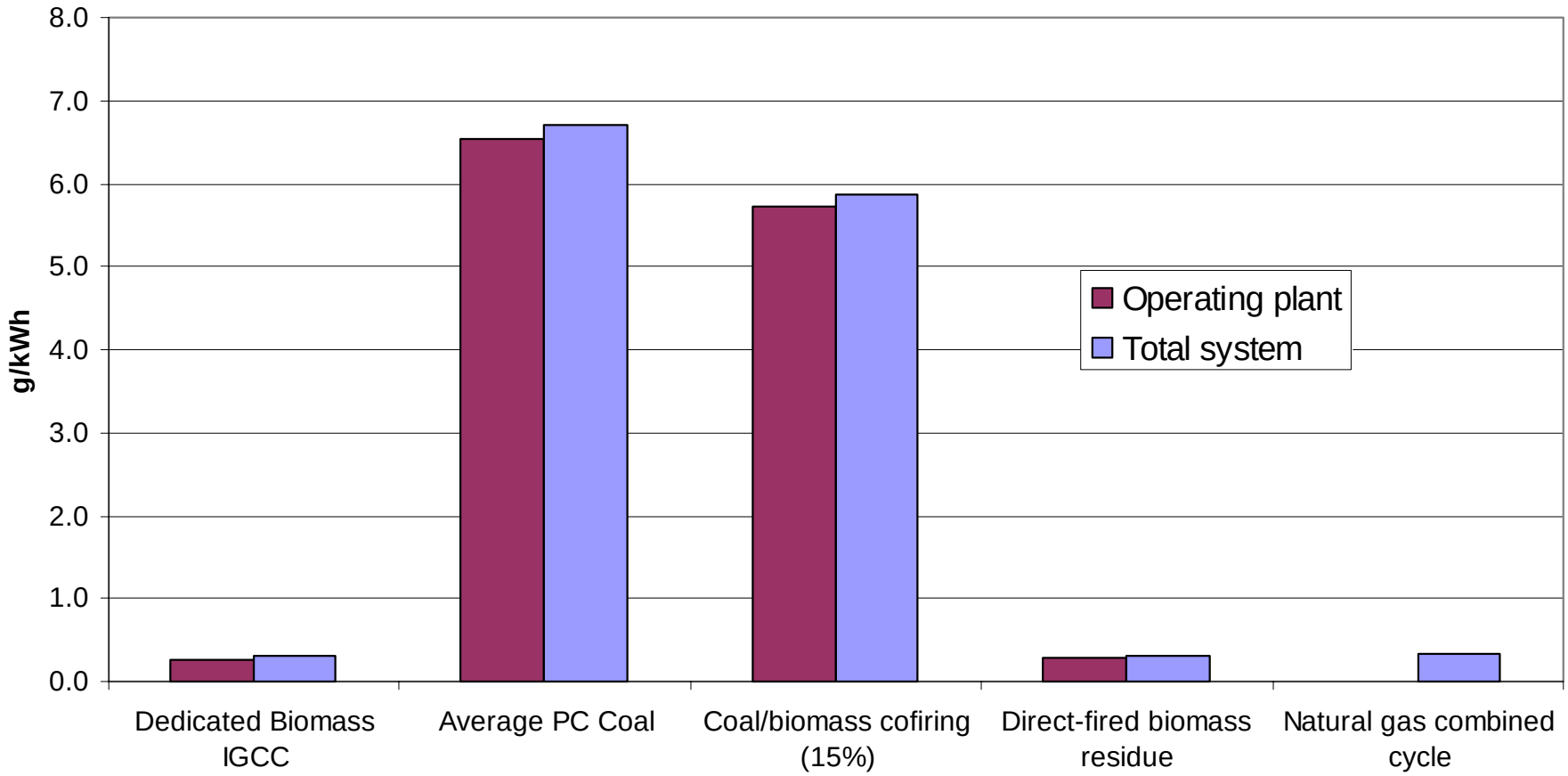
Life Cycle & Plant CO Emissions



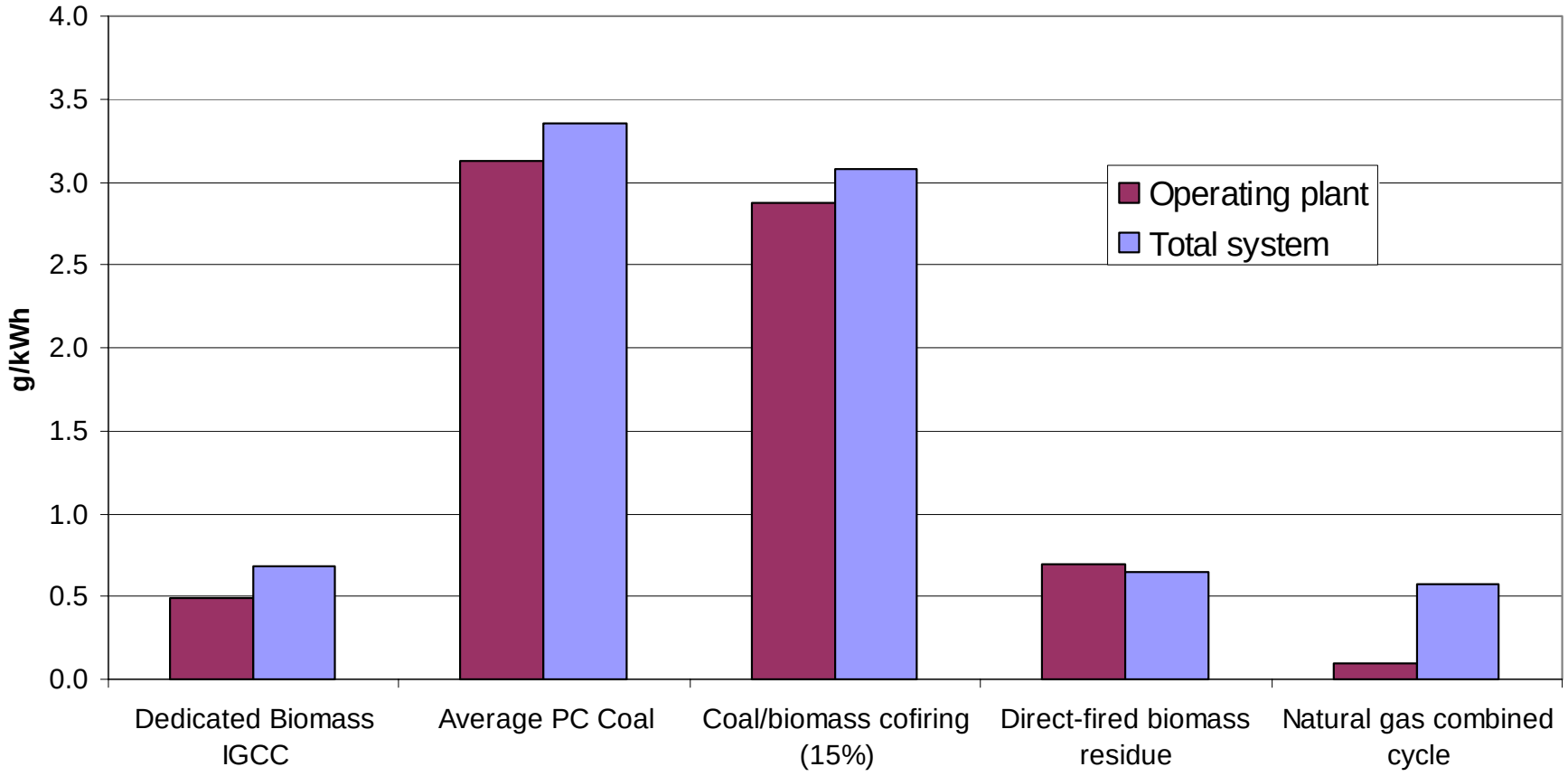
Life Cycle & Plant Particulate Emissions



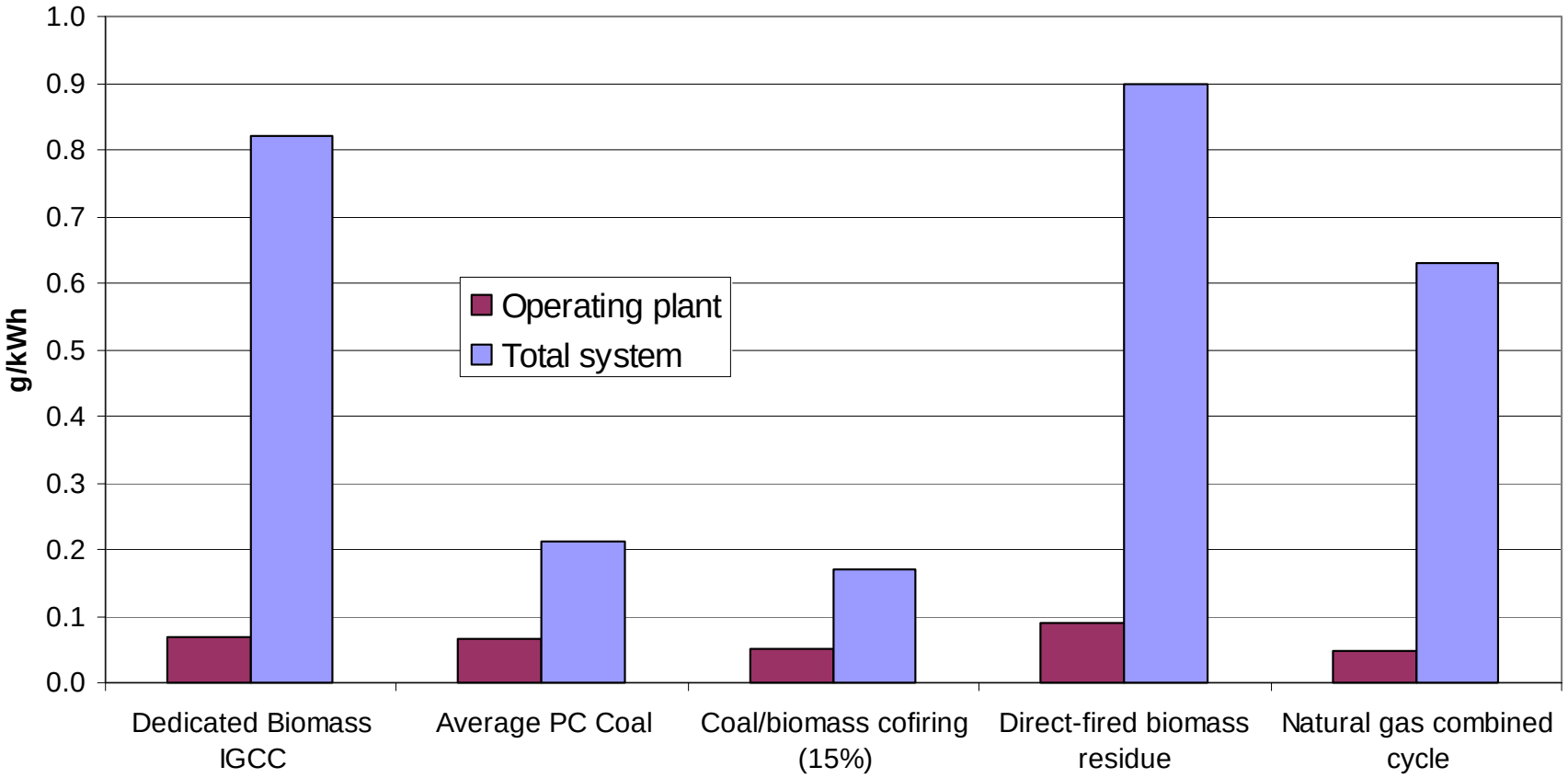
Life Cycle & Plant SO_2 Emissions



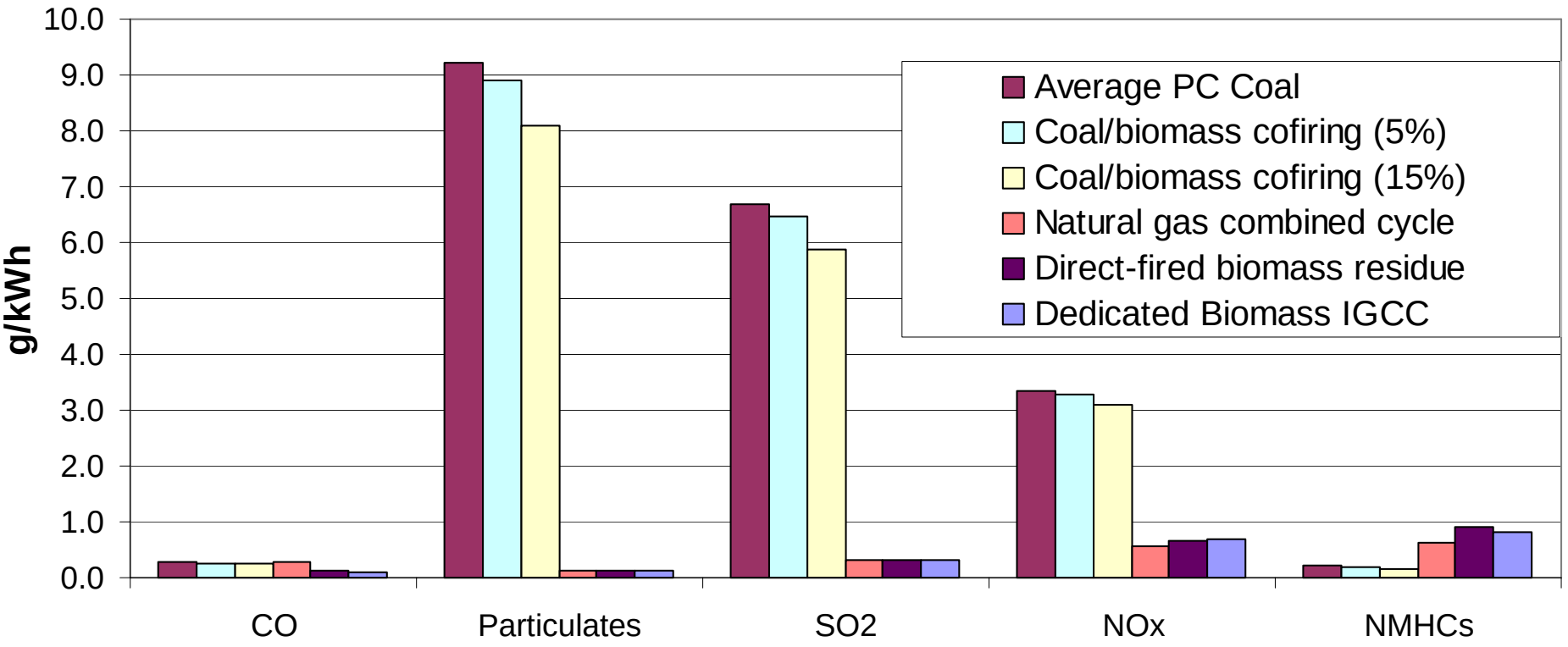
Life Cycle & Plant NOx Emissions



Life Cycle & Plant NMHC Emissions

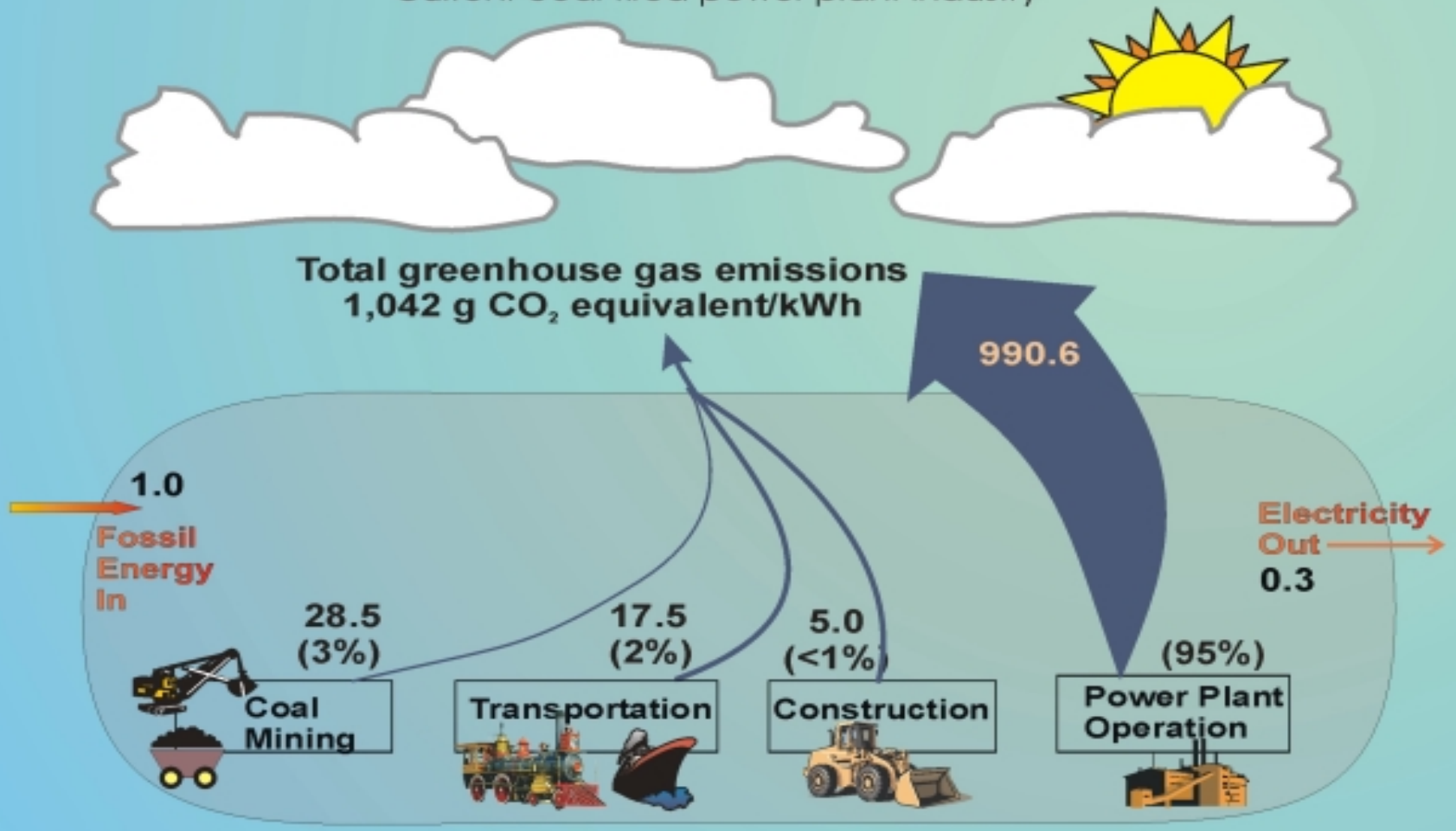


Life Cycle Air Emissions



Life Cycle GWP and Energy Balance for a Coal-fired Power System

Current coal-fired power plant industry

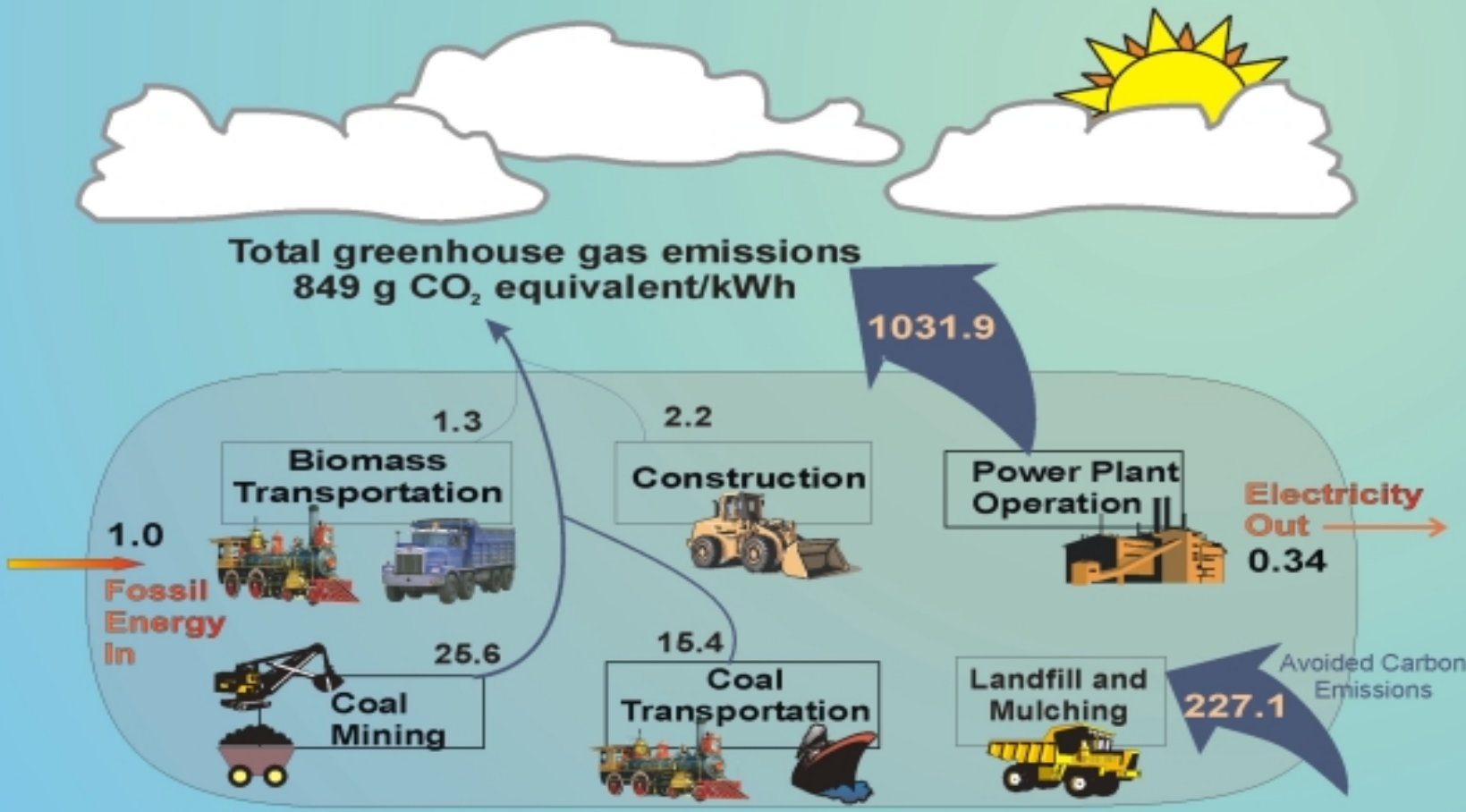


Coal Power System

0% carbon closure

Life Cycle GWP and Energy Balance for Cofiring 15% Residue Biomass with Coal

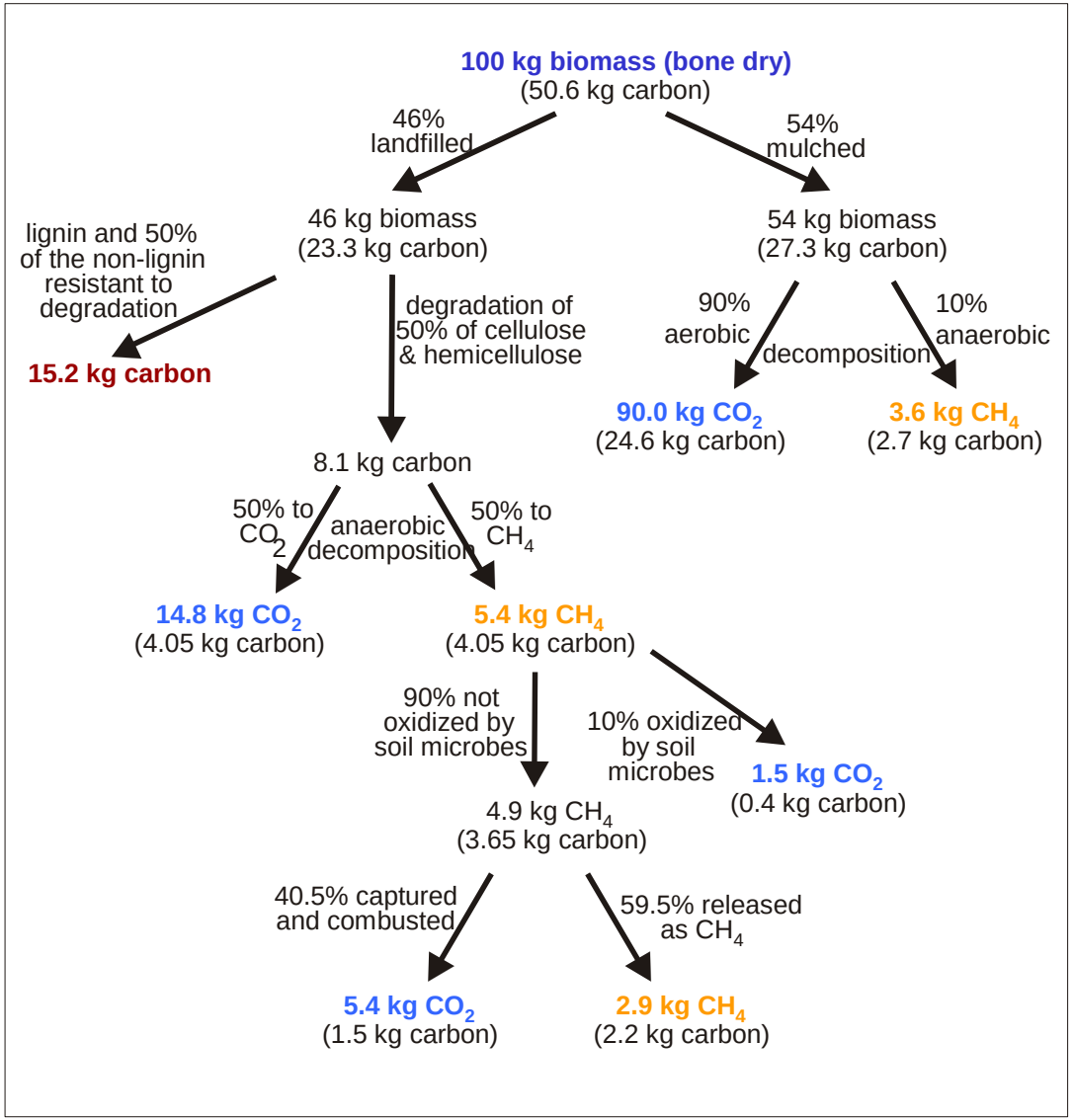
Greenhouse gas emissions reduced by 18%



Coal/Biomass Cofired System

26% carbon closure

Avoided Biomass Decomposition



Avoided per 100 kg of biomass:

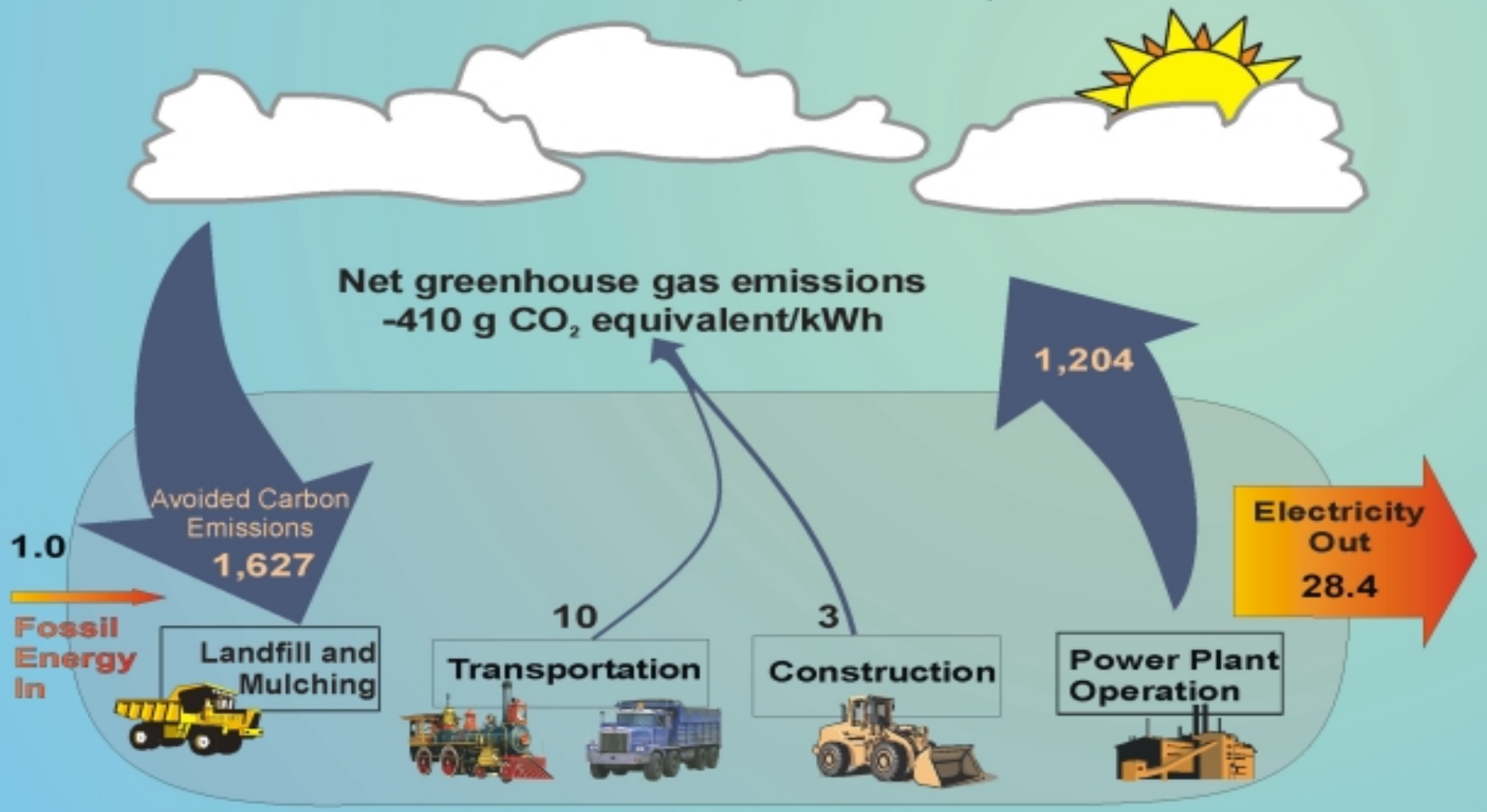
111.7 kg CO_2 + 6.5 kg CH_4

= 248.2 kg CO_2-equiv

If 100 kg biomass were to completely decompose aerobically: 185.4 kg CO_2

Life Cycle GWP and Energy Balance for a Direct-Fired Residue-Biomass Power System

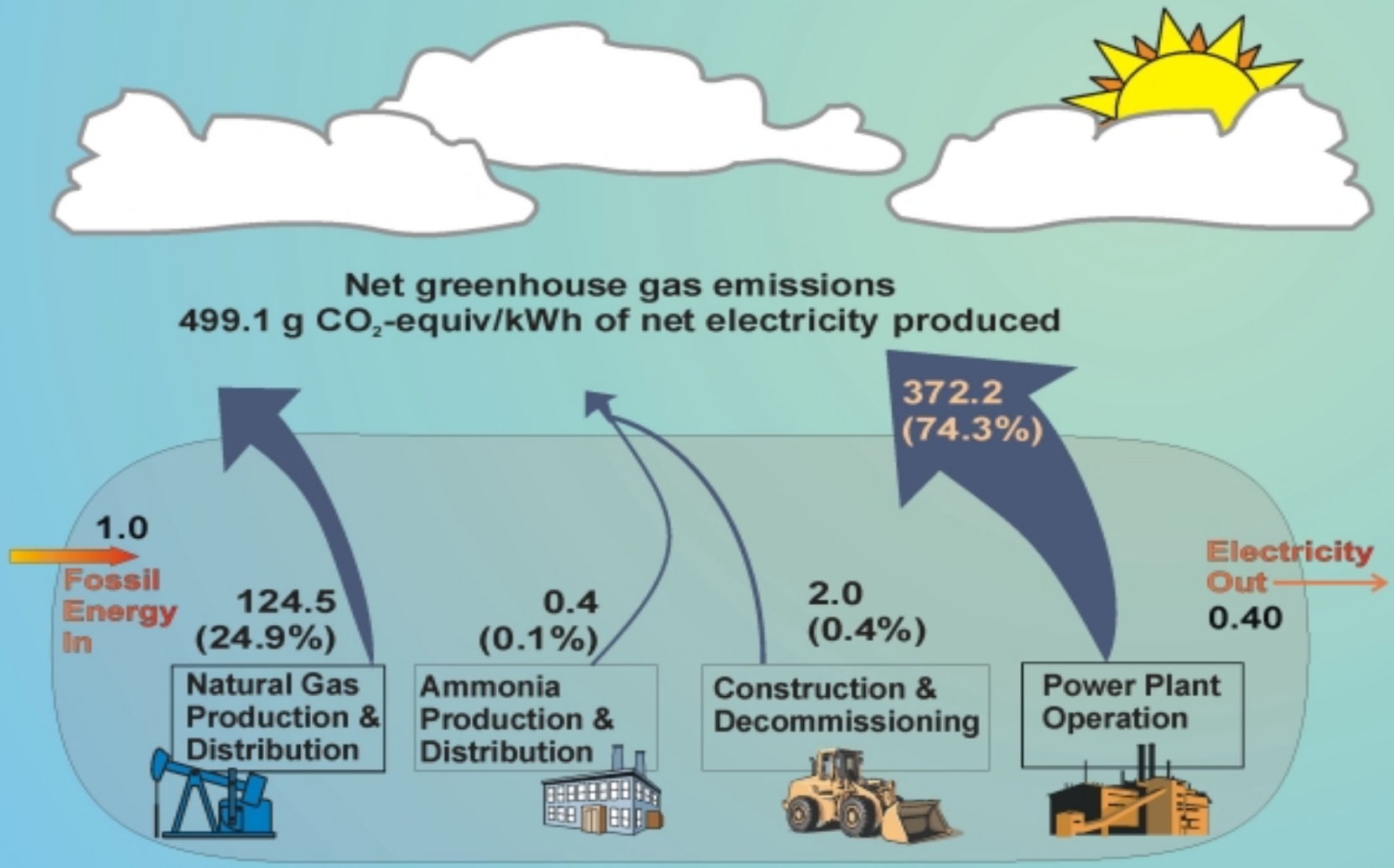
Current biomass power industry



Direct-Fired Biomass Residue System

134% carbon closure

Life Cycle GWP and Energy Balance for a Natural Gas Combined-Cycle System

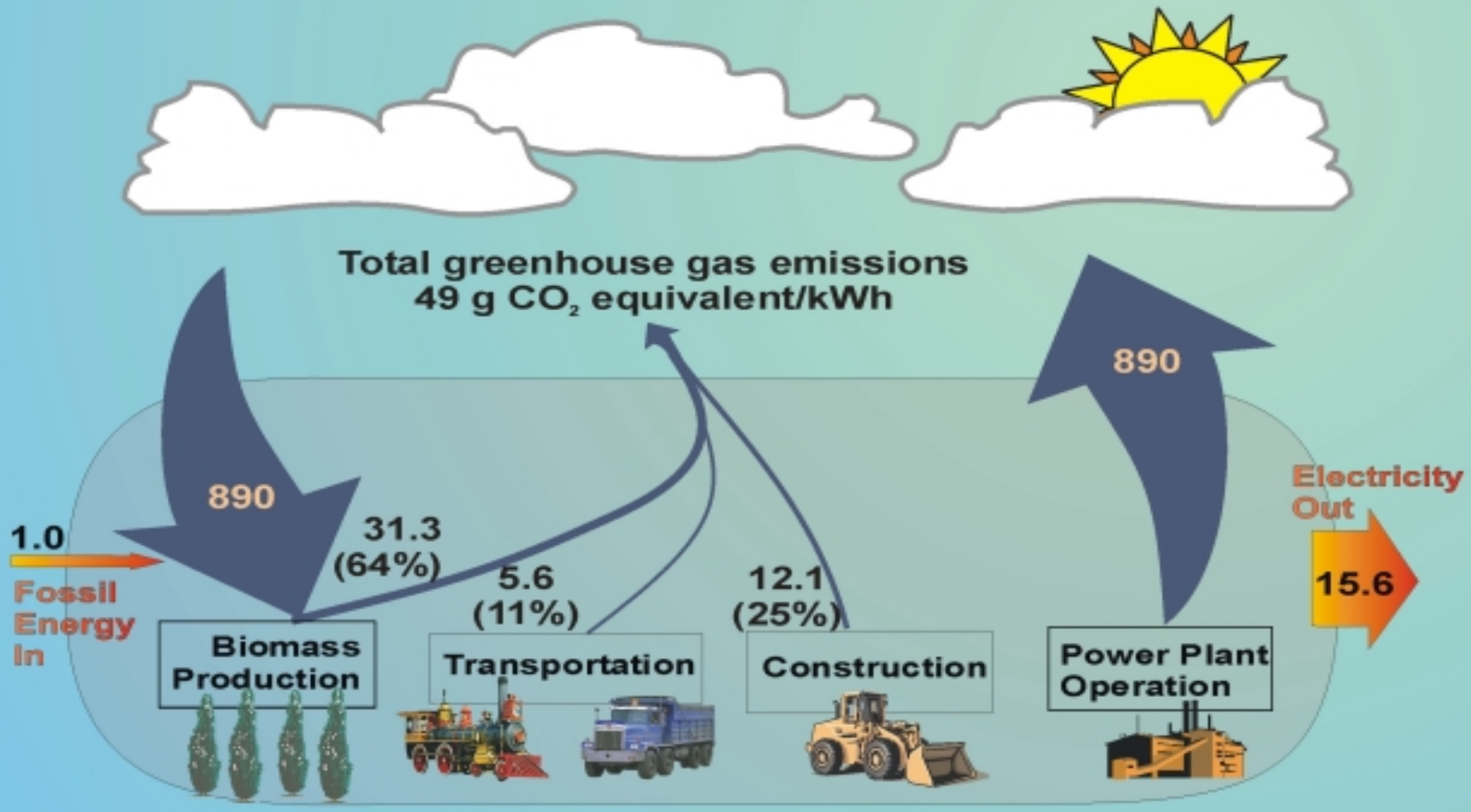


Natural Gas Combined Cycle System

0% carbon closure

Life Cycle GWP and Energy Balance for Advanced IGCC Technology using Energy Crop Biomass

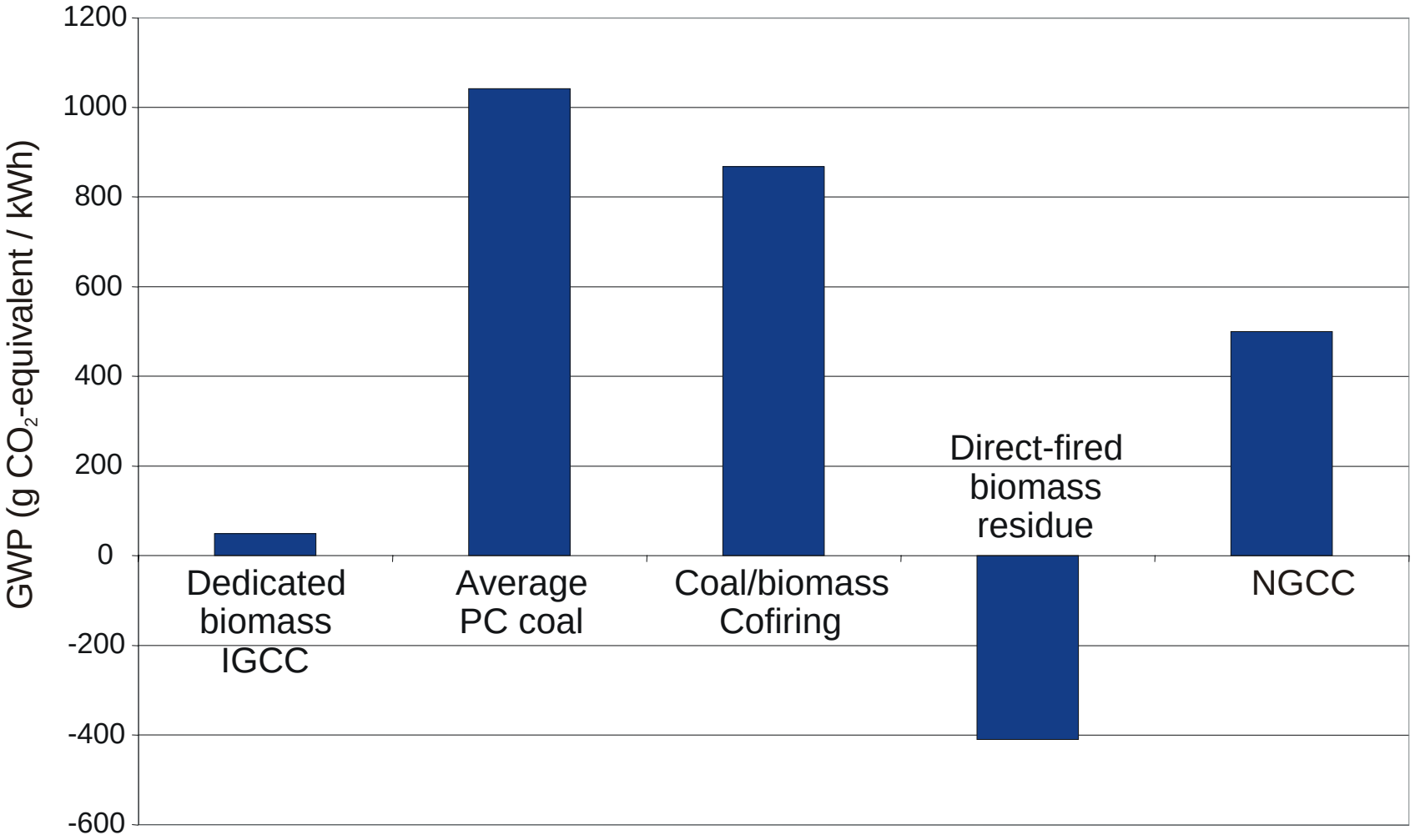
Future, wide-spread potential



Advanced Biomass Power System

95% carbon closure

Life Cycle Greenhouse Gas Emissions



Summary

Air emissions:

- Biomass: few particulates, SO_2, NOx, and methane
- Coal: upstream CO and NMHC emissions lower
- NGCC: system methane, NMHC, CO emissions high

Greenhouse Gases:

- Biomass IGCC nearly zero net GHGs
- Average coal system: ~1,000 g CO_2-equiv/kWh
- NGCC system: ~500 g CO_2-equiv/kWh
- Today's biomass systems remove GHGs from atmosphere
- Cofiring: greater reduction than rate of biomass input