

# Technology Investments for New Energy Systems: Regime, Market and Cost Uncertainties

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- Energy system innovation needs more investment and business models
- This research investigates potential barriers to energy investments
- We take an individual investor's perspective on the impacts of these barriers on overall valuation and investment timing
- Specifically, we model the *real option* to build a virtual power plant (VPP) to market distributed energy resources (DER)
- Negative impact of policy regime uncertainty dominates market uncertainty impact, moderated by expected regime change frequency
- The value of subsidy-exposed technologies responds to policy regime uncertainty differently than market-exposed technologies

## Change to new energy system...

## ...requires investments and operations

### Supply

- Fossil-fueled → Renewable
- Central → Distributed

- New asset investments
- Old asset write-offs

### Grid and flows

- Unidirectional → Multidirectional
- Power only → Data + power








- Smart grids
- DER pooling / ICT-based coordination

### Demand

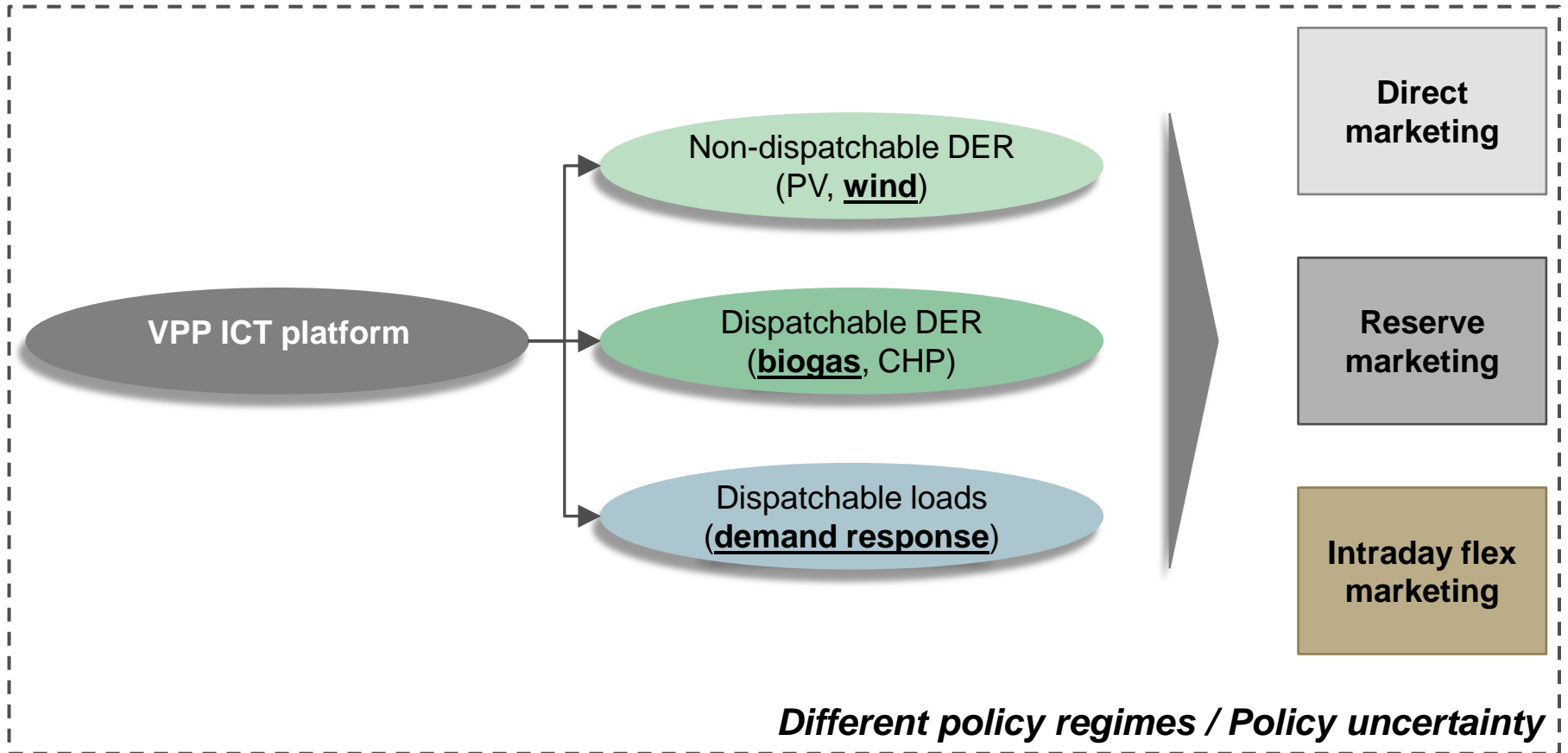
- Price taker → Price (re-)actor
- Predictable → Flexible

- Dynamic pricing
- Smart meters
- Home automation

- **Annual investments in clean energy** need to more than double by 2020 and increase by a factor of 6 by 2030 to support achievement of climate policy goals (*IEA 2014*)
- **Renewable energy and energy efficiency business** plays a minor role in utility portfolios, e.g. ~5% of retail sales each for 32 of the largest US utilities (*Ceres 2014*)
- **DER aggregator business models** are still underrepresented – VPPs control less than 1% of DER (*Navigant Research 2014*)
- Overall, a strong dependence of investment activity on **subsidies** exists to date

Potential investment barriers	General research	Energy innovation research
● <b>Low profits</b> in wholesale business, further lowered by renewables (e.g., <i>Hirth 2013</i> )		
● <b>1st mover</b> and <b>incumbency issues</b> ( <i>Zhu &amp; Weyant 2003, Katz &amp; Shapiro 1987,...</i> )		
● Some <b>technology risks</b> , esp. lead time and costs ( <i>Schwartz &amp; Zozaya-Gorostiza 2003</i> )		
● Uncertainty about <b>markets</b> and about the <b>policy regime</b> (e.g., <i>Fan et al. 2012</i> )		

**The focus is on market and policy regime uncertainties in the energy innovation context**



# Model: Discrete-time compound real options evaluation under market and policy regime uncertainty



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	Key equations	Explanations
Market uncertainty	$\frac{dP(w)}{P(w)} = \alpha_P dw + \sigma_P dZ_P$ $dP(w) = \alpha_P dw + \sigma_P dZ_P$	<ul style="list-style-type: none"> <li>Modeling of various stochastic market prices (+ subsidies, spreads)</li> <li>Geometric and Arithmetic Brownian Motions with correlation</li> </ul>
Policy regime uncertainty	$p_{g',t^*} = \frac{1 - e^{-\lambda t^*} \times (1 - e^{-\lambda(t^*-1)})}{G - 1}$	<ul style="list-style-type: none"> <li>Uncertainty about the stability of any given regime <math>g</math>; risk of switch to <math>g'</math> modeled by Poisson-like process</li> </ul>
DER investment	$S(t)_x = \sum_{m=1}^M R(t)_m \times \phi_m^x - C_x, \text{ s.t. } \phi_m^x \leq \eta_m$ $O(t)_x = \max \left[ S(t)_x - I_x, \frac{O(t+1)_x}{1 + \tau} \right]$	<ul style="list-style-type: none"> <li>Contribution margins subject to value pools <math>m</math> and market share cap</li> <li>Option value depends on investment costs, discount and volatility</li> </ul>
Platform investment	$S(t)_F = \sum_{x=1}^X O(t)_x - C_F$ $O(t)_F = \max \left[ \frac{S(t + L_F)_F}{(1 + \tau)^{L_F}} - I_F, \frac{O(t+1)_F}{1 + \tau} \right]$	<ul style="list-style-type: none"> <li>Similar logic to DER; however, option evaluates claim on DER options rather than claim on contribution margins</li> <li>Lead time can be accounted for, increasing exposure to risks</li> </ul>

# Application to German-market-like conditions – 4 scenarios of policy regime uncertainty simulated



Preliminary findings

Regulated world	Current state	Free market world
<ul style="list-style-type: none"> <li>● Stable subsidies</li> <li>● Price declines in flex markets (-3%)</li> <li>● Low volatilities throughout</li> </ul>	<ul style="list-style-type: none"> <li>● Declining subsidies (-2%)</li> <li>● Medium volatility (2.5% in balancing market, 10% intraday price spread)</li> </ul>	<ul style="list-style-type: none"> <li>● Slight price increases in flex markets. (1-2%)</li> <li>● Subsidy decrease (-3%)</li> <li>● Volatilities between 5-20%</li> </ul>
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<div style="border: 1px solid gray; padding: 5px; margin-bottom: 10px;"> <ul style="list-style-type: none"> <li>● DER / platform acquired at <math>t=1</math> <span style="float: right; border: 1px solid black; border-radius: 50%; padding: 2px 5px;">1</span></li> <li>● Wind and biogas drive profit</li> </ul> </div>		
<div style="border: 1px solid gray; padding: 5px; margin-bottom: 10px;"> <ul style="list-style-type: none"> <li>● Platform <b>waiting value up</b> vs. exercise value <span style="float: right; border: 1px solid black; border-radius: 50%; padding: 2px 5px;">2</span></li> <li>● <b>Policy uncertainty &gt; market uncertainty</b> (free market uncertainty parameters should speed up subsidy-exposed investment)</li> </ul> </div>		
<div style="border: 1px solid gray; padding: 5px; margin-bottom: 10px;"> <ul style="list-style-type: none"> <li>● Less impact than free market scenario <span style="float: right; border: 1px solid black; border-radius: 50%; padding: 2px 5px;">3</span></li> <li>● However, market uncertainty reduction not fully captured due to market uncertainty reduction</li> </ul> </div>		
<div style="border: 1px solid gray; padding: 5px;"> <ul style="list-style-type: none"> <li>● Ratio waiting values vs. exercise values between scenarios 2 and 3 <span style="float: right; border: 1px solid black; border-radius: 50%; padding: 2px 5px;">4</span></li> <li>● No increase since same expected rate of regime change <math>\lambda</math></li> </ul> </div>		



- Policy regime uncertainty increases the value of delaying investment; this *policy process effect* is separate from *policy content effects*
- Expectations about the frequency of change are strong moderators of the *policy process effect*
- Thus, even sound policy design changes may have adverse effects – **process transparency reduces valuation subjectivity and increases investment levels**
- Subsidy-exposed technologies respond differently to both policy regime and market uncertainty than market-exposed technologies
  - Subsidy-exposed technology investments are less affected; indeed, results support the idea of a *lock-in race* in view of declining subsidies
  - Market-exposed technologies are much more exposed to adverse effects of uncertainty – thus, sound policy process even more important in a subsidy-free world

**Thank you!**

***I look forward to your questions and remarks***