Framework for Teaching K12 Science and Engineering Bioenergy Concepts

A Delphi Expert Study

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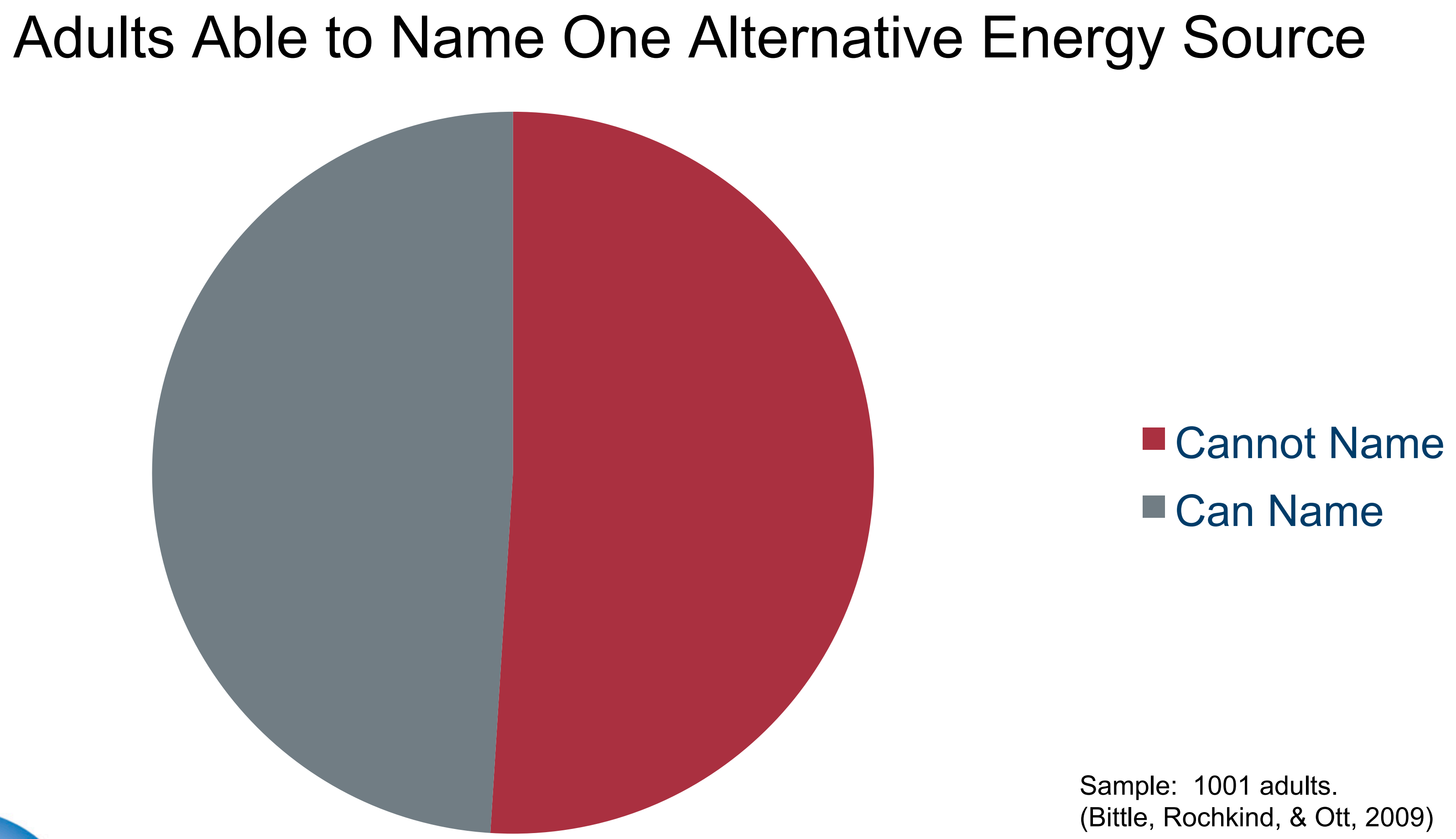
USDA United States Department of Agriculture
National Institute of Food and Agriculture

What is Bioenergy?

Source: Flickr.com

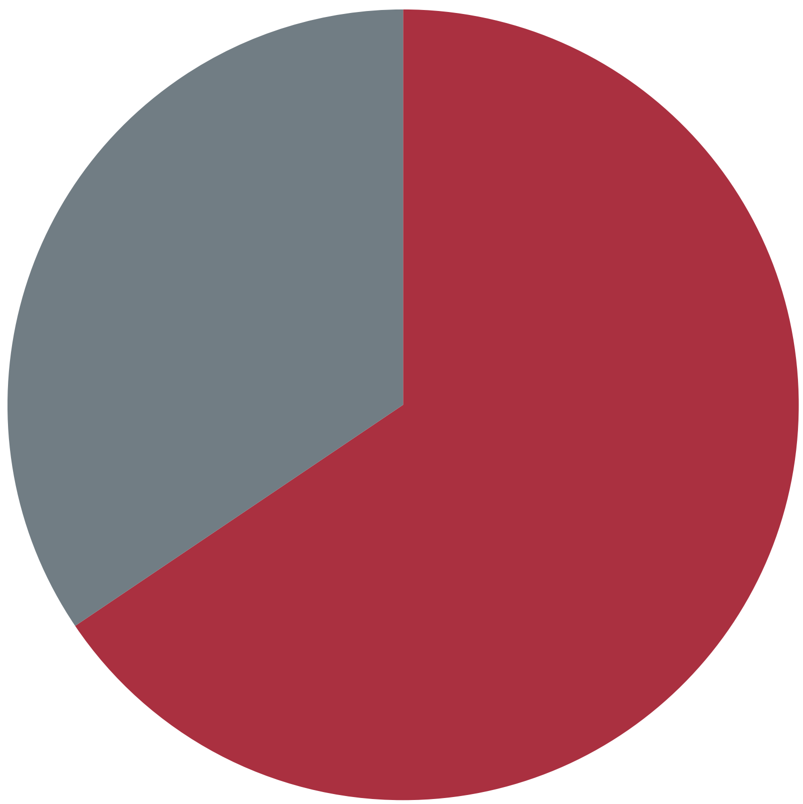
Adults Don’t Know Energy



Sample: 1001 adults.
(Bittle, Rochkind, & Ott, 2009)

Children Don't Know Energy

Middle School Students Able to Identify a Biofuel in List



Sample: 3254 MS & HS Students in NY
DeWaters & Powers, 2011

Motivations

- Low bioenergy competency
  (DeWaters & Powers, 2011)
- STEM integration
- NGSS cross-cutting concept – Energy
  (National Academy, 2013)
- Energy often taught in silos
  (Chen, Scheff, Fields, Pelletier, & Faux, 2014)
- Situate Learning in socio-scientific context
  (Sadler, 2009)

Delphi Methods

- Group Problems
- Delphi Technique – Mixed method
  - Experts at a distance
  - Anonymous communication
  - Multiple iterations
  - Statistical analysis
  - Develop consensus

Osborne, J., Collins, S., Ratcliffe, M., Millar, R., & Duschl, R. (2003).

Participants

- **Criteria:** PhD in bioenergy, published in the field, or taught bioenergy courses
- **Background**
  - Ecology
  - Sustainability
  - Environmental engineering
  - Transportation engineering
  - Biology
  - Spatial Technologies
  - Horticultural

Delphi

Level	Invitations	Agreed	Round 1	Round 2	Round 3
K12	180	42	21	9	8
College			20	14	12

- Question: What science and engineering concepts are essential in K12?
- Round 1 – Brainstorming (Qualitative)
- Round 2 – Narrowing Down (Quantitative)
- Round 3 – Rating (Quantitative)

Round 2: Science Results

Concept	Rating	SD
Climate Change: Historical record and projected consequences	4.6	0.5
Energy Fundamentals: Work, energy, conversions	4.5	0.5
Photosynthesis: How light energy is stored in plants	4.4	0.9
Chemical Cycles: Water, carbon, nitrogen cycles	4.3	0.7
Ecosystems: Ecology and human impact	4.2	1.0
Conversion Principles: Types of conversions	4.2	0.8
Lifecycle Assessment: Environmental impacts from cradle to grave	4.2	0.9
Economics: How economics impacts biofuel use	3.9	1.1
Biomass Sources: How solar energy is stored	3.8	1.1
Laws of Thermodynamics: Conservation of energy	3.8	1.0
Public Policy: Impacts of politics on bioenergy production	3.3	1.4

Round 2: Engineering Results

Concept	Rating	SD
Energy Consumption: Current and historical energy sources	4.8	0.7
Energy Fundamentals: Types and conversions of energy	4.2	1.0
Energy Requirements: Quantity and type of energy needed	4.2	1.1
Nature of Engineering: Role of engineering in bioenergy	4.2	1.1
Conversion Technologies: Types of conversions	3.9	1.2
Bioenergy Products: Types of biofuels	3.7	1.1
Lifecycle Assessment: Social, environmental, and economic impacts	3.7	1.1
Process Economics: Economic analysis of conversion processes	3.4	1.0
Chemical Engineering Fundamentals: Conservation mass/energy; heat/mass transfer	3.3	1.5

Round 3: Findings

Concept	Rating	SD
Energy Requirements: Quantity and type of energy needed	4.88	.35
Energy Consumption: Current and historical energy sources	4.88	.35
Climate Change: Historical record and consequences	4.88	.52
Nature of Engineering: Role of engineering in bioenergy	4.62	.52
Energy Fundamentals: Work, energy, conversions	4.63	.52
Lifecycle Assessment: Environmental impacts cradle to grave	4.50	.52
Photosynthesis: How light energy is stored in plants	4.38	.46
Conversion Principles: Types of conversions	4.38	.52
Chemical Cycles: Water, carbon, nitrogen cycles	4.25	.35
Ecosystems: Ecology and human impact	4.25	.52

Bioenergy Framework & NGSS

- **Climate Change**

  MS-ESS3.D: Global Climate Change

  Human activities, such as the release of greenhouse gases from burning fossil fuels, are major factors in the current rise in Earth's mean surface temperature (global warming).

- **Energy Fundamentals**

  HS-PS3.A: Definitions of Energy

  PS3.B: Conservation of Energy and Energy Transfer

NGSS: Cross-cutting Concepts

"What is added in this cross cutting discussion is recognition that an understanding of these core (Energy and matter flow) ideas can be informative in examining systems in life science, earth and space science, and engineering contexts."

(NGSS Framework, 2011, p 96)

Limitations

- Small number of participants (Linstone & Turoff, 2011)
- Experts primarily research-based bioenergy, few educators
- Mixed methods challenges
- Additional development needed for classroom practice

Implications & Next Steps

- Engineering concepts are highly rated
- Basic energy knowledge emphasized
- Emphasis on core science concepts
- Results are compatible with NGSS
- Expands on NGSS Energy and Matter
- Guide development of additional curriculum

References

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Paper available at:

ResearchGate.com/profile/Brian_Hartman

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