Level 2 Emerging Technology Scenario

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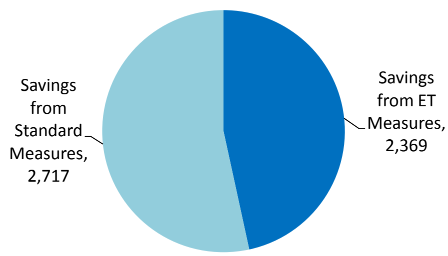
Background

- Purpose:
  - Very low or no carbon resource scenario (3B)
  - What resources to displace high-carbon generation are most economic?
  - Consider emerging generation & EE technologies
- For conservation, technologies that are:
  - Beyond our existing supply curve
  - Available within next 10 years
  - Significant steps in efficiency/cost

Existing Supply Curves Include Large Share Level 1 ET

Total Savings Potential (Year 2035)



Total 5086 aMW by 2035: All Cost Bins

Savings from Emerging Technologies	2035 (aMW)
Residential	**1,460**
Advanced Power Strips	262
ASHP	122
Behavior	45
Clothes Dryer	53
DHP Ducted	158
EV Supply Equip	7
HPWH	289
Lighting	462
Lighting PPA	42
WasteWater Heat Recovery	8
WIFI enabled tstats	12
Commercial	**848**
Advanced Rooftop Controller	119
Exterior Building Lighting	142
LEC Exit Sign	19
Lighting Controls Interior	37
LPD Package	391
Smart Plug Power Strips	47
VRF	92
Agriculture	**22**
Irrigation Efficiency	19
Lighting	3
Industrial	**38**
Lighting	38
Grand Total	**2,369**

Level 2 EE's Competition

- Solar PV (distributed* and utility scale)
- Combined Heat & Power (CHP)*
- Geothermal
- Small Modular Nuclear
- Wave Energy
- Offshore Wind
- New Gas Combined Cycle Generation
- Higher Use of Existing Gas Generation

*discussed today

Combined Heat & Power

Description	Combined Heat & Power
How it Saves Energy	Distributed generation that produces electricity from a natural gas generator, using waste heat primarily for water heating loads.
Efficiency	Overall efficiency for a CHP is around 70%, compared to a typical genset electric efficiency of ~40%. In addition, located on-site eliminates T&D losses.
Cost (first & levelized)	$2000-3000 capital; $40-140/MWh levelized
Possible Start & Ramp	2016
Tech Potential	4300 aMW for both Com and Ind (some also in Res but not included in the estimates).
Notes	Cost-effectiveness depends on spark spread. Likely ~1/4 of technical potential would be cost-effective. Requires coincident thermal and electric loads.
Sources	ODOE - Oregon CHP assessment (2014), CHP Market Assessment in PNW (2004), WA CHP Tech Potential (2010)

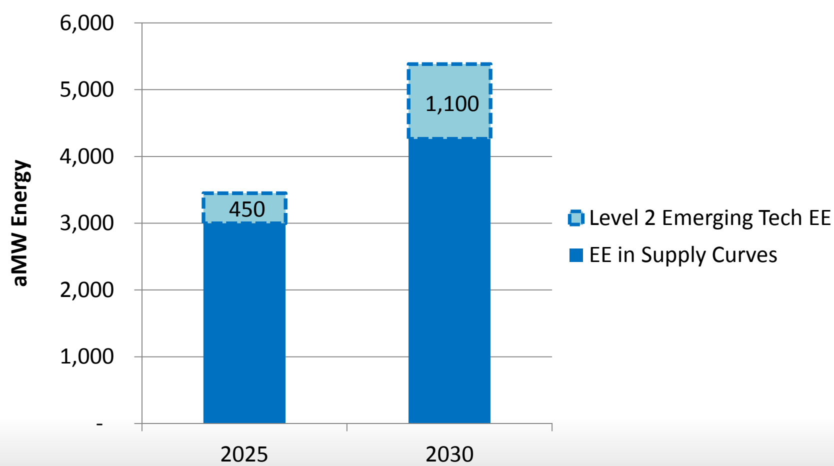
Distributed Solar PV

Description	Distributed Solar PV
How it saves energy	Displaces grid generation. Little energy savings except for reduced line losses.
Efficiency	Solar cell efficiencies range 6% to 40%. Typically 14%-19% for commercial products. Capacity factor ~11% in PNW. Inverter and power losses about 20%. Carbon free.
Cost (first & levelized)	About $4/watt falling to $2.5/watt by 2035. Levelized costs range $100-$200 per MWh by 2025. Not including storage costs.
Possible Start and Ramp	2016; Slow ramp up due to infrastructure limits.
Tech Potential	About 1800 aMW energy by 2025 and 3500 aMW by 2035. But could be limited by storage/distribution system constraints. Provides some daytime capacity. Small contribution at time of winter system peak.
Notes	High penetration will require on-site storage or distribution system upgrades, added integration costs, high-volume production & labor infrastructure
Sources	NREL, ETO, PSE, Idaho Power, Sandia, GRAC, others.

Level 2 ET Efficiency Measures Considered

- Solid State Lighting
  - Improved efficacy, color, drivers, optics, control, life
  - Could cut lighting power 20%-50%
- CO_2 Heat Pumps Space Heating
  - Could double heating efficiency
- CO_2 Heat Pump Water Heaters
  - Could double efficiency
- ~~Next advance in silicon wafer technology~~
  - ~~Photonics~~
- Highly Insulated and Dynamic Windows
- Optimized HVAC Controls
- ~~Ultra-low Energy Buildings~~
- Evaporative Cooling

Potential Additional Level 2 Emerging Tech EE



Summary
Estimates Emerging Tech EE Measures
(All are approximate - based on limited data!)

	2025			2030			
Emerging Technology	aMW	MW	Lev Cost ($/MWh)	aMW	MW	Lev Cost ($/MWh)	Required Conditions
Solid State Lighting	200	400	$0-$30	400	800	$0-$30	Continued tech improvement, resource availability
CO2 Heat Pump Water Heater	110	200	$100-150	160	300	$90-140	UL approval; US market development
CO2 Heat Pump (space heat)	50	120	$170-220	130	300	$140-180	Best suited for hydronic heating, need R&D for US applications
Highly Insulated Dynamic Windows - Com	20	100	$500+	30	150	$250	Intensive R&D effort needed to bring down cost; slow ramp due to window replacement schedule
Highly Insulated Dynamic Windows - Res	80	425	$500 +	120	580	$250	
HVAC Controls – Optimized Controls	140	370	$90-120	200	560	$80-110	Significant developments expected in next 5 years
Evaporative Cooling	50	3	$130-150	80	5	$130-150	Need R&D on configurations & applications in PNW

Solid State Lighting

Description	Solid State Lighting
How it Saves Energy	Improved efficacy, power electronics, color, design, life, and control systems. Expect better phosphors, quantum dots, thermal management and materials science advances will continue to increase performance
Efficiency	Forecast improved efficacy from 20% to 100% above 7P 2017 baseline depending on application. Example: Linear fluorescent replacements from 110 to 180 lumens per watt by 2030
Cost (first & levelized)	Low first cost; $0-30/MWh levelized. Approach zero incremental cost over incumbent technology in 5 -10 yrs
Possible Start and Ramp	Start 2020. Fast ramp. Lighting system replacement rates could increase due to non-energy benefits, would increase ramp rate
Tech Potential	Approx 200 aMW by 2025, 400 aMW by 2030 (all sectors)
Notes	Dependent on continued technological advances. Potential large non-energy benefits could advance or retard energy savings
Sources	USDOE Energy Savings Forecast of Solid-State Lighting in General Illumination Applications, August 2014. Council model for replacement.

CO2 HPWH

Description	CO2 Heat Pump Water Heater
How it Saves Energy	Produces water at higher temperatures than standard HPWH. CO2 is a refrigerant that requires high operating pressure.
Efficiency	Has a COP of about 3.0+ (compared with 2.0 for standard HPWH).
Cost (first & levelized)	$3,000 – 4,000, $100-150/MWh
Possible Start and Ramp	2016 (some units available later this year), slow ramp rate.
Tech Potential	160 aMW for both Res and Com (some also in Industrial but not included in the estimates)
Notes	Significant benefits is the CO2 refrigerant include a zero ODP and 1 GWP. Japanese product, currently available in the US. Good experience in Japan and Europe. US introduction this year (Sanden).
Sources	WSU Energy Program (Ken Ecklund), BPA (Jack Callahan), Sanden, Mitsubishi, Sanyo, Mayekawa, US DOE

CO2 Heat Pump (Space Heat)

Description	CO2 Heat Pump (Space Heat)
How it Saves Energy	Most likely configuration may be in combination with the HPWH, producing hot water for hydronic heating. However, stand-alone heat pump configurations are also possible.
Efficiency	Has a COP of about 4.2.
Cost (first & levelized)	$3,000-4,000, $170-220/MWh
Possible Start	2022
Tech Potential	160
Notes	Significant benefits is the CO2 refrigerant include a zero ODP and 1 GWP. Japanese product, currently available in the US. Good experience in Japan and Europe. The high pressure refrigerant lines make standard heat pump configurations more difficult.
Sources	WSU Energy Program (Ken Ecklund), BPA (Jack Callahan), Sanden, Mitsubishi, Sanyo, Mayekawa, US DOE

Highly Insulating Dynamic Windows

Description	R>7 windows, Varying SHGC
How it Saves Energy	Improves the thermal barrier of commercial and residential buildings. Also, dynamic shading to reduce solar heat gain coefficient during high solar insolation
Efficiency	Traditional windows have R-values of around 3, up to R5. Project up to R-10 for residential and R-7 for commercial. SHGC varies from <0.5 to 0.4
Cost (first & levelized)	Down to $8/sqft; ~$170/MWh
Possible Start and Ramp	2020
Tech Potential	150 aMW for both Res and Com (some also in Industrial but not included in the estimates)
Notes	Price projected to fall from $20/sq ft to $8/sqft.
Sources	DOE Roadmap 2014 BTO windows & Envelope report, Assessment of Energy Impact of Window technologies for Commercial Buildings, LBNL-6035E, EC Windows with NIR switch; Building and Environment 61 (2013) 160-168

Optimized Controls

Description	Optimized Controls
How it Saves Energy	Reducing HVAC consumption by further optimizing controls in all commercial buildings.
Efficiency	Assumption is to save an additional 10% of regional HVAC consumption by further optimizing controls (beyond 7P levels).
Cost (first & levelized)	$0.50/kWh, $90 - $120/MWh (could drop quickly)
Possible Start and Ramp	2021
Tech Potential	200 aMW
Notes	Many different companies working on all aspects of optimized controls and data management. Expect to see significant advancements in the next 5 years.
Sources	"ICT-Enabled Intelligent Efficiency: Shifting from Device-Specific Approaches to System Optima," April 2015

Evaporative Cooling

Description	Evaporative Cooling Systems
How it Saves Energy	Cools air through the evaporation of water instead of the traditional vapor-compression or absorption refrigeration cycles.
Efficiency	25 – 70% better than standard vapor compression. Assumed 15% above most efficient cooling 7P baseline and due to PNW weather
Cost (first & levelized)	$130 - 150/MWh (levelized)
Possible Start	2016, slow ramp due to climate configuration constraints
Tech Potential	80 aMW (com only)
Notes	A variety of configurations are available, research is needed for best fit in PNW. High ventilation requirements for effective cooling.
Sources	ASHRAE Handbook, Southwest Energy Efficiency Project, Southern California Edison/NBI