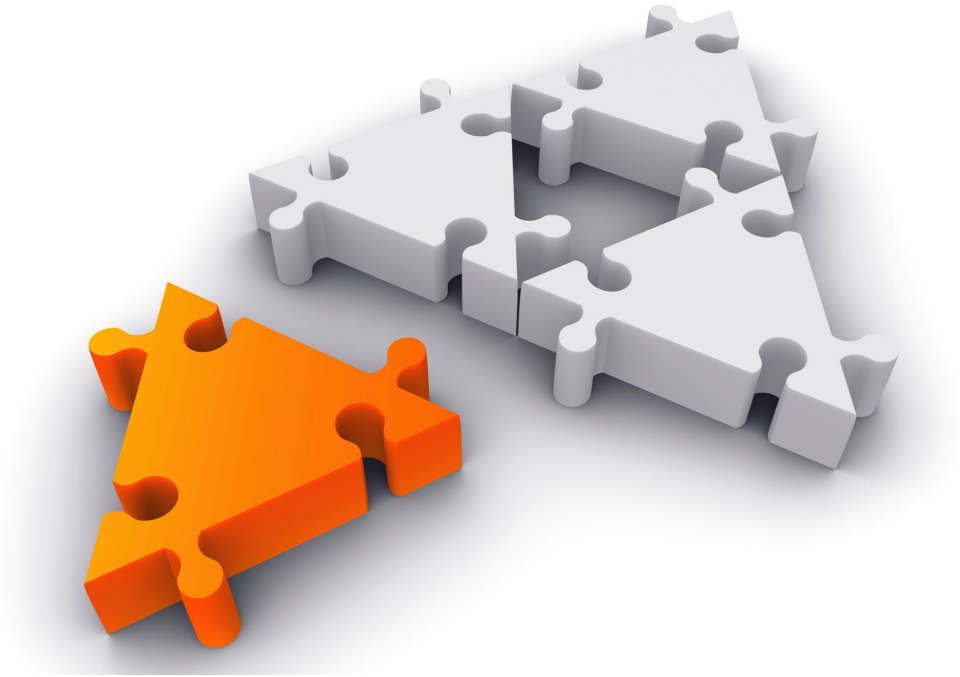
Connecting the Pieces of the EV Ecosystem
Market Overview and Technical Realities

Andrew Daga, CEO
Momentum Dynamics



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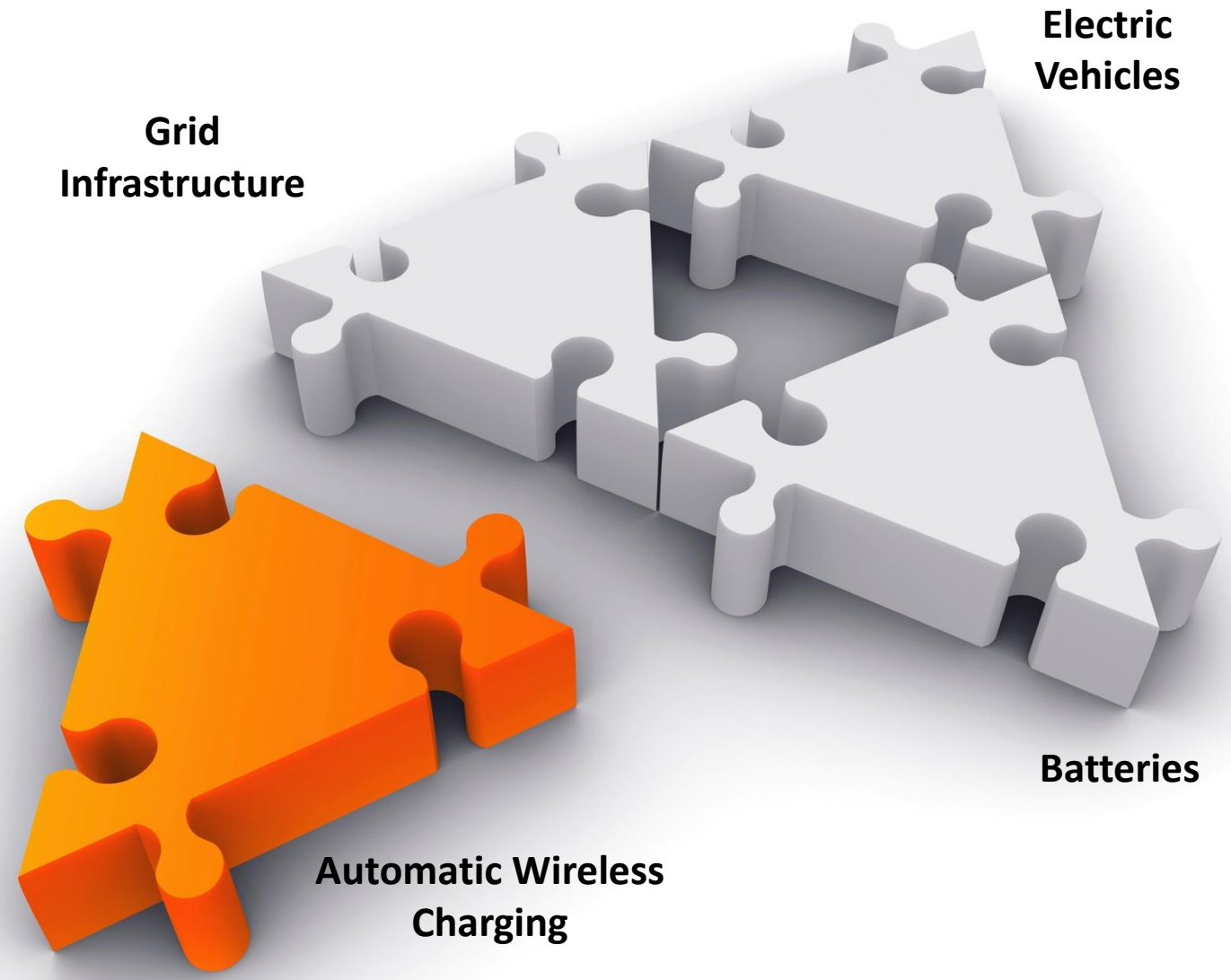
Wireless Charging is the Essential Enabling Technology for the EV Market



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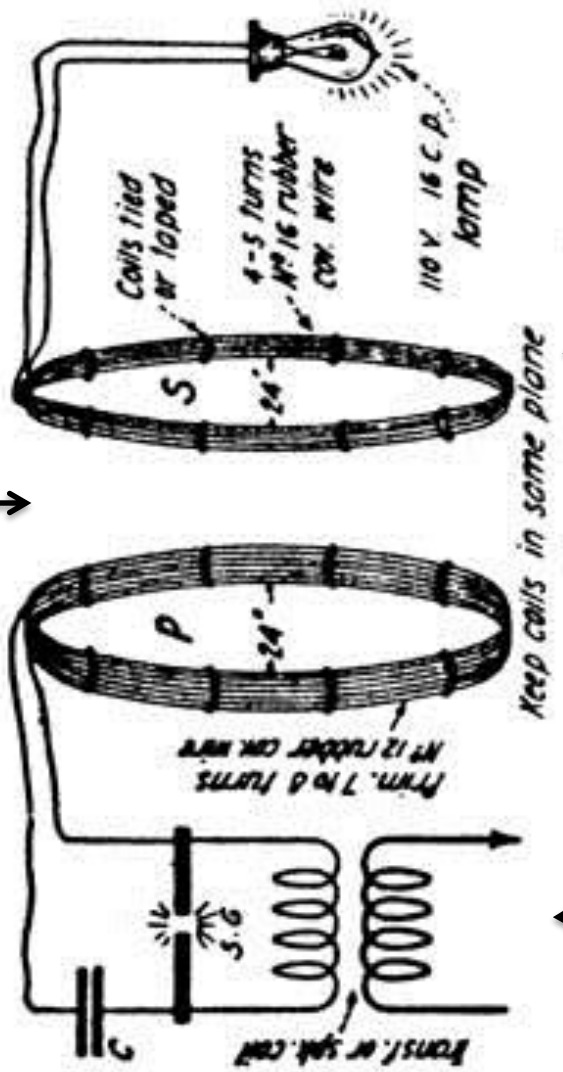
How it works…

Resonant Induction is not new. This is a sketch from Nicola Tesla from the 1920's. However, using induction to charge EVs at very high power levels requires new technology.



Power Receiver

Air Gap

Power Transmitter

Mains Power Supply

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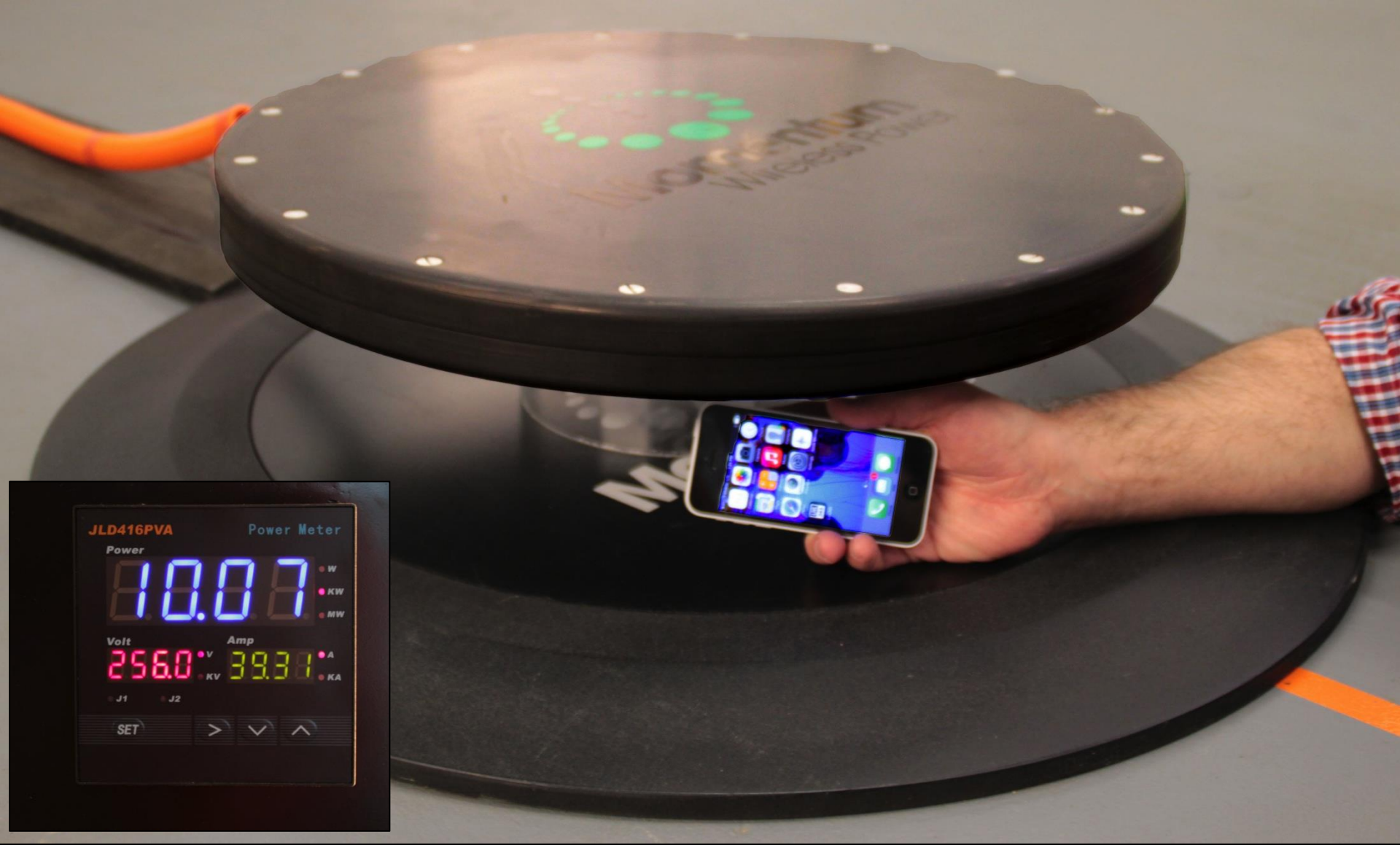

Momentum Dynamics has been developing safe high power WPT systems since 2009.

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Wireless charging is not just about convenience.

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What are the major impediments to EV adoption?

#1 – Range Anxiety

#2 – Battery Lifetime

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Wireless Charging is enabling because it provides:

Automated fueling.
Driving range extension.
Battery lifetime extension.

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Automated charging means that "fueling" can happen more frequently.

And not once a day.

(That's range extension)

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And more frequent charging also leads to extended battery life.

(That's because mid-SOC charging means fewer deep discharge cycles and reduced heating due to lower internal resistance.)

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EVs need to meet consumer expectations.

They must meet or exceed expectations for performance and lifetime cost.

The "fueling" system is critical to this.

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The technology should not require consumers to alter their lives to fit the technology.

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Essential Precursors

Electric Industrial Vehicles

Many types, includes forklifts, airport ground support equipment and port facility drayage vehicles.

Electric Commercial Vehicles

Multiple classes, must save fuel, 33 million registered in US.

Battery Electric Buses

Mandated to go to alternative fuel, must save fuel costs, Electric buses save $1 per mile on maintenance costs over diesel buses – not including fuel savings.

BEV & HEV Passenger Vehicles

The largest market, worth billions in sales. Goldman Sachs predicts a sharp S-curve to 25% market penetration in 10 years.

And all of them require automatic fast charging (high power)

Passenger vehicles **10 kW to 100 kW**
Municipal Buses **250 kW**
Fleet Trucks **10 to 100 kW**
Industrial Vehicles ***25 to 100 kW***
Port Vehicles and GSE ***25 to 200 kW***

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So what about efficiency you ask?

What are the facts?

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Wireless charging is 90%-92% efficient.

Energy is not lost by being "radiated into space."

Wireless charging is comparable to plug-in charging.

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It's safe.

It does not need to cost more.

It costs about the same to install as plug-in.

It is available today.

Nearly every EV automaker and bus OEM is integrating inductive charging.

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Battery Electric Buses

Battery electric buses (BEBs) will lead the EV market and the S-curve is inflecting rapidly today.

But in order to compete with fossil fuel ICE buses, BEBs must be able to drive the same routes and with a safe reserve of energy. And the battery must last 12 years.

The solution is On Route Wireless Charging.

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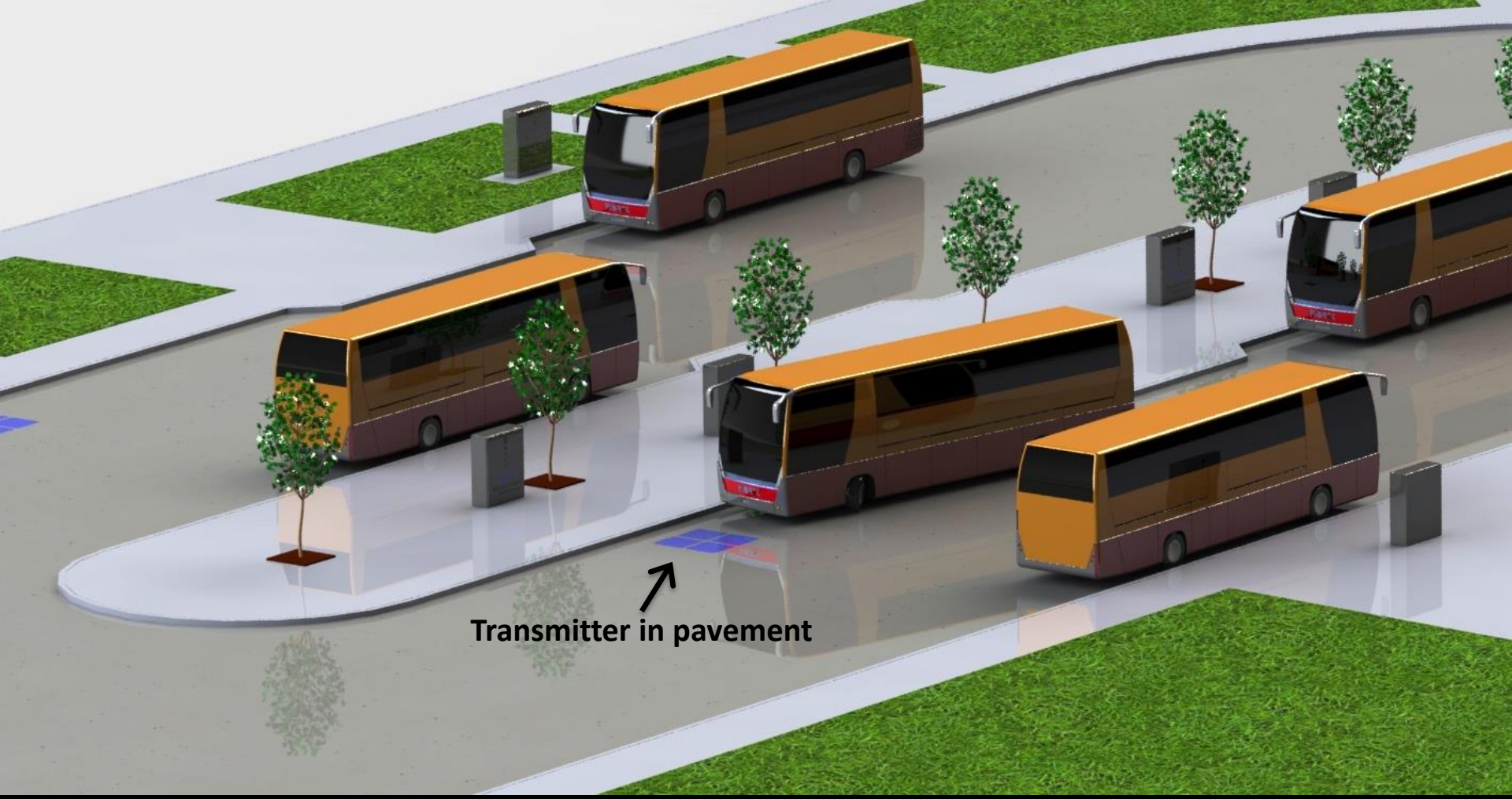

In this image, notice the blue tiles in front of the bus. As the bus pulls in the driver is guided to an aligned stopping position. The operator needs to take no action, charging commences immediately when the bus stops.

Table on left shows battery State of Charge if bus is charged once per day at the depot. After 12 driving cycles, battery would be deeply depleted and range will be limited. Table on right shows effect of opportunity recharging after each driving cycle. Short intermittent recharges allow unlimited driving range.

Avg kWh per Mile	Starting kWh
2.25	350.00

Energy Added per Minute
3.3

Depot Charge Only

Loop	Miles	Energy Used (kWh)	Energy Remaining (kWh)	SOC
Depot to Transit Plaza	2.00	4.50	345.50	99%
1	9.00	20.25	325.25	93%
2	9.00	20.25	305.00	87%
3	9.00	20.25	284.75	81%
4	9.00	20.25	264.50	76%
5	9.00	20.25	244.25	70%
6	9.00	20.25	224.00	64%
7	9.00	20.25	203.75	58%
8	9.00	20.25	183.50	52%
9	9.00	20.25	163.25	47%
10	9.00	20.25	143.00	41%
11	9.00	20.25	122.75	35%
12	9.00	20.25	102.50	29%
13	9.00	20.25	82.25	24%
14	9.00	20.25	62.00	18%
15	9.00	20.25	41.75	12%
Transit Plaza to Depot	2.00	4.50	37.25	11%
	139.00	312.75		

Effect of Opportunity Charging

Charging Time at Plaza (Minutes)	Energy Added (kWh)	Revised Energy Remaining (kWh)	SOC
5	0.0	350.00	100%
5	0.0	329.75	94%
5	0.0	309.50	88%
5	0.0	289.25	83%
5	0.0	269.00	77%
5	16.5	265.25	76%
5	16.5	261.50	75%
5	16.5	257.75	74%
10	33.0	270.50	77%
5	16.5	266.75	76%
5	16.5	263.00	75%
5	16.5	259.25	74%
5	16.5	255.50	73%
10	33.0	268.25	77%
5	16.5	264.50	76%
5	16.5	260.75	75%
5	16.5	272.75	78%

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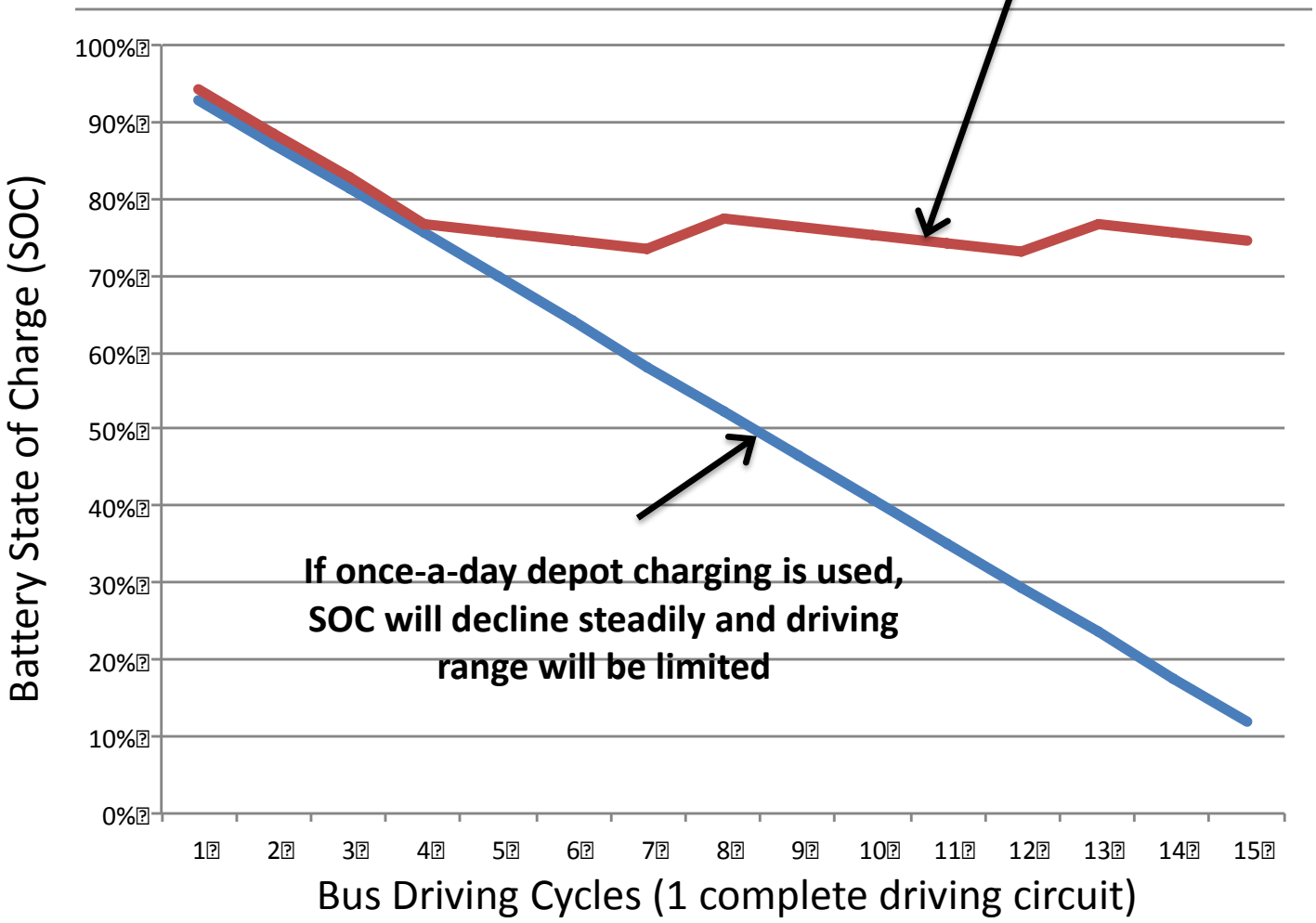
With fast opportunity charging after each driving circuit, the battery SOC never falls below 50%, even if some charge opportunities are missed or duration is irregular



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Thank you

For more information, please contact Scott Carroll, VP Business Development, at (484) 320-8222.