York University
Joint Special Lecture
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Lecture Leaders

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FACC 6885 Blockchain Course

Masters in Financial Accountability Program York University

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- Executive Leadership
  - Compute Canada
  - Ontario Society of Professional Engineers
  - Ontario Research & Development Challenge Fund
  - Digital Power Networks
  - COS Computer Systems
  - Booz Allen & Hamilton
- Experience
  - Advanced computing, HPC, AI, Big data
  - Data Centres, Energy-efficiency
  - Power Grid, Smart Grid, Reliability
  - Enterprise IT and Infrastructure
  - Communications technologies (Fibre, Satellite, Cellular)

Lecture Objectives

Resolutions:

Be it resolved that Alectra Board approved $10 million to implement a blockchain solution for electric supply (“BIRT”) ;

That Farmer Hall be allowed to establish a blockchain micro- grid

Strengths, weaknesses ,opportunities and threats (SWOT) of the proposal

Issues

- how do we:
  implement integration of local energy positive geographies
  flexibility adaptations
  decision-making
  local distribution utilities
  "*behind the meter*" issues
  regulatory issues
  business models
  how to generate revenue stream ?
  which blockchain?

Blockchain Background

Blockchain Definition

Think of blockchain as a type of database

structured collection of information

- Blockchain refers to a specific type of database that uses certain cryptographic functions to achieve the requirements of data integrity identity authentication
- Since blockchain commonly tracks transactions they are often referred to as ledgers

What is Blockchain ?

- Distributed ledger technology (“DLT”)
- *Block*
- #1- initial tranche
- Link two blocks (a “chain of blocks”)
- Reference to previous block
- Cannot reverse (immutable)
- Decentralized

What is a *Block*?

- A block consists of two parts:

a block body containing the transactions that the block records

the block header include the hash of the previous block and some metadata such as a timestamp

Distributed Ledger Technology (DLT)

Distributed ledger technology (DLT) refers to a ledger that is stored in a distributed manner across a peer to peer network

A distributed ledger (DL) is also a blockchain if it uses a blockchain data structure to record transactions

However, a blockchain that is stored in a centralized manner is not a DL because it is not distributed

Data Integrity and Hash Values

To create a persistent tamper evident record of relevant transactions

Identity authentication:

Public key infrastructure
to authenticate the party or parties associated with each transaction

Blockchains can be applied in a variety of ways to create platforms with different properties and features

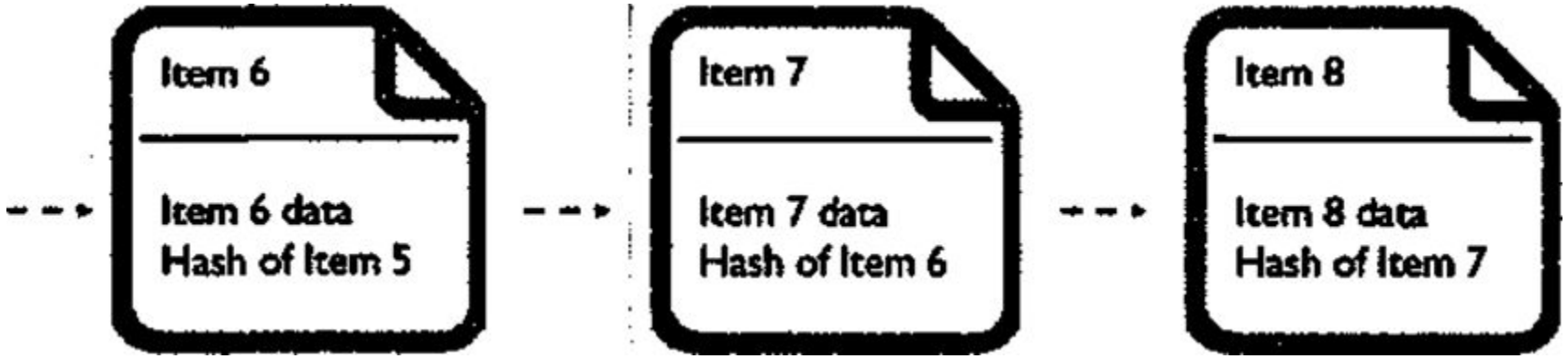
As blockchain technology is adopted for purposes other than currencies the early requirements may not necessarily be carried forward

Closed or permissioned systems

participation is limited to certain groups of approved users
in such cases there is a higher level of trust among users reducing the need for distributed storage and consensus protocols

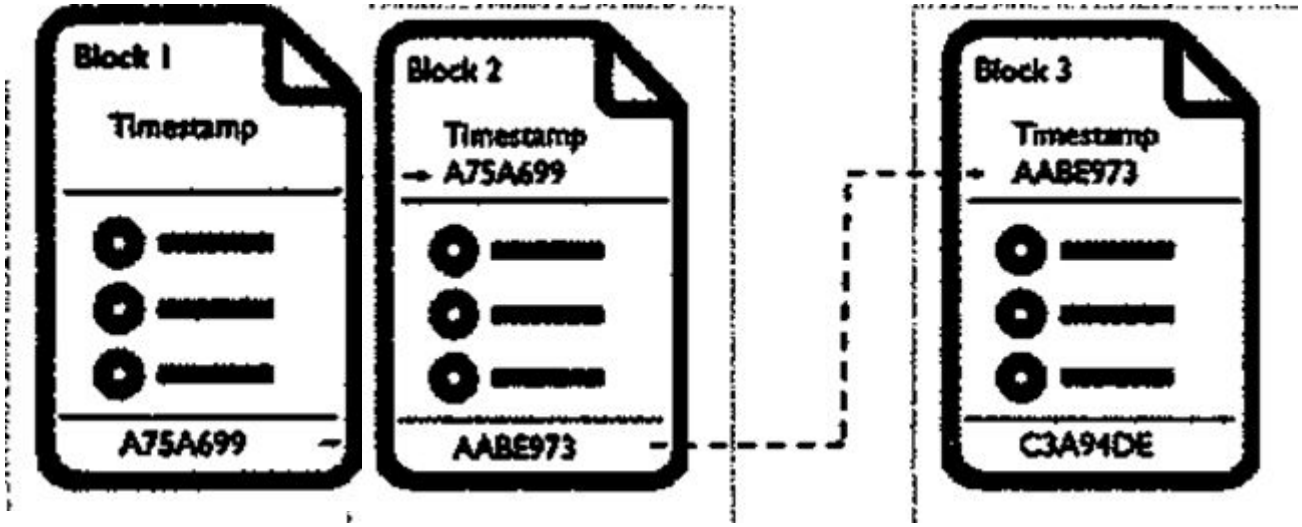
Hash Function Outputs a Hash Value= AABE9739FA699

Tamper Evident Chain of Items Using Hash Pointers



Simple Blockchain Representation of Three Chained Blocks

Source:gers/https://jolt.richmond.edu/blockchain-demystified-a-technical-and-legal-introduction-to-distributed-and-centralised-led



Ethereum

A general purpose DLT platform call the Ethereum was launched in 2013

It allows any type of digital asset to be defined created and traded

It also enable smart contracts which allow a DLT to execute the terms of a contract automatically providing more functionality than simply transferring one specific type of asset

[Source: BUTERIN 2013]

"Vitalik" Buterin inventor of Ethereum (ERC 20 Blockchain code for developers)

•Vitaly Dmitriyevich "Vitalik" Buterin is a Russian-Canadian programmer and writer primarily known as a co-founder of Ethereum and as a co-founder of Bitcoin Magazine.

·Founder "Etherium Foundation" https://ethereum.org/

·**Born**: January 31, 1994 (age 26 years), Kolomna, Russia

·**Award**: Thiel Fellowship

·**Education**: University of Waterloo (2012–2014), Abelard School, University of Waterloo

·**Nationality**: Canadian, Russian

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Smart Contracts

Smart Contracts

Definitions and features

What are smart contracts?

The benefits of using smart contracts

Enforceability

What is a Smart Contract?

- Definition:

computer code embedded on a distributed ledger technology that incorporates all or part of a legal agreement and self executes when a set of predefined terms and conditions are satisfied

Another Definition

Computer programs that enable automated execution of an agreement between consenting parties once conditions are met with little to no human intervention

Why is a Smart contract *smart*?

- *smart* refers to the execution of a contract being *automatable*
- there must be some extent of self- operating or self conclusion without the need for third-party validation or intervention for the contract to be considered smart

A Vending Machine is a Smart Contract

- a vending machine is an automatic machine that provides certain goods and services in exchange for payment
- vending machines are programmed with certain rules and conditions that the finding that could be defined as a contract if the conditions are met then it performs the outcome,
  - e.g. if I have the required currency to buy a good and a vending machine and it automatically executes the transaction

What is not a Smart contract?

- Smart contracts do not adapt and learn (intelligent) (You replace with a new SC)
- Smart contracts may require off the blockchain data as input to execute the transaction
- Example: Environment Canada determines that there has been a heavy snowfall which automatically triggers an insurance payment from an insurance company

Loss and damages in law arising from Smart Contracts

- Courts need to consider that smart contracts raise issues of conventional loss
- if a Smart contract is a record of terms of legal contract for the implementation of a legal contract when should the legal contract be enforceable when are smart contracts against public policy or contrary to statutes and what should the remedy be if they are
- the law about enforceability of contracts is not directly related to smart contracts because they are not contracts

Smart Contracts cannot deal with:

ambiguity

good faith

fair dealing

negligent

reasonable efforts

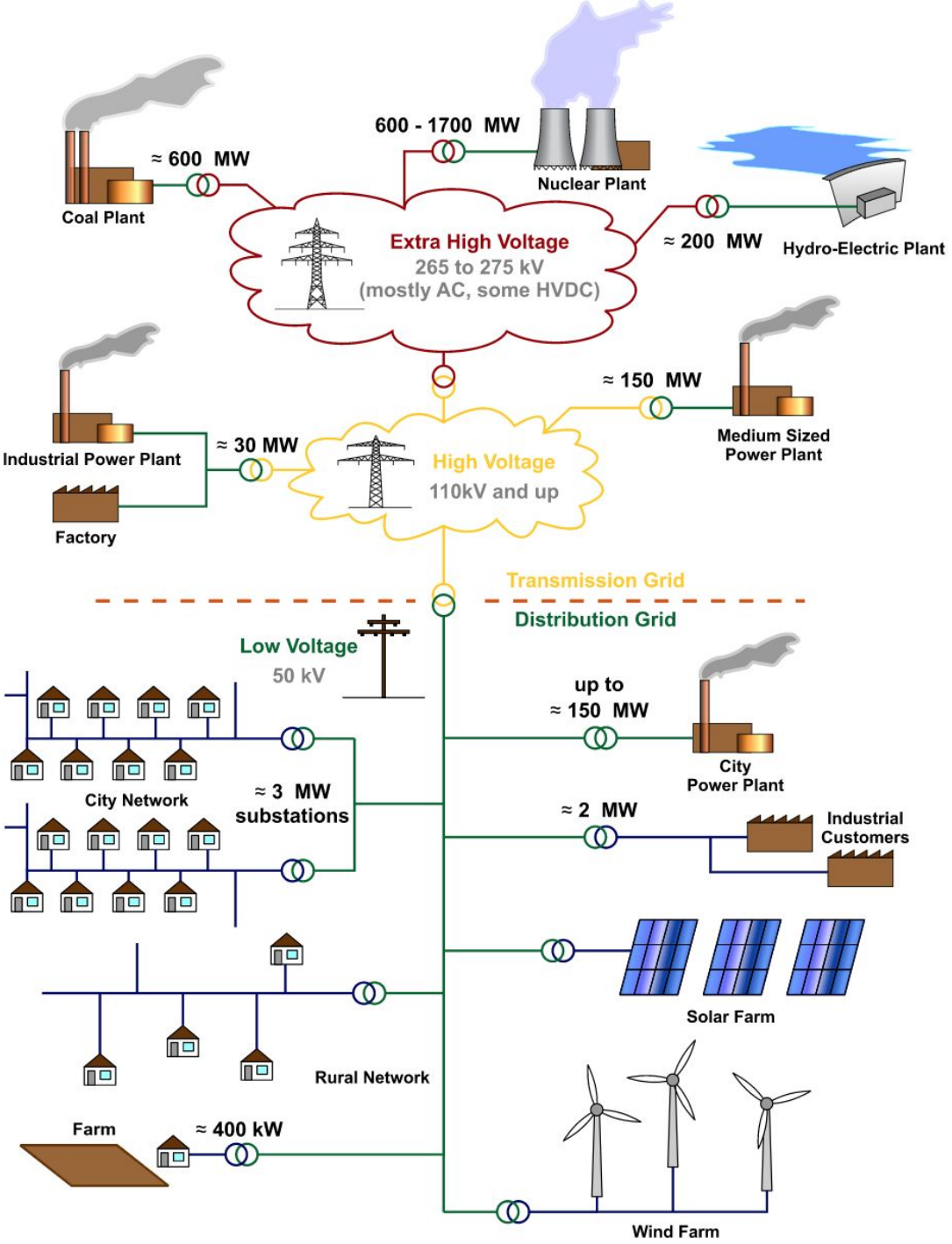
notice

Electric Power Market Background

Definitions

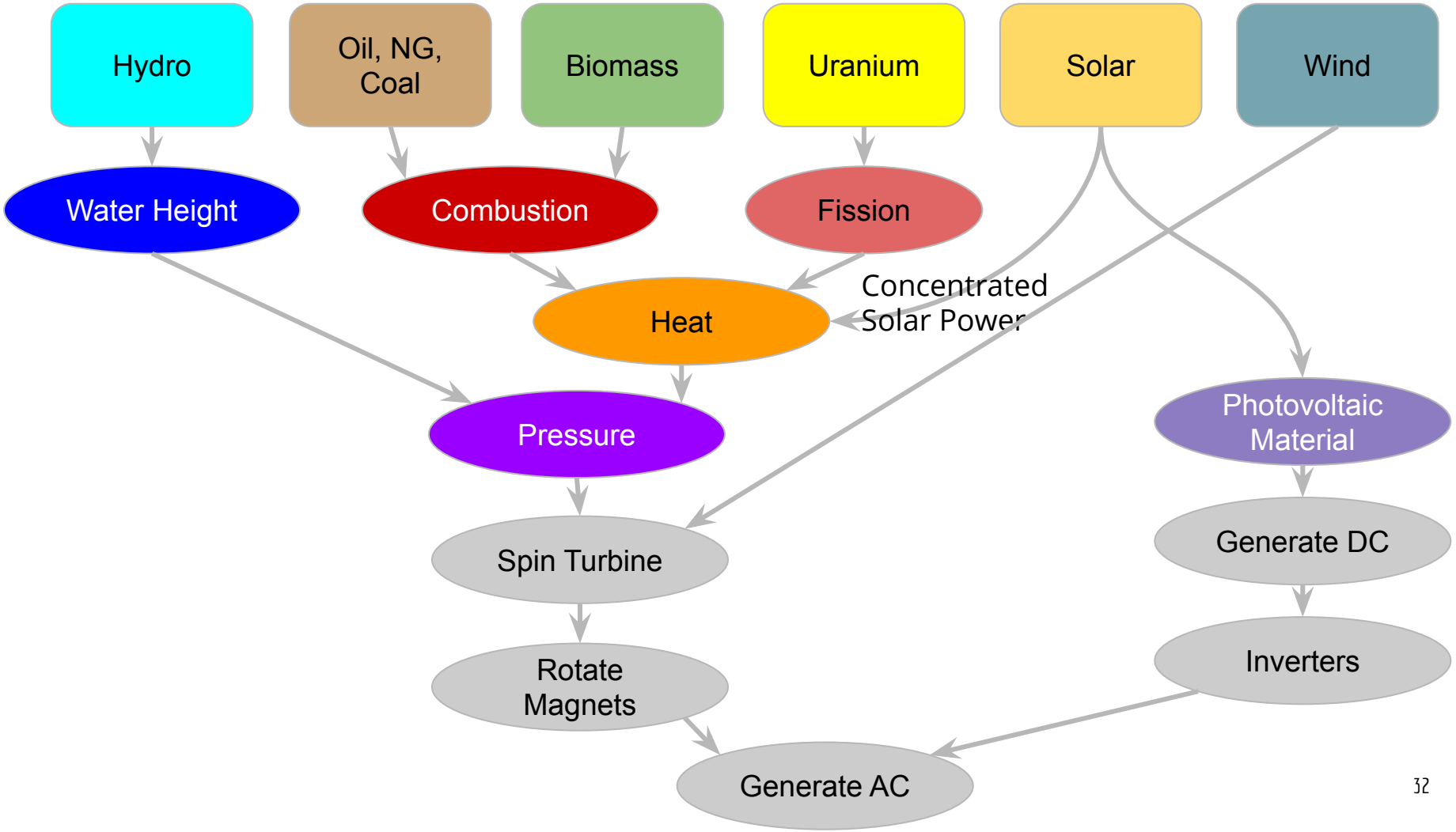
LDC: Local Distribution Company
W: Watt, unit of power
kW: kiloWatt (thousand W)
MW: MegaWatt (thousand kW)
GW: GigaWatts (thousand MW)
Wh: Watt-hour, unit of energy
W vs. Wh: power vs. energy -- analogy: speed (km/h) vs. distance (km)
EV: Electric vehicle (can include hybrids)
kV: kiloVolts (thousand V)
AC: Alternating Current

Electric Grid: Connects *Generation* to *Transmission* to *Distribution* to End Use

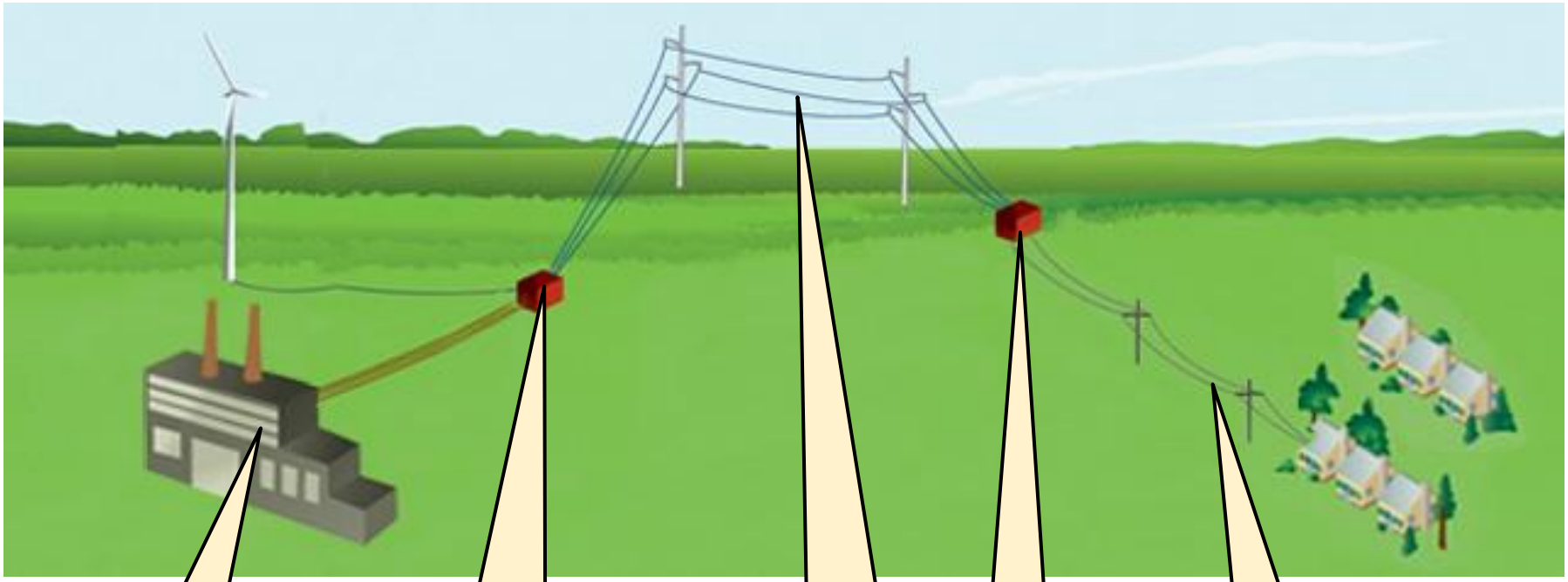


By MBizon - Own work Originally derived from de:Datei:Stromversorgung.png, CC BY 3.0, https://commons.wikimedia.org/w/index.php?curid=9676556

How do we generate electricity?



How do we move electric power?



Generators produce medium voltage (~13kV) alternating current

Step-up transformers increase voltage (100-500 kV) and reduce current (intensity of electron flow)

HV transmission lines carry current over long distances. Low current minimizes power loss.

Transformers lower voltage and increase current level.

Distribution lines (and switchgear) distribute power to users.

Image courtesy of American Transmission Company

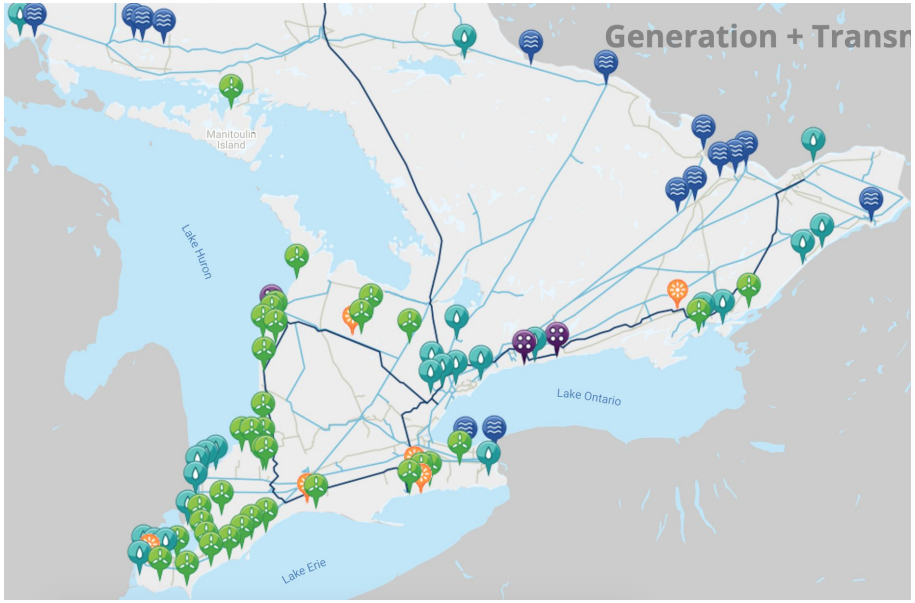
How is the electric power business organized?

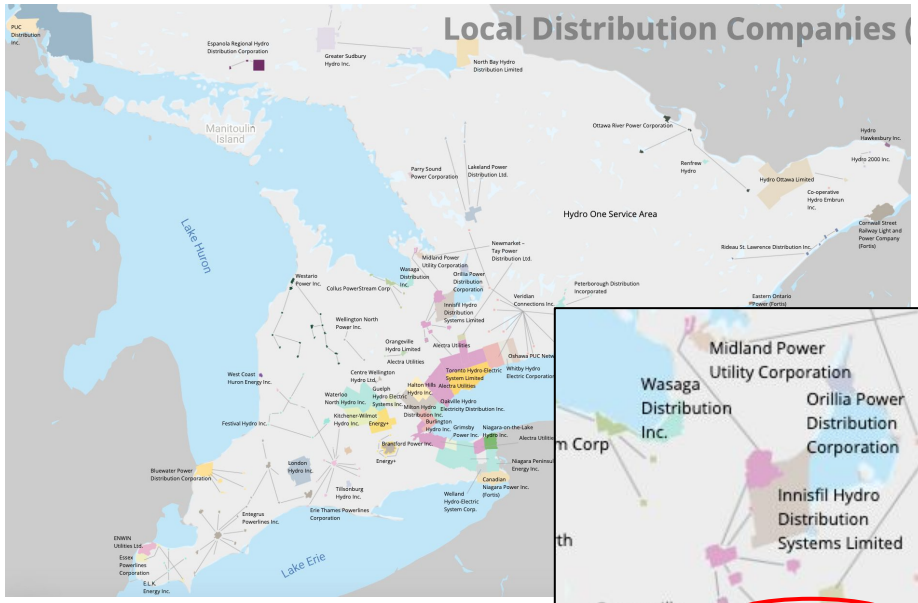
In the beginning, utilities were more local, and managed the full grid from generation to local distribution.

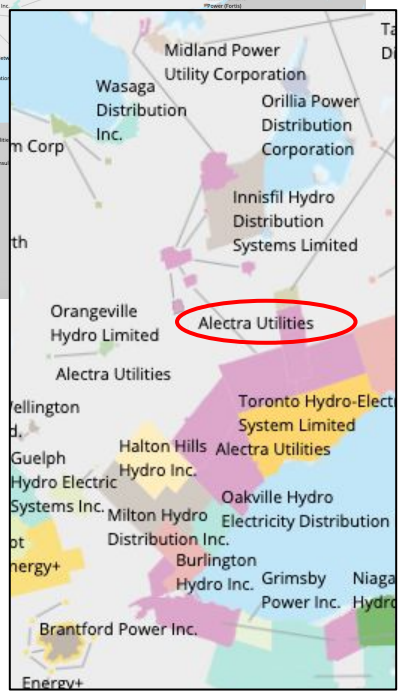
- Natural monopolies, therefore regulated.
- “Rate regulation” means that proposals to invest in new generation or transmission or anything were considered by bureaucrats to determine what “rate of return” the utility could earn on the investment.
- Utilities cooperated with neighbors to provide backup capabilities.

In the 1980s, deregulation prompted splitting integrated monopolies into Gencos, Transcos, LDCs, “marketization” off previously internal functions (e.g. HV power transmission). Power could be traded among utilities and large users. “Merchant” power plants were built to sell power to utilities. Coordinating the different parts of the system moved from an internal function to “System Operators” (like the IESO in Ontario). Regulation evolved from rate regulation to system coordination and planning for the future.

Ontario's Electricity Grid







Nuclear	Hydroelectric
Gas-fired	Wind-powered
Biofuel	Solar

All images courtesy of IESO

Does not include Distributed Energy Resources (DER) ~10% of Ontario generating capacity.

What happens when I turn on the microwave?

The electric grid is fully connected, so that incremental power comes from either

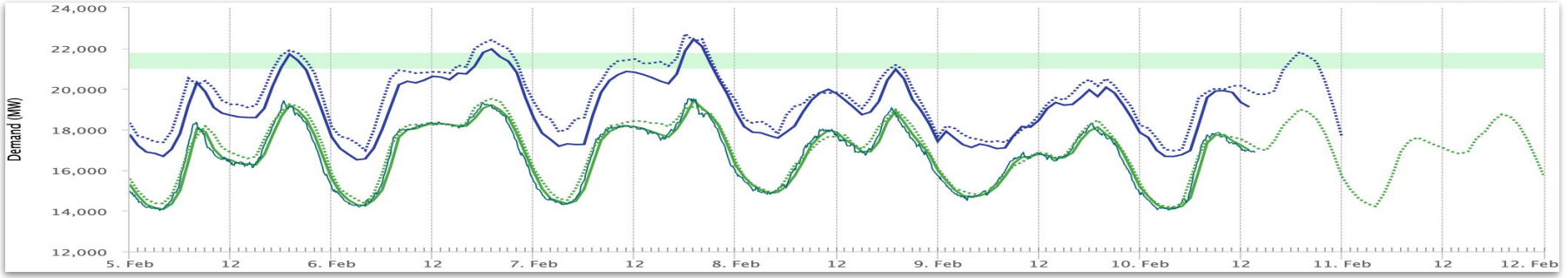
- Someone else turning something off, or
- Power generated somewhere -- perhaps 1000s of km away.
- VERY LITTLE capacity to STORE power (plus, it's ~5-10x cost of generation)

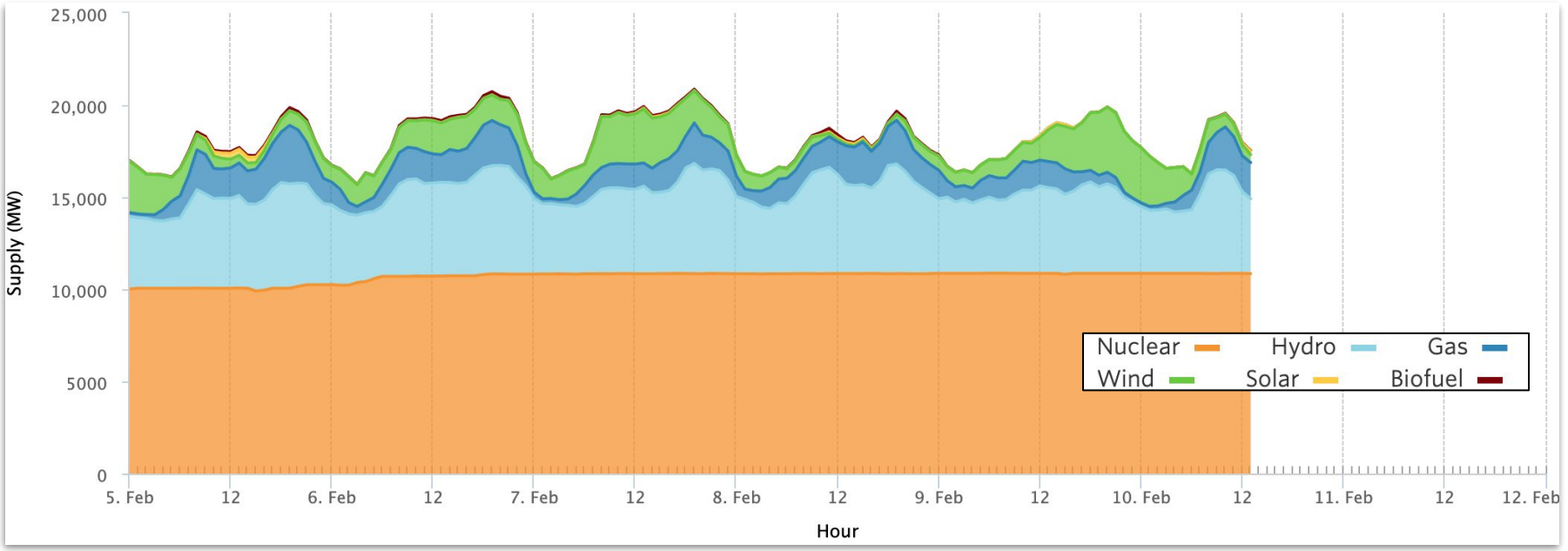
Historically* aggregate power demand averages out nicely hour by hour.

Utilities have built generation and transmission systems to match historical daily and hourly changes in power demand, balancing lower costs of generation with greater ability to follow demand.

- Nuclear: high capacity, lower incremental operating cost, slow to dispatch
- Natural gas: medium-capacity, higher operating costs, but quick to dispatch
- Renewables: low-capacity, zero operating cost, not really dispatchable (you can't make the wind blow or the sun shine)

Ontario Demand and Supply





All images courtesy of IESO

Limits on the power grid...

Generation/ Transmission/ Distribution built to handle historical demand peaks.

- If peaks exceed built capacity, demand is “curtailed”
  - Brownouts, Blackouts
  - Large users (e.g. arc furnaces in metal production) forced to shut down.
- Limited economical energy storage: can’t “time shift” loads off peak times
  - Offer smart meters to incent off peak energy use (e.g. time-of day pricing)
  - Add technology to allow utility to control equipment
- Yearly growth in energy use
  - “Demand SIde Management” cheaper than building new capacity.
- Customers want to generate their own electricity:
  - Large factories: co-generation plants (e.g. burning wood waste to generate power)
  - Community-based energy systems (district heating/cooling plus power generation)
  - Private Solar/Wind/Geothermal installations

Introducing Alectra, Ontario's largest LDC

Customers: ~1,000,000

Power delivered: ~26,000 GWh

Revenue: ~Cdn $600 million

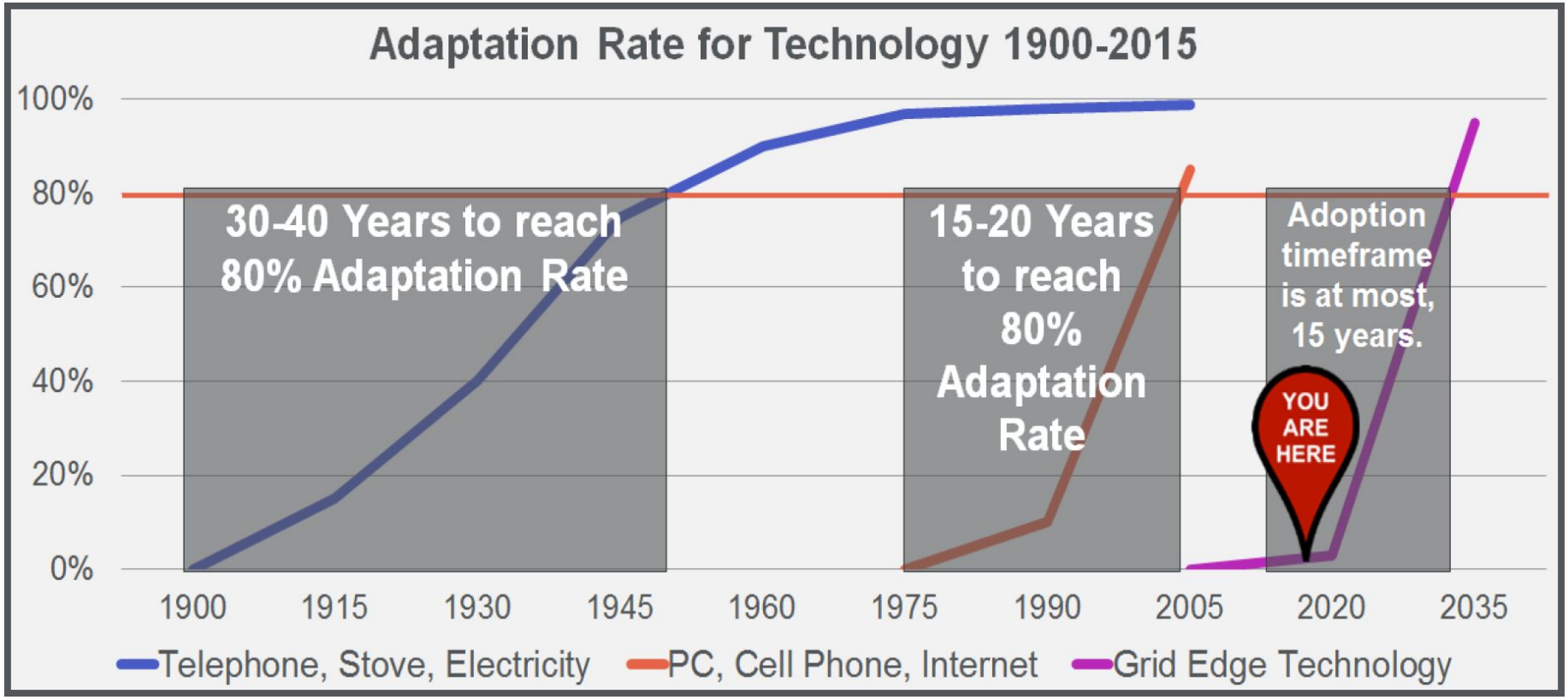
Net Income: ~Cdn $140 million

Shareholders: 7 Municipalities (Mississauga, Hamilton, Guelph, St. Catherine's, Barrie, Vaughn, Markham) + Borealis

"Role" Low-risk cash cow for shareholders

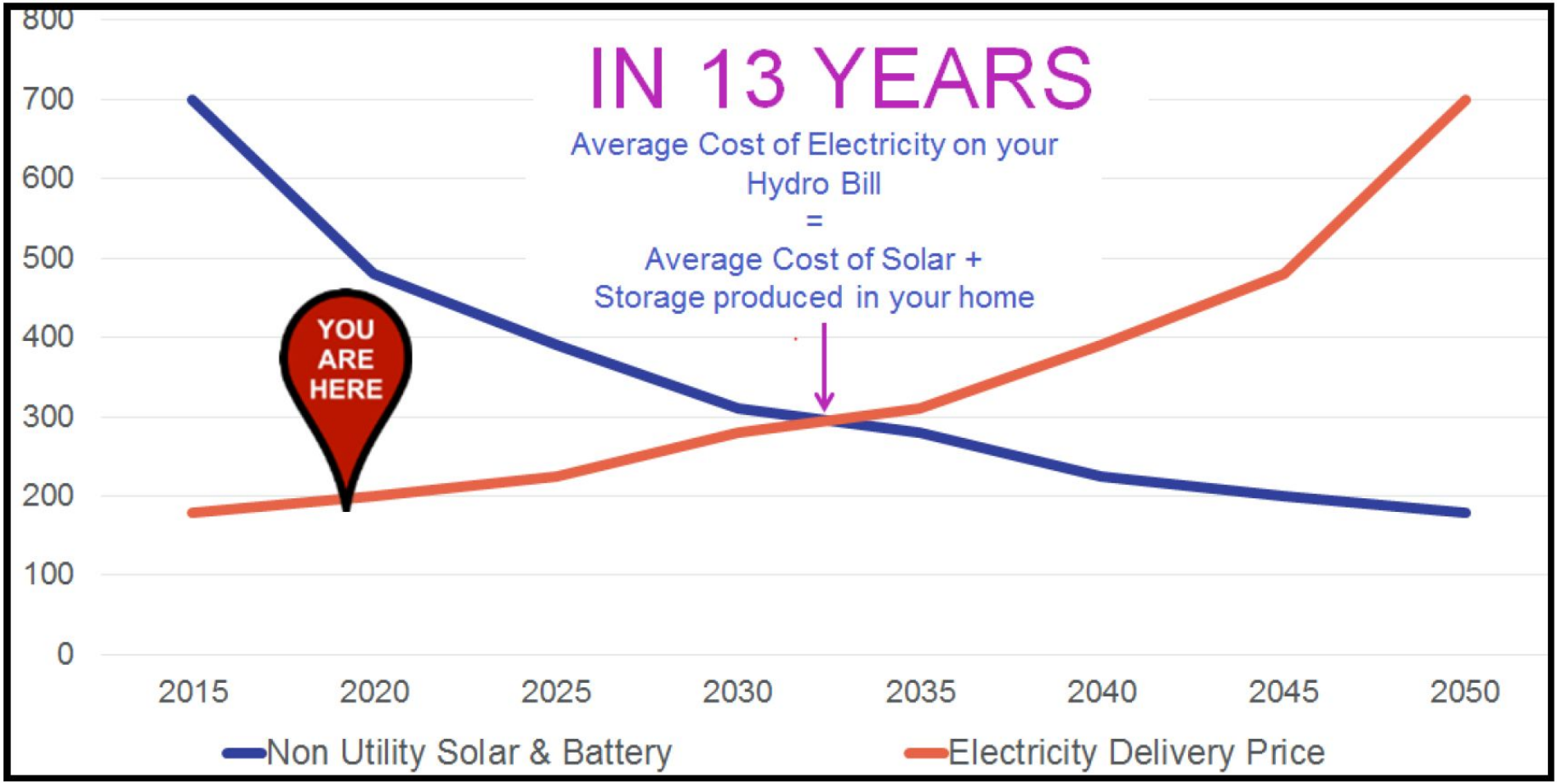
WHAT IS ALECTRA WORRIED ABOUT?

Alectra is worried about the future!



Source: Alectra 2018 AGM presentation

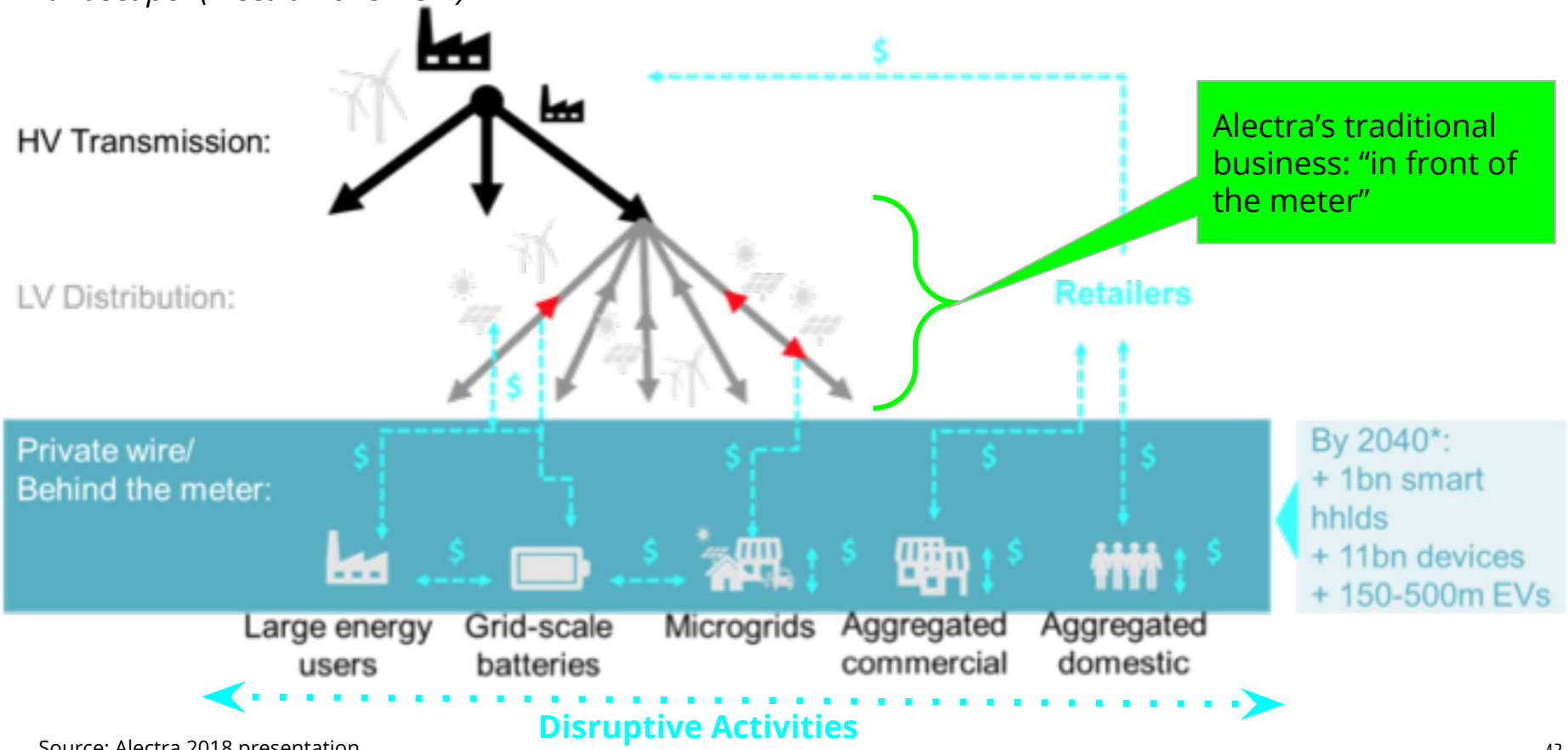
Alectra is worried about the future!



Source: Alectra 2018 AGM presentation

Alectra's strategy

"*Alectra is … focusing on the development of variety of microgrid solutions, including the use of Distributed Energy Resources ("DER") and energy storage, to meet the needs of the customers in the changing energy landscape" (Alectra 2018 AGM)*

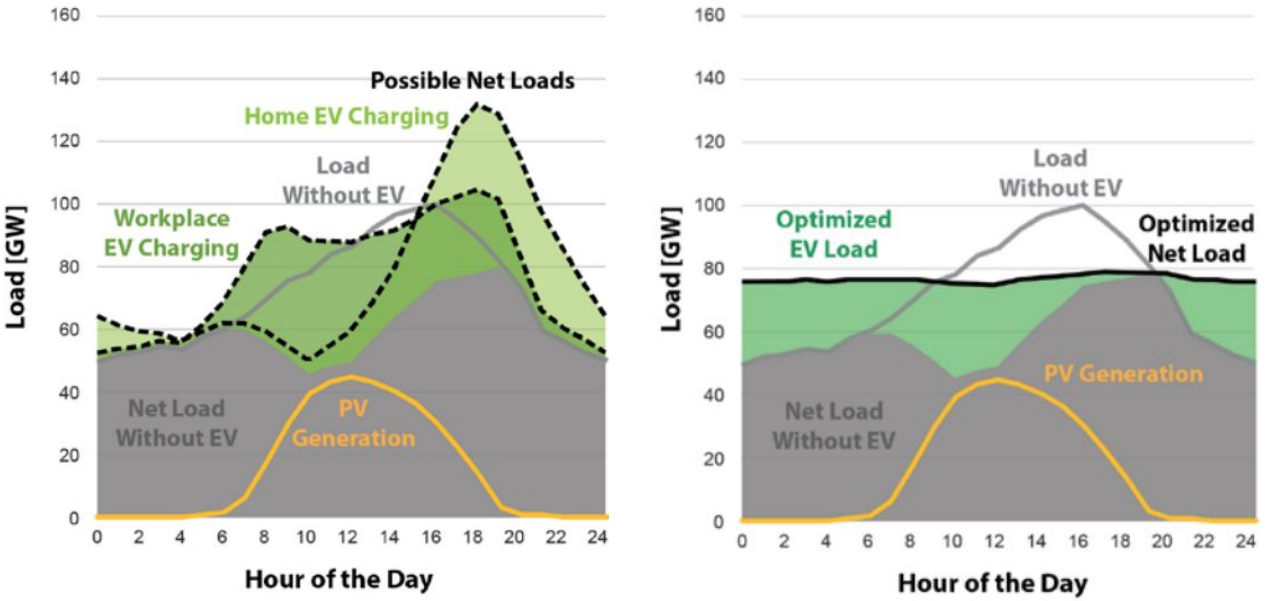


Source: Alectra 2018 presentation to IESO, Dietrich annotations

Disruptive scenario 1 (of many)

Electric Vehicles:

- If Ontario purchased EVs at ¼ the rate they do in Norway, 37,500 new EVs would hit the road. ~7,500 of those would park in Alectra's service territory -- looking for fast charging. Power demand could more than double, especially when everyone drives home and plugs in!



Projected Impact of EV Charging on Daily US Load Profiles

Graphs: https://www.nrel.gov/docs/fy18osti/71500.pdf.

Disruptive scenario 2 (of many)

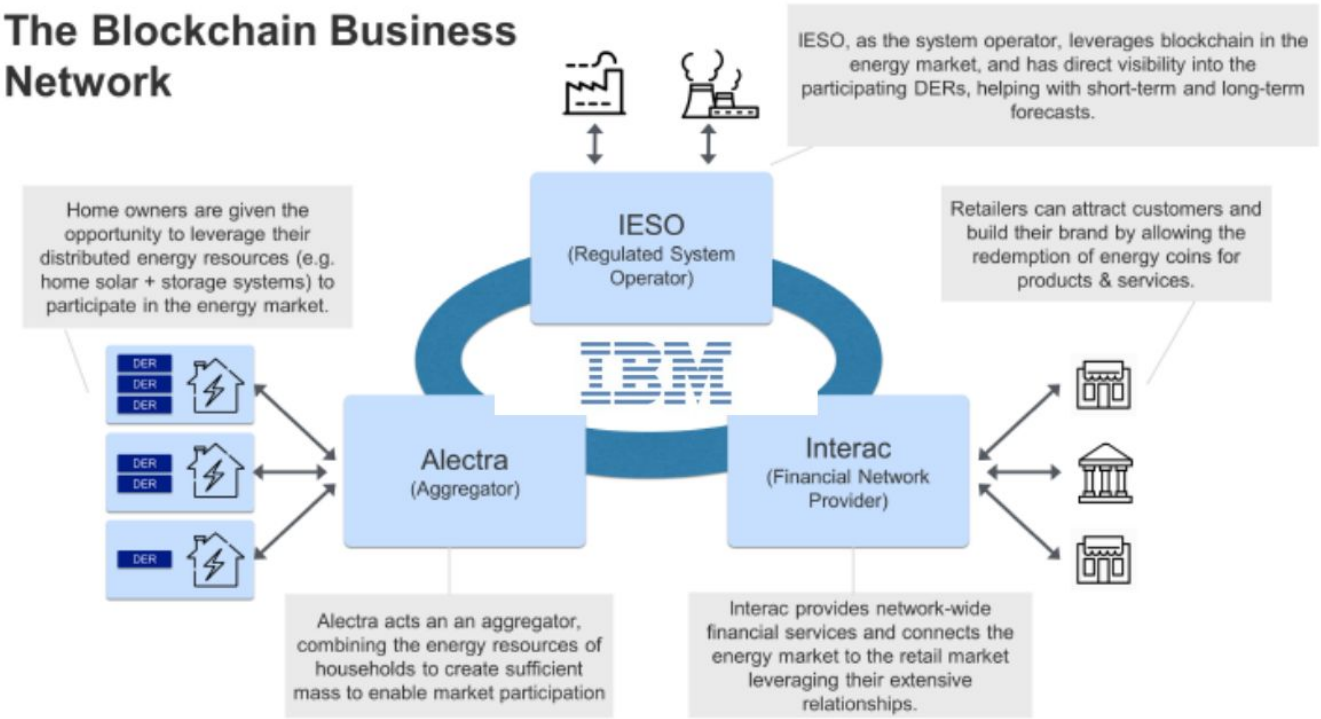
Dairy Cooperative

- A group of dairy farmers in Alectra's service territory want to form their own electric cooperative to share on-farm generating capacity (wind, solar). Their power demand from Alectra will go down significantly, while at the same time, they want Alectra to continue to support their farms (when the wind stops blowing).

How can Alectra get "ahead of" these scenarios?

Alectra's Blockchain Pilot (June 2018)

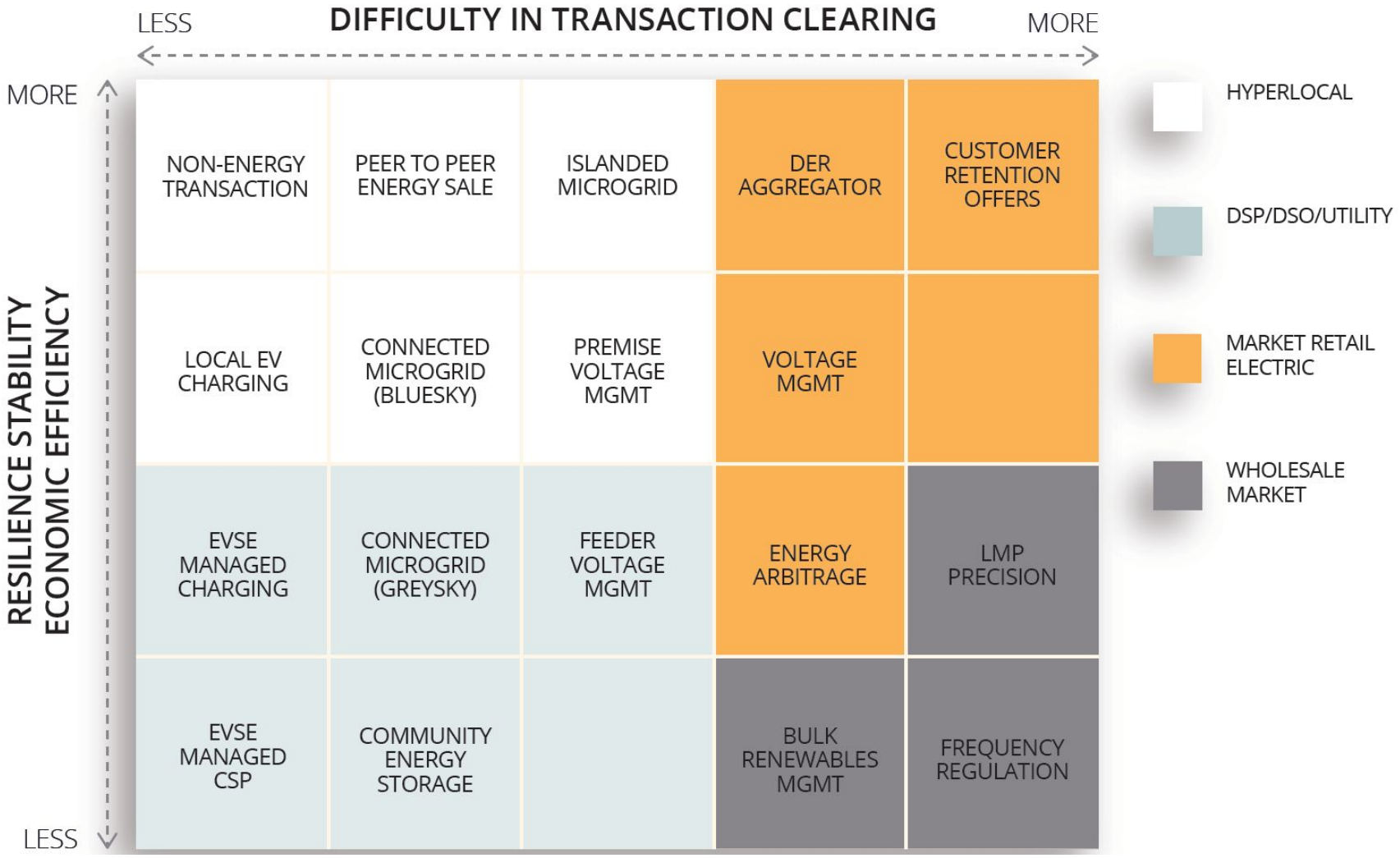
Blockchain Project Concept



1. Build an end-to-end platform to facilitate contracting, compliance, and settlement of distribution level market services
2. Track and assign attributes to renewable energy generation that can be exchanged among parties with minimal agency cost
3. Develop a rich data set of customer behaviour to build custom products or services to benefit both customers and the grid

Source: Alectra 2018 presentation to IESO

Blockchain Use Cases



Source: L03/Exergy Technical Whitepaper

Brooklyn Microgrid Project (BMG) (L03)

"If in the future you find yourself selling your excess solar panel energy to your neighbor via secure blockchain, you'll have one startup's actions on President Street in Brooklyn to thank."

-Fast Company

"This project..., is the first version of a new kind of energy market, operated by consumers, which will change the way we generate and consume electricity."

-New Scientist

Source: Brooklyn Microgrid Website

LO3's Pando platform for BMG

Source: https://lo3energy.com/pando/

Pando App Screenshots

https://youtu.be/SA-Vq3ZlkEg

Source: https://lo3energy.com/pando/

How Blockchain works in Pando/ L03 Energy Co-op

Flexible Trading: Configure your marketplace to trade energy or energy attributes and enable your consumers to source renewables from their local community

Powerful Metrics: Analyze the market with customer and trade analytics, trading dynamics, offer subscriptions, and other configurable analytics from your consumers in an easy-to-use portal

Personal Energy Management: Lead your customers on a new energy journey, starting with valuable energy tools on a branded mobile application, to learn about their energy profile and renewable engagement opportunities

Highly Extensible: Securely integrate to third-party software such as your billing system and energy devices to power your marketplace and streamline your customer's experience

Simple Deployment: Launch a marketplace in 90 days with a team of experts who partner with you through every implementation stage from design collaboration, to test and turn up, and ongoing support

Secure and Scalable: Purpose built using Blockchain technology to ensure personal and system data security from day one and as trading transactions scale

Case Study

Case Study (1)

Doug Hall runs a dairy farm in southwestern Ontario in the County of Narnia.

- His farm is net energy positive due to presence of solar panels, a deep well heat pump, and a wind turbine.
- He wants to go “off-grid” and disconnect his farm from the local PUC for the supply of hydro to his farm.
- He is worried that, despite having installed battery back up and LED lighting on his farm, he might experience a power shortage and be unable to run his milking machines.

Here's What Doug Hall's Alectra bill looks like now

Electricity…$ xxx…(one-third).....

This is the cost of generating the electricity you used this period. Usage is measured in kilowatt-hours (kWh) and depends on the wattage of devices you use and how long you use them. The Ontario Energy Board (OEB) sets the cost per kWh and the money collected goes directly to the electricity generators.

Delivery....$xxx.....(two-thirds).....

This is the cost of ensuring you have reliable power when you need it Hydro One collects this money to build maintain and operate the electricity infrastructure, which includes power lines, steel towers and wood poles covering 960,000 sq. km. A portion of this cost is fixed and a portion varies depending on the amount of electricity used.

Regulatory Charges…$ xxx.....(a few dollars).....

The Independent Electricity System Operator (IESO) uses this money to manage electricity supply and demand in the province, which is necessary to ensure that there is enough electricity to meet Ontario's needs at all times.

Case Study (2)

There is very little energy used on his farm or in his County of Narnia so there is energy to export.

The local utility commission is subject to Ontario Energy Board regulations, and Alectra is the current single source of hydro to his farm.

There are 100 other dairy farms in Farmer Hall's County of Narnia.

They all want to jump on the bandwagon and become energy self-sufficient.

Case Study (3)

Assume that the The Ontario Co-operative Corporations Act, .S.O. 1990, c. C.35 allows the Narnia farmers to form an energy co-operative.

Farmer Hall and his fellow farmers want a way to sell their surplus power to neighbouring farms in their county instead of feeding excess hydro energy to Alectra.

Neighbouring farmers without solar panels want to buy excess hydro from other co-op members.

Renewable Energy Co-operative (1)

A renewable energy co-operative is a co-operative whose articles restrict the business of the co-operative to,

(a) generating, within the meaning of the *Electricity Act, 1998*, electricity produced from one or more sources that are renewable energy sources for the purposes of that Act; and

(b) selling, as a generator within the meaning of that Act, electricity it produces from one or more renewable energy sources

Renewable Energy Co-operative (2)

As part of its business of generating and selling electricity produced from one or more renewable energy sources, a renewable energy co-operative,

(a) may establish or develop one or more generation facilities, within the meaning of the *Electricity Act, 1998*, to generate electricity produced from one or more renewable energy sources; and

(b) may promote the purchase by electricity users of electricity produced from renewable energy sources

Source:Co-operative Corporations Act, R.S.O. 1990, c. C.35

Case Study (4)

The Narnia Co-op has heard that Blockchain:

- can be used to manage power consumption, tracking and billing
- is a Trusted Third Party System (TTP) that allows them to “cut-out” the Alectra
- can be used for a variety of functions including approval of expenditures (voting), energy management, billing exchange

The Narnia farmers co-op has hired you as a consultant to make this happen (the “Proponent”).

Each Co-op Narnia farmer can buy or sell hydro power from their proposed TPP system as long as there is consensus among the Narnia “block” of farmers

They can use **Smart Contracts** to manage billings and payments among themselves.

Each farmer may go so far as to pay any amounts owing by way of **Bitcoin** (“BTC”) directly to a specific farmer instead by EMT or cheque thereby potentially also cutting out reliance on the local *Vicious and Greedy Bank.*

Potential Financial Problems with New Ecosystem

Local farmers in Narnia don't know how to repair any broken equipment or program in ERC 20 code to set up their blockchain

Alectra might be threatened as there will be no need for a local hydro utility and could render them obsolete

Life Cycle cost analysis unknown

May need to fund solar panels on other Narnia farmers' rooftops

Potential Financial Problems with New Ecosystem

The Narnia Co-op still needs the local Alectra and Hydro One hydro poles, lines and transformers to connect the 100 farms in the Narnia Co-op.

Does the Narnia Co-op have to issue a bond to pay for all this or will Alectra change their business model and pay for a slice of revenue or hydro power generated by Narnia Co-op?

Does Narnia Co-op have to issue an **Initial Coin Offering** (ICO) ("Narnia Utility Coins") to pay for all of this?

Fund solar panels with an ICO or IEO?

Utility Token Functions

- An ***Initial Coin Offering*** (ICO) allows access to a service from the issuer
by investors at a prepaid price
reward participants to the network
- provide financing for development of protocols
- generate profits for developer

Initial Exchange Offerings (IEOs)

•Initial exchange offerings (IEOs) are a recent development in the rapidly evolving digital asset space. IEOs are similar to initial coin offerings (ICOs) in that they are initial offerings of digital assets (*e.g.*, coins or tokens) to raise capital. However, IEOs are being touted as an innovation on ICOs because they are offered directly by online trading platforms on behalf of companies—usually for a fee—to provide immediate trading opportunities for the digital assets.

Promote Your Project/Build Your Solution

- **Services for an ICO**
- **Services for an IEO**
- **Services for a company**
- Premium Listing
- IEO Rocket Listing
- Priority Listing
- Analytical Review
- Blockchain Company Listing
- Exchange Listing

Blockchain Company Listing

- List your blockchain company.
- Price: 0.02 BTC
- Order Now

The “Proposal”

The “Proposal”- How Farmer Hall interacts with the Narnia Co-op

Hall signs in to the Narnia Blockchain

Hall agrees to a Smart Contract with the following rules:

He is credited for selling power into the block

He is debited if he uses power from the block

If he plugs in his four Tesla cars to charge all at once and consumes more than 110% of his allotment of power from the block:

His bank account, or crypto account is automatically charged with an agreed amount to pay for his excess consumption

The block agrees to mark-to-market the notional cost of block power to current market rates to prevent the “free rider” problem in economics

Advantages of a Narnia Blockchain (1)

Avoid slow and elaborate bureaucratic processes:

Votes on Narnia “corporate” issues to happen more often and be more accessible for Narnia farmer (shareholders).

Enable Narnia Co-op to streamline proxy voting and provide shareholders with end-to-end confirmation as to how their shares have been voted

Perform real-time accounting, as ledgers of Narnia Co-op are made available for anyone interested in consulting

Advantages of a Narnia Blockchain (2)

Achieve accurate, real-time, straight-through processing of financial transactions

Allow to aggregate all of the Co-op's transactions into a real-time income statement or balance sheet, sparing Narnia farmers the wait for quarterly financial statements.

Access to ledgers will avoid the need for costly audits since falsifying or destroying records in the blockchain is nearly impossible.

keep track of real and physical assets

Issues in using Proponent's Blockchain Solution

- The Narnia farmers and local utility are all interested in the efficiencies and opportunities that a TTP- based system could provide relative to current centralized hydro distribution systems
- Can Alectra act as the trusted party between Narnia co-op farmers in tracking and recording transactions in their central ledgers? Is Alectra needed at all?

Issues in using Proponent's Blockchain Solution

Many recent advancements in TTP/ blockchain have focused on ways for traditional operators of centralized systems such as local hydro utilities to realize the benefits of DLT while mitigating its disadvantages.

Is Alectra up to investing and deploying blockchain solution?

Regulatory Problems

How does Alectra fund necessary infrastructure upgrades?

Rate base?

Non-regulated affiliates on service cost recovery?

Role of LDC/Alectra vs. IESO local markets vs. 3rd party aggregators

Ontario Feed In Tariffs Cancelled

Ontario's Government for the People Introduces Legislation to Repeal the Green Energy Act

Ontario to Cancel Energy Contracts to Bring Hydro Bills Down

Large Renewable Procurement and Feed-In Tariff Contracts

Panel Discussion

Regulatory Problems

There remains in Ontario an underlying problem of the lack of any framework for discussions about the future structure of the province's electricity system.

The IESO, OEB, EDA and others around have initiated a series of *ad hoc* processes around DER development.

See following slides for an overview.

The IESO

In June 2019, the Energy Transformation Network of Ontario issued a report titled "*Structural Options for Ontario's Electricity System in a High DER Future*."

The report is designed to address "…options for the allocation of roles and responsibilities for DERs in Ontario.

Regulatory Issues

Aggregation of resources being managed through a microgrid, and what role blockchain could play in facilitating that?

There is also then the question of how those resources interact with the grid - do they do so at an IESO/wholesale level, or more likely through an LDC or Hydro One? (Depending on location).

The either of those options raises the question of the role of the LDC in managing the actual movement of energy, and whether infrastructure upgrades will be needed to do that - which could lead the LDC to the OEB if they want to do it on rates - or can they see a way to make enough money off those transactions to justify the capital investment internally

Could blockchain provide a means to capture a service charge/revenue stream for the LDC for those transactions that would enable the necessary capital investments?

Energy Transformation Network of Ontario Report "*Structural Options for Ontario's Electricity System in a High DER Future*." June 2019

The report is designed to address "…options for the allocation of roles and responsibilities for DERs in Ontario." The report also examines "…the potential for conflicts of interest and synergies among the roles and responsibilities required for DER integration into Ontario's electricity system, and existing entities in Ontario's electricity sector."

One of the major issues in the report "…is the question of who should own, operate, buy and sell, services related to DERs."

Local Electricity Market

In August 2019, the IESO announced an intention to test the province's first Local Electricity Market (LEM). According to the IESO, the benefits of the LEM are:

> The local electricity market will allow resources like solar panels, energy storage, and consumers capable of reducing their electricity use to compete to be available during periods of high demand. Leveraging existing local resources could help avoid the need to invest in new transmission lines and stations, while competition will drive down costs.

The Ontario Provincial Government

There were also some surprising references to energy storage, smart grids and DERs in the Progressive Conservative provincial government's December 2018 Made in Ontario Environment Plan.

The document was otherwise primarily concerned with dismantling the previous government's cap and trade system for GHG emissions.

The Province has yet to follow-up on DER related elements of the plan.

What is a DER?

A DER is exactly what Farmer Hall and the Narnia Co-op are trying to implement

Distributed Energy Resources (DERs)

DERs are “a decentralized source of energy that provides electricity services to individual customers or to the wider system located nearby.”

DERs are often located near customers and “provide all or some of their [customers] immediate electric and power needs and can be used by the system to either reduce demand or provide supply to satisfy energy, capacity, or ancillary service needs of the distribution grid.”

Distributed Energy Resources (DERs)

DERs involve the integration of a of range technologies, including solar photovoltaic, wind power, cogeneration, renewable natural gas, energy storage, and electric vehicles, into stable and reliable energy resources at a local level.

Is Blockchain a solution for Farmer Hall and the Narnia Co-op? (Summary)

Additional Readings

York University Bookstore sell a comprehensive Course Kit on Blockchain under FACC 6885 **Blockchain and Cryptocurrency** (T. Storus)

David Furlonger.**The Real Business of Blockchain**

(October 2019 , Harvard Business Review**)**

Don Tapscott, **Blockchain revolution how the technology behind bitcoin is changing money business and the world**

(Penguin, January 2016)

Aaron Grinhaus, **A Practical Guide to Smart Contracts and Blockchain Law** (LexisNexis,March 22, 2019)

Sources

Jean Bacon, Johan David Michels, Christopher Millard & Jatinder Singh, *Blockchain Demystified: A Technical and Legal Introduction to Distributed and Centralised Ledgers*, 25 Rich. J.L. & Tech., no. 1, 2018.

https://jolt.richmond.edu/blockchain-demystified-a-technical-and-legal-introduction-to-distributed-and-centralised-ledgers/

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