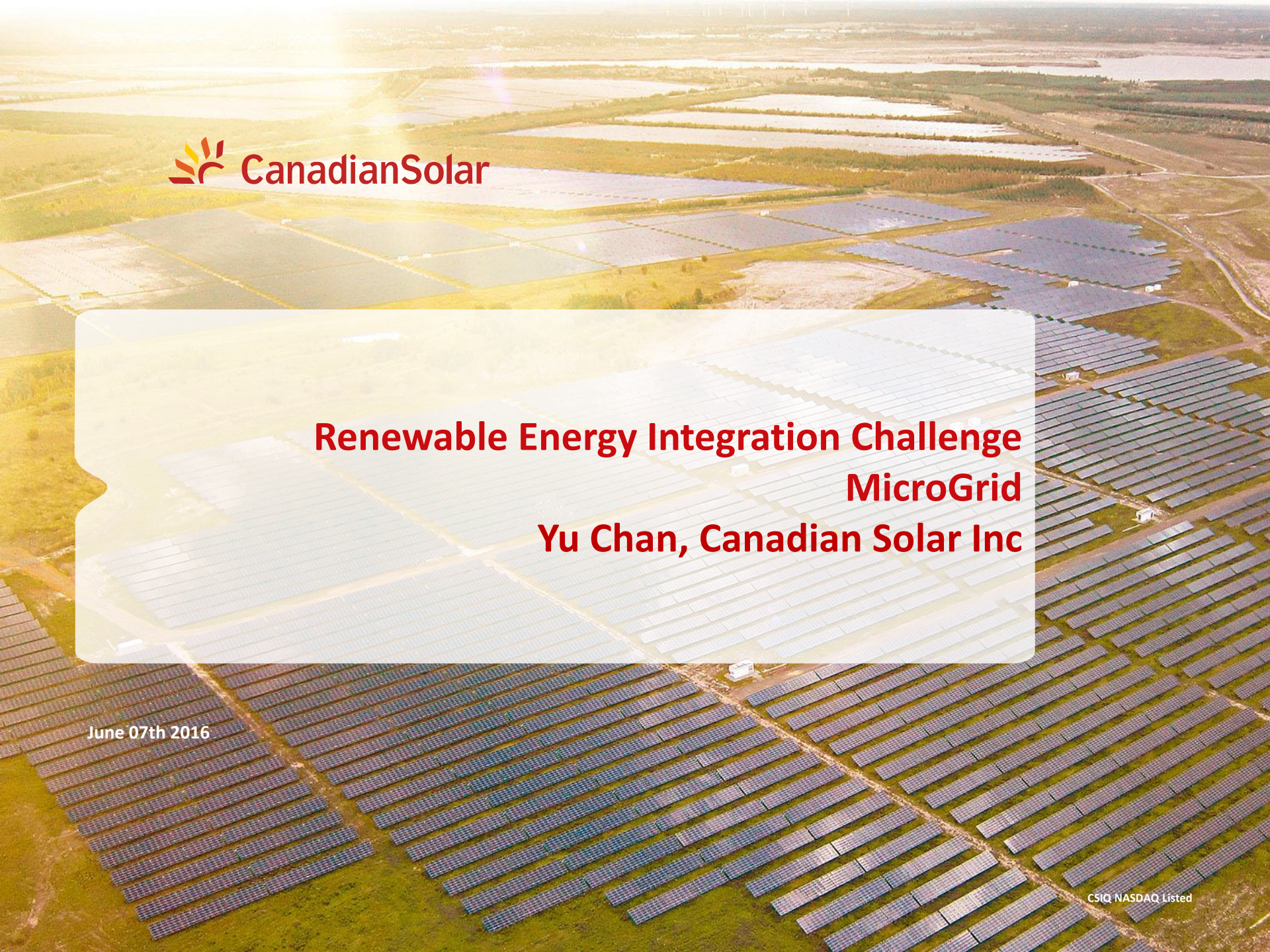


CanadianSolar

Renewable Energy Integration Challenge
MicroGrid

Yu Chan, Canadian Solar Inc

June 07th 2016

CSIQ NASDAQ Listed

Company Overview

- Founded in Ontario, 2001
- Listed on NASDAQ (CSIQ) in 2006
- Over 8,000 employees globally
- Presence in 18 countries / territories
- > 13 GW of solar modules shipped cumulatively
- > 1.8GWp solar power plants developed, built and connected (incl. Recurrent)
- Yield Co expected to be launched in the quarters ahead
- **Top 2 solar company by MW shipped, revenue and profits in 2015***

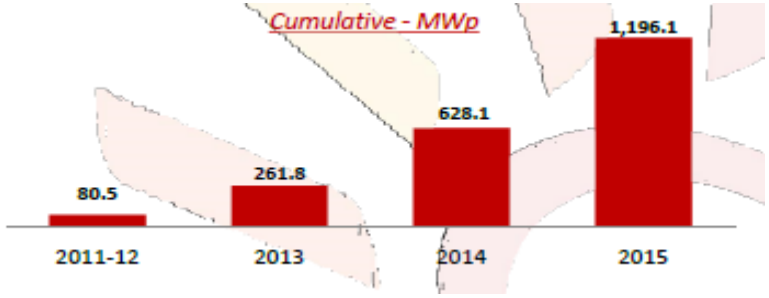
Global Footprint and Brand

Highlights

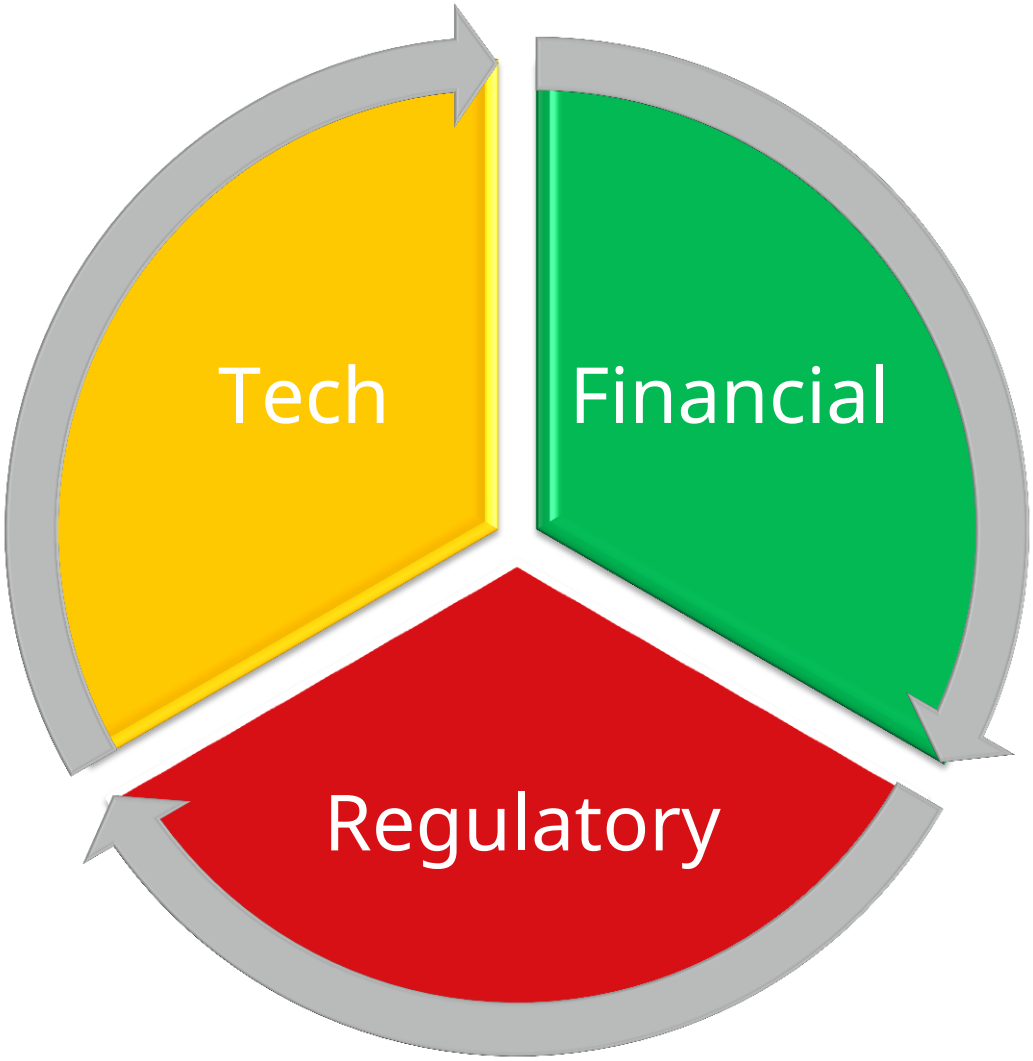
- 2015 Revenue: **$3.5 Billion**
- 2015 Shipments: **4.7 GW**
- 2015 Net Income: **$172 Million**
- 2016 Shipment Guidance: **5.4 – 5.5 GW**

*Source: Factset, company analysis

Solar Power Plants Built and Connected



Major Challenges



Financial Challenge: Bankability of the Project

Return

- Is the return on investment attractive? ROR %
- What would be the revenue generated? Excess Energy paid by Utility?
- Generate stable cash stream?

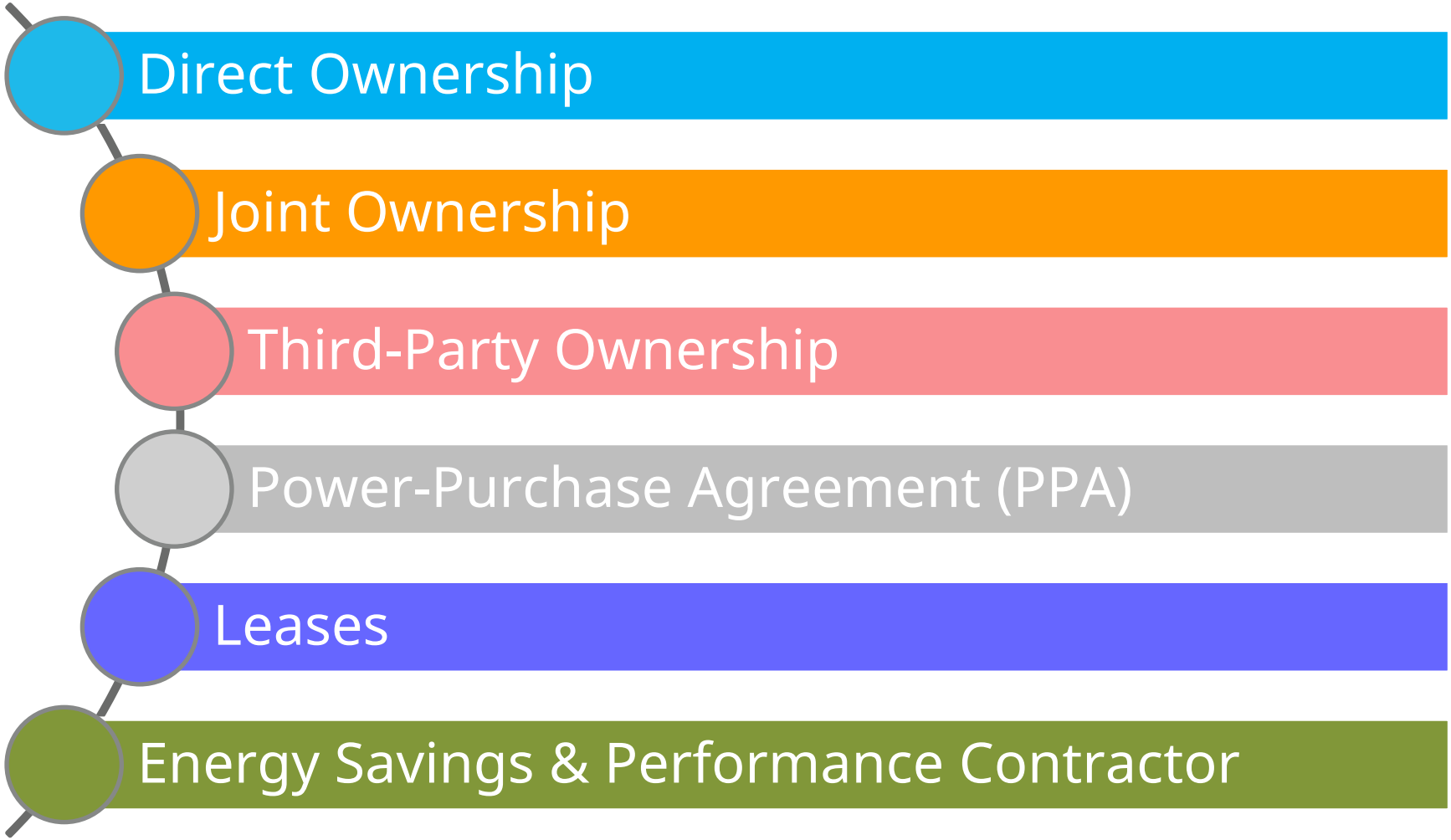
Risk

- What risks to take and how much?
- Proven track record on the selected technology, EPC, JV-partners?
- Is there sufficient measure to mitigate the risk?
- Stable Country Credibility rating, forex forecast?

Viable

- Large enough to attract institutional investors?
- Any other external factors might impact the development of the Microgrid system?
- What is the off-taker?

Financial Challenge: Ownership Structure

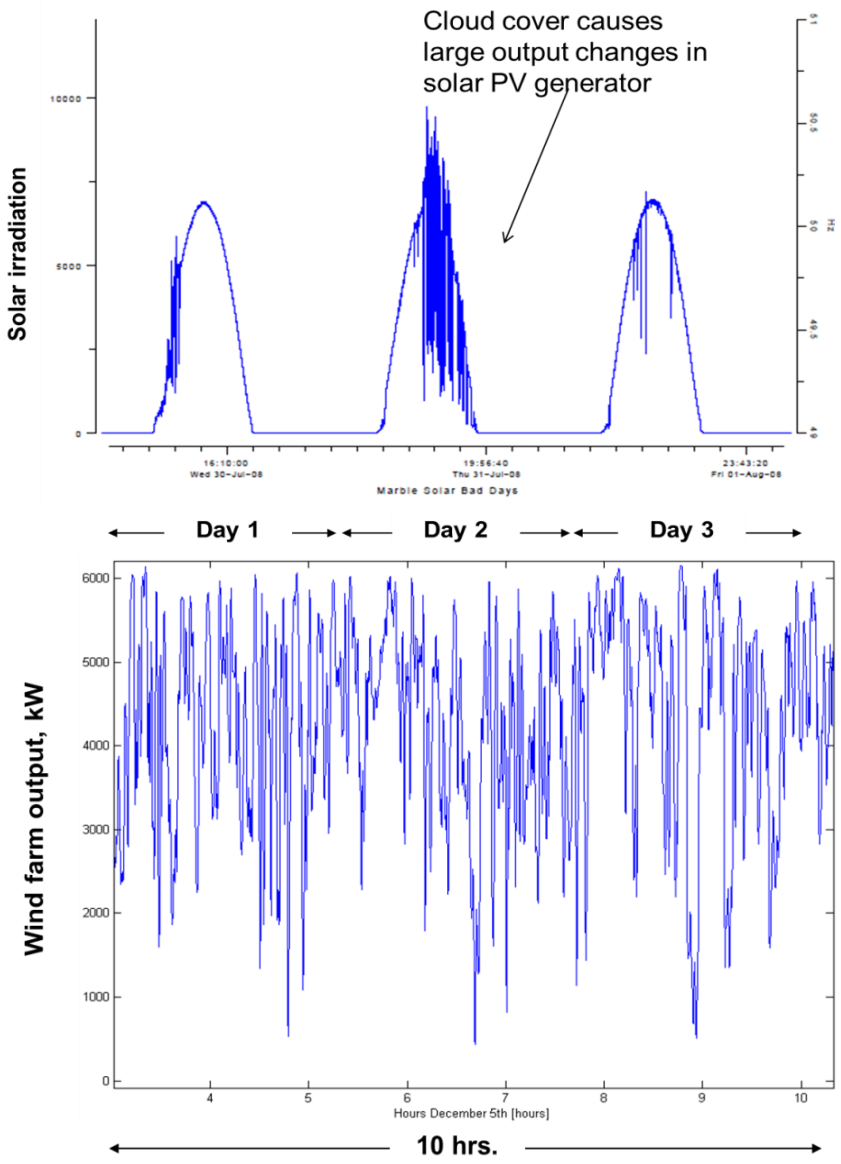


Financial Challenge: Funding Vehicles

Structure	Potential Advantages	Potential Disadvantages
Equity	No impact on debt profile	Potential future capital constraints
Debt	Fast, drawable options	Higher rates, on-balance sheet
Operating Leases	Tax benefits, low transaction costs	May require on-balance sheet
Capital leases	Tax benefits, low transaction costs	On-balance sheet

Source: Siemens_Deep Dive on Microgrid Financing, Nov 2014

Tech Challenge: Managing Renewable Power Output Fluctuations



- Inherent volatility of renewable energy can compromise grid stability
- The renewable energy integration solution must address requirements traditionally fulfilled by diesel generation (base load)
  - Frequency and voltage control
  - Sufficient spinning reserve
  - Sufficient active and reactive power supply
  - Peak shaving and load levelling
  - Load sharing between generators
  - Fault current provision
- Renewable energy generation capacity should be sized to maximize ROI and fuel savings

Tech Challenge: Integration & Enabling Technologies

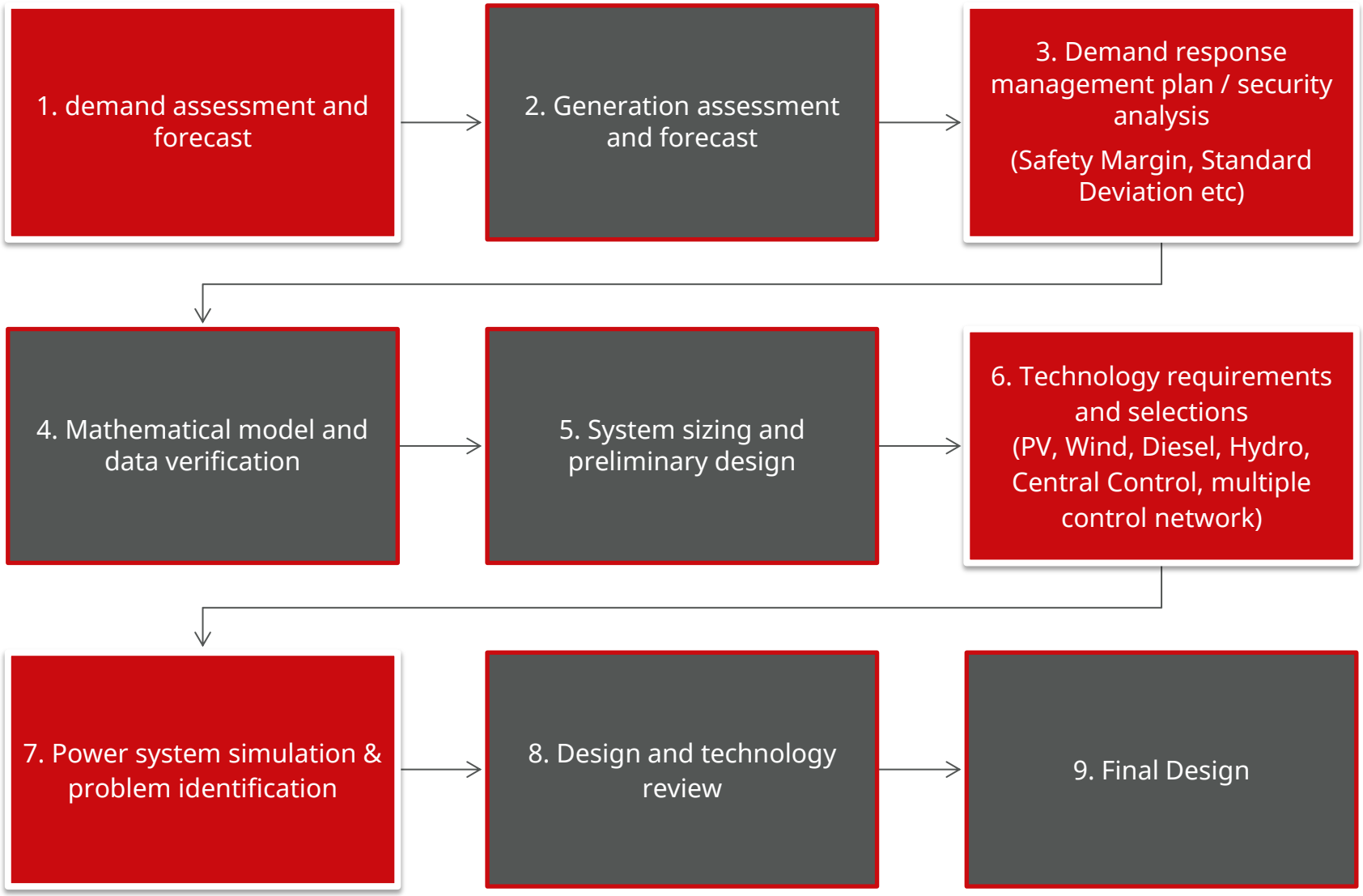
MicroGrid Integration Technologies	Average Renewable Energy Contribution	Maximum Renewable Power Penetration
No integration technology	7 - 10%	20 – 30%
Power control & Optimization (GEN+RE)	10 - 15%	20 – 50%
Microgrid stabilising (high power; low energy)	25 - 40%	100%
Power control & Optimization (Gen+RE+Load)	60 - 80%	100%
Energy storage (low power; high energy)	100%	100%

Note: Percentages vary between wind/diesel and solar/diesel Energy contribution is the measure for fuel savings

Tech Challenge: Grid Stabilizing versus Energy Storage – Applications Integrating RE

	Application	Time Frame	Energy	Power
1	Standalone (diesel off)	millisec	low	high
2	Stabilize (f,V support)	seconds	low	high
3	Statcom (Power Quality)	seconds	zero	high
4	Spinning Reserve	seconds/ minutes	medium	high
5	Smoothing (Renewable Energy)	minutes	medium	medium
6	Shaping (Peak Lopping)	minutes/hours	medium	Low
7	Shifting (Load levelling)	hours	high	low

Tech Challenge: Design Steps for Microgrid



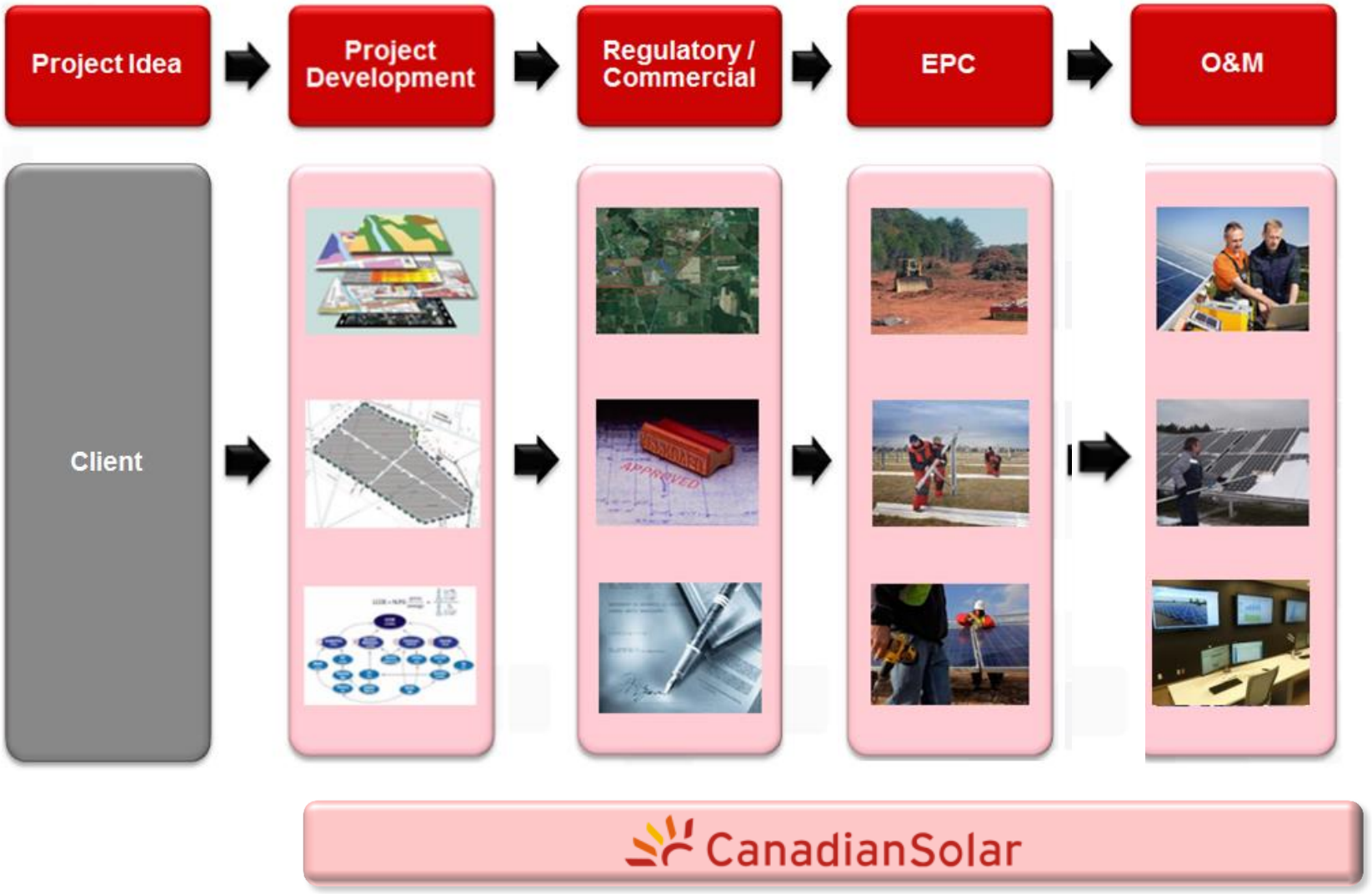
Conclusion

- Good acceptance and support from the public, and efficient permitting process.
- Fix first the network and distribution problems; generation at point of losses.
- Not enough bankable off-takers and no long-term PPAs → direct PPAs enable growth, i.e. Public Transport or Councils.
- Increasing corporate social responsibility and sustainability targets of companies are important drivers.
- New business models will emerge (game-changers)
- Solar is affordable now and happening
- And yes, we're ready … and yes, we can deliver and move forward very quickly.

Why Canadian Solar?

- A Bankable Partner
- Tailor made technical solution with high flexibility on Financial and Business models
- In-house Microgrid research and development lab in Canada Headquarter
- A Strong global reputation with trusted top tier tech solution provider
- Highest PV Module quality in the industry
- Global warranty provider with local/regional office support

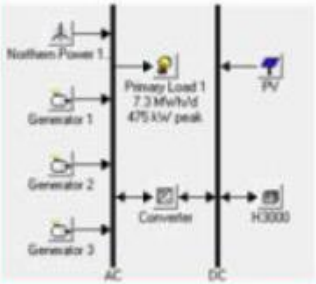
CSI MicroGrid One-Stop Shop Service - Turnkey



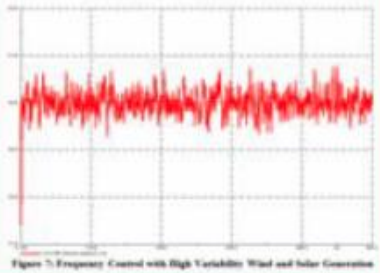
CSI MicroGrid One-Stop Shop Service – Power Analysis & Verification

Community Energy Plan including load long term planning, conservation, efficiency and demand response opportunities, and local wind and solar resource evaluation

Static Power System Sizing and Feasibility Study



Dynamic Power System Feasibility Study and System Sizing fine Tuning



Design Validation at the Renewable Energy (RE) Testing Centre

System EPC and Commissioning

MicroGrid Test Centre Services

Hardware Simulation Services | **Software Simulation Services** | **System Analysis and Design Services**

----What will MTC offer?

- MTC will focus on micro-grid solution testing, and system solution design and smart grid assessment services.
- MTC will allow to simulate proposed smart microgrids with their unique characteristics under near real life conditions verifying steady state and dynamic performance including stability, reliability, power quality and safety of the microgrid system in both islanded and grid connected modes.
- MTC offers dynamic simulation, system analysis, and modelling service which finds the optimal system, energy storage sizing, control system strategies, using the Canadian Solar MTC simulation package developed in PSCAD, for both islanded and grid-connected systems.
- The results of this testing will provide confidence to utilities, investors, and CSI to support smart grid technology and systems implementation and to facilitate field testing.

- Energy planning
  - Modeling
  - Real/historical data
  - Analysis
  - Energy Sizing

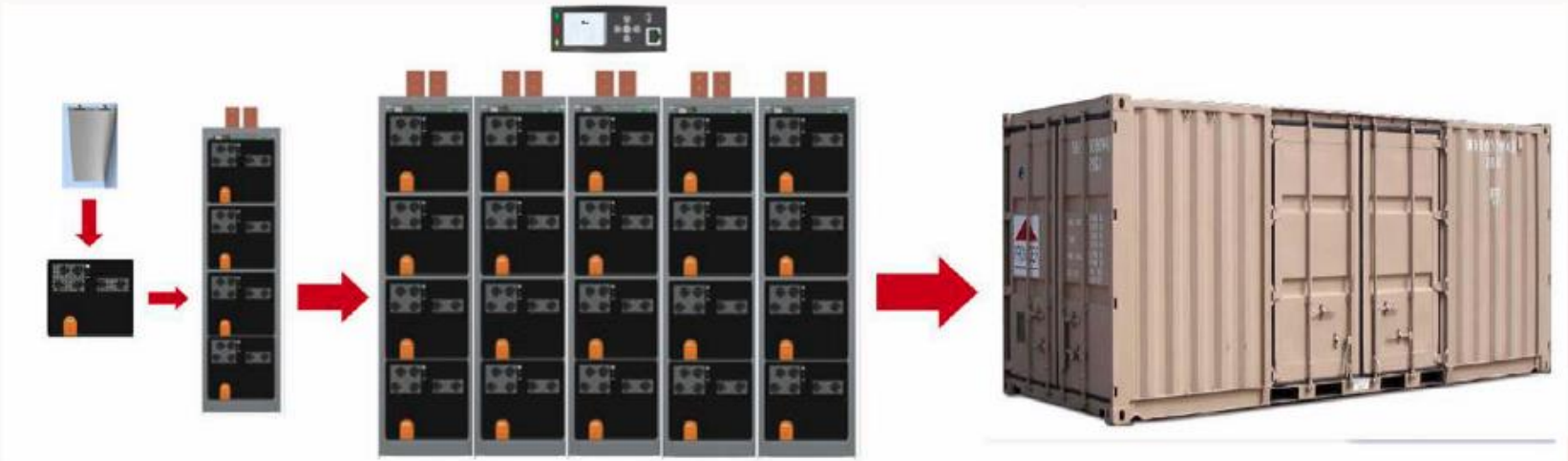
- Dynamic analysis
  - Modeling & Development
  - Validation
  - Analysis
  - Power Sizing

Energy Planning Software
- HOMER
- PVSYS
- MATLAB

Power System Analysis Software
- PSCAD/EMTCP
- MATLAB

CSI MicroGrid One-Stop Shop Service – Energy Storage

- CSI is using proven technologies in a unique architecture which is not only viable but superior to that offered by most energy storage providers
- The unique benefits that CSI offers comes from the leverage of other mature and stable applications to ensure that the energy storage systems are reliable, cost effective, and efficient
- Higher energy density and system efficiency
- Commissioning, preventative maintenance, software upgrades and user interface thru PC, tablet, mobile phone or network operating center provides 24/7 visibility and flexibility



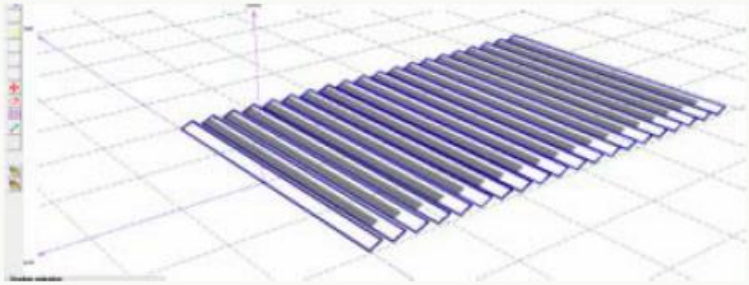
Module	Rack	BESS Sub-system (self-contained)	BESS Container
- 900V, 15A - 12.8kW - 10.24kWh	- 900V, 75A - 64kW - 51.2kWh	- 900V, 370A max. (Controlled by an M1000) - 320kW - 256kWh	- 900V, 1650A max. w. 5 individual outputs - 1,400kW - 1,126kWh

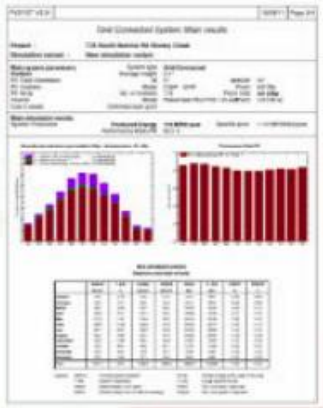
Our Capabilities - Globally

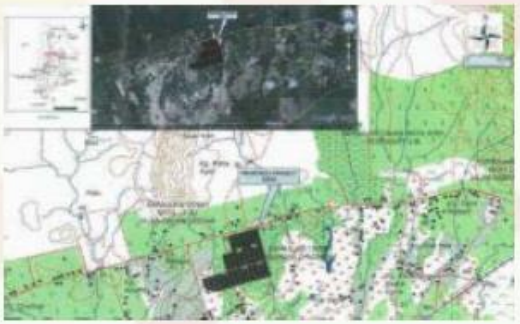
What Does Our Experienced International Team Offer?

Consulting / Planning / Development

- Support in feasibility study, project due diligence and pre-engineering together with technology selection.
- Energy yield assessment (available tools: PVSyst, PVSol, RETScreen®).
- Support in viability assessment and financial modeling.







Selected Diesel Hybrid Projects: First Nation Communities

Deer Lake First Nation School, Ontario
Size: 150 kW
CSI Role: Project Developer
Status: Commercial Operation Q1, 2014

Selected Utility Scale Energy Storage Projects: IESO

- 4MW/2.76MWh Li-ion battery storage for frequency and voltage support.
- Purpose is to provide Bulk Energy Storage and Reactive Power Support to the Independent Energy Supplier of Ontario - IESO
- Commission in Q3, 2016.


CanadianSolar
THANK YOU
yu.chan@canadiansolar.com