



$$\dot{m}_{fuel} = \dot{Q} \cdot \frac{\Delta CO_{fuel}}{LEO} = \frac{\dot{Q}}{R_{fuel}}$$
$$CO = \Delta t \cdot \sum_{i=1}^n \dot{m}_{fuel}$$
$$K_e = \frac{\dot{Q}}{L}$$
$$\dot{m}_b$$
$$\omega = \frac{90}{\Delta t}$$
$$\sum_{i=1}^n \frac{Q_{fuel}}{\omega}$$
$$= \max(Q_{fuel}) / (\omega + \epsilon) \cdot \Delta t$$
$$= t_f$$



Getting the Power Out: Challenges of Small Hydropower Development

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Agenda

- What is small hydropower?
- Small Hydropower Research at CSU
- Opportunities and challenges

What is Micro-Hydro?

- Characteristics
 - Small drop – “low head”
 - Small flow
 - ... relative to traditional hydropower
- Colorado



Wide Variety of Sites



Size Range

10-30 KW



100-200 KW



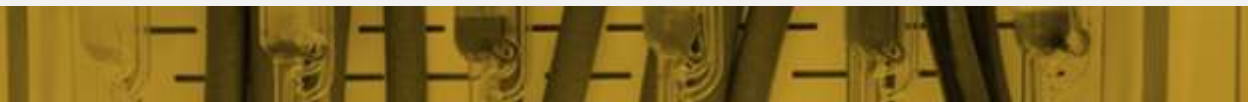
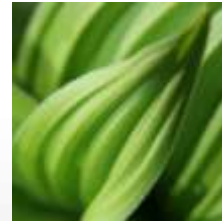
300-400 KW



Types



Small Hydropower Work At CSU



Why?

- Renewable energy source
- Additional revenue for irrigation companies
- Rural development

Why Now?

- FERC / Colorado Agreement*
- Enabling technology – turbines, power electronics, controls

* Memorandum of Understanding Between The Federal Energy Regulatory Commission and The State of Colorado Through the Governor's Energy Office To Streamline and Simplify The Authorization of Small Scale Hydropower Projects, Signed August 24, 2010

Small Hydropower Activity at CSU

- **Done:** *Exploring the Viability of Low Head Hydro in Colorado's Existing Irrigation Infrastructure*



Colorado State University

- http://www.applegategroup.com/sites/default/files/file-attachments/final_report.pdf

- **Hydro Research Foundation Fellowships**

- Brian Campbell – *Design Standardization for Integrating Micro Hydropower into Existing Infrastructure and Utility Systems*
- Andre' Dozier – *Integrated Water and Energy Systems Analysis Tool Development*

“Rules” of Our Current Research

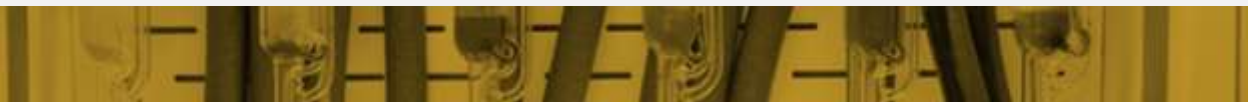
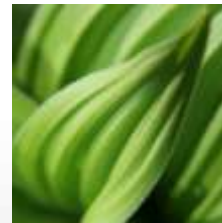
- Consider *only* existing “constrained” flows
 - No free stream projects
 - Diversions, irrigation systems, existing structures ...
- No site is too small
 - Complete survey ... then cull the list
- Build census from the “ground up”

Resource + Standardization Assessment

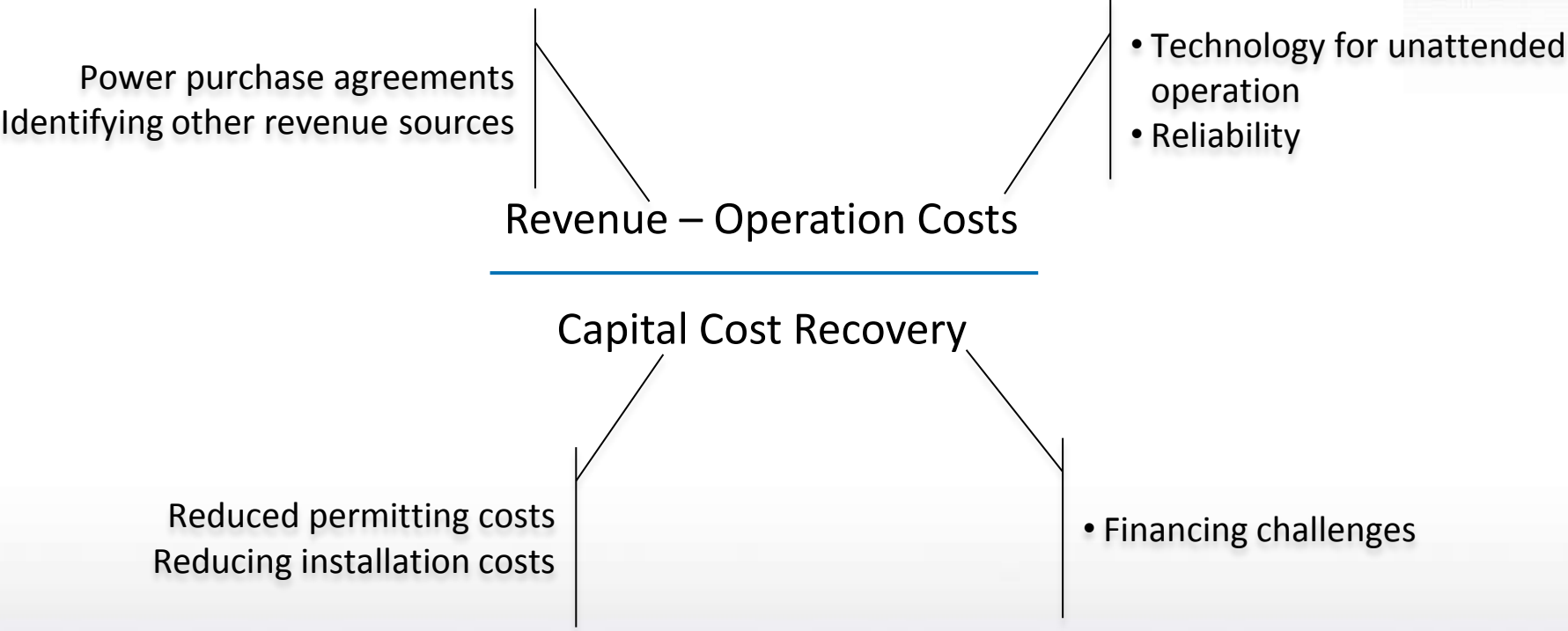
Where are we?

- 1 Grad Student + 1 Car + Many tanks of gas
 - Sample systems in all 7 water divisions of Colorado
 - Count ‘em, measure ‘em, classify them
- Use statistical techniques to extrapolate to potential to entire state
- To Date:
 - Visited >180 sites in >16 irrigation systems

Opportunities & Challenges



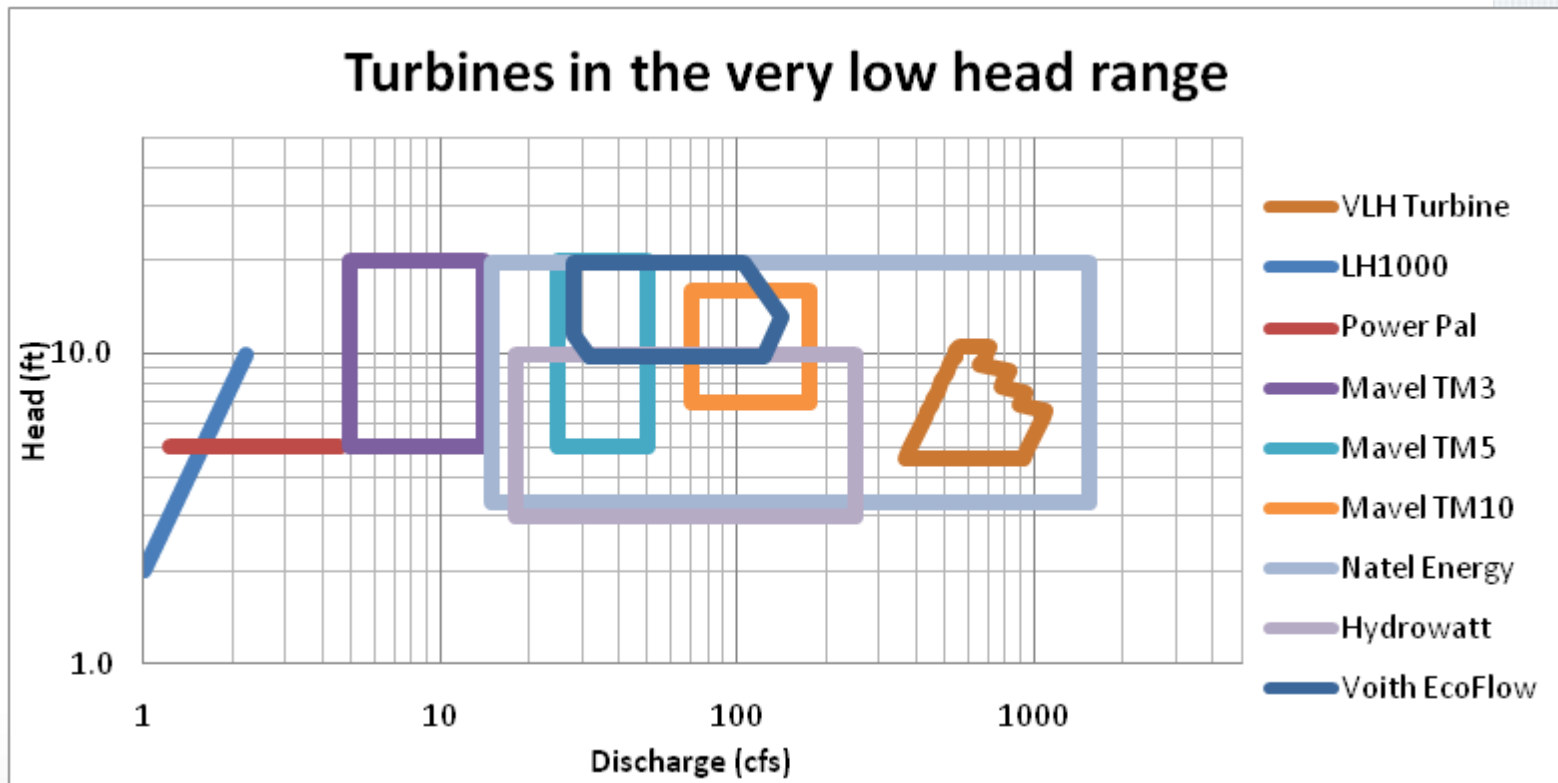
Challenges



Path from Idea to Power...

1. Identify site with proper flow, head, ownership, space, etc.
2. Build the site
 1. Civil construction
 2. Turbine & generator
 3. Interconnect
3. Sell the power

Turbines Exist



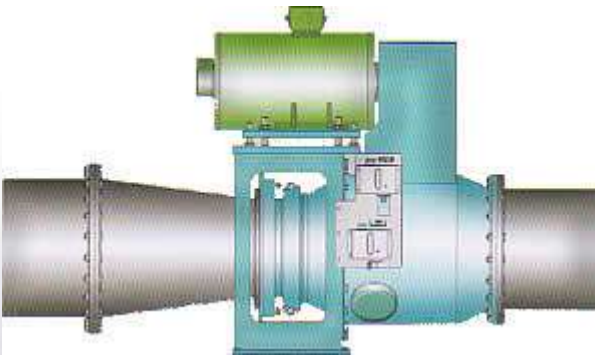
Proven Equipment Exists, At Least at Medium Size



Canyon Hydropower - Kaplan



Ossberger - Crossflow



Toshiba - Propeller



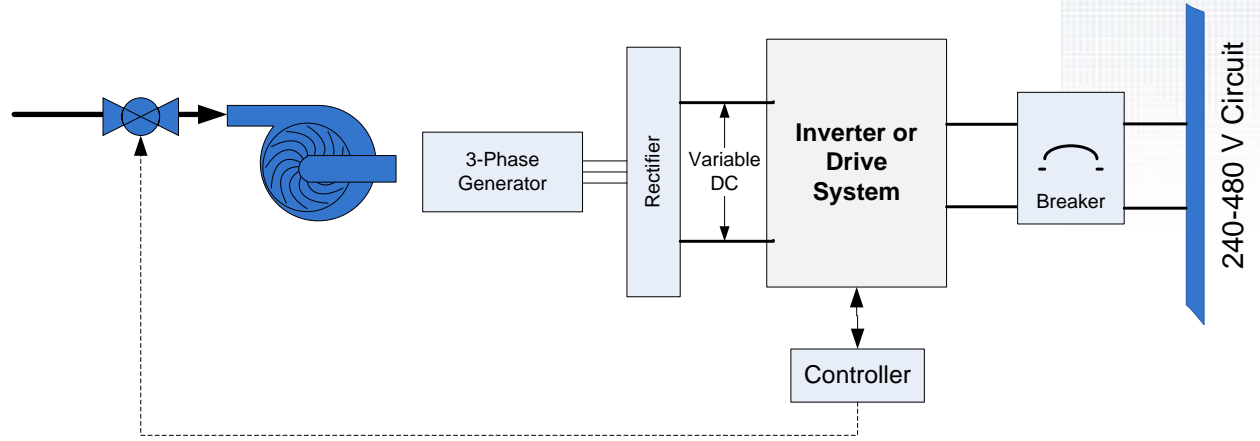
VLH - Low-head Propeller

Active Development at Small Scale

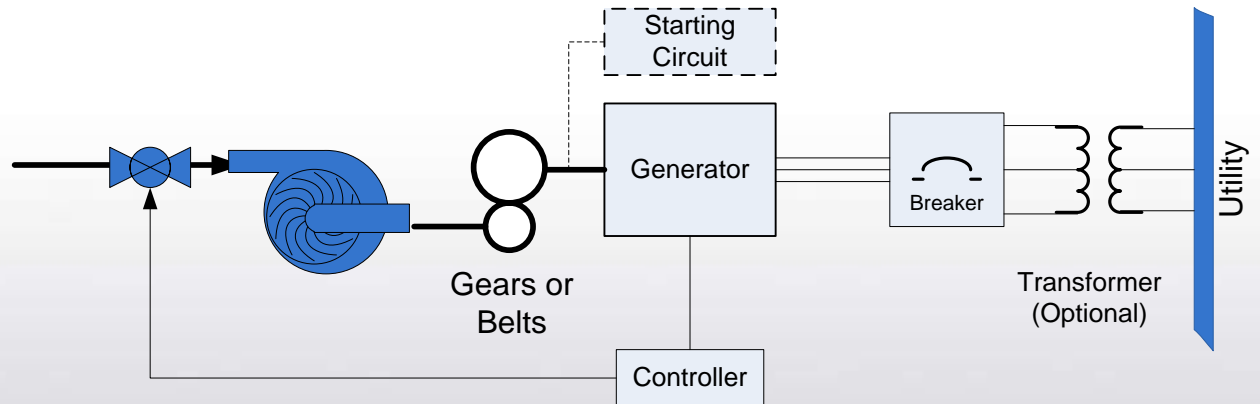


Interconnect Choices

- Small



- Larger

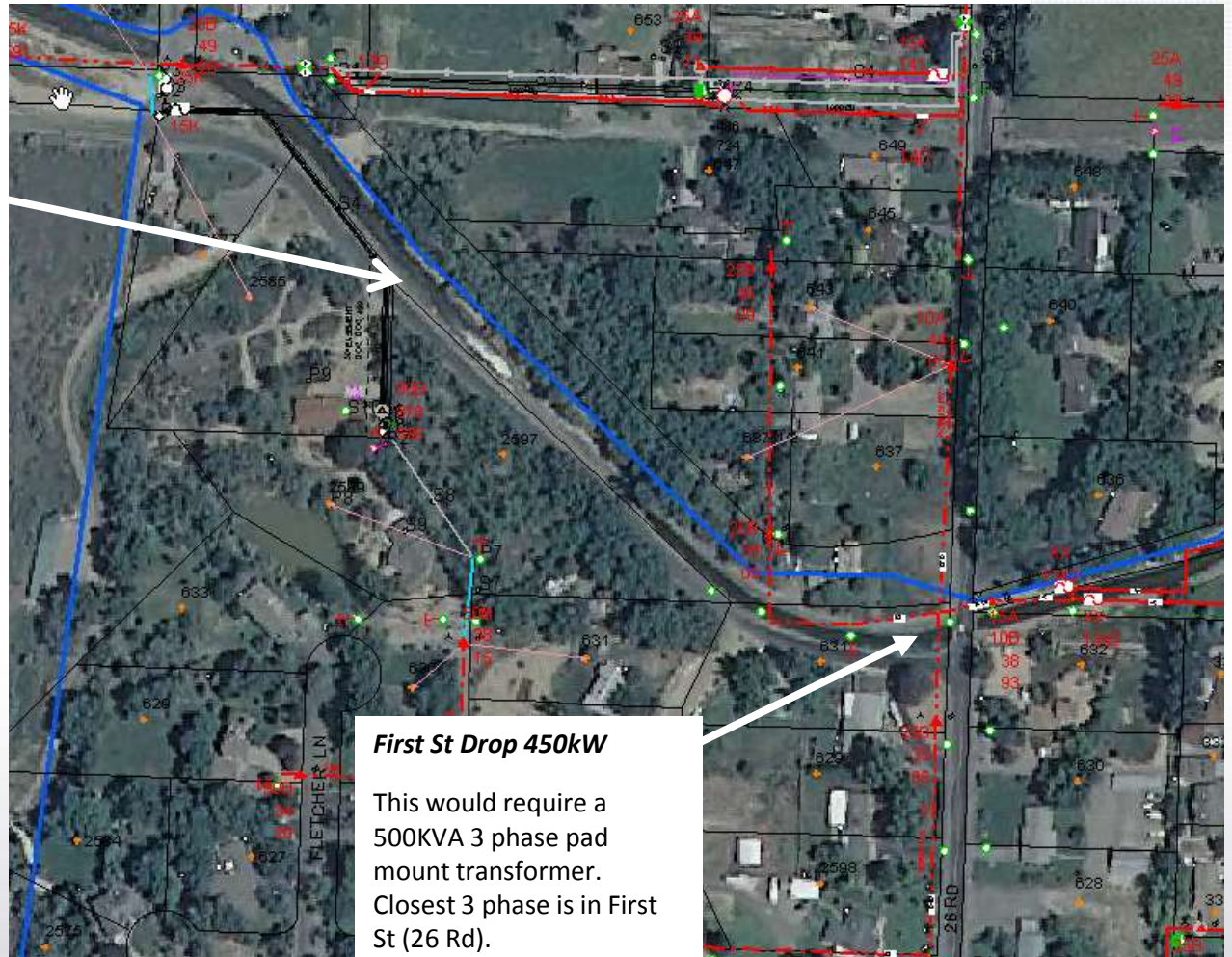


Where Will the Power Go?

- Very Small (10s KW)
 - Net metering against local loads
- Small (100s KW)
 - Small producer power purchase agreement
- Large (MW)
 - Bid into planning & procurement process of local operators

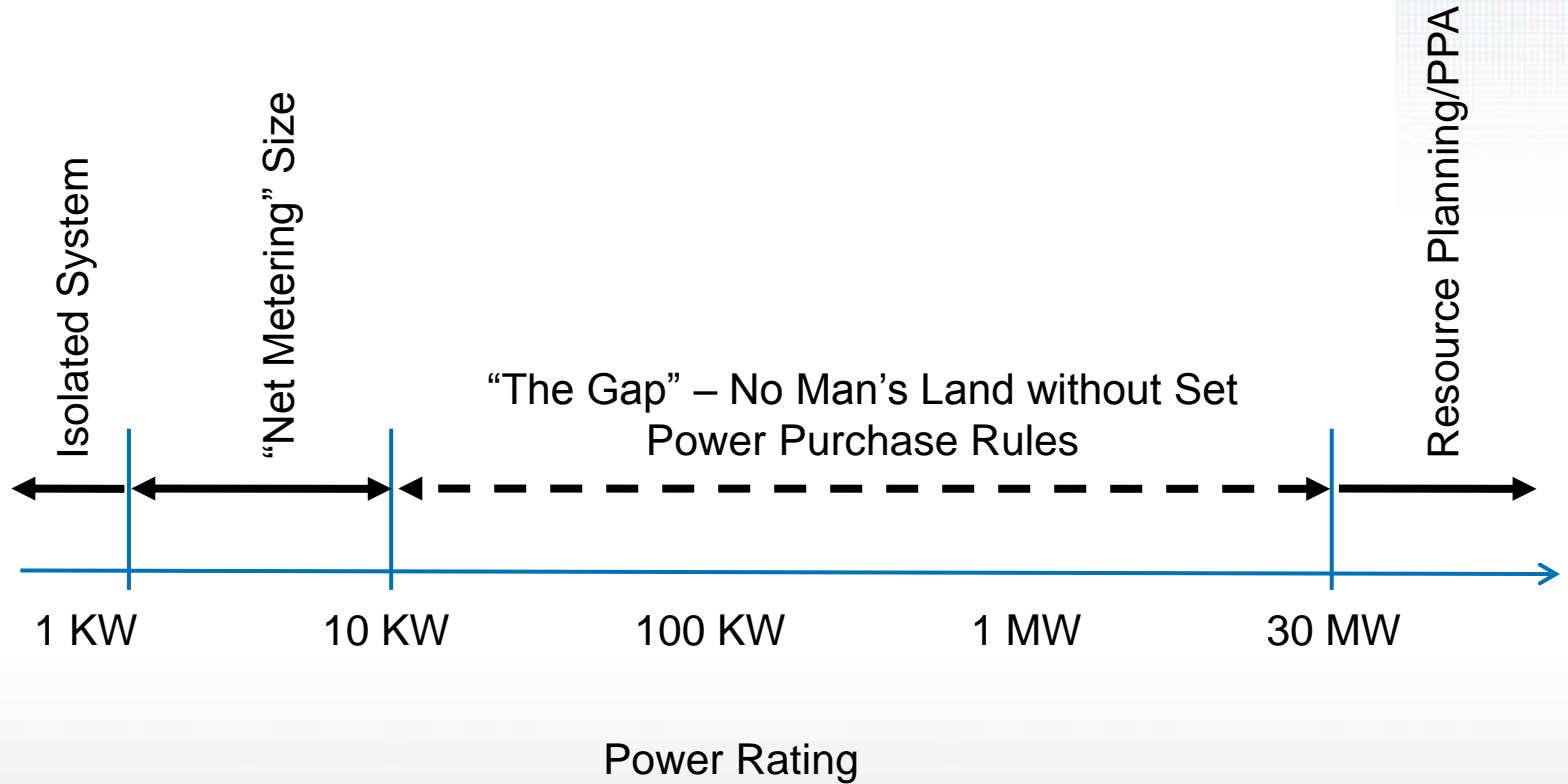


Interconnect Choices & Costs



First St Drop 450kW
This would require a 500KVA 3 phase pad mount transformer. Closest 3 phase is in First St (26 Rd).

Power Purchase Treatment



What's Next

- Complete field survey
 - Only NE Colorado left
- Summarize data & publish
- Investigate standardization
 - Identify promising site types
 - Can a common system be developed for many sites?
 - Is electrical interconnect practical?

Thank You

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